ON THE HISTORY AND ENVIRONMENT OF TEKTRONIX

Some basic information about Tektronix history, instrument concepts, technology, and some overviews of related industries, important customers, and key competitors.

INTRODUCTION

This volume contains basic information about the history and environment of Tektronix. It was prepared jointly by the Management Development Department and the Marketing Information and Research Department for use in management development programs at Tektronix.

The materials are intended to acquaint new middle managers with basic factors and forces that have shaped and are shaping Tektronix. They are meant to be used in a class or other discussion format. The materials reflect a Tektronix commitment both to long-range planning and to involving middle managers in discussions of the nature, values, and prospects of the firm.

October 1978

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TABLE OF CONTENTS

CREDITS

The History materials owe much to W.K. "Dal" Dallas, the first sales manager for Tektronix. Although Dal left Tek more than 15 years ago, he still feels strongly and warmly about the Company, and with patience and care he helped me gain a perspective on the early days.

Other people who gave generously of their time included Earl Scott, Derrol Pennington, Bill Webber, Oliver Dalton, Norm Winingstad, Lang Hedrick, Wim Velsink, Keith Williams, Paul Bennett, Frank Hood, Jean Delord, Barrie Gilbert, Tony Sprando, Bill Strong, Marlow Butler, Rich Reisinger, Joe Floren, Clif Moulton, Guy Frazier, Jim Castles, and Don Ellis. This list is not complete as many people have helped me out along the way. I accept full responsibility for the results, for each of these people experienced Tektronix in a slightly different way, and I doubt if a definitive history will ever be possible.

The History materials were sponsored by the Management Development Department, and I wrote them in Spring 1977 while in their employ. Larry Reierson, Manager, deserves credit for both sponsoring and protecting the history effort. I hope that someday soon someone else will pick up this effort and carry it on.

The article on advanced instruments was written by Gene Chao of Tek Labs, and once it is read it sticks in mind as the definitive way to envision instruments in a conceptual sense.

The article on programmable instruments was written by Harry Gregor who now works to market Spectrum Analyzers.

The technology overviews of semiconductors and displays were contributed by Norm Heyerdahl, Doug Ritchie, and Aris Silzars who wrote in their various roles within Tek Labs. (Doug Ritchie, however, has since left Tektronix.)

The Industry Overviews, the Competitor Overviews, and the Customer Overviews represent the mainstream of the Department's work and concerns. Specific contributions were made by Bill Mumford and Harry Watkins to the articles on the computer industry, the telecommunications industry, and the American Telephone and Telegraph Company.

The Customer Overview on the U.S. Government was written by Duane Bowans and updated by Herb Richardson.

Robert Bosler
Editor/Project Leader
October 1978

TEKTRONIX: THE ENTREPRENEURIAL PERIOD, 1946-1954

PART 1: BIOGRAPHIES

Charles Howard Vollum

Charles Howard Vollum was born on May 31, 1913, in Portland, Oregon. He graduated from St. Agatha's School and St. Stephens (now Central High School), and he attended Columbia University (now the University of Portland) for two years.

Legend has it that he built his first oscilloscope while at Columbia University. An early acquaintance, Frank Hood, remembers one of those early instruments as looking like a "breadbox crammed with parts with a piece of sewer pipe on top" (the sewer pipe was to shield the display from the earth's magnetic field).

Legend also has it that Howard tried to transfer to Oregon State but was turned down for lack of credentials; he then took his oscilloscope over to Reed College, where he was accepted.

Reed College at the time had some extraordinary educators in its physics department, including Dr. Marcus O'Day and Dr. A. A. Knowlton. Dr. Knowlton particularly was noted for the quality of students he trained which resulted in Reed College ranking ahead of colleges such as Stanford in numbers of graduates listed in American Men of Science during the 1930's. Dr. Knowlton published a textbook in 1928 which revolutionized college physics instruction by approaching physics from a humanistic rather than purely technical standpoint. Dr. Knowlton was also noted for his fierce and lifelong espousal of academic freedom. He taught at Reed College for 33 years. Dr. Knowlton consulted for industry and found, for example, a method for solving the problem of static electricity blotting out airplane radio reception.

Howard's senior thesis in physics at Reed was "A Stable Beat Frequency Oscillator Equipped with a Direct Reading Frequency Meter". The thesis reflected Howard's determination to design instruments that would, as Frank Hood remembers that

Howard said many times during this period, "produce not qualitative readings, but quantitative readings." In fact, the instrument that Howard built and described in his thesis offered an accuracy in measuring frequency of 1 percent at a time when conventional designs could measure to only 10 percent. Howard also built an oscilloscope at Reed that was still in regular use 22 years later (on the 10th anniversary of Tektronix).

After graduating from Reed in 1936, Howard worked on his own for a while repairing electrical appliances, then joined the M. J. Murdock Company. Howard worked at servicing and installing home and auto radios and air conditioning devices for four years until, in 1940, he placed first in a competitive exam and for $150 a month supervised the Radio Project of the National Youth Administration, a defense project to teach young people the basics of electronics.

At the age of 26, Howard Vollum was drafted. He would later say that it was "the only lottery I ever won". On March 4, 1940, his military career started with infantry training at Camp Roberts, where he stayed for nine months. Legend has it that during this period the Camp General's radio broke down, and Howard fixed it with ease. In any case, Howard received the first direct commission ever given at Camp Roberts and was transferred into the Signal Corps and was assigned to the Electronics Training Group.

At the time, the custom was for members of the Electronics Training Group to be sent to England for a period of eight months duty as radar maintenance officers since British radar technology was foremost in the world. Instead of radar maintenance, Howard was sent to the English radar laboratory, the Air Defense Research and Development Establishment. The January 10, 1956, issue of Tek Talk describes that assignment as follows:

"There he worked for almost two and one half years as a development engineer on a high resolution radar for aiming the 15-inch Coast Artillery guns at Dover. This radar was easily the most accurate in service at that time, having a range error of three yards at 20,000 yards (about 11½ miles) and asimuth or angular error of 1/20 of a degree. This radar was very effective in aiming guns which sank German ships trying to sneak out of the English Channel at night. For this work, Howard was awarded the Legion of Merit Medal."

"On his return to the USA just a few days before 'D Day', he was assigned to the Evans Signal Laboratory at Belmar, New Jersey. There he worked on radar detection and location of enemy mortars. This is accomplished by observing the flight of the shells and using this data to compute the location of the mortar. The same radar-computer combination is used for laying our own mortar fire on enemy mortar positions. For this work, he was given an Oak Leaf Cluster indicating a second award of the Legion of Merit Medal."

While at the Evans Signal Lab, Howard met Bill Hewlett, who was stationed at a nearby Signal Corps lab in Washington, D.C. Bill Webber, who knew Howard at the time, remembers Bill Hewlett saying years later, "our biggest mistake was not hiring Howard Vollum. I wrote Dave Packard telling him to hire Howard, but he never did it . . . ."

In any case, after the war, Howard Vollum decided not to move to Palo Alto, California, where the electronics industry was starting to form. Instead, in late 1945, Howard returned to Portland.

Melvin Jack Murdock

Jack Murdock was born in 1917 in Portland, Oregon. While attending Franklin High School he wrote in an autobiography the following:

"After leaving high school and establishing a business of my own, I intend to go further into the study of radio phenomena. I would like to learn all there is to know about radio, if it is possible. I shall probably carry on many experiments in this field, and also, possibly some other branches of science. If I do all that I hope to do, I shall probably make some inventions. I have at present several ideas for inventions, which if put to use would be of great benefit to the people of the world . . . . . I believe that the possibilities of radio are unlimited, and that the majority of the people have no idea of what radio's future holds in store."

When Jack Murdock graduated from high school in 1935, his father told him that some money had been set aside and that Jack could use it either to go to college or else to start his own business. In 1935, Jack opened a radio and electrical appliance sales and repair shop at 67th and Foster Road in southeast Portland. About a year later he met and hired a recent Reed College graduate, Howard Vollum, to handle the radio service duties.

The January 10, 1956, issue of Tek Talk continues the story:

In 1939, the 67th Avenue location became too small for Jack's operation. As a result he bought a building at 59th and Foster. After remodeling and painting, this became one of the most complete and attractive appliance stores in the city. The main feature was a G.E. model kitchen, complete with everything necessary to cook and serve meals."

"Just as things got going in good style, World War II broke out. Appliance manufacture stopped and Jack closed up the appliance business to join the Coast Guard. His knowledge of radio was immediately put to use. First assignment was at the Seattle maintenance base. After a year of this duty, Jack came back to Portland, in charge of a group of radio technicians. His last assignment was as radar and racon installation man, operating out of Seattle."

While in the Coast Guard, Jack Murdock seemed to make friends easily. Later some of these friends would work for him: Miles Tippery, Milt Bave, Bob Davis, Ken Walling, Howard Gault, Paul Belles, Sandy Sanford, Chuck Gasser, and Jim Castles.

In the January 10, 1956, issue of Tek Talk the following description of Jack Murdock appears.

"In characterizing Jack, we can say he gains the respect and admiration of all who know him by his quiet, sincere and genuine interest in arriving at the most fair, reasonable and considerate solution to an individual's and to Tektronix's problems.

"Jack's personal philosophy is of interest to all. He believes that success is available to anyone with ability, initiative, and a willingness to risk personal security . . . . ."

Shortly after Jack Murdock's death on May 16, 1971, as a result of a seaplane accident on the Columbia River, Howard Vollum wrote of Jack:

"Jack was a modest and unassuming man with no taste for the limelight. Yet he was warm and outgoing. . . . .a person you could bring your problems to. . . . . Jack was always oriented toward the customer's viewpoint, and toward the ideal of service. . . . .He led by setting an example. Despite his achievements, he was a humble man, without pretense. He always felt that knowledge was the key to solving any problem, and that if you knew enough about it you could arrive at the appropriate solution."

W. K. "Dal" Dallas

W. K. Dallas was born and raised in Galion, Ohio. His first job was with North Electric performing wiring and assembly on telephones. His next job was in New York in 1924 working as a field salesman/engineer for Cutting and Washington (later Colonial Radio), a small manufacturer of radios. In 1926 he returned to Galion; then in 1928, he returned to New York to join Electrical Research Products (ERPI). Electrical Research Products was a subsidiary of AT&T formed to handle by-products of Bell Labs, principally "talking movies." At ERPI, Dallas was a field engineer whose job was to sell, install and maintain movie equipment. In 1930 Dal was transferred to Hollywood, California, as a part of the Recording Division of ERPI, where his job was to install and maintain electrical equipment for recording and movie producing studios. During this period in 1930, he married the boss's secretary, Hazel. In 1932 they had a daughter.

In 1941 Dal transferred to the Radio Division of Western Electric, where he was a radar engineer attached as a civilian to the Navy and Air Force in a liaison role in numerous places in the Eastern U.S. In 1942 he was assigned to an Air Force anti-submarine squadron and served in Newfoundland, Britain and North Africa. In late 1943 he returned to New York where he was the supervisor of field engineers going into the Pacific Theater.

One of the field engineers that Dal supervised had long had a dream of returning to Portland and to establish an FM station. Dal agreed to join him and at the conclusion of the war drove from New York to his home in California, via Portland. At that time, however, Dal stayed with his recording studio job. Finally, in 1946, Dal came to Portland to join Stanley Goard in starting KPFM radio. Since this was the start of FM broadcasting, times were hard financially so he became a manufacturer's representative for Neeley Enterprises, a distributor of electronic components. One of Dal's first accounts in 1947 was Tektronix, then located at 7th and Hawthorne. At the time, however, selling electronic components was difficult because there was really not much of an electronics industry. One day, Howard Vollum asked Dal whether Neeley was going to be able to successfully maintain an office in Portland, and Dal expressed some doubt. Then Howard said, "Well, someday we'll need a sales manager," and in May 1948 Dal joined Tek as sales manager. Dal was Tek's thirteenth employee (not counting the five founders).

Later Dal would say, "I had had contact with these people as a supplier of components. I had other job options, but what made me really want to be a part of what they were doing was their integrity."

TEKTRONIX: THE ENTREPRENEURIAL PERIOD

PART 2: THE FOUNDING

Tektronix was founded on January 2, 1946, to produce oscilloscopes of unique and advanced design. The premises of the firm were the corner store of one of the founders, Jack Murdock. To support the firm through the design period, a separate company was formed to sell and repair electrical appliances.

The principal owners of the firm were Howard Vollum and Jack Murdock. Howard had been involved during the Second World War in advanced radar design and application work in England and the U.S. and had twice received the Legion of Merit award for his work. Jack had employed Howard in his appliance store before the War.

The first product, the 511, took a year and one half to develop. This was a hard period for the firm, as the retail appliance store did not do well. One of the founders lost his nerve and left, taking the retail operation. He was replaced by two other men, bringing the total number of partners to five: Howard, Jack, Miles Tippery, Milt Bave, and Logan Belleville.

The 511 incorporated many of the advances in radar circuitry that had been developed during the War, including automatic triggering. The scope was calibrated to an accuracy of ± 5 percent, had a good bandwidth, and weighed 65 pounds; preliminary estimates suggested that it would cost under $400 (all expenses). It used a CRT tube produced by the Dumont Company. Dumont was also the principal competition, although their product was uncalibrated, did not trigger automatically, weighed 200 pounds, and cost $2000.

By mid-1947 the first oscilloscope was ready for sale. The founders gathered to decide upon how best to sell this new product.

TEKTRONIX: THE ENTREPRENEURIAL YEARS

PART 3: THE FIRST FEW YEARS

In mid-1947 Tektronix offered the 511 for sale at a price of $595 (cost plus a "fair" profit). The 511 featured automatic triggering, calibrated readings, high accuracy, good bandwidth, and relatively light weight. The primary competition was a product without calibration and triggering that sold for about $2000.

Early sales were handled by sales representatives, but by 1950 Tek began to set up its own field offices in order better to channel product design information to the design engineer. The Field Engineers were chosen from factory personnel for their technical abilities and were directed to place first priority on restoring malfunctioning instruments to service. The home office regularly air-mailed replacement parts and charged cost plus a small margin for the replacement parts. However, neither the Field Engineers nor the factory personnel seemed to be able to provide much information on how the products were being used; no information system existed that would tell who bought how many; and manufacturing and sales forecasts were consistently inaccurate.

In order to maintain product leadership, a team of men from the Portland area was assembled. The engineers, as well as other employees, were not sought out but rather were hired only after lengthy interviews and written and manual tests of ability. Often the selection process would stretch over a period of several months. Friends and relatives of existing employees were given preference in the hiring process.

In general, the new engineers each strove to be identified with a product, and a steady stream of new products resulted. During this period, individual work teams were often fiercely independent, and occasionally the tools and designs of rival groups disappeared during the night.

During this period the founders were familar sights. Howard Vollum in particular walked about and was known for asking a favorite question: "why are you doing it that way?" Howard also taught electronics courses for employees in perhaps a throwback to his NYA days before the War. Every now and again an engineer angered at some comment or decision of Howard's would storm into the office of Jack Murdock, who would listen quietly and sympathetically and smooth the engineer back to work.

During the late 1940's and early 1950's no significant competition appeared. The Dumont Company was engaged in a broad sweep of activities principally centering on production of televisions, establishment of broadcasting companies, production of television entertainment programs, and manufacture of radars and television transmitters. The R.C.A. Company was similarly distracted by other ventures. The Hewlett-Packard Company did not produce oscilloscopes at the time and shared with Tektronix a common distributor in California, Neely Enterprises.

By about 1952 a new crisis had begun to develop. The limitation on product advancement began to be components and not circuit cleverness. The CRT tubes purchased from RCA and Dumont were particular problems. The investment required to develop a CRT facility and hire the necessary industry experts, however, could break the small company.

Another problem also began slowly to develop. The oscilloscope was proving to be a ubiquitous instrument indeed, finding uses in a wide variety of applications. The Field Engineers, however, were not in a position accurately to gauge market sizes or even to specify how the products were used once sold. The FE's could, however, speak for the customers in specifying in detail the performance and feature requirements needed. Since each instrument was designed to perform within specific parameters, it increasingly seemed important to determine with precision the nature and sizes of the markets involved or else find a way to design more flexibility into the instrument. Another alternative was for the company to focus only on selected segments and diversify into other instruments based on the success of such products as the 105, a square-wave generator.

TEKTRONIX: THE ENTREPRENEURIAL YEARS

PART 4: THE EARLY 1950's

In late 1952 Tektronix commited itself to producing its own CRTs. The principal persons involved in the effort were Derrol Pennington (a biochemist who had taught at a medical school for the previous six years), Jean Delord (a physics teacher at Reed who at first worked only during summer breaks), and John Griffin (a glass blower). None had expertise with CRTs, but they were given total responsibility for the task.

The principal method for developing the CRTs was brute force. In Derrol's words:

> "We worked hard making the first tubes. We had to succeed. But we could move much more quickly then. We would make a gun during the day, insert it into a tube, then put the tube on a pump to pump all night. We would test it the next day, design a new gun and repeat the cycle day after day. Over time that sort of schedule was tiring, but it was thorough and effective. Every idea got tried out."

And, typically, at a key moment Howard Vollum made a suggestion--to try a helix shaped accelerator--which revolutionized CRT technology.

Tektronix by that time also made other components: transformers, capacitors, and instrument panels.

The new Tek CRTs were principally used in a new line of plug-in scopes, the 530 series, which were flexible and could be adapted to a wide range of customer needs. The 535, introduced in 1954, was so flexible and of such quality that it sold steadily for 22 years.

All suggestions that the firm diversify into other product lines were rejected by Howard Vollum who preferred to stick with oscilloscopes as long as the growth and profits were there.

By the early 1950's Tek also began to be known for its innovative personnel practices, including: profit sharing, reluctance to fire employees, good working conditions, free coffee, few status symbols, informal dress styles, company newsletters and magazines, open cash boxes in the cafeteria, open stock shelves in the engineering areas, area representatives kept informed of company business, employee development, promoting from within, encouragement of friends and relatives to work at Tek, a full-fledged human relations department, open offices, and no reserved parking spaces.

CONSOLIDATED FINANCIAL STATISTICS

Calendar Years

	1956	1955	1954	1953	1952	1951	1950	1949	1948
NET SALES	16,061	8,651	7,294	5,935	5,540	4,022	1,206	742	257
EARNINGS	2,293	822	798	395	490	388	117	135	26
% of Sales	14.3%	9.5%	10.9%	6.7%	8.8%	9.6%	9.7%	18.2%	10.1%
Per Share	29¢	10¢	10¢	3¢	4¢	3¢	1¢	1¢	0.3%
INCOME BEFORE INCOME TAXES	5,021	1,779	1,733	1,367	1,737	1,279	246	236	41
% of Sales	31.3%	20.6%	23.8%	23.0%	31.4%	31.8%	20.4%	31.8%	16.0%
ANNUAL INVESTMENT IN FACILITIES	784	238	174	472	200	304	75	13	3
FACILITIES	2,256	1,482	1,247	1,073	604	404	100	25	12
DEPRECIATION EXPENSE	146	95	72	49	38	18	2	2	--
ACCUMULATED DEPRECIATION	417	276	182	110	61	23	5	3	1
PAYROLL BEFORE PROFIT-SHARE	3,950	2,212	1,614	1,245	1,120	301	282	176	113
EMPLOYEE PROFIT-SHARE	2,140	1,585	857	794	638	330	77	46	--
Employees at Year End	1,241	665	501	385	359	321	109	77	32
COMMON SHARES OUTSTANDING*	7,980	7,980	7,980	12,000	12,000	12,000	12,000	12,000	8,820
CURRENT ASSETS	5,470								
CURRENT LIABILITIES	3,679								
WORKING CAPITAL	1,791								
INVENTORY	2,464								
LONG-TERM BORROWINGS	--								
TOTAL ASSETS	7,309								
SHAREHOLDERS' EQUITY	3,630								
COMMON SHARE CAPITAL	266								
RETAINED EARNINGS	3,364								

(DOLLARS AND SHARES IN THOUSANDS)

EXCERPT FROM TEK TALK DECEMBER 1960

Ideas That Have Built Tektronix:

Believing that Tektronix owes its growth and stature not only to the research, engineering and productive skills of its people but also to the unique and vigorous ideas of its leaders, Tek Talk has begun a search to learn just what some of these ideas are.

All too often, because we've grown big fast, we lose track of these philosophies. Often they become hearsay, and sometimes even distorted, but still they are a pervading influence.

The first interview is with President Howard Vollum.

Tek Talk: We hear a lot about the "Tektronix philosophy." Just what is that philosophy?

Vollum: It's more an atmosphere than anything else. We try to give the maximum amount of responsibility to everyone--depending on what his job is. It's preferable to do that rather than set up a series of rules or laws.

Here, it's the responsibility of each person to do as he sees fit, within the framework of his job.

Although some things we do are governed by our job-for example, how we must dress--others things like common parking facilities, open cash boxes, trusting people to do their own timekeeping, these are things common to all of us as human beings.

We prefer not to have a series of status symbols--two more feet of office space when you get promoted, then a rug with the next promotion, then a pad under the rug. . .

Tek Talk: Do you feel people have no need of status symbols?

Vollum: The needs of individuals differ. We try to meet those needs reasonably. I believe people who do have to rely on status symbols are insecure. My experience has been that the most valuable people are those who don't have to.

In any case, it's a matter of degree. If it doesn't interfere with others, we don't pay too much attention. The big problem is, once you get this status thing going, it gets competitive.

Some newcomers may mistake lack of status signs here for lack of position or authority. This is not so. . .

Your real status is the status you've earned--and when you've really earned it, you don't need the symbols.

Tek Talk: How much does our atmosphere contribute to the company's success?

Vollum: It's hard to make a formal assessment, but many customers have told me they like to deal with us, and that if our product and that of another company were equal they would still do business with us because of our attitude toward service and quality of product.

The willingness, for example, of our field engineers to do more than is called for is quite an important thing. . .

Tek Talk: From what does our attitude of service and quality stem?

Vollum: One factor is that good morale tends toward good products. We don't ever want to let the customer down.

I'm convinced that almost everyone wants to do a good job. The percentage who do not is very, very small. One of the biggest causes of frustration is the inability of a person on a job to meet his own standards. No one knows better than he himself if he is or isn't meeting them. . .

Tek Talk: How important is backing up each employee with all the equipment he needs?

Vollum: I don't know that quality depends on equipment. You can go overboard on this very easily. Several unsuccessful companies I know of concentrate more on ways to do things than the atmosphere to do them in.

Often you hear, "If only we had this or that machine. . ." We have to guard against this attitude.

Once again, it's a matter of judgment. You can pay a tremendous price for having too little equipment--and you can decrease your profitability with an excessive amount. Often, here because we're growing and changing so fast, the life of equipment is short as to actual usefulness.

Buildings are no different. Inefficiency results from having too little space. Yet they're pretty costly to build and maintain. We're doing our best to steer an optimum course in our present building program.

What is really needed to do the job? This is an extremely important question to work on.

Tek Talk: Is it hard to keep the Tektronix atmosphere as we grow bigger?

Vollum: It's a lot harder to maintain the atmosphere, just as it must be in any company of any size, but it's still possible. Sometimes growth is used as an excuse for lack of a creative atmosphere, just as, "If only we had this or that machine" is.

Or at Tektronix we may hear, "It's not as nice as it used to be, but that's the price we must pay for growth. . ." It's a convenient excuse, but not necessarily true.

Keeping our atmosphere can be done, but it requires hard work. A company accomplishes this goal almost automatically when it's small, because then everybody sees everybody else.

When it gets big, directly informing each other is difficult because the top people are insulated by the requirements of their job. The solution is to get the people who are in direct contact to act like the top people did at the start. This isn't easy, because the people we hire for this purpose have different backgrounds, outlooks and obligations to the company.

We feel that promoting large numbers of people from the plant to supervisory positions, even if some may not be quite ready, is better than hiring supervisors from outside. It gives each employee a feeling he has a chance.

Tek Talk: What about hiring staff from outside? There seem to be feelings both for and against.

Vollum: There are times when both sides are right, and I'd hate to see either in a dominant position. Some jobs require training--especially education--that it's hard for us to duplicate.

There are exceptions, but we can't count on them happening in sufficient numbers, and we can't expect to grow if we do.

However, sometimes there's a tendency for the grass to look greener elsewhere, and just because we and our people are unable to do something, we may feel there is a person somewhere outside who can. All too often this is not true. Our basic philosophy is to attempt to develop the abilities of our own people to meet our needs. Many things contribute to this development: Experience, natural ability to adapt, private study and reading, formal courses, Tektronix training programs. . .

Tek Talk: Does our attitude toward profit differ from other companies?

Vollum: I don't think we're much different from most well-managed companies.

It's easy to confuse long- and short-term goals, but we try to balance them. We can't do everything just to maximize the profit this year, nor can we put off the idea of making profit to never-never land.

We try to look ahead, and also to act now in the way that customers like to see us act. They don't expect us to give them anything. They expect to receive something of value for their money. By giving just a little more than they expect, we gain a great deal in dollars and good will.

Tek Talk: Could we be more efficient if we had a more highly structured organization?

Vollum: There is a very serious tendency in some areas to do too much time-wasting, but it's offset by the employees' willingness, energy and enthusiasm for work when the pressure is on.

Again, somehow we must come to a balance and compromise between the two extremes. Too much restriction brings on this attitude: "If they're going to make me act thus and so, then the heck with any extra effort. . ."
We have to be careful we don't destory morale. I don't think the problem of goofing off is true of anything like a majority, nor does anyone do it consistently, but some have more of a tendency than others.

Just because there are a certain amount of abuses in our system doesn't mean we should condone them. We should do all we can to see that they stop.

Such abuses don't produce happiness for the persons who indulge in them. The only happy persons are the ones who do good jobs and know it.

We don't want to give up the atmosphere in which each person is free to contribute as much as he can. Yet it's not fair for the creative person--who thrives on such an atmosphere as ours--to carry others who may take advantage of it. The individual supervisor should talk to these latter people.

We can maintain our atmosphere by educational programs, by setting personal examples, by counting it as a "plus" for an employee who does work hard. . .

Whatever faults we have, attempts should be made to correct them without the necessity of making them the subject of a new rule or law. It's easy to develop habits which can become insidious growths and can sap our strength very rapidly.

Tek Talk: Does growth of the company mean adding more rules?

Vollum: We do have to add rules when we grow bigger--or to express those we already have more formally. Everyone's needs are different, including the rules and regulations optimum for him.

There is an optimum number of rules which gives a maximum of freedom. No rules at all means anarchy. Without traffic rules you probably couldn't have driven to work today. On the other hand, it's bad to have rules that are disregarded.

We have a general policy of permissiveness. Management people differ in their approach. Some are more authoritarian. Some only seem to be--and vice-versa.

There are different styles in management. A person is best off in his individual style. When you try to put everyone in the same mold you have trouble. We all can still have the same goals and so on, but just take a little different route to reach them.

Some people prefer one type of management in a company, some another. . .

Tek Talk: How much individual difference will our system tolerate?

Vollum: We couldn't have dishonesty, in the broad sense--persons who may say one thing and do another. I don't think we can stand much in the way of alcoholism either. These are the basic things. . . Also, actual insubordination is a problem for the supervisor. It indicates the employee's basic insecurity, and his need for help.

By contrast, take a person who maybe is too outspoken at the wrong times. There is no disgrace or moral failing to that, only bad judgment.

The more individual differences we can tolerate, the better off we are.

TEKTRONIX: THE 7000 SERIES STORY

Note: references to sales performance by years refers to fiscal years and not calendar years. (Tektronix fiscal years end on May 31).

Part 1: Prelude

On June 5, 1962, Howard Vollum, co-founder and co-owner of Tektronix, re-entered Company affairs in a decisive manner. Although sales had doubled in the last three years to a level of $60 million, the return on equity had dropped from 34 percent to 19 percent with no prospects of improvement in sight. Further, the Company had recently been stung by the actions of its arch-rival, Hewlett-Packard, and a tiny firm known as Lumitron. These firms had both announced in 1962 sampling oscilloscopes which represented significant advances in the state of the art; both the H-P and the Lumitron products were elegant approaches to the problem of capturing a high speed signal, while the Tektronix product response (which required the hiring of expertise from outside the Company) was not only a year later, but it also got hung up in manufacturing and when produced showed an alarming tendency to destroy with large bursts of current whatever it was supposed to measure.

In any case, the Company seemed to be getting out of control, so Howard's first act was to edge out his dynamic and aggressive--albeit disorganized and abrasive--Executive Vice President (who had been running Company operations for the past four years) and take the reins himself. As events were to prove, Howard's reassertion of control was well-timed, for the following fiscal year, 1962-63, was a period of down-turn in the electronics industry although Tek came through with a sales increase of 16 percent (the 1963 annual report still called it the "year of the down-turn").

About a month after taking over again, on July 17, 1962, Howard presented plans for a thorough re-evaluation of Company problems, which he saw as primarily deriving from a lack of "horizontal flow of information among managers at various levels" which was causing "unnecessary duplication and. . .a frustration in trying to get things done. . . . ." Accordingly, Howard announced the formation of a "Management Group" consisting of nine principal officers who would each head up one or more ad hoc planning groups on topics such as the long-range building program, coordination of domestic and overseas operations, central vs. dispersed services, cost accounting procedures, training at all levels, and so on.

On November 30, 1962, the "Ad Hoc Committee to Recommend a Product Planning System for Tektronix" published its final six page report. Principal recommendations were:

1. The various segments (Marketing, Research, Instrument Design, Future Products, Manufacturing) should be adequately represented throughout the phases of planning and development.

2. Innovation should be encouraged. Adequate scope should exist for projects to be initiated within the departments themselves. An environment should exist whereby creative abilities are fully utilized.

3. Effort should be made to develop products consistent with our product goals that will open new markets both here and abroad.

4. Activities of the various departments should be effectively coordinated.

5. The Tektronix product line should contain the best of overall solutions to customer needs and the minimum harmful redundancies.

6. Tektronix products should be adequately tested prior to market to assure a maximum degree of reliability taking into consideration intended use of the product.

7. Instruments, accessories, and auxiliaries should be correlated throughout the various stages from development through production to assure appropriate availability and compatibility.

8. Marketing strategy (advertising, timing of announcements of new products) should be an integral part of product planning.

9. Those most directly responsible for product development should understand the product planning system and know how to use it.

10. The overall success of the product planning system should be evaluated and used to improve the system itself.

This Report also listed the activities necessary to be carried out by the total system for product planning and set up a Product Planning Strategy Group headed by Howard Vollum himself. A year later, in October 1963, this start was reinforced by a major reorganization of the Engineering function into five product related groups: Advanced Circuitry, Instrument Engineering, Cathod Ray Tube Engineering, Electron Physics Research, and Pre-Production Engineering. Somewhat later the manufacturing areas were also reorganized into separate product manufacturing and component manufacturing groups and the overseas manufacturing operations were integrated organizationally with domestic manufacturing.

The reorganization and the Product Planning Strategy Group must have had good effect, because by 1964 significant new oscilloscope models began to appear. Seventeen years after the first 500 series oscilloscopes, the 511, had been launched, Tektronix announced a new 500 series line of general purpose scopes: the 544, 546, 547, and 549. The 547 particularly represented perhaps a new "ultimate" in performance and is remembered fondly to this day for its sophistication, crisp and sharp display, and reliability based upon years of product development in circuitry, vacuum tubes technology, mechanical design, and CRT displays. Also part of this new line was the 564, a storage oscilloscope of exceptional capability.

On February 20, 1964, Howard Vollum wrote a memo to his new Executive Vice President and new Engineering Manager outlining a next generation of scopes and then, well-pleased as we must imagine, he withdrew from daily affairs to watch sales and return on equity start rising again.

In 1965 a second new line of oscilloscopes, the portable 400 series was launched with great success, although Tek had had to be forced into developing the product line by the IBM company, (they had backed up their threats by setting up a 50 man engineering group to design oscilloscopes). In 1966 the Annual Report noted that the firm's substantial increase in sales (25 percent) was "in large part attributable to new instruments to meet unsatisfied needs of the computer and television industries."

A further triumph occured in 1965 when the 3A5 plug-in was announced. The 3A5 "searched for its own correct settings". . . . .a stunning programmable instrument whose capabilities would not be copied by competitors for ten or more years.

A final triumph was a military version of the 547, called the 647, which was fully transistorized and ruggedized.

Fiscal Year	Sales	Return on Equity
1959	$31.6 million	34%
1960	43.0	30
1961	50.3	24
1962	60.1	19
1963	70.5	16
1964	75.5	16.5
1965	81.1	16.5
1966	101.8	20.3
1967	129.0	19.8

TEKTRONIX NEWSLETTER

#114 Dated: June 5, 1962

On December 18, 1958, the directors of Tektronix decided that Bob Davis would be given the responsibility for the operation of Tektronix, thus taking over many of the duties which up to that time had been mine. It was the intention of the Board, and my own too, that Bob be free, within the general Tektronix philosophy, to operate as he saw fit. As you can see from the growth of Tektronix facilities, employment, the establishment of our Guernsey and Heerenveen operations and in many other ways his operation was effective.

It was my hope when Bob took over that in a few years I could devote most of my time to a number of personal projects in which I have a strong interest. As time went on, however, the rapid expansion of Tektronix brought with it many problems. Efforts to provide solutions to these problems resulted in decisions which appeared to me not in the best interest of Tektronix. I emphasize "appeared to me" since it is quite possible that I am wrong, and I know of no way to find out except to wait some months or years. I hope, however, that the impression is not made that my viewpoint was superficial. It may be incorrect but it was the result of much study and discussion. As a result of my effort to get an adequate basis for the evaluation of these decisions and, more importantly, their basis, there has been an increasing confusion in many people's minds as to whether Bob Davis or I was the chief operating executive. As you probably know, Bob and I have different managerial styles. Which is better or even more appropriate I cannot say, but in any case, Bob and I agree that we had to use one or the other, not both.

Since it was my duty as president to make the decision, I studied the problem to the best of my ability and reluctantly concluded that the best way to meet my responsibilities as I saw them was to take over the duties of chief operating executive. Under these circumstances Bob feels that he should step out rather than take a subordinate operating position. He has agreed, however, to stay on as a member of the Board of Directors. This seems to be an excellent way to benefit by the years of experience and many good ideas which Bob has.

Any change in top management brings up fears and questions as to future changes in organization, policies, etc. I have no plans for any sudden changes, in fact, the opposite seems most important. Any changes that do come will be the result of meeting needs as expressed by the people concerned, and will, whenever possible, be those recommended by the people concerned. When these changes affect various areas and conflicts come up, I will take the responsibility for the necessary decision. I would like to assure you that changes will be made only after as careful and thorough consideration as conditions permit.

I am confident that we have the abilities and willingness to work out policies and practices which will be to the benefit of all.

Howard Vollum
President

TEKTRONIX NEWSLETTER

#115 Dated: July 17, 1962

A little over one month has gone by since I returned to an active operational role in Tektronix management.

It seems appropriate that a report be made as to some of the activities which have taken place in that period.

As stated in the June 5 Newsletter, I have no plans for sudden major changes. Some changes, mostly of a preliminary nature, have been made. One of these has been the transfer of the responsibility of Hawkin Au's Company Planning group to Bob Fitzgerald. This enables Hawk and Frank Consalvo, who are working closely, to coordinate their efforts more easily.

One of the problems which I feel is not being well taken care of at Tektronix is the horizontal flow of information among the managers at various levels. This has at least two results. One is unnecessary duplication, and the other, a frustration in trying to get things done which must involve the cooperation of several areas. The logical starting place for an attempt to improve in this area is at the top.

The method which I have chosen to attack this problem is the formation of a group chosen from those people already reporting directly to me. This is called the Management Group.

The membership of this group at present is as follows: Byron Broms, Jim Castles, Don Ellis, Bob Fitzgerald, Guy Frazier, Jack Murdock, Bill Polits, Bill Webber, Howard Vollum.

As you can see, all areas of the company are represented, but certainly not equally. The choice of people for this group was necessarily a compromise between adequately representing all areas and viewpoints and keeping it small so that effective discussions could be obtained. The particular choice made may not be optimum but it was made after much thought and consideration. One of its principal functions is to study and recommend the organization and management which is best for Tektronix; therefore the present group may well be changed when those recommendations are made. At present we meet on Tuesday from 9:30 to 12 and Wednesday from 10 to 12.

The principal functions of the Management Group at the present time are as follows (not necessarily in the order of importance):

1. Be the principal two-way link between the Board of Directors, President and the operating managers.

2. Be the center for ad hoc groups formed to study and recommend solutions of problems affecting more than two areas of responsibility. (Items affecting only two areas should be solved by the two managers concerned.) The topics assigned to ad hoc groups may range from long-term items, such as optimum company organization, to problems needing only a single meeting.

3. Serve as a central focus from which flow the policies and decisions resulting from the ad hoc groups or the Management Group itself.

4. Serve as advisors for individual members of the group on their problems and problems brought to their attention.

5. Inform each other by means of formal, detailed, weekly reports regarding operations and plans of their respective areas.

6. Be well-informed individuals on Tektronix policies and plans, and communicate these to their areas of responsibility.

This is accomplished by the weekly reports mentioned in Item 5, the general discussions of problems and by setting aside portions of the meetings for hearing formal prepared presentations of important subjects. For instance, the July 17 meeting will hear a presentation on Long-Range Planning.

All of these functions are built around the principle of individual responsiblity, not group responsibility. To carry out this principle each ad hoc group will have a chairman who will be a member of the Management Group. He can choose members of the ad hoc group from anywhere in the company and use outside consultants if necessary. The chairman can delegate any or all of the detail work but remains accountable for completing the task and reporting to the Management Group.

I will be responsible for:

1. Defining the mission of each ad hoc group.

2. Naming the chairman.

3. Approving and disapproving recommendations of ad hoc groups. Except in unusual circumstances I will not approve recommendations which meet with opposition from more than one member of the Management Group.

4. Designating the method of carrying out approved recommendations and checking to see that they are accomplished.

Each member has made up a list of topics he would like to see studied by ad hoc groups. I am in the process of combining these into a single list which will be ranked in priority by the group at our next meeting. Some examples of the topics suggested: Long-range building program, planning for specific buildings, coordination of domestic and overseas operations, central vs. dispersed service functions, cost accounting procedures, training at all levels, patent policies, priority of various product areas, and many others of equal or greater importance. We hope to have ad hoc groups operating very soon.

When people act as members of ad hoc groups they act as designated representatives of Tektronix central management and not in their normal job capacity. All members of an ad hoc group have equal status as members of that group.

I hope the impression is not given that the Management Group and the ad hoc groups will solve all of the problems posed by a dynamic and growing company like Tektronix. My hope is that it will be able to hasten solutions of some important company-wide problems and further develop a climate which will encourage problem solving at all levels.

As you can see, the success of this effort depends on a high degree of cooperation from everyone. I am confident this will be obtained, and ask your patience and understanding for the times when things do not go as smoothly or rapidly as expected.

Howard Vollum
President

TEKTRONIX NEWSLETTER

#125 Dated: November 30, 1962

FINAL REPORT OF THE AD HOC COMMITTEE TO RECOMMEND A PRODUCT PLANNING SYSTEM FOR TEKTRONIX

Between September 17 and November 19, 1962, the ad hoc committee met twelve times. We published rough draft statements on the objectives of the system (October 3, 1962) and of the activities it would require (October 31, 1962). In response to these we received letters or had conversations with a number of employees who were interested in the development of a more effective product planning system.

On November 19, we decided that we had enough agreement on the general details of the system that it could be put into effect and the finer points worked out within the operating system itself.

Accordingly, Howard Vollum, President, authorized the preparation of this report as the statement of the intent and general details of the Tektronix Product Planning System.

PHILOSOPHY

Successful product planning results when individuals are enabled to use their creative abilities cooperatively to initiate and develop products in the best interests of the company and its customers.

Each individual directly concerned with the product planning process should know the long-range goals of the company as well as what is considered to be currently in our best interest. He has a right to expect that careful study by responsible and competent people will precede decisions about projects of interest to him.

Management needs to assure that projects considered essential to our success (current and long-range) are being carried out effectively.

The effectiveness of product planning and development depends upon the mutual confidence and respect displayed by those who create and innovate, those who make decisions for the company, and those who carry out projects.

OBJECTIVE

An effective product planning system should assure that: Projects are effectively carried out that have been carefully studied by responsible and competent people who have decided that they are (1) in line with long-range goals of the company, and (2) in the best interest of our world-wide customer group and of Tektronix.

POLICIES

We believe the possibility of reaching this objective will be increased if the following policies are used as guides.

1. The various segments (Marketing, Research, Instrument Design, Future Products, Manufacturing) should be adequately represented throughout the phases of planning and development.

2. Innovation should be encouraged. Adequate scope should exist for projects to be initiated within the departments themselves. An environment should exist whereby creative abilities are fully utilized.

3. Effort should be made to develop products consistent with our product goals that will open new markets both here and abroad.

4. Activities of the various departments should be effectively coordinated.

5. The Tektronix product line should contain the best of overall solutions to customer needs and the minimum harmful redundancies.

6. Tektronix products should be adequately tested prior to market to assure a maximum degree of reliability taking into consideration intended use of the product.

7. Instruments, accessories, and auxiliaries should be correlated throughout the various stages from development through production to assure appropriate availability and compatibility.

8. Marketing strategy (advertising, timing of announcements of new products) should be an integral part of product planning.

9. Those most directly responsible for product development should understand the product planning system and know how to use it.

10. The overall success of the product planning system should be evaluated and used to improve the system itself.

ACTIVITIES

Important: This is a list of the activities to be carried out by the total system for product planning. Various departments must work together if our product planning is to be effective. Many of the activities listed are already being done by various departments. They will continue to be done as at present. We hope that most of the new activities can be carried out by existing departments. Those activities that do not fit into the present organization will be carried out by the Strategy Group or the Implementation Group to be described in the last section of this report. Here is the detailed view of the activities making up product planning.

I. <u>ACTIVITIES RELATING TO PRODUCTS</u>

A. <u>To provide a point where people may submit proposals and to initiate proposals for</u>:

1. New products.

2. Major revisions of current products.

3. Technical research projects (aimed at exploring technical problems rather than producing additions to the product line).

B. <u>To study or request departments to study and report on</u>:

1. Feasibility of specific proposals.

2. Customer needs; uses of Tektronix products.

3. Profitability of current products by items.

4. Estimates (developmental costs, proposed selling prices, ease of selling, areas of application, order rates, profitability).

5. Competitors' products: Specifications, effect on our sales, customer reaction to, etc.

6. Total product line: Compatibility and interrelations, duplication, etc.

7. Technical information about:

   a. Engineering design problems.

   b. Manufacturing problems.

8. Present commitments and to decide for which inventions patent applications should be made and in what countries.

C. <u>To evaluate proposals and authorize (or disapprove)</u>.

1. To authorize commitments of personnel and funds to:

   a. Exploratory projects.

   b. Technical research (investigation of specific areas of interest. For example, semiconductor devices, automated measurement systems).

   c. Development of a new product.

   d. Projects for major revision of current products.

2. To authorize an addition to or withdrawal from the product line and to decide the best timing.

3. To decide about compatibility within the product line.

   a. To decide whether and on what new products compatibility with existing instruments will be sacrificed.

4. To decide whether or not to provide modification for instruments already in use.

5. To decide the warranty and the service policy that will accompany an instrument added to the line.

D. <u>To develop coordinated plans for authorized projects</u>.

1. To assign and change priorities for various stages of projects.

2. To set target dates and establish review points for amount of effort and costs involved in various stages of projects.

E. To increase inter-departmental coordination by assuring that information is distributed about projects and products.

1. Information to each department about similar, related, and interlocking projects elsewhere in the plant.

2. Information about individually initiated exploratory projects.

3. Information for the field about new products with emphasis upon potential uses, design concepts, compromises.

4. To recommend changes in deployment of engineering and research manpower.

F. To assure that prototype products are demonstrated to the field and to selected customers whose opinions are valued.

G. To advise regarding the use with Tektronix products of equipment made by other manufacturers (pulse generators, sweep generators, etc.) To make such information available to the field.

H. To compare obtained versus expected results by establishing criteria that will insure review and re-evaluation when appropriate of:

1. Status and progress of all projects in development.

2. Status and future of all products currently marketed.

I. To recommend changes of types or classes of products to the President.

II. ACTIVITIES RELATING TO THE PRODUCT PLANNING SYSTEM.

A. To educate in the use of the system.

1. To develop consistent definitions for such terms as "product", "accessories", "components", that will be agreed to by departments throughout the company.

2. To prepare and keep current a description of the steps and phases in product planning.

3. To see that information about how the product planning system works is available to any who need it.

4. To prepare and keep current a linear chart that records the decision-making structure for product planning.

5. To develop an effective system of meetings with clear agreement on the purposes of meetings, the responsibility of individual members for agenda, minute-taking, etc.

6. To develop a system for evaluating the meetings and the effectiveness of the members.

7. To publish advance notice of topics on the agenda that various departments might wish to influence.

8. To record decisions (such as authorizations and disapprovals) and the reasons for the decisions, and to report these to people involved in product planning.

B. To measure the effectivenes of the product planning system.

1. To secure information about customer acceptance of new products.

2. To determine whether the needs of departments (regarding product planning activities) are being met.

3. To secure information to enable evaluation of our methods of developing a new product. Information about costs, problems, successes, etc., in the research, design engineering, and manufacturing phases.

C. To recommend changes in the product planning system to the president.

OPERATING DETAILS

Accountability: Ultimate accountability for the effectiveness of product planning at Tektronix rests with the President. He delegates responsibility for certain results to the Vice President, Operations, and holds him accountable for achieving them. Likewise, delegation and accountability pass along the managerial line. Nothing in this system should be interpreted as changing this basic principle of accountability.

Communication: Product Planning Representatives will be located throughout the company. They will be contact points for any person who wishes to initiate suggestion for new products or major revisions of existing ones. The Product Planning Representative will consult with appropriate people to evaluate such ideas. He will let the initiator know the results. If preliminary screening indicates the idea is worth more consideration, the Representative will follow through to make sure it is appropriately described and presented to the Product Planning Strategy Group.

The Representatives will also participate as members of:

1. The Product Planning Strategy Group, chaired by Howard Vollum, or

2. The Product Planning Implementation Group, chaired by Bob Fitzgerald.

Advance agendas as well as minutes of both groups will go to each Representative.

Overlapping memberships in the two groups should provide more background than could be given in minutes and written reports.

Product Planning Strategy Group: This group will consider topics of longer range concern and those most directly related to external relations such as with customers, the military, etc.

This group will advise the President on decisions listed under I-C in Activities. These are such as: (1) authorization of projects or products, (2) authorization of addition to or withdrawals from the product line, (3) deciding about compatability within the product line, (4) deciding about modification for instruments already in use, and (5) deciding about warranty and service policy.

This group will have an executive assistant (a member of the President's staff) who will prepare agendas, see that decisions and supporting reasons are recorded and communicated where needed, assure that materials and displays for the group are developed and distributed, supervise the correlation of information from different sources, ensure that matters requiring review are brought up at the proper time with the necessary information and other tasks as the group or the President shall determine.

Product Planning Implementation Group: This group will help the Vice President, Operations, with his responsibilities for implementing decisions made by the President with the Strategy Group. They will develop coordinated plans for authorized projects, review the status of various projects and products, assure that information is distributed that will increase intra-departmental coordination, and other tasks to be agreed upon.

Members: The following are Product Planning Representatives. Their assignments to the groups are as shown.

Product Planning Strategy Group

Chairman: Howard Vollum

Executive Assistant: Doug Cure'

Byron Broms	Derrol Pennington
Frank Consalvo	Bill Polits
Jean Delord	Jack Rogers
Egon Elssner	Dick Ropiequet
Bob Fitzgerald	Oz Svehaug
John Kobbe	Norm Winningstad
Mike Park	

Product Planning Implementation Group:

Chairman: Bob Fitzgerald

Erwin Ashenbrenner	Frank Kopra
Byron Broms	Mike Park
Jack Cassidy	Derrol Pennington
Frank Consalvo	Bill Polits
George Edens	Bill Walker
King Handley	

Further Details: Will be worked out by the managers, representatives, and groups as the system operates.

Byron Broms
Bob Fitzgerald
Bill Polits
Howard Vollum

TEKTRONIX NEWSLETTER

#150 Dated: October 7, 1963

For several months now we have been studying ways to improve our engineering effectiveness. Study and discussion brought out clearly the desirability to consolidate our design efforts. To bring about this integration we have combined all product design and developmental efforts into a single organization. Bill Polits has been assigned the responsibility for overall Engineering activities.

Our success is highly dependent on our ability to bring out advanced products at the right time. Engineering will have a prime responsibility for product and project planning. To this end, planning activities within Engineering are being established. In light of these the Product Planning Strategy Group will be reassessed. Howard Vollum, Bill Polits and myself will form the nucleus of a group that will re-evaluate the activities of the Product Planning Strategy Group and provide during the interim a review of our technical programs.

The new Engineering group will include the activities carried on in Research and Future Products and will embrace the Cathode Ray Tube Design Engineering now carried on within Manufacturing. Engineering will now consist of five departments, described briefly below:

Instrument Engineering: This group will be responsible for the design and development of all products including instruments, accessories, cameras and scopemobiles, and the technical content of the related manuals. It will have a primary responsiblity in product planning. It will contain its own supporting facilities. The group will have the responsibility for a product from the idea to the stage where it is suitable for manufacture.

Advanced Circuitry: Will be responsible for investigation and development of new circuits. It will explore developments and demonstrate their application to new products. Products resulting from this activity will be transferred at an appropriate stage of their development to Instrument Engineering. This group will also have an important role in planning products and programs and will fulfill a technical staff requirement for Bill.

Cathode Ray Tube Engineering: Cathode ray tube development efforts formerly carried on in Future Products together with design efforts in the present Cathode Ray Tube Engineering group will be assigned to an overall Cathode Ray Tube Engineering group. This group is now responsible for the design and development of cathode ray tubes and display devices. Some projects with Research relating to cathode ray tubes will be continued there until they are completed or until it is determined that they are best reassigned to Cathode Ray Tube Engineering.

Electron Physics Research: Research will now be called Electron Physics Research. It will have a similar mission to its present one. The group will be responsible for investigation of the basic physics of new devices and the exploration and development of basically new devices. They will do physics and materials research on a project basis in support of other programs. Programs relating to physics of display devices will be carried on in Electron Physics Research and be implemented at the appropriate stage of their development in Cathode Ray Tube Engineering.

Pre-Production Engineering: Will assist Instrument Design in the preparation of products for production. They will be responsible for building engineering models, preparing drawings, performance specifications, parts lists, reliability studies and environmental testing. They will contain component evaluation and have cognizance of component design and see to the assurance of their specification and availability to new products. They will provide the major liaison between Manufacturing and Engineering regarding products. They will provide design for custom and special instruments.

Although there are specific departmental responsibility assignments for basic research and advanced circuits, it in no way is intended to exclude investigation into advanced products and methods from the other groups. Each group will be expected to carry on exploratory work.

Because many individuals are involved in the above changes and it will take time to firm up responsibilities within these groups, Bill Polits has asked me to announce for him appointments of the managers of the Engineering departments:

Pre-Production Engineering	Lang Hedrick
Advance Circuitry	John Kobbe
Cathode Ray Tube Engineering	Norm Winningstad
Electron Physics Research	Jean Delord
Instrument Design	Jack Rogers

Bill Polits will have, in addition to the above, an administrative staff. Within a short time Bill will announce Engineering assignments among these groupings and will expand the definition of the mission of these groups for those whose work requires further explanation. Thank you.

Robert G. Fitzgerald
Vice President, Operations

TEKTRONIX: THE 7000 SERIES STORY

PART 2: HOWARD VOLLUM'S PROPOSAL ON FEBRUARY 20, 1964

INTER-OFFICE COMMUNICATION

To: Bill Polits
Bob Fitzgerald

Date: February 20, 1964

From: Howard Vollum

Subject: New Tek Wide Band General Purpose Oscilloscopes

As agreed at our meeting on February 12 I have written down my suggestions for a new generation of Tektronix wide band general purpose oscilloscopes. The oscilloscopes described here are proposed as replacements for 530, 540, 550 and 580 series. Because of the widespread use of the letter series plug ins I suspect the 540B, 544, 546, and 547, and the letter series storage scope will be in production for sometime. No effort is made in this memo to consider other important segments of our line or any extension of it.

The ideas included in these proposed instruments have come from many people. My purpose in presenting them is to stimulate thought and have a starting point for discussion.

The following basic instruments are proposed:

1. 20-30mc single beam

2. 50mc single beam

3. 100mc single beam

4. 30-50mc single sweep dual beam

5. 30-50mc dual sweep dual beam

6. 75-100mc dual sweep dual beam

All of the instruments would share the following features, not necessarily all in one instrument though.

1. Accept 560 series plug-in.

2. Split screen storage with remote erase, supplemented, if possible, by a "write through" ability.

3. Powered operation of sweep speed, vertical sensitivities, beam position, trigger polarity and trigger level. Operation of these controls would be any of the following ways:

    a. Small remote box on cord.

    b. Push buttons on probe.

    c. Easy to turn control knobs on plug in (small knobs would ease panel crowding).

    d. Sensing of signals for amplitude and/or repetitive rate.

    e. Punched cards (could also operate auxiliary input and trigger selector unit).

4. Easily changed, graticule projected on the CRT phosphor.

5. In addition to the traces and graticule the following would be visible on the CRT phosphor at the same brightness as the stored trace.

    a. Sweep time/on (one or both sweeps).

    b. Sweep uncal. signal.

c. Sweep magnification.

d. Vert. sensitivity for appropriate number of channels (could be four).

e. Vert. sensitivity uncalibrated signal for each channel.

f. Polarity for each vertical channel.

g. Digital readout of time and amplitude (see 6).

6. Digital readout of time and amplitude difference between any two selected points on a stored trace.

7. Provision for easy mounting of a 1-1 camera which photographs the back of the CRT screen. Automatic exposure and processing would provide a black on white paper print ten seconds after the exposure was started.

Now, in an effort to give some of the background and suggest possible ways of accomplishing these goals, let us consider in more detail the numbered points.

1. The 560 series plug-ins are widely used, convenient in shape and would form the essentials for a complete line of low frequency and sampling plug-ins for the new series of instruments. We could thus concentrate on the necessary new wide band and power operated plug-ins.

   The single beam instruments proposed would be intermediate in size between the 560 and the 540 scopes and would have vertical and sweep output amplifiers of appropriate characteristics built in. 560 series would connect to the output amplifiers via appropriate attenuator-DC level changing circuits.

   If the sweep output amplifier had magnifier capabilities controled by reed relays or diodes, only two sweep plug-ins would be needed; one with sweep delay and one without. Faster sweep could be available if necessary on the 100mc instrument by means of faster sweep output amplifiers and appropriate magnifications. The dual sweep dual beams could use either of these units in either hole thus giving excellent sweep flexibility. It could, for example, have sampling and real time simultaneously available in one scope. The first five of the proposed instruments would replace ten existing instruments. The 75-100mc dual beam would, I believe, be an excellent addition to the line as judged from the popularity of the 580 and 555 series.

I would suggest making 5 and 6, and perhaps 4, (the dual beam instruments) in 17" wide units so that the same instrument would serve for normal and rack mounts. The 129 has four plugs-ins mounted in this fashion.

2. Having used a 564 for some time now in my extra curricular electronics work at home, I am more convinced than ever that at some time in the next few years all lab-grade general purpose oscilloscopes will have a storage ability. This may entail in the beginning some loss of conventional mode writing rate but since the only loss is in single shot photography it would not seem too serious. For respective signals the "integrate" storage mode gives easy viewing and photography of fast signals.

The split screen can be considered an extension of the dual beam or dual trace concept since it enables one to compare two signals, but without the necessity for them to be happening at the same time. The popularity of multi trace and dual beam instruments shows how valuable signal comparison facilities are.

In addition to the split screen comparison technique I feel we should work hard to achieve the ability to display a non-storing trace at the same time a stored trace is being viewed so that superimposed comparisons could be made. Perhaps a combination of increasing the range of non store to store, contrast enhancement techniques, and the development of equal brightness for differing writing rates by varying CRT beam current inversely with signal writing speed, could make "write through" practical. The idea of a writing beam of relatively uniform brightness is an old one and one which many customers have suggested. Perhaps it is worth a look now to see what could be done in this area.

3. The ease, speed and convenience with which a scope can be operated is becoming increasingly important. It now seems possible to provide remote powered operation of the essential controls with a flexibility and low enough extra cost to make this feature attractive to a wide range of users. The use of power operation is not to merely make the knobs turn easier, but to permit operation from a more convenient position, from perhaps a punched card or even by the signal itself.

The basic feature needed in the scope or its plug-ins would be the replacement of the complex multi section sweep and attenuator switches by a group of reed relays, conventional relays and diodes. Since these components can be placed throughout the instrument directly in their associated circuits rather than concentrated on the rotary switches as now used, better mechanical and electrical layouts would be possible. With panel space at a premium the small, easy to turn switches controlling the powered system would be a great benefit. Since the position is indicated on the CRT face, a very small knob and scale could be used (see 5).

The possibility of changing sensitivity or sweep speed from a small control box on a cord, or from buttons or switches on the probe would seem attractive. Four buttons on the probe might be labeled; Increase Sensitivity, Decrease Sensitivity, Increase Sweep Speed and Decrease Sweep Speed. Each time a button was pressed the appropriate circuit would change one step with the result always shown on the CRT face. Provision could be made for insertion of circuit boards in the plug-ins which would sense the characteristics of the signal and operate the switches which set the sensitivity and/or sweep for optimum observation of the trace. I feel that vertical sensing would be valuable, but except for certain cases, sensing the sweep would be difficult and not too desirable.

When oscilloscopes are used to check to check out complex electronic devices such as radars or computers, etc., it would be very desirable to be able to set the controls quickly and without error to the correct positions. With powered controls this would be easily done by a punched card. If a plug were provided on the plug-in connecting directly to the relays and diodes the contacts made through the punched card could operate the appropriate circuits and set up the scope for a particular measurement very quickly. It could change the characteristics from one end of a range to the other without going through any intermediate positions. A very large number of operations could be made without the problems of mechanical wear present in rotary switches. An auxilliary input and trigger switching box, also controlled by the cards or perhaps by a punched tape, could make a long succession of observations rapid and error free.

4. With non-parallax graticules now standard, the need to provide a more flexible method than a permanently printed one on the tube is evident. A very simple projection system using a glass photographic negative which can be easily changed as graticule seems an easy answer. An inexpensive f3.5 lens requires only a small port of flat, clear glass in the CRT envelope. For a 70mm lens the opening need be only 2cm in diameter. 10w or so of light seems ample since only 100 sq. cm needs to be illuminated. The same projection system can also project the data referred to in the next item.

5. The concept of having indications of the sensitivity, sweep rate, etc., visible on the CRT face or in the CRT area is obviously a desirable one if it can be achieved at reasonable complexity and cost.

   If a projection system is to be used for the graticule it seems logical to use the same system to project these data also. The problem comes in transferring the switch positions from the plug-ins to the film plane of the projection system.

   In the scheme suggested here the sensitivities of the various channels and sweep speeds would be on concentric dials having transparent numbers. Each dial is one row of numbers larger than the preceeding one. When projected on the CRT screen through a suitable mask, a column of numbers, one for each channel and sweep would be seen at the top of the tube. Other information such as polarity, uncal., etc., would be projected through the same lens but each illuminated by a separate small bulb which could be switched on or off.

Now consider the means of turning the dials in the projector from the plugin unit panel. For this I am proposing a stepping servo which can also serve to position the control switches of the powered controls mentioned in item 3.

The largest number of positions needed is on the sweep dial. Thirty-six positions in a 1, 2, 5 sequence will cover 10 picosecs/cm 10 secs/cm. This seems adequate for the present at least. On the vertical, luv/cm to 100v/cm takes only 24 positions.

The basic idea is to standardize on some agreed voltage to represent each step. For example, use 1 volt / step. Then on the sweep scale 15v would represent lusec/cm, 24v lusec/cm, etc. These voltages would be obtained from a precision divider on the sweep switch. The dial in the projector has a 36 position divider, and a step servo to position it to the voltage of the sweep switch. If all dividers were powered from the same supply, voltage variation would have no effect. The only requirement would come on the precision of the dividers. For 36 positions a little better than 1 percent is needed. These, I believe could be large production devices consisting of a small ceramic disc on which a pattern or resistive metal film would be deposited. Metal contacts could be silk screened or otherwise put on connecting with the resistive pattern. It would seem possible to make a fairly simple automatic machine to grind or otherwise adjust each step of the divider to be equal resistance. The absolute value of each step would not matter within wide limits.

The actuator could take several forms. A simple one consists of two solenoid operated claws which move two ratchets in opposite direction. Thus operating one solenoid with a pulse would move the dial or switch one segment forward for each pulse. The other solenoid would move the dial back a segment for each pulse.

The voltage for the dividers would come from a pulser in the scope operating at a few cycles/sec. The error signal from the dividers would be amplified and applied to the solenoids to position the dividers and dials to a null.

Bob White thought up an actuator which steps like a ratchet but has no ratchet wheels and would seem to be excellent for this application.

The same components and pulsed power source could be used to position the switches in the plug-in from a remote control box, as suggested in 3.

This system makes it easy to take the attenuation of the probe into account automatically for 10X probes. Since three volts represent three steps and therefore 10 times on a 1, 2, 5 scale, it would seem easy to have the locking collar of the BNC on the probe have a small protrusion attached, which would actuate a switch which would add three volts to the output of the divider and thus cause the dial in the projector to decrease the indicated sensitivity by ten. A 10X magnifier on this sweep could be indicated by a contact on the Mag. switch.

6. The idea of being able to read digitally selected amplitudes and times on a waveform has been suggested many times. The problems of actually sampling amplitudes at selected times is very difficult for fast signals. Fractional name second samples have very little energy and thus need repetitive signals. The problem of seeing the actual spot being sampled is difficult too, since very small differences in time between the sampling and viewing pulse cause large errors. In order to make the mark visible on a wide range scope the viewing pulse must be lengthened as the sweep is slowed down thus requiring additional complications.

A scheme suggested for the scan conversion oscilloscope might be a solution. The basic idea is to measure on the stored trace. This is made possible by the signal obtained when the storage surface is scanned with a beam. Briefly, the idea is this. Store the image to be measured. Change the sweep speed by a "Readout On" switch to cause it to scan at say 30 per sec. Two identical pick-offs are provided, each positioned by an uncalibrated knob. Among other things, the "Readout On" switch positions the sweep at the bottom of the screen. When the beam reaches the stored trace a signal is sent to the pick-off to reset it, leavng the capacitor charged to a voltage equal to the signal as measured from the base line below the graticule. At the same time the stop signal is sent to the pick-off, the CRT beam is brightened putting a bright spot on the trace. The second pick-off is identical with the first so we now have two capacitors changed. The difference in voltage of these capacitors can be measured by a servo driven helipot coupled to a digital dial. This could be projected by the graticule projection optics to the CRT screen. A similar system reads and projects the voltage difference between the two pick-offs which is proportional to the time difference. In both cases, the digital readout must take into account the correct scale factor from the attenuator or sweep switch. The accuracy should, of course, be as high as possible but I believe a 1 percent system would be very satisfactory.

7. The problems of viewing and photographing with the camera and viewer looking at the same side of the phosphor are familiar to all of us. It seems logical to separate these functions. Some time ago Maurie Merrick suggested photographing the back of the phosphor. Magazines have reported this being done for military purposes. Maurie suggests a port on the top of the tube parallel to the beam, with a 45° mirror inside the tube just out of the way of the beam. This seems an excellent idea. An additional mirror is necessary to get the image correctly on the paper, but this helps rather than hurts the mechanics of the camera.

Since all photography with this camera is on a stored image (you can store any repetitive signal) a very slow inexpensive lens can be used. For Ektaline paper and an f-11 lens about five seconds exposure is necessary. This means a very simple shutter. The camera would contain a roll of paper and the chemicals and heated rollers necessary for rapid development. Ektaline paper is rated to be processed at 150 ft/min. This paper has a water resistant base. Since only the emulsion need be wetted by the chemicals it would be virtually dry when it was delivered, ten seconds or so after the exposure was started. The operating cost of this camera giving actual size prints with a white background so that it is easy to make notes on them would be about 20 percent of the cost of Polaroid prints.

If all CRTs had the camera port, the camera could be plugged on to the top of the scope when needed and thus be an optional accessory.

TEKTRONIX: THE 7000 SERIES STORY

Part 3: "Oh, My God"

On February 20, 1964, Howard Vollum presented the key managers of Tektronix with a specific proposal for a new line of general purpose oscilloscopes. What happened next is clearly remembered by the engineers present at that time: nothing much happened at all.

Then, as Wim Velsink remembers, "one day in 1965 Howard Vollum said to John Kobbe (head of the Advanced Circuitry Group), "do it, today". And then John Kobbe went to Wim and said, "do it, today". And so we finally got started."

The first task was to establish the basic architecture. Critical issues during this period included the number of plug-ins, the height of the plug-ins, and various technical approaches for readout, two-dot automatic measurement capability, an internal camera that would spit a picture out the front, the interface specifications, the power requirements of the plug-ins, and the circuit logic needed to orchestrate the functioning of the various plug-ins. Key tasks were trying to build the first TEK-made ICs, designing a new CRT, developing new interface connections, designing new cam switches, color coding the front panel, developing readout ICs, working out a camera arrangement, and developing probes. As it turned out just one of the architecture decisions, the power supply voltage decision, got started in September 1965, involved virtually every engineer in the company, and was not settled until March 1967.

The implementation effort had just started when Hewlett-Packard's 180 series was announced. Suddenly, the situation became one of crisis, for the H-P oscilloscopes were superior to the 500 series instruments. In the words of Win Velink, "we realized clearly then that our ass was in a sling . . . we had had a 'king of the mountain' attitude because of the 547, but all of a sudden it was, 'Oh, my God.'"

From then on developing the 7000 series was an intense project requiring an all out effort from virtually all areas at TEK. During this period, Howard personally pushed the various groups hard. The top talent of the company was gathered into a "riotous but stimulating" group. The engineers involved were innovative and probably close to their peaks of ability. At night, the parking lot would be filled to about 10 to 20 percent of the daytime level. On Saturdays, the engineers would come in, and a familiar sight was Howard in his blue jeans picking components from supply bins.

But Howard then threw another challenge to his group: plug-in height. Work up through late 1966 had assumed a seven inch plug-in height which would provide room for the needed components using readily available and proven parts. But the H-P scopes were smaller in size and quite attractive in appearance. So, one day, Howard said, "the plug-ins will be 5¼ inches in height."

Oliver Dalton recalls the decision to reduce the plug-in height as a traumatic one:

> "The decision set us back at least one year. . . . .for the height decision required three major electro-mechanical component efforts in addition to the IC read-out effort: 1) new lit push-buttons. . .we needed 25 on a panel; 2) cam switches-these were Howard's ideas. . .we needed them to be small and reasonably cheap; 3) relays. . .we needed them to be small and reliable. . .We then largely had to make do with other available parts, like potentiometers.

Today, over ten years later, it is difficult to piece together how everything got done. For example, the components effort proceeded in parallel with the instrument design effort even though the instrument design obviously depended on the components.

Going back to Howard's 1964 proposal, here is basically what happened:

1. Performance: Using transistors, the performance goals were easily met. . . . .but, as it happened, the transistors allowed a broader bandwidth than proposed, but in the press of events the additional performance potential was not pursued.

2. <u>560 Plug-ins</u>: The power requirements of tubes proved to be so basically different frm transistors that after much effort the goal of making the 560 plug-ins compatible with the 7000 series series mainframes was abandoned.

3. <u>Split-screen Storage</u>: Split-screen storage was accomplished but abandoned after the product was on the market because the tube and its surrounding circuitry were so complex that the instrument was unreliable and hard to service; also, the main thrust of the storage idea was to handle higher speeds, but the bi-stable storage tube was not fast enough.

4. <u>Powered and Remote Operation</u> of sweep speeds, vertical sensitivities, beam positions, trigger polarities, and trigger levels:

To accomplish this small, cheap, reliable switches were needed. As Oliver Dalton recalls, "the problem was that there were no components available that could do the job. The switches, buttons, and relays available were either too large or too expensive, so to perform powered and remote operations we would have had to develop our own components. We did have two or three project teams work on this and Howard Vollum had many ideas. We ended up with a standard relay that we still use although they are not cheap or reliable. (We still operate some front panel-switches through these relays, as on the 7A13.) To really do remote operation we would have needed small motors to turn the switches. But these motors required too much power. . .they really took a jolt of current. And space considerations were a related problem, especially when it was decided to reduce the size of the plug-ins."

5. <u>Easily Turned Knobs</u>: Easily turned knobs were developed after a major electro-mechanical effort.

6. <u>Programmability</u>: Microprocessors were not developed until the early 1970's, and programmability just could not easily be accomplished given the technology available in the 1967-69 time period.

7. <u>Projected Graticule</u>: Howard's memo suggested an "easily changed graticule projected on the CRT phosphor." This was to be done by projecting a film image through a side port on the CRT onto a mirror mounted inside

and then onto the CRT screen. Two principle problems were encountered: 1) it was hard to get enough light to project thin, bright lines. . .it would take perhaps a 250 watt bulb using 35mm slides, which was a lot of heat to dissipate, and 2) the mirror inside had to shine through all the gun apparatus. Also, the related electro-mechanical components were too expensive and unreliable. However, something similar was used on a TV vectorscope prototype.

8. Read-out: Howard's memo suggested a read-out that would include the following: sweep time cm., sweep uncalibrated signal, sweep magnification, vertical sensitivity, vertical sensitivity uncalibrated signal and polarity. All of these goals were achieved, although there were many false starts. As Oliver Dalton remembers:

   1. We first tried a wheel run by a motor and switch. The wheel had a negative image of the numbers we wanted to display, and a light would shine to project the image onto fiber optic strands which would carry the image to the front panel.

   2. Another approach was to use gas discharge tubes, but a major problem was that we could not get a good life. Sperry and Owens-Illinois are starting to use them for displays.

   3. We also tried using little motors to drive tapes with numbers on them.

   4. Finally Barrie Gilbert came up with a readout IC and we all breathed a sigh of relief. It was a medium scale integration IC and was years before its time.

9. Two-dot:

*The memo also suggested digital readout of time and amplitude and time and amplitude difference between any two selected points on a stored trace (a two-dot system). As Oliver remembers:

"We had two, high-level people work on this part-time for perhaps three years. We couldn't solve the basic problems, so we couldn't involve more people on the project. In those days memory was much too expensive, so we couldn't just digitize the signal and then make the required measurements on the memorized waveform. Even if this were feasible, the small computer needed would have been far too expensive for a general purpose instrument. Now we would just use a microprocessor and some cheap IC storage."

"So the two-dot system failed for technical reasons. It would have made the instrument too complicated and expensive and at even moderate speeds it was hard to make sure the dot stayed on the trace and didn't hover just off the trace (we had problems at only 30 MHz). At higher speeds the accuracy was much less than visual estimates with reference to the graticule. Wim was the overall manager and asked me to decide. I said we should drop the effort. But the exploratory effort may have been worth it and I often pull out my old notes for reference as it now becomes possible to do something similar.

"John Horn did work on a system that would get the electrical information from the trace by 'worming' the signal back through a 'hole' on the left side of the screen. The signal generator output required to put the trace through the 'hole' or gap would then be the signal you wanted. The correcting signal was to be displayed on a paper/pen recorder. There were some problems with this method too: voltages of 20 KV were present; it was hard to get precise registration between the screen graticule and the recorder graticule; and an unknown was how to handle multiple traces and readout. In the end it was felt that the system was too complicated and so much accuracy was lost that the customer might not like it.

10. <u>Cameras</u>

"Morris Merrick did come up with a processing camera that would do the job, but there were a lot of problems: it was expensive, there were nasty, wet chemicals (Xerox circuitry would have taken up too much space), and the system was unreliable." In the end a Polaroid camera shooting from a mount on the front of the scope was adapted and used.

11. Plug-ins

Oliver Dalton also recalls the outcome of the plug-in proposal (the memo suggested using the 560 plug-ins as a model for size and shape).

Number of Plug-ins

"It was Wim's idea to use "up to" four plug-ins and somewhere along the line it became assumed that there would be four holes. The reasoning was that most people wanted dual trace, but it was a good idea to use two kinds of amplifiers, one for each trace. Then it was felt that maybe there should be two horizontal time-base plug-ins so that the oscilloscope could be used normally or a second plug-in could be added for a delaying sweep. We had originally thought we would sell mostly single trace, amplifier plug-ins, but we had made a dual trace plug-in so four traces could be displayed if desired. What happened is that people mostly bought the dual trace plug-in and used the extra hole for other purposes. Now the dual trace plug-in outsells the single trace by ten to one. The extra hole is, for example, used for the logic analyzer (which takes two holes) or for sampling (the extra hole allows using the oscilloscope both for real time and for sampling simultaneously.)

Configuration of plug-ins

"There were many discussions on configurations, and the final decision was made in a committee. Kobbe proposed square plug-ins, although nobody else seemed to like it. Howard seemed to like horizontal, "wide" plug-ins stacked one above the other. Wide plug-ins might have been a good way to go, because they made it easy to associate a trace with a plug-in. But they were bad for cooling and would have required fans. The "tall" configuration made cooling and connections somewhat easier, so after the decision to have four plug-ins was made, the arguments went on for awhile and then vertical plug-ins were decided upon. There were problems in getting the dual time base into one hole, and in fact it's still a problem.

Height of plug-ins

"Plug-in height was the most traumatic decision. H-P's 180 series plug-ins had a height of 5¼". . . . .(so Tek had to match that height)".

At the WESCON show in mid 1969 Tektronix announced the 7000 series. Oliver Dalton recalls what happened.

*"As a result of the one year delay due to redesign of mechanical components, when the 7000 Series came out it was too expensive and the performance was out-of-date. . .we had had no time to make a new CRT and develop better performance. At the WESCON in 1969 we announced the 7504 with a bandwidth of 75 MHz and the 7704 with a bandwidth of 150 MHz. The 83 had just previously announced a bandwidth of 250 MHz with a new mainframe and new plug-ins. We had known H-P was coming along with something better, but we had to just go ahead and finish what we had. We then had a crash program to improve performance and lower cost. Val Garuts, Thor Hallen, and Dave Hannaford worked on higher speed; Val got the project started then Bill Peek managed it after DC. We announced the product, the 7904 with a bandwidth of 500 MHz, about nine months before delivery. The 7904 now in production is virtually the same instrument they developed then. Phil Crosby worked on a cheaper instrument, the 7403 N, the N meaning "no read-out." A later effort was high-speed storage.

The 7603 which had a bandwidth of 100 MHz and the 7613 (variable persistence storage) instruments were brought out simultaneously with the 7623. The 7003 replaced the 7403N. Many years previously (1964?) Tom Hutchins had demonstrated storage of an 100 MHz sinewave on a MgO "fuzz" target. However, it faded very rapidly. Someone then came up with the idea of transfer storage which made it practical to use the fuzz target and transfer the "image" rapidly from it to a slower, more stable, storage target. Chris Curtin's group developed the first transfer tube which was used in the 7623.

"The rest of the story is one of filling out the line and developing the product over the years.

As it happened the H-P 180 series did not destroy Tektronix. Jim Walcutt attributes Tek's survival during this period to Tek's Field Engineers. . . "H-P's salesmen just didn't know how to sell oscilloscopes effectively. . . they couldn't, for example, counter customer objections. There seems to be something special about oscilloscopes. . . . ."

Other observers credit a general economic down-turn in 1970-1971 as freezing the market share positions. (Certainly the down-turn did have the effect of shaking out numerous smaller competitors.)

Today, in the words of Wim Velsink:

"Today, the 7000 series is in a strong position. It includes a full line with 9½ orders of magnitude spread in voltages and 12½ orders of magnitude in speed. It can measure in time, frequency, and logic domains. In terms of sheer capability, there is "nothing like it. . .the 7000 series can measure virtually anything."

Reflecting on the 7000 series development, Wim Velsink also said:

> "the technical leadership role of Howard was critical. We would not have been so motivated if he had not understood the degree the company was exposed by the technical advantages of H-P.

And, after the intense, epoch-making effort, in 1969 the <u>Tektronix Annual Report</u> noted in a diffident manner:

> "We don't vary much from year to year, presenting rather a continuum. Its ingredients are technical innovativeness; youthful and assertive management (the average age of our vice-presidents is 43); heavy investment in research; and, we are sure, the finest employees."

Or, as with the closing lines of the movie <u>Grand Hotel</u>:

> "People come, and people go. Nothing much ever happens here."

APPENDIX A: THE RECOLLECTIONS OF BARRIE GILBERT REGARDING THE READ-OUT EFFORT AND THE 7000 SERIES IN GENERAL

NOTES FROM INTERVIEW WITH BARRIE GILBERT
November 30, 1977

The Read-Out Effort

*Barrie Gilbert joined Tek in 1964. He had previously been working on sampling oscilloscopes in Britain. After only two months of working for Al Zimmerman on sampling scopes, he joined the "New Generation Group" under Wim Velsink.

*A critical issue at the time was a readout system for the New Generation. Fiber optic, mechanical and simple electrical systems were being proposed, but there were problems with each of these approaches. Barrie was convinced from the beginning that the readout should be done electronically, although the cost of prevalent character generators was estimated at about $1,000. Some of the many advantages of electronics readout included the potential for virtually any message content and a same-plane display, which would make it easier to take a picture of the information.

*It was clear from the first that custom ICs were needed to meet most objectives; and, anyway, general purpose ICs were not available. Barrie also decided that the coding should be in the form of analog current levels, which would greatly simplify the plug-in coding circuits. Barrie also adopted several other ground rules: the code organization should be optimized for the major plug-in applications and yet every plug-in should have the potential of being used with a mainframe with the readout; there should be built-in accounting for probe multiplication factors; all alphabetic characters, numerals, mathematical symbols, and some Greek characters should be available; there should be two ten-character words available per plug-in; there should be no restrictions on the message content; a set of preprogrammed instructions to the readout system should be included; future expansion of the coding matrix should be possible; etc., etc.

*One of the concepts that Barrie felt strongly about was "superintegration." Most electronic circuits are built up by inter-connecting discrete elements. The conventional approach to IC design is to continue this approach, except put them on a chip. Barrie felt it desirable to try to achieve the desired electrical functions by merging elements and by relying upon the electrical functions by merging elements and by relying upon the electrical interplay that occurred between the elements themselves (a "juxtaposition of diffusions"). The result of the superintegration approach is a "sort of glob" that does not make sense in any schematic terms. Although to this day superintegration is still an esoteric approach not much used, Barrie's thoughts about superintegration are credited with inspiring IBM's Berger and Weidmann (who developed I^2L) and Barrie used superintegration extensively in the final design of the readout system.

*Barrie's first design generated the analog input signal spatially on the chip itself. This approach took advantage of the two-dimensional nature of an IC chip and drew the characters as a series of vector strokes. Barrie checked out this approach on a 'boot-legged mockup'. . .a prototype fashioned with teledeltos paper and dime store earrings (a prototype made from ICs would have been very expensive). Although the mock-up worked, in practice it would have required fashioning a separate IC chip for each character desired. Also, in Barrie's words, "it was a misapplication of the superintegration concept."

*Since Barrie wanted to put at least ten characters on each chip, he abandoned the two-dimensional replica approach. Each character was conceived of as consisting of eight points with seven vector strokes connecting the points. Barrie then represented the points with an "x," "y," positional scheme which was scanned by a dee-shaped region. There was still a snag with this approach. . .it required separate emitter masks for each set of ten characters, which was undesirable from the point of view of low-cost manufacture.

*Barrie's third design required only one mask to program. It was an "analog read-only memory" which could deliver two waveforms, one for the "x" coordinate, one for the "y." The majority of the circuits involved were designed by Barrie Gilbert with Les Larson also supplying some crucial contributions.

*The read-out effort had been started in mid-1965, and a prototype version that could simulate the performance desired was completed by about September, 1967.

*Barrie Gilbert has recently returned to Tek after a six and one-half year absence, working for Plessey and Analog Devices in Britain. On reflecting of the differences between Tek and Plessey and between Tek and other firms in general, Barrie remarked on two differences that seemed important: 1) at Tek, you were assumed to be able to do things until you failed whereas at Plessey (and in Britain, generally) you were assumed incapable until you proved yourself, and 2) all materials to do a job were readily available at Tek, many on an open-shelf, at Tek, it was assumed that you would make good use of the material. . .if you used them for a hobby project, then that at least improved your technical ability; in Britain, everything had to be ordered, and you had to go to a stock man who would go get things for you; the Tek System is "invigorating" and gives you a feeling that the company is ready to support you; the Tek System also reduces schedule shippage and helps engineers evaluate instrument cost. (Unfortunately, many of these erstwhile advantages under Item 2 are less tangible, as cost accounting procedures in engineering development tighten their self-defeating grip.)

NOTES FROM SECOND INTERVIEW WITH BARRIE GILBERT - JANUARY 17, 1978

BIOGRAPHICAL NOTES

*Barrie Gilber seems always to have been interested in electronics and oscilloscopes. At age nine he became involved with a deaf friend who made his own hearing aids from tubes wired into tobacco tins. This friend helped Barrie to make a three-stage triode amp and taught him how to solder. By age 11 Barrie had made his first oscilloscope using as a display a VCR 97 (Valve Common Receiving Tube. . .six inch green phosphor. . .war surplus). Barrie also built several of his own televisions and vividly remembers watching the Coronation in 1952 on a set he had made. To Barrie this was a "golden age" for a boy learning electronics because of the availability of cheap, ex-government radar tubes and beautifully-built surplus equipment. A small hardship was the refusal of his father to have electricity installed in their home (because he had just redecorated the house throughout), so Barrie had to take his early oscilloscopes to his friend's house about a mile away to try them out. So, while Barrie's engineering experience has centered around circuits and semiconductors, he has always been interested in visual displays and oscilloscopes.

THE 7000 SERIES IN GENERAL

*Soon after Barrie had joined Tek, Lang Hedrick called and Barrie was shifted to the 7000 series. Other people on the team then were Roy Hayes, Les Larson, Bill Peek, Joe Burger, John Horn and Wim Velsink (the leader).

*The ideas for the 7000 Series seemed to come from a variety of sources. . . the 540 and 530 series had been in existence for a long time and a catalog of ideas for improvements had been built up over the years. And, Howard had a lot of ideas. It was clear that with the maturation of transistors and the age of the 500 series, "the time was right for a new line. . ."

*"There was no master architect for the 7000 series. . .no one as an individual planned the features. It was a democratic evolutionary process. There

was no awareness or feeling of enforced management. We dealt with matters in a pragmatic way. All the engineers were in this together. We knew the project was important: we were piecing together the Cadillac of Oscilloscopes."

*The preferred form of communication was verbal. There was a lot of common discussions. "We were excited by the project. . .all the technical talent was assembled in Building 50 and there was no sense of diffusion. There was still a small company feeling. And, usually all the materials and components we needed for the job were readily available. . ."

*There was little emphasis then on what it ought to cost in terms of engineering effort to do this project. We knew we had to do it whatever. Today we think (necessarily) in terms of our limited resources and think in terms of costs. Now and again a project comes along that short circuits the long approval process because it is so important."

*"I had the feeling that somebody, somewhere knew what the 7000 development was costing, but guys like Kobbe and Velsink thought as engineers not managers. . .they also were not hierarchical. So I knew that I could always do what I had to do--there was no need to write proposal documents that would then get approved. I could basically lay out a plan verbally and then do it. Documents were not written as required by a process, but rather they were written to explain with great excitement what now could be done. . ."

*"At the time we knew that not even a founder could stand in the way of a good idea. . .and Howard never would stop a good idea if it was presented to him. . . he was reasonable. I never thought of him as a barrier, even though he doubtless had veto powers. He was more visible then, interested in everything, but still he was not a barrier.

*"Most importantly, from my experience, the very best ideas were bootlegged into existence, often by working through the night."

GENERAL COMMENTS

*"The development of Integrated Circuits has altered the way we now approach instrument design, but not in any inconoclastic way. Rather ICs have opened up new possibilities. The key thought is not whether IC designs are becoming mature, it's that ICs have added a new dynamic to the profession. These days, in the course of the development of a product you never really know what will happen before you are through that will change your basic approach. Before it was easier to decide what to do--and then the struggle was in doing it. Now the struggle is to decide what to do--what will have market appeal. Almost anything is possible. . .there are fewer challenges in which purely physical constraints are the problem."

Growth at H-P is from the inside out, but we seem to need to take our cues from the outsides. . .reaction engineering vs. action engineering."

*"We do have the inclination to pursue high technology in projects where the state-of-the-art is involved. . .But these projects are usually undertaken only when its clear everybody else is going down the same road. We are not a strong research outfit. . .we do not really have a Tek Research Lab in the way H-P does. Tek Lab programs sit squarely on the shoulders of other companies' processes and inventions, in the majority of cases, and they are much more tightly coupled to short-term needs."

*"Maybe we can do more by making clever adaptations of available technologies rather than trying to pioneer new and better technologies. We might be able to cut off all advanced projects and still address our market, but that seems unlikely. Once we were out there all alone, and we were forced to do our own research into basic technologies. . .The 7000 Series was a dazzle, a broad spectrum triumph. There was nothing else on the market like it. When it came out we were good at everything from circuits and CRTs to read-outs, relays and push-buttons. Our human engineering was way ahead. But now the rest of the world has caught up and now we have fewer distinctive abilities."

*"In the 7000 Series development days, engineering was the center of Tek universe. . .the success of the entire company rested on the engineers. I

sometimes feel that engineering is becoming almost a service operation. . .there to serve the entity which is 'The Company.' We are no longer primarily a superb engineering company. . .we are now a manufacturing, marketing, money-making <u>machine</u>. I am not saying that it is necessarily bad. . .it pays my salary. But we need to be aware of these things and make our management decisions in accord with these realities. I liked it better when our slogan was "Committed to <u>Technical</u> Excellence."

APPENDIX B: RECOLLECTIONS OF BILL STRONG ON THE BACK CONNECTOR DESIGN EFFORTS

New Gen Connector Efforts

The first idea for a plug-in connector involved an intermediate connector. The circuit board edge idea was originally received with skepticism by those who thought it would not work and by those who felt that it unduly committed circuit designers to working with a circuit board spatially inmovable with the plug-in frame.

The specifications for the back connector were challenging:

- Less pull-out force--the goal was five pounds for 76 contacts at a time when the best available commercially was greater than five pounds for 30 contacts.

- Wear--the goal was 4,000 cycles at a time when the best available was 500 cycles.

- Spacing--the goal was to reduce the spacing between contacts from 156/1,000 to 100/1,000.

- Flow solderability--the contacts had to be easily soldered.

The design effort started in March 1967. The first task was to establish specifications in detail. This was difficult, and, for example, some finally had to be set arbitrarily. . . .Tony Sprando finally said, for example, that the contact force should be 20 grams.

The first design called for individual pins held in a plastic holder. This scheme worked, but it was much too hard to assemble, especially as run lengths would not justify automated insertion of the pins.

Soon Marlow Butler conceived of a carrier strip approach, and design work started along those lines. By August 1967 Bill was going step by step through the design process, looking for ideas. He would do a layout, look at it, and then try something else. He was close to final design by September 1967.

The concept of the final connector design involved the following:

- The carrier strip and pins were designed to hold themselves on the body of the connector carrier, which would aid hand assembly.

- Long, thin strips were desired in order to use a low spring rate, to minimize tolerance problems, and to reduce withdrawal force while maintaining contact force; a cantilever scheme was out, because of tolerance problems, contact force problems, and deformation problems; the final scheme was to use a snap-on cover to pre-load the contact against the body. The cover also protected the contact and positioned it.

The conceptual design and layout were, by and large, finished by September 1967.

The next steps were performing dimensional analyses, choosing materials, making dies, considering alternate assembly procedures, and working on assembly details. Tolerances were a particular problem. These considerations required major efforts. In July 1968 changes were made to the ramp angles for the snap on cover. In August 1968 Bill was still testing prototypes and evaluating different materials. Final design drawings were not prepared and released until September 1968.

A particular problem was the cracking of the snap-on cover due to grain structures set up during molding. The final resolution required locating two gates at just the right position in the die. . . .no other location or number of gates would work.

In October 1969 design efforts were still going on in terms of re-evaluting screws and dielectric constants of the plastics. In 1976 there was a switch from overall gold plating to a gold inlay. In Bills words, "the fine tuning never ends. . . .old projects never die, they just hand around the designer's neck. . ."

APPENDIX C: RECOLLECTIONS OF TONY SPRANDO ON THE RELAY AND SWITCH DESIGN EFFORTS

The Sprando Relay

Bill Walker approached Tony Sprando in spring 1966 and hired him because of an urgent need for new switches and relays for the 7000 series. When Tony joined Tek two other groups were working on relay concepts, one group focusing on pizo- electric approaches and the other focusing on an air-driven relay (apparently Howard Vollum was interested in developing a fluidic scope). Tony with the help of a draftsman (Dick Sollors) were to develop the electro-mechanical possibilities.

The specifications for the new relay were developed by Oliver Dalton and others and were for a "remotely operated switch with two contacts and extremely low power consumption." The first step was to engineer the design: lay-out a contact system, then develop a motor circuit, then tailor the design to the envelope specified. The next step was to determine the materials to be used. Then the effort turned to how to plate the materials and what manufacturing processes to be used. All of this was essentially a one-man effort. Tony found it hard to describe this process. . . . ."it was based upon a lifetime experience, not upon a particular breakthrough. . . . .Howard would come by and ask some questions to make sure I knew what I was doing. . ."

Problems developed when the relay was passed over to manufacturing. "They would try to redesign the relay or substitute materials without understanding the engineering concepts involved. For example they decided on their own to use a plastic pivot. The problem was they didn't tell us they were going to do this, so there were problems with the relays, of course. Other times they decided not to thermal cycle to our specifications, or keep the parts clean enough, or relax quality control. . . . .I was responsible for the product, but didn't have the authority I needed. . . . .so there were lots of meetings, a lot of time spent trying to influence the process."

The Cam Switches

The next major effort that Tony was involved in was the development of cam switches. At the time the Switch Department had developed expertise in the acquisition of commercial switches and had not attempted to do original designs. Then Howard Vollum made the decision that Tek would develop its own switches, and Tony, Bill Verhoof, and Howard jointly developed the cam switch. The design ideas emerged from a "a lot of way-out brainstroming. . ."Howard played a key role by taking an "unlimited funds, the sky's the limit" attitude, while the other members would bring the ideas back to reality.

Once the concepts were established, the manufacturing problems began. The prototypes had been made on numerically controlled machines, and the proposal was now to cast key pieces in plastic. But the Plastics Group said it could not be done. Finally, Tony came up with a four piece die design that would do the job (previous approaches to die design had assumed there would be only two pieces). The four piece die was the critical breakthrough which then made production possible at a reasonable cost.

There were then the usual difficulties in establishing tolerances, materials, fixtures, and so on. The skill involved in making a device producable cannot be over-emphasized, for it is a key element in the mechanical design process.

Tony remembers that "there was a lot of manufacturing resistance; they kept insisting at every meeting we held that they couldn't make this switch. It was tough going. And they would keep changing the specs on their own, which would make the final product unusable."

The Push-Button Switches

Howard Vollum was the person who started the push-button effort because he wanted small buttons. Some of the key inputs on the design came from the Model Shop, such as from John Winkelman who came up with a latch mechanism.

General Comments

"Tek would give you rope, but you had to be sure you knew how to use it."

ADVANCED INSTRUMENTS

by Gene Chao

Introduction

I would like to illustrate for you some basic issues that design engineers are struggling with while thinking about what instruments will look like in the future. To do this I will use a typical digital instrument as an example, going through the functions each of its major component parts perform.

There should be three disclaimers set forth at the beginning: the first is that this is only an example and refers not at all to some exciting developments in other types of instruments, such as analog instruments; the second is that the future of advanced instruments can best be characterized by a set of trends, not predictions. The third is that these views are from much thought and the result of many hours of discussions with key people at Tek. I do, however, stand by the comments made here.

Of these three caveats or reservations the one about the future being unclear is perhaps most important: the future of advanced instruments will be a series of "nows," rather than a foreseeable or planned future that is orderly and predictable. The future depends on what market segments you are talking about, upon some very unpredictable break-throughs in technology, and upon what key people in key areas decide to do.

It is possible to talk about some "basics" that will shape future instru-ments, but that is not the same thing as making predictions. To me, talking about the basics of an instrument means identifying each function that an instrument performs and describing some of the key events and trends that are taking place with respect to each function.

Another basic that deserves special attention is how people interact with instruments and how that interaction may be made more productive.

Evolution of Advanced Digital Instruments

The starting point for any discussion of advanced instruments must be some reference to microprocessors and semiconductor memories. These devices are in the news a lot, but even though we hear a lot about them, their importance cannot be overemphasized.

Very low cost and cost/performance semiconductor devices are what make new types of instruments possible. Their limitations are what will guide the development of future instruments.

Microprocessors represent a class of cost effective general purpose devices that will perform basic computation and control functions. They impose on designers some arbitrary parameters...such as a certain number of pins, eight-bit or 16-bit word sizes, and speed in the one to ten MHz range. There is no law that says designers must use micioprocessors, but at ten dollars a piece they are very difficult to ignore.

So the first assumption that I will make is that Advanced Digital Instruments will be designed around the possibilities and limitations of high-volume, low-cost semiconductor devices. This has an immediate effect of focusing our discussion on some key areas. For example, a clock rate of ten MHz means a signal handling capability of two to four MHz...which is fairly slow for many applications of interest. So, it immediately looks like real time continuous signal processing is out and some separation of the functions of signal acquisiton--at high rates of speed--processing--at slower rates of speed, will be necessary.

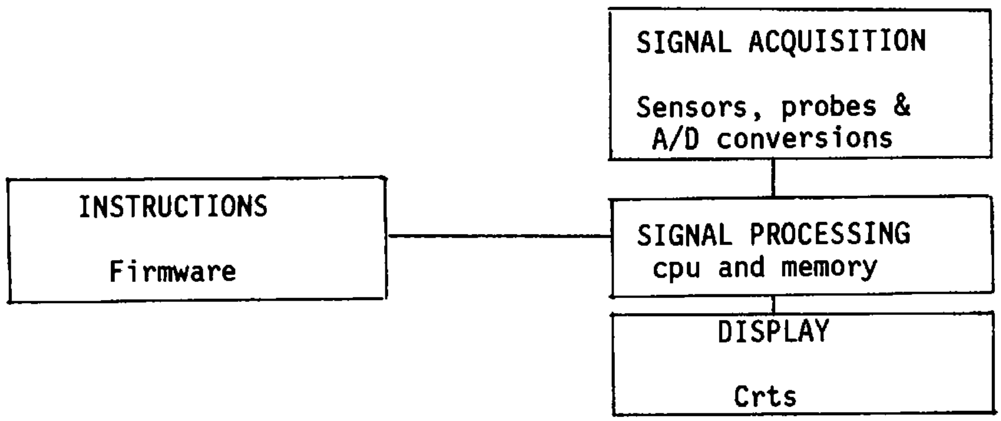
On the other hand, the general purpose nature of the microprocessor opens up other new areas....three of which are the types of instructions instruments may act upon, the types of mathematical computations instruments may make based upon information form signals received, and the nature of the man-machine interface.

I think that the best way to talk about some of these considerations is to take the various parts of an instrument one at a time and talk about how semiconductors are influencing them.

A Tour of a Digital Instrument

The Early 1970s

In the early 1970s people often thought of a digital instrument in the terms of this drawing:



Signals were received by a probe and sent into a processor for analysis. The analysis was performed with reference to a set of instructions and displayed on a CRT. Basically, all this happened in real time.

What this instrument did was measure something.

The instructions typically were placed in something called a ROM, or read-only-memory. A ROM was a general purpose semiconductor memory that could be "loaded" with instructions, and then the instructions could be "burned" permanently into the device.

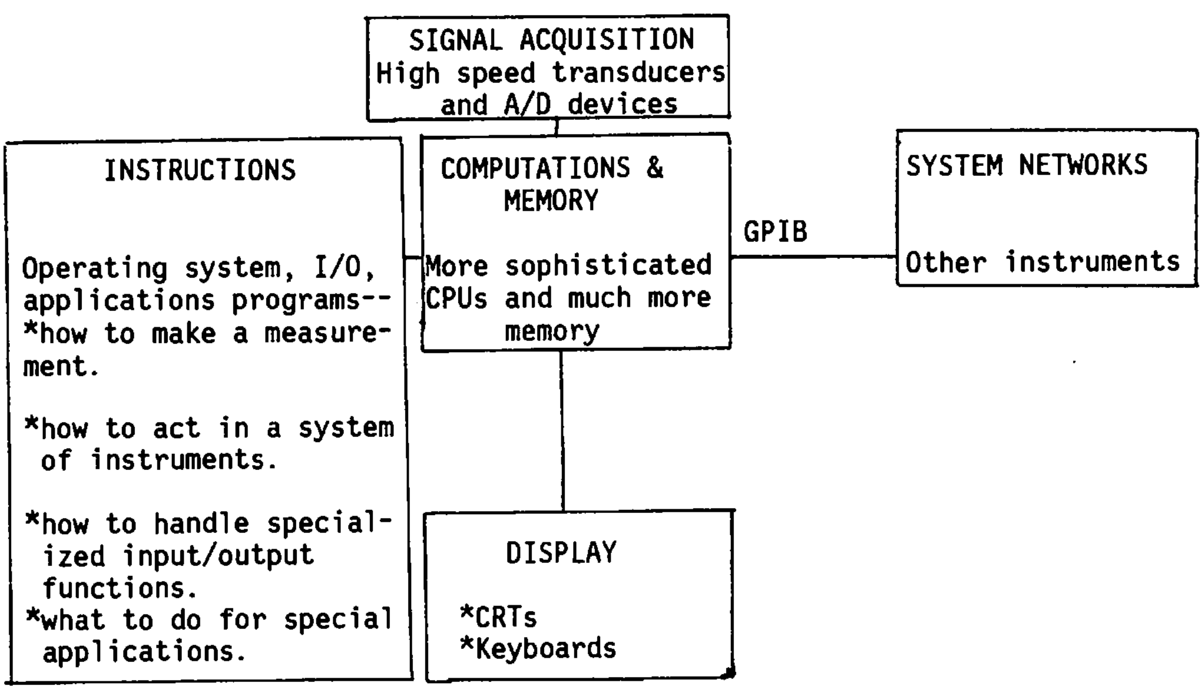
The combination of ROMs and microprocessors were a major improvement over what had been used..."random logic" or "hardwired logic." With hardwired logic the instructions for any particular instrument had to be physically assembled and hardwired into place. That meant that each instrument was a unique design and assembled in a unique way. ROMs, by comparison, are basically general purpose devices into which instructions can be placed and then fixed in permanently...the same hardware could be used for a myriad of designs.

In the early 1970s semiconductors had not yet had a major impact on the way signals were acquired or displayed. Rather, the first impacts were on the core processor and on the way instructions were assembled and held.

Still, even in the early 1970s the ability to plug in ROMs as instruction sets was recognized as an important development. ROMs meant that the same central hardware could just about do anything...anything from measuring voltages to analyzing waveforms. It is this trend towards a general purpose core that is perhaps the most profound and decisive development that has occurred to instruments as a result of the power of semiconductor technological advances.

The Late 1970s

By the late 1970s people were beginning to refer to something more complex when they said the words "digital instrument:"



Basically, this instrument can both measure and calculate.

Some of the instructions are in ROM, as in the previous example, but now instructions may also be entered by a keyboard into something called a RAM--a Random Access Memory.

An important development made possible by microprocessors is the ability to tie instruments together in groups. The channel over which communications among instruments and central processors may occur is known as a data bus, and the most commonly used configuration is known as the General Purpose Interface Bus, or GPIB.

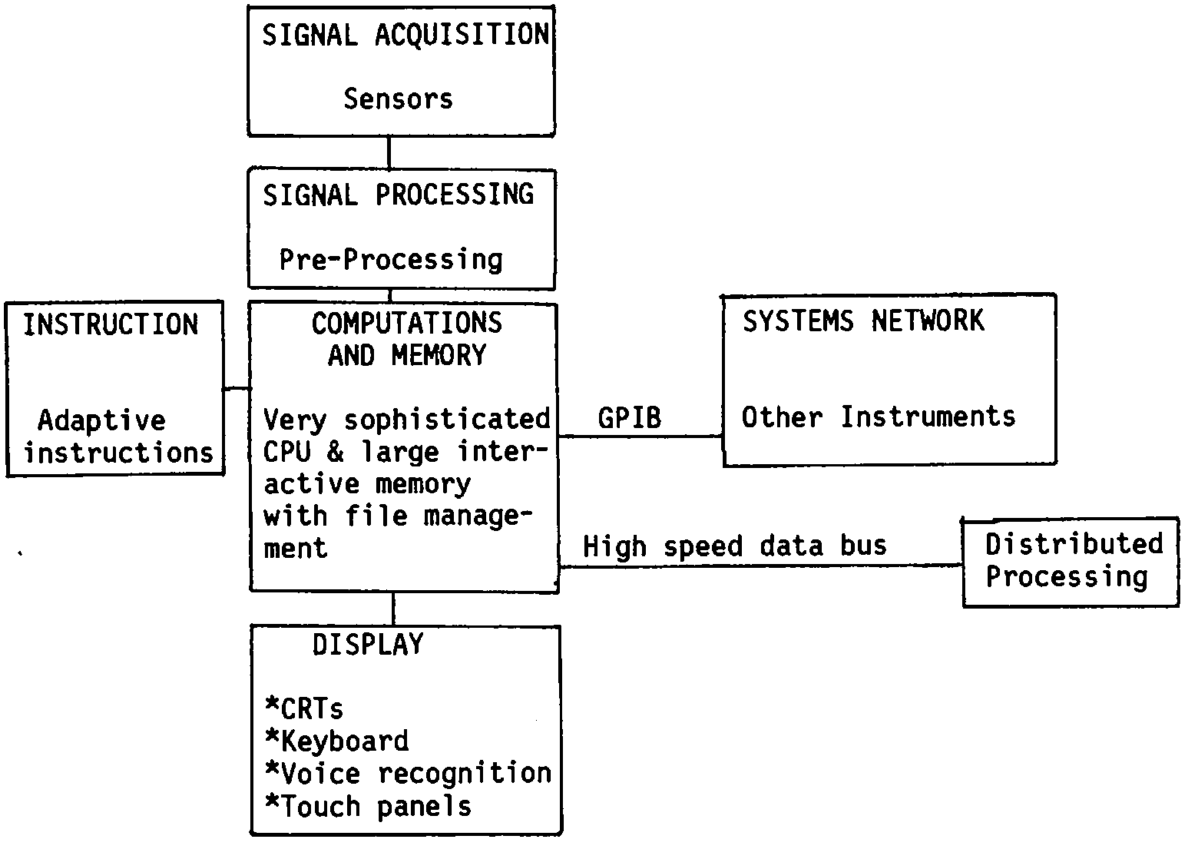
The GPIB bus, it should be noted, is a physical channel along which information may be sent. A GPIB is like a voice; GPIB "protocal" are rules of order... like when should I sepak and when should you speak; GPIB as a hardware standard says nothing about how messages are to be coded...like whether we should speak in French or English.

The performance of a system of instruments tied together by a GPIB bus is limited to the slowest element of the system, usually the semiconductors in the instrument CPU and memory.

It should be noted that the CPU in this diagram is now truly general purpose in nature. Such a CPU could easily be used to make calculations based on numbers entered through a keyboard. Such calculations could even be occurring while the rest of the instrument is engaged in a measurement task.

The Future

Following the general layout of an instrument presented so far, a conceptual scheme of a digital instrument of the 1980s might be:



This chart now pictures what might be called an advanced instrument. This instrument can measure, calculate and make decisions.

The ability to make decisions flows from the more advanced nature of the instruction set. Such instructions, limited primarily by amounts of memory and software expertise, would allow the instrument to make if-then decisions. For example, if a signal rises above a certain level, then the machine might decide to send a warning signal. Or if an operator enters a confusing command, then the machine might ask for clarifications. Such if-then decisions should not, of course, be confused with "thinking" or "making decisions" in the sense that humans think and make decisions.

More advanced instructions also facilitate the trend towards a greater flexibility in applications. Now that the core of the instrument looks like a computer, then all that is needed to expand applications is to write a new program.

Note on the diagram the addition of a second sort of data bus. It seems to me that the inherent limitations of CPUs and the need to perform calculations at some speed approaching that of the signal acquisition speed leads directly to the need for a distributed processing capability...i.e., to share the load with other CPUs or computers. To make distributed data processing work will require a high speed data bus with its own protocols and hardware standards. This data bus would not just handle individual signals but rather would handle large chunks of data and instructions transmitted all at once. If you visualize a GPIB as a telephone line on which two people can talk and agree on analyzing a report, a high speed data bus is like handing someone a thick report and saying "Here, this is the report to analyze."

Note on the diagram the further separation of the signal acquisition function from the CPU. Fast data acquisition is required to track many events of interest. Since the CPU is relatively slow, fast acquisition means either some sort of buffer arrangement or else some way to pre-process the signal to throw away the information that is extraneous.

An example of pre-processing might be the case where an instrument is trying to locate and read a character on a page. To find the character, the instrument might have to scan a large area at a high rate of speed. Pre-processing would allow the CPU to ignore the blank space that is scanned and only allow information about the character itself to be sent to the CPU for analysis. This reduces the essential information enormously to just two simple statements: where the character is and what it looks like. The speeds required and the special nature of each pre-processing application make signal processing devices inherently a custom design activity.

Another feature of the advanced instrument will be greater concern with how the user interacts with the machine. This concern may be called a concern for productivity, or customer satisfaction, or a more "friendly" instrument. The concern arises from the fact that the machine will be analyzing and presenting data faster than the human can understand it so humans will <u>require</u> machines to present the data in forms more acceptable to humans.

How People Will Use Instruments

The goal of advanced instruments is to make people more productive.

One area where productivity can be improved is the quality and speed with which people and instruments interact. To understand how the interaction may be improved we first need to say something about what people can do well.

Here are some basics about people:

*good at visually receiving vast amounts of information at high speed;

*good at hearing information;

*good at speaking information.

These considerations immediately suggest that advanced instruments will need to be able to recognize voice commands and display information visually and/or (depending upon application) orally.

Instruments can at present "speak" and "understand" words.

Instruments can speak through speech synthesizers that, in one West German product, store about 250 sound elements in a 65K byte memory that can be combined, chopped, mixed and timed to produce almost any word in the cadence and inflections typical of a human voice.

Instruments can understand words because frequency analysis of speech can allow them to recognize patterns. There are some difficulties because each person pronounces words slightly differently, but machines can be "taught" each user's idiosyncrasies on the spot.

Except for simple "commands," voice recognition does cause many problems for machines. Human speech is typically both redundant and incomplete and relies heavily on context,inflections, and common knowledge about the subject to communicate effectively. Language understanding is a problem of several more orders of magnitude of difficulty, and no practical machine understanding of language...as apart from pattern recognition...seems foreseeable in the next few decades.

The ability of humans to receive information visually is truly remarkable, however....Humans can do what is called parallel processing... simultaneously analyze large amounts of data on a pattern and focus very quickly on the most important points in the pattern. This ability to focus on what is important is largely indescribable at the present time, but it does mean that displays, particularly high resolution faster scan displays, will almost certainly be an important part of advanced instruments.

Advanced instruments might also conceivably take advantage of the fact that humans have a remarkable ability to remember things (computer people call this a good data base structure along with efficient compare registers). For example, when you are asked for the name of a childhood sweetheart, you may not be able immediately to recall the name, but, probably, sooner or later you will.

Similarly, when people hear certain trigger words, say "Nixon" or "high school," whole hosts of images and associations immediately appear. The mind has the ability to <u>sort out and prioritize</u> while it is not active (say while you are asleep) such that the next time you need the information, it's in a very usable form. When two people talk, scientists let's say, a tape recorder might hear only a succession of meaningless phrases or sounds, but in reality some quite vivid and clear thoughts may be passing back and forth. Conceivably, advanced instruments might be programmed to trigger such images so that an engineer scanning a system at a high rate of speed might suddenly see a particular pattern and immediately know what was going on.

I am tempted here to go on and talk about the entire field of artificial intelligence research. A large fraction of the faculties at the three of the most prestigious computer science departments (MIT, Carnegie-Mellon, and Stanford) are now involved in artificial intelligence research. But they are running into at least three sorts of roadblocks:

1. Computers don't have an experience base so they don't know much about what is being talked about...as a result, in order to get computers to understand language, ways need to be found either to pin down the raw rules of languages and dialects or else find a way to give computers some experience...perhaps with pattern recognition capabilities (an eye) and proactive physical abilities (a hand).

2. In humans the mind and body are one...in computer terms humans are distributed processing systems and the brain doesn't just receive electrical signals, rather it receives signals pre-processed in some way either by the sensor or else by the transmission mechanism; visual, audio, olfactory, tactile, etc., inputs are concurrently received and patterns based on these parameters (some of which are themselves patterns) are recorded in recognizable ways.

3. According to the latest sociobiological findings humans at some sub-cellular, DNA level have some basic programming regarding basic values or "morality."

In any case, none of this presentation is meant to be definitive. It is meant to be illustrative of the kinds of considerations that research and design engineers are reflecting upon as they think about what instruments might be like in the future.

PROGRAMMABLE INSTRUMENTS

By Harry Gregor

Introduction

What is a programmable instrument?

A program is a sequence of instructions. So it might seem that a programmable instrument is one capable of acting on a sequence of instructions to make measurements and generate signals reporting on those measurements.

By this definition, a stereo record player is a programmable instrument. And it is, in a way.

But, regardless of propriety, what is really meant by the term "programmable instrument" is much more than stereo sets. The term in its usage is actually a reference to a new technology, semiconductors, that make it possible to perform conventional tasks in enhanced ways at much cheaper costs than ever before.

Instruments measure time, voltage, current, and resistance. It has always been possible to make programmable instruments, only never before has it been so easy. The difference is the development of microprocessors, commonly called a "computer-on-a-chip", which make it possible easily to connect instruments together, operate them remotely, mathematically process the signals being received, and display signals in creative ways.

Connecting Instruments

It takes a lot of circuitry to make it possible to connect instruments together. Generally speaking, instruments must know when they are being spoken to, must interpret the instructions they are given, and must send messages in an appropriate code. Even when instruments are set up only to "talk", i.e., send messages only, each instrument must send the message in an understandable format.

Until recently, the average engineer probably could not put systems of instruments together. What has changed is:

- Development of electrical standards of protocol between instruments; one popular set of standards is called "General Purpose Interface Bus" or "GPIB"; these standards mean only that instruments may be connected like one telephone to another;

- Development of cheap minicomputers and microcomputers of sufficient power to understand different codes; these controllers are like interpreters speaking and listening to differing telephone conversations in a variety of languages, like English, Spanish, Japanese, and the like.

- Placement of microprocessors in instruments which makes code reception and generation more a matter of software than hardware design; these microprocessors make it possible for instruments to speak a language at all.

Many of the current issues involved in designing a programmable instrument center around this issue of connections. An analogy may be made with computers. One of the major limitations to the development of large and powerful computer networks is not the cost of the computers, but rather it is the cost that the telephone companies charge for the connections and the software costs to sort out the complexities of connecting large numbers of terminals, computers, and message switches. Similarly, there are limitations in connecting instruments because of the costs of communications.

The primary interconnect problem is that over distances of more than a few years copper wires cause time irregularities. Also, in many environments, such as factories, the presence of powerful electrical motors or power lines will create spurious signals called "electrical noise."

Another problem is the "narrow band width" of electrical wires, which limits the amount of information any particular wire can handle.

One of the new and potentially most promising ways to connect individual instruments is with glass wires in a technique called fiber optics. With glass wires the signals are sent with bursts of light, which are immune to capacitance and noise effects and have extremely wide bandwidths.

Remote Operations

The word "programmable" usually means that an instrument can be given instructions digitally, by pushing buttons on a keyboard, for example, rather than in an analog fashion, by turning a knob, for example.

Once an instrument can be given instructions digitally, the possibility for operation from a remote location readily exists. Some programmable instruments, for example, have only an on-off switch and receive all instructions from a controller connected to the instrument with a wire cable.

Signal Processing

All instruments, by definition, process the signals that they receive. What is special about "programmable" instruments is that they process the signals a little more than the usual instrument.

For example, a conventional multimeter may display voltage on a dial, a programmable multimeter may display voltage digitally or, maybe, it will compute a running average of the voltages measured at differing points of time. There are no set rules here; the differences are ones of degree and no set definitions exist for the word programmable.

Display

"Programmable" instruments require that, at some point, the signals being measured be expressed in digital form in order to make sense to the microprocessor. Once the signals have been expressed digitally, it makes little sense to convert them back to analog form. So, associated with programmable instruments has usually been certain types of display, namely digital readouts.

Digital readouts are not universal for programmable instruments, even though they are commonly associated with them. A "programmable" oscilloscope, for example, is an oscilloscope with the usual CRT analog display, only the front panel control is partially keyboard in nature.

Market Dimensions

A recent study made by Tek marketing people has outlined the characteristics and the size of this market. This type of forecasting is something like gazing into a crystal ball, but a few assumptions and small pieces of recent history can point the way to some reasonable estimates.

The eventual size of the market depends most upon how and how quickly people adopt GPIB instrumentation. It is expected that the market for programmable instruments will be at least as big by the early 1980s as the oscilloscope market is today. That's around $500 million--and that is a conservative estimate.

There are many variables involved here--it's entirely possible that all instrumentation could be programmable. In that case,the market would be many times the size of the present oscilloscope market. Either way we are talking big dollars.

Competition

It is expected that the present leaders in the instrument industry such as Hewlett-Packard and Tek will also be prominent in this market in the future. Hewlett-Packard presently has the lions share of this business and is clearly ahead of everyone else.

It is not yet clear whether this market will attract some companies from the semiconductor industry or possibly some computer companies. If this happens, competition could be fierce.

We may also find that we will be selling to a different set or class of customers. If so, we may have to revamp our entire approach to selling and marketing as well as develop new types of products. I think that along with selling probes and cameras as accessories, we will also be selling software and computing calculators to go along with our instruments.

If we take a more global look at programmable instruments tied to a GPIB or IEEE 488 bus to form automatic test equipment systems, then we can possibly see some economic reason for their existence. In order for our gross national product to continue to increase, the output capacity of each individual must increase. Humans however, have finite capabilities or capacity, so the additional outputs will have to come from machines, just as it did during the first industrial revolution in the 19th century.

It is possible we may be at the dawn of a new industrial revolution. The first industrial revolution was driven by the availability of a source of cheap energy--coal. This one may be driven by the lack of the availability of cheap energy which requires us to strive harder for higher and higher efficiencies. And, I feel, automatic, programmable, smart, intelligent, etc., etc., machines may be the only way to achieve these necessary efficiencies.

TECHNOLOGY OVERVIEW: SEMICONDUCTORS

By Norm Heyerdahl

Tektronix was founded in 1946 to supply an essential tool, the oscilloscope, to the infant electronics industry. That same year, work resumed at Bell Telephone Laboratories to produce electronic devices in all-solid form. The materials which made that effort possible are called semiconductors.

In this report, I will try to give an overview of what semiconductors are; how they affect Tektronix; and what I see happening in the future.

We Start With The Transistor

The basic semiconductor device, the transistor, controls the flow of electric current through itself in accordance with an applied control current. Tracing the interaction of these two currents in a single transistor is commonly done with a Tektronix curve tracer, an oscilloscope with a built-in source of control current.

Transistors are small and rugged but, most importantly, can be fabricated simultaneously in large numbers by successive surface treatments of a single slice of material. With the addition of a surface network of metal interconnections an "integrated" circuit or IC chip is formed. It is tiny--about a quarter of an inch square and quite flat. Under the microscope, it resembles a Navaho rug or the aerial view of a railroad switching yard. Like the grains of sand on a beach, it is made of silicon--next to oxygen the most abundant element on the surface of the earth.

Some 250 IC chips are made from one razor-thin wafer of precisely polished silicon about three inches in diameter. These wafers, in turn, are sliced from cylinders of extremely pure (99.999%) crystalline silicon. Why silicon? Because it is a semiconductor and can be either electrically conducting or nonconducting, depending on the impurities added to it. Thus one small area of a chip can be "doped" (as scientists say) with impurities that give it a deficiency of electrons--making it a so-called p (or electrically positive) zone, while an adjacent area gets a surplus of electrons to create an n (negative) zone. If two n zones, say, are separated by a p zone, they act as a transistor which is an electronic switch; a small voltage in the p zone controls the fluctuations in a current flowing between the n zones. In this manner, thousands of transistors can be built into a single chip.

Build Hundreds of Identical Chips

As in silk-screening, a chip's complex circuitry is created a layer at a time. It is a slow, painstaking and error-prone procedure. No other manufacturing process is quite like the IC process. Only a single speck of dust can ruin a chip, so work must be done in "clean rooms," where the air is constantly filtered and workers are swathed in surgical-type garb.

First, racks of wafers are placed in long cylindrical ovens filled with extremely hot (about 2,000 F.) oxygen-containing gas or steam. In effect, the wafers are rusted--covered by a thin, electrically insulating layer of silicon dioxide that prevents short-circuiting. Then the wafers are coated with still another substance: the resist, a photographic-type emulsion sensitive only to ultraviolet (UV) light. (To prevent accidental exposure, clean rooms are generally bathed in UV-less yellow light.) Next, a tiny mask, scaled down photographically from a large drawing and imprinted with hundreds of identical patterns of one layer of the chip's circuitry, is placed over the wafer. Exposed to UV, the resist's shielded areas remain soft and are readily washed away in an acid bath. On the other hand, the unshielded areas harden, forming an outline of the circuit.

Back in the ovens, the wafers are baked again in an atmosphere of gases loaded with "dopants." Like oil stains in a concrete driveway, these impurities soak into the underlying silicon. Since chips usually contain as many as ten layers, all these steps--"rusting," photomasking, etching, baking, etc.--must be repeated for each layer. Then the entire wafer is coated with an aluminum conductor, which also must be masked, etched and bathed in acid. Finally, a computerized probe scans the wafer for defective circuitry and marks the bad chips in red. The wafer is then separated by a diamond cutter, the bad chips are discarded and the good ones externally wired, sealed in plastic or metal and shipped off to the user.

To Produce the Most Complex Electronic Functions

It is the sheer numbers of transistors in a single chip that gives the IC its astonishing powers, up to 75,000 per chip being possible today. The present chips have a calculating capacity equal to that of a room-size computer of only 25 years ago at a price of a few dollars. And the historical ability of IC manufacturers to double the number of transistors per chip every year makes it probable that all electronic functions from the largest computer to the most complex controller will eventually be available in chip form.

The Bottom Line

The effect on Tektronix--along with the rest of the world--will be profound. We continue to sell curve tracers, but the engineer who looks at only one transistor is vanishing. Engineers are now concerned with hooking chips together to perform complex jobs like a graphics terminal or an automobile sensing and control system. They need to monitor chip input and output, model chip behavior, and emulate chip performance in actual applications.

New tools are required like the microprocessor design aid and the logic analyzer. The essential tool today must not only measure computer signals, but, to do this, must be a computer itself.

Many different chips will be available from chip manufacturers like Intel and Motorola but Tektronix will continue to need its own special chips.

It seems obvious, therefore, that Tektronix must continue to be expert in the use of semiconductors. We need highly complex chips to control and model complex circuits, and we need faster, more powerful chips to drive bus lines.

The task of developing new microcircuitry itself involves basic research: research on semiconductor and polymeric materials; research on the chemistry of surfaces and etching; research into advanced electron and ion optics and into the effect of radiation on matter; and research on the mathematical properties of large data systems. The government has moved to support research in this area by establishing a national facility at Cornell University. But the task of reducing the results to practice, making it work, devolves back on Tektronix.

In return, we have the opportunity to be front-line contributors to an electronics revolution that will change our society as much as the industrial revolution.

Additional Reading:

Science Magazine, March 18, 1977, special issue on electronics.

Scientific American, September 1977, special issue on microelectronics.

Time Magazine, February 20, 1978, special issue on the computer society.

TECHNOLOGY OVERVIEW: TRENDS IN THE SEMICONDUCTOR INDUSTRY or "The Engineer Rides Again"

By Doug Ritchie
With the assistance of Ron Olisar
and Robert Bosler

"One day soon the instrument world will again be controlled by applications types...engineers who will pick and choose from available technologies, worrying about costs, about the personal relationship of man and machine, about the job to be done. But, as always, nothing is for free, and both instrument engineers and their companies will have to bring something to the party or else get run over." Doug Ritchie.

Introduction

In the 1950s breakthroughs in airplane design occurred at a rapid rate, and that was exciting. Faster speeds, larger sizes, and lower costs meant a whole new world for everyone.

Breakthroughs in airplane design are still occurring at a rapid rate, and that is still exciting, but the breakthroughs don't seem to mean so much anymore, for the breakthroughs are getting expensive to achieve and are becoming marginal in nature. Now we worry about breakthroughs in peripheral services, like computerized reservation systems and baggage handling systems, and concern is directed more at schedules, efficiences, fares, and the right airplane for the right job. As a result of this attention to applications the new $239 round-trip jet fares to Europe mean more to more people than a $1700 round trip at supersonic speed.

Similarly, breakthroughs in steel and aluminum technology and fabrication are occurring daily, only now we care more about the right materials for the right jobs, about energy costs to fabricate and what 1000-foot tall buildings do to the tax base of a city.

Now let's talk about semiconductors.

In 1960 solid-state circuits were constructed transistor by transistor, resistor by resistor, and so on. Each circuit element performed a single electrical function and each was about the size of a nickel.

By 1979, over a million circuit elements will regularly be produced on silicon chips about the size of a quarter. And that's still only the beginning, in a technological sense.

According to Dr. Gordon Moore of Intel, over the next five years the number of components fabricated per silicon chip will double every year. There will be improvements in line widths and depths, circuit design cleverness, device materials, lithography, and device size.

The technology has far to go before the ultimate limits are obtained. Nonetheless, many observers are already talking about a "maturation period" for the semiconductor industry--a time when applications and economics will be more important than raw speed. The nature of this coming maturation period and its implications are the subject of this report.

Some Perspectives On Where We Are

Let's get the big picture first.

To build an instrument these days you need first to have some idea about a possible application. Even when a scientist goes into a lab to come up with a new type of semiconductor, it is with some basic belief that semiconductors are useful and that the world needs a better one. Most talk about "pure research" is misleading, for it comes down to some person standing on top of 2000 years of culture and knowledge and saying, "I think it would be interesting to try this."

In the 1960s the archetypal engineer was some ham who picked tubes and their transistors off the shelf and wired them up with resistors and so on and put something together. This was the same type of person who with a "Why not" attitude had built railroads, radios, and blimps. This person was an engineer whose role involved far more than understanding technology...he was also a Lindbergh who could squeeze money out of bankers, negotiate purchasing contracts, perform prodigious athletic feats, as well as design an airplane tailored to a specific application.

In the 1970s the engineer got overwhelmed by a simultaneous onslaught of scientists and professional bureaucrats.

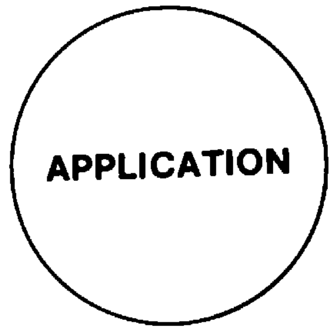
The scientist said, "Screw your circuit board, I'm going to put it all on a chip." And the bureaucrats, perhaps misunderstanding the glamour of the Harvard Business School, said, "Oh, you have an idea? Well, where's your project number, where's your cash flow projections, and where, for Christ's sake, are your overhead projector slides?"

But, I don't see such a world in the 1980s. True, any company without advanced expertise in some critical area...say lithography or mesfets or software or cybernetics...is not going to have much of a future because its existence will be completely dependent upon other companies who will have no incentive to share their technologies.

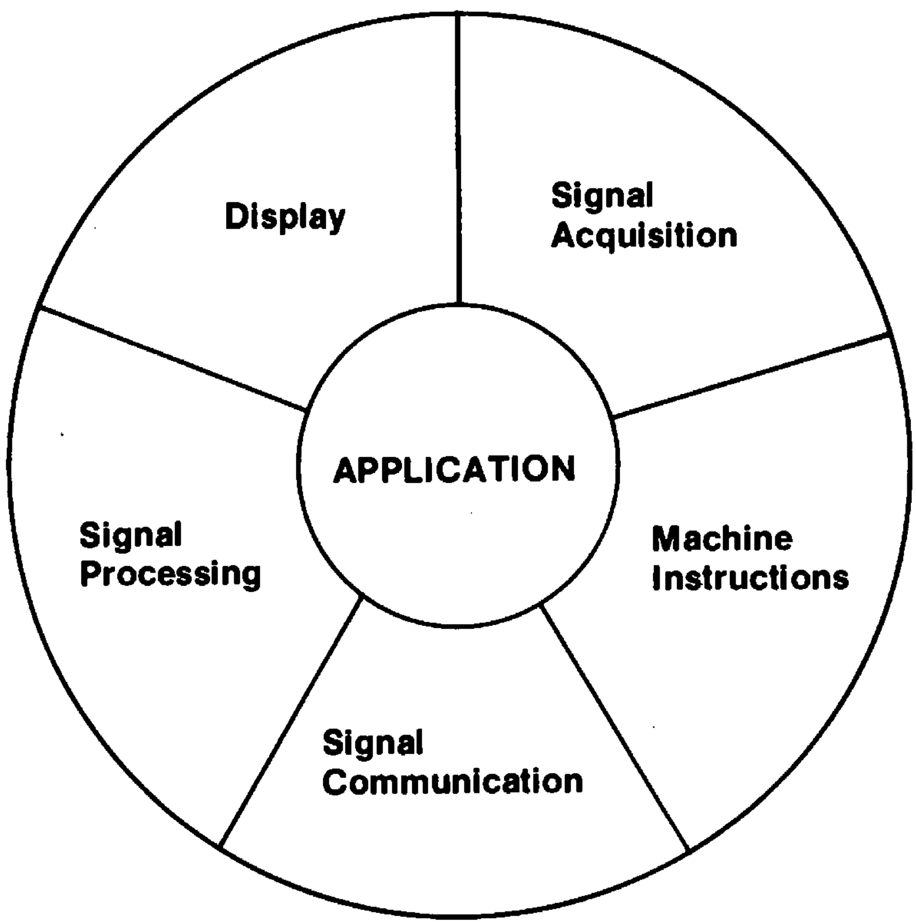
Still, VLSI chips are going to be so powerful, and so cheap, and so wonderful that we will start to think of them as black boxes, as tools in the tool chest, as things to design with, things to take for granted.

And, that's exciting. We could put the TM500 line on a bunch of chips and sell standalone displays and connector wires. This means a whole new world, a whole new set of opportunities for engineering companies like Tektronix. But the new world will require people who can work across interfaces, who can both collate new technologies and take action, even in the face of muttering bureaucrats.

I said before that the most basic fact about an instrument is that there is some need for it. Let me draw that as a circle which will be the core of all that follows:



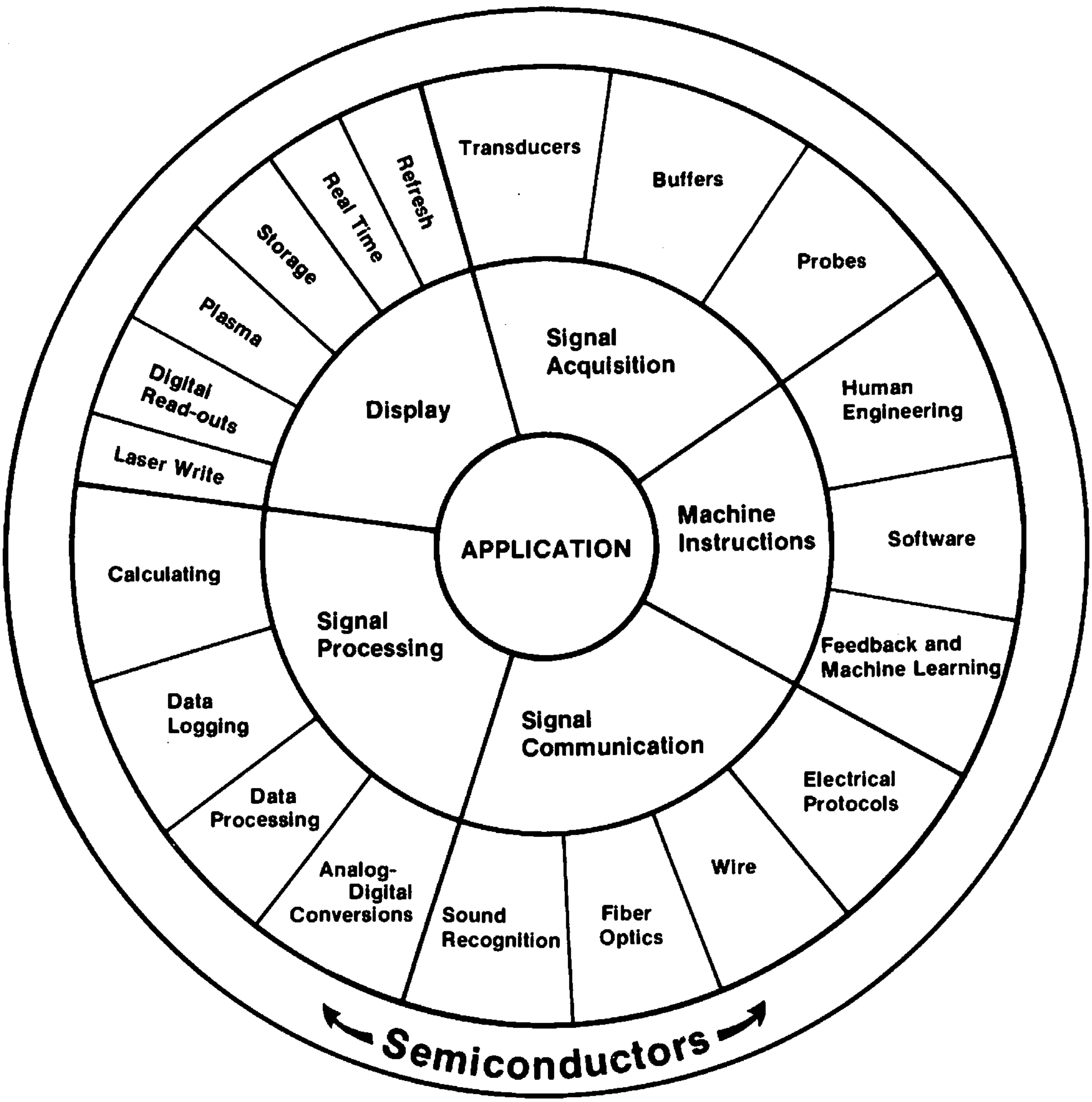
Next in importance are the concepts underlying the instrument. Let's illustrate those as surrounding the instrument:



Now, the first thing to say, before we go any further, is that the relative importance of each of these functions shifts back and forth over time. Sometimes the key issue is display, sometimes it's programmability, sometimes it's signal acquisition, sometimes it's signal communication.

I am now about to assert that semiconductor technology has profoundly changed our understanding of each of these basic instrument functions.

My final conceptual diagram of an instrument would look something like this:



Well, now we have a fairly complicated diagram, and as you might expect of me, I have surrounded everything with a giant circle entitled "semiconductors," because that's the basic technology that is rewriting the rules in every part of an instrument, without exception.

Let's take some of the segments one by one.

Displays: Cheap, fast memories mean refresh displays will soon be competitive with bi-stable storage tubes.

Signal Acquisition: Fast microprocessors, say silicon or GaAs mesfets, mean it will be both possible and advantageous to move signal processing very close to the signal source, which in turn will dramatically change the nature of what we call an instrument. Why not then pump the output of a smart probe into a minicomputer and use a standalone display and forget all about the boxes we now call instruments?

Signal acquisition considerations may, more than any other factor, change the structure of our industry; new signal acquisition capabilities mean sophisticated transducers designed specifically for special applications. There is room here for small specialized companies able to live by their wits and their focused endeavors. By comparison, the signal processing advances due to semiconductors are improvements rather than quantum jumps and in fact may begin to make the core of all instruments become more and more similar rather than different...which means competition among the giants rather than among entrepreneurs.

Signal Processing

1. VLSI means that you don't need fast clock rates to process large amounts of data...instead you can expand allowable word sizes and build in efficient algorhythms for elaborate mathematical operations and comparisons. With respect to the needs for data processing of most instruments, VLSI silicon technology is now approaching the point where most signal processing can be done on a single chip.

2. Signal acquisition still requires fast clock rates and will require ever more performance. Signal acquisition can be performed by SSI.

3. Since it is costing ever more in research to get more performance and since the performance needs of signal acquisition and signal processes are so different, the signal acquisition and signal process functions may drift apart in terms of design approaches.

4. A similar split off of display functions may occur, particularly as refresh allows more flexibility and faster scan becomes more predominant.

5. So, the cores of instruments may begin to look more similar and general purpose in nature, trending towards "minicomputers," and utilizing cheaper, more commonplace technologies.

6. If instrument cores become more similar and general purpose, then they may become commodities.

7. If instrument cores become commodities, then the competition in signal processing will be based on software and corporate ability to finance market share penetrations.

8. If the game is cpu's, software, marketing, and financing then the instrument business may be vulnerable to inroads by semiconductor, minicomputer and/or computer companies.

These statements are speculative and they are set out here to get some thinking going on what semiconductors really mean to instrument companies.

Basics of Semiconductors

Norm Heyerdahl's article on semiconductors covers how semiconductors are made. Research and development efforts in the field are focused on trying to improve performance and manufacturing ease. There are only two basic concepts involved in improving performance: capacitance and channel lengths. The most important process involving manufacturing ease is lithography.

Capacitance is related to performance because of the time and energy it takes to turn a gate on or off. The larger the capacitance, the larger the time and energy required. Related to capacitance is dielectric isolation of individual components on a chip; a lack of isolation increases capacitance effects and creates "cross-talk" between components on a chip... which makes the performance of the final circuit difficult or impossible to predict.

Here are the ways in which design engineers are now working to decrease capacitance and/or decrease channel length:

*Mesfets (either made from silicon or GaAs):

This involves an additional etching step which makes each component an isolated little "island" on the nonconductive substrate.

*V-MOS:

This involves cutting V-shaped notches in the chip which provide a three-dimensional structure which saves 40 percent in surface area. . .thereby decreasing channel lengths which make the circuit smaller, faster and cheaper.

*Computer Aided Design:

CAD reduces channel lengths and improves the predictability of the circuit being designed by improving the circuit layout.

*D-MOS:

This involves "printing" components on both sides of a chip so that they may communicate vertically as well as horizontally, which shortens channel lengths.

*New Substrate Materials:

New materials are being developed which improve dielectric isolation; two of the most promising substrate materials are GaAs and sapphire.

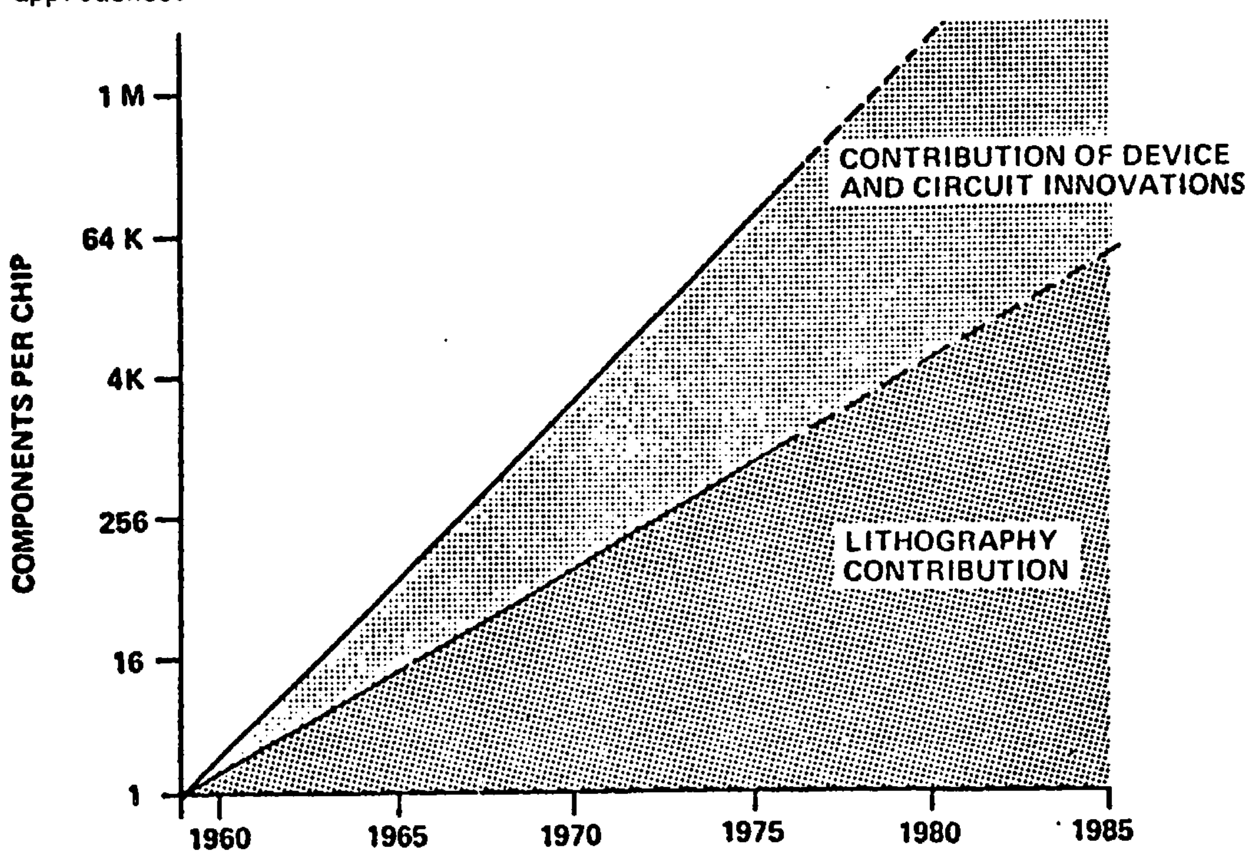
*Diffusion Depths:

Here the idea is to find materials on which narrow but deep lines may be created through lithographic processes; narrow lines mean denser circuits which mean shorter channels.

*Larger wafers and chips:

Larger chips allow more circuits to be placed on one chip rather than two. Larger wafers reduce the labor costs to make each chip. At present most semiconductor firms are shifting from three-inch wafers to four-inch, a trend which makes lithography a more crucial consideration since errors become more expensive the larger the wafers involved.

Not all efforts related to improving performance are oriented towards device and circuit innovations. In fact, lithography. . .the process of forming devices on the chip. . .is even more important than device type in determining both performance and costs (by influencing manufacturing ease). EXHIBIT 1 below illustrates the relative importance of the two approaches.



Here are some of the ways design engineers are working to improve lithographic techniques:

*Contact Printing:

Contact printing is the predominant lithographic method now, and numerous improvements such as more uniform light sources, larger wafers, larger dies, better alignment systems, and the like are planned.

*Deep Ultraviolet Lithography:

The use of deep ultraviolet light permits the definition of narrower features before diffraction effects interfere; the major disadvantage is the high cost of quartz mask substrates.

*Proximity Printing:

By separating the mask and wafer slightly the mask life is improved although resolution decreases.

Projection Printing:

In projection printing an image of the mask is projected by a lens system, which avoids mask damage, which in turn justifies the use of more expensive defect-free masks.

*Electron-Beam Lithography:

The use of electrons rather than light to make either masks or devices directly allows extremely high resolution...including the drawing of lines with widths on the order of several times typical molecular spacing; electron beam lithography systems have a high cost, (about $1.5 million) and at present are too slow for most direct writing applications. But watch your Electronics magazine for news of faster speeds.

*X-Ray Lithography:

X-rays are short in wave length, which improves resolution, but most device materials do not respond quickly to short wave-length radiation.

*Conformable Photomask Lithography:

Conformable masks maximize resolution by increasing the wafer-mask contact quality.

*Step and Repeat:

Step and repeat lithography overcomes wafer irregularities by covering small, and therefore relatively flat, areas on a wafer and then moving to an adjacent area.

*Plasma and Ion Milling Lithography:

These techniques use charged ions to etch patterns on semiconductors; these techniques are experimental at the present time.

Another area of interest is process automation, which improves ease of manufacturing and reduces costs by improving yields. The major automation concerns at present are:

*Use of air conveyor systems to transport wafers through the various lithographic steps.

*Substitution of plasma dry etching for acid wet etching when removing protective layers.

*Automation by minicomputer and microprocessor of the diffusion process and related activities.

*Automation under microprocessor control of final testing and scribing processes.

A final area of interest is computer aided circuit design, which improves circuit layout and cleverness.

Industry Perspectives

At this point I am hoping that you will be able to reason out some of the implications of these technology improvements. As a sampling, here are some of the things that I have been reading in Electronic News:

*Microprocessors are devastating the older firms who dominated the transistor business. The LSI techniques have created a business so basically new that the existing firms have just not been able to adapt, even though both transistors and LSI devices are semiconductors made from silicon.

*Semiconductors are basic to computers which are basic to modern industrial society. As a result foreign governments have been intervening in the development of semiconductor technology in major ways in Japan and Germany. These governmental interventions may mean the end of American domination of semiconductor production within a relatively short time.

*The large American semiconductor houses are integrating upwards into applications. As a trend, this upward integration may impact both minicomputer companies and instrument companies.

*The competitive strengths of the large semiconductor houses are causing an industry shakeout. One sign of the change is the increasing number of small semiconductor firms signing cross-licensing agreements.

*R&D costs are rising rapidly...electron beam lithography machines, for example, cost $1.5 million each. As advances become more expensive, large firms will dominate advanced areas and cheaper and more conventional methods will be used in more commonplace applications. That is to say, the technology and industry are starting to mature.

*It is cheap memory more than cheap processing that is changing the ground rules. Cheap memories mean interactive software, large data banks, and new applications.

*Transducers are becoming a limiting factor, particularly for high speed data acquisition. As mentioned above, transducer design will be an area requiring specialized knowledge of individual applications, a situation favoring small quick-witted entrepreneurial ventures.

*General purpose "kitchips" (chips which can be programmed to perform various circuit functions depending upon application) may reduce costs further for applications that up to now were custom in nature and requiring high cost special designs.

*Small Scale Integration (SSI) devices may soon start replacing electromechanical devices such as switches, potentiometers, and attenuators.

POSTSCRIPT: from Electronics, 21 July 1977

ELECTRON-BEAM WAFERS ARE CLOSER THAN YOU MAY THINK

It's a mistake to believe that the use of electron beams to write circuit patterns directly on wafers is still years away from the production stage, for it already looks like a viable alternative to photolithography. In-house designed prototype electron-beam fabricating stations now in operation at semiconductor laboratories in the U.S. and abroad can complete a one-mask pass on a fully populated four-inch wafer in as little as eight minutes--tantalizingly close to the six minutes per mask that specialists agree will make electron-beam wafer fabrication a production feasibility.

But even at the present throughput rate, ICs fabricated with electron beams can be cheaper than those made twice or three times as fast with photolithographic methods. That's because the wafer can contain from four to sixteen times more bits or gates, so that simply by transferring the eight-minute electron-beam machines to production, semiconductor manufacturers will immediately halve or quarter their chip fabrication costs. And that's too much of an advantage for them to hold back for very long.

Additional Reading:

Electronics, 18 August 1977: "Five Technologies Squeezing More Performance from LSI Chips".

Tektronix Engineering News, 15 August 1977: "Trends in Microlithography."

TECHNOLOGY OVERVIEW: DISPLAY TECHNIQUES

By Aris Silzars

This brief report will try to give an overview of where CRTs have been, where they are today, and what is seen as the future for the next five to ten years.

Certainly, anyone who has been around Tektronix at any time during its history can readily identify with the key influence that CRTs have had on Tektronix products. Displaying wave forms as time on the horizontal axis and amplitude on the vertical axis has become a standard measuring technique in the electronics industry.

The CRT has evolved into an ever more sophisticated device, with features that were unknown just a few short years ago. The basic CRT consists of some type of electron-emitting source, a method to modulate the electron beam, and a surface on which the beam impinges and produces an optical output. In more common terminology, there is an electron gun consisting of cathode and focusing elements, some deflection plates, and a phosphor screen.

Over the years, progress has been made in all three of the basic CRT elements. Cathodes and electron guns have become more sophisticated, with improved focus lenses and greater electron emission capability. Deflection plates started with simple pieces of metal and have ended up with some of the newer tubes using tapered helical windings to match electron beam velocities to the signal propogating along the circuit. The phospor screen on which the information is displayed has also seen many improvements and increases in complexity. Some of the newer storage screens, for example, use complex dot structures, or even additional fine meshes to retain the information for viewing after the original signal has long disappeared.

The CRT of today has indeed become a very sophisticated and refined display device. High-speed CRTs can display single events that contain signal components above one gigahertz. Other designs can display and store signals of 400 megahertz or higher. And, all of this is done with input signals that several years ago would not have been sufficient even barely to move the beam around the screen.

Because of the key role that CRTs have played in the growth of Tektronix, and because they are used in so many of our products, it would be natural to assume that CRTs will continue to be developed at their present rate and will continue their strong contribution to the future of the company.

This assumption, however, may not be correct. Recent trends in the electronics business, and particularly in the instrumentation business indicate that the development of ever more sophisticated and higher performing CRTs is coming to an end. The high-speed CRTs that have been developed today will certainly continue to contribute to our business in the future, but the new growth areas will be in other types of displays.

To date, the CRT has played the role of both signal acquisition and display. In the future, signal acquisition may become a separate function from the display. In many new instruments a signal will be acquired, stored in memory, processed through some mathematical manipulation, and then displayed at the user's convenience. This separation of acquisition, processing and display functions will, incidentally, make it necessary to put additional information on the screen to describe what the signal that is being displayed really represents.

Another important consideration is the tremendous growth of instruments that operate in the digital domain as opposed to traditional analog instruments such as our present line of oscilloscopes. Instruments that work in the digital domain do not always require detailed information on every wave form. They are often displaying only ones and zeroes, or simply "On" and "Off" states. However, this simplified display is then complicated by the requirement to display many of these wave forms simultaneously, and one must be able to spot anomolies in a complex set of sequential events.

A third area that has shown growth, and is expected to grow rapidly in the future, is the display of computer generated information. The Tektronix Information Display Group was founded primarily to meet this customer requirement. Here, again, we do not have much need for high speed or high performance CRTs. What is needed are displays that can put lots of information on a screen and to retain it for some period of time.

It is very apparent, then, that the evolutionary period of higher speed CRTs has reached maturity. The future trends in this area will be the refinement of performance, manufacturing methods, and cost reduction.

We are now in a very exciting and rapidly changing period of developing displays that give our customers the capability of seeing, not only wave forms but also alpha-numeric information, as well as computer generated graphs. What this means for us in the display areas is that we must now concern ourselves with the complete chain of events from signal acquisition, to display and, in some cases, to the creation of a hard copy permanent record.

To summarize, the trend that I see in the various display areas will be ones of providing higher resolution displays, including displays using color. Scope cameras will be replaced, in many cases, by hard-copy printers or plotters, and instruments will become interactive--with such features as touch panels that provide preprogrammed learning modes and data manipulation.

Some final questions that need to be addressed are: "How long will CRTs be with us? Will they be replaced by other types of displays, or will displays be needed at all?"

It is my opinion that the display of information will continue to be a necessary part of much of our instrumentation. However, in some of our less complex instruments, the display does not need to be a CRT, but may be a simple array of lights or digits that provide a numerical or simple written data output. In an increasing number of applications, instruments will communicate directly with computers. However, I believe that all of the more complex instrumentation will continue to use some type of display to output information.

A considerable amount of research today is going on in the electronics industry to try to come up with a replacement for the Cathode Ray Tube. It is not always clear why one would want to replace a Cathode Ray Tube, but some of the reasons given are that a solid-state display would be smaller in volume, perhaps more rugged, and not have the need of a high-voltage power supply. For example, a very small, portable oscilloscope could be made if the CRT could be replaced by a thin display panel that could be driven directly from a low-voltage integrated circuit.

Tek has a few, relatively modest efforts in the flat panel area and we are trying to monitor the rest of the industry to see if there are any breakthroughs. However, at the present time, we do not see a revolutionary switch to another type of display. In spite of all of its disadvantages, the CRT turns out to be a very convenient and high-resolution displayer of information. And, as it continues to improve, it becomes ever more difficult for another technology to displace it as the display medium of choice.

What I expect to see happen is that the new display technologies, such as liquid crystals, light emitting diodes, gas discharges, or plasma panels, will start to replace CRTs in those areas where the display requirements are relatively modest. For example, one does not need to use a CRT if only a few lines of information, of perhaps 50 characters, are required. Some of the solid-state, flat-panel technologies will slowly make inroads into the more complex information display areas.

However, I would estimate that even in ten years we will still be building more than half of our instruments with some type of CRT.

Finally, I believe that it is important to know that we do not feel threatened by the new display technologies because we expect to be able to contribute technologically in those new areas, just as we have to the development of the CRT.

EXCERPT FROM ELECTRONICS, 21 July 1977

TEK INTERESTED IN BEAM-INDEXED CRT TECHNOLOGY

Tektronix, Inc., is studying a variety of color displays for use in future data terminals, including the beam-indexed color cathode ray tube. The tube, which dates back to the mid-1950s when it was under development at Philco Corporation and General Electric and was called the "Apple" tube, can display characters much more sharply than conventional shadow-mask-type color CRTs, which suffer from convergence problems across the screen. The beam-indexed tube uses a single electron gun rather than the three guns of the shadow-mask type, hence it's better convergence. Tek has built a six-inch feasibility model at its Wilsonville, Oregon facility, and now is moving on to a 19-inch developmental version, which will display 35 lines of 80 characters each. Among the major problems remaining are getting uniform phosphor deposition and forming the stripe structure of the red-green-blue triplets.

A Tek spokesman says that each of the feasibility models has certain deficiencies, and there has not yet been a definite management decision on any single technology. Meanwhile, the company says it expects to rely heavily on its direct-view, storage-tube technology, both for existing and planned products requiring high-resolution capability.

INDUSTRY OVERVIEWS: SIGNAL AND DATA PROCESSING INDUSTRIES

INTRODUCTION

The exhibits and text of this section provide an overview of the semiconductor, minicomputer, computer, general purpose test equipment, and telecommunication test equipment industries. These industries are all driven by a semiconductor performance/cost push. The products of these industries have certain functional elements in common: They acquire data, process data, display data, and operate under instructions.

The various individual industries separate into three general categories: instruments, semiconductors, electronic data processing. Semiconductors are key components that are central to both the EDP and instrument industries. The instrument industries produce products that help other manufacturing industries in design, manufacturing, test, and service tasks. The EDP industries produce products to help end-users process data.

To provide an overview several exhibits have been prepared. Exhibit 1 lists and defines the principal industries involved in signal and data processing. Exhibit 2 discusses the relationships among selected industries. Exhibit 3 provides a competitive overview of these industries.

With respect to Exhibit 3, it may be useful first to look at the column labeled "semiconductors". Industries to the right are data processing industries selling to end users, and industries to the left are instrument industries selling to other manufacturers. The further each industry column is from the semiconductor column, the lesser the dependence on strictly semiconductor expertise and the greater the relative importance of understanding the complex and diverse needs of relevant customer groups. Such is the pace, technologies, and human talent requirements of the various industries, that in general it is relatively easier for a firm to move from the center outward than from the outside in. This is not a usual pattern, incidentally, as in non-electronics industries most firms find forward integration very difficult.

Exhibit 3 will provide a reference point for the following sections. In general, it should be remembered that the most important historical trend at present is the crumbling of the barriers between these various industries. Perhaps in a few years similar overview charts will have labels not based on product descriptors but upon customer descriptors. An increasingly customer orientation will perhaps be caused by the general purpose nature of VLSI devices which make it easily possible to dedicate products through use of software to the needs of each specific set of customers.

SPECIAL COMMENTS ORIENTED TOWARDS THIS MOMENT IN TIME

CURRENT COMPETITIVE SITUATION

HEWLETT-PACKARD: Has both the EDP and Instrument industries in turmoil with a distributed processing network approach to both.

GOULD, PHILIPS: these "newcomers" (actually Philips has been in the test and measurement business since 1896) see technology turmoil, industry fragmentation, price politeness, complacent leaders, and some good chances to make money.

INTEL, T.I.: these aggressive determined companies are pushing both into instruments and EDP, determined to diversify and become major world forces.

IBM, DEC: the powerful EDP firms, typified by IBM and DEC, are sweeping back and forth looking for every possible market segment and route for expansion. Their technology, marketing savy, and size are unparalleled in human history.

AT & T/WESTERN ELECTRIC: there is no longer any important differences between the computer and communications equipment industries, and these two interrelated, huge, capable, politicized companies are coming alive.

DISTRIBUTION ISSUES

If one blurs one's eyes while looking at Exhibit 3, it may occur that something new is occurring in terms of product groupings: a lot of products, particularly in the instrument and small scale EDP areas, are coming up in complexity and down in cost. These new clumpings of products, unprecedented in power for their prices, are costing in the range of $1,000 to $4,000. Products in these price ranges just cannot go through conventional distribution channels: they are too cheap for direct selling, and they are too complex for conventional distributors. So how are these awesome, compelling products to be sold?

The Yankee Group recently published a light-hearted look at this crucial problem. They first noted "Moore's Law" (named after Gordon Moore, President and CEO of Intel). Moore's Law notes that the number of components per semiconductor chip has doubled every year since 1959 and appears as if it will continue for the foreseeable future. This is a common observation and a profound one. Yankee then offers their own law: "The Yankee Lemming Theorem": "Any number of semiconductor manufacturers will gladly throw themselves, like Lemmings, into the sea of red ink by drastically reducing costs to gain a fractionally larger market share".

At first glance these two laws taken together seem to promise a new golden era of virtually free computers, cheap communications, and televisions as common as tubes of toothpaste. But not so.

IBM Self-Correcting typewriters cost $965 to buy and $100 to make. Razors cost $0.25 to buy and $0.0025 to make. In general, copiers, intelligent terminals, and computers have a manufacturing cost of 15 percent of sales cost. That means, if the products cost nothing to make, prices might only come down 15 percent.

Where, then are the remaining costs? It's advertising, distribution, service, selling, and overhead costs that account for 60 percent of the selling price, with 25 percent going for profit and taxes. Seen in this light, calculators were not only a revolution in technology, they were also a revolution in distribution with prices coming down so drastically because of the new channels of distribution. If calculators were sold through direct sales forces then their economics and volumes would be entirely different.

Because of the increasing performance/cost ratios of a critical component, semiconductors, small instruments and data processing devices will become ever more powerful. But it will take a rationalization of distribution to create a true revolution in these areas. Oscilloscopes through Sears? In fact, T-900's are sold in retail shops in Germany at the present time. Television ads for counters? Walk-in instrument stores similar to walk-in home computer stores? DEC now calls computers in a shopping center retail store. Or perhaps a better idea is demonstration centers in convenient locations, such as Texas Instruments now uses to sell a wide variety of semiconductor based products.

Exhibit 1: Signal and Data Processing Industries

INDUSTRY DEFINITIONS:	1977 World Market Size ($ Billions)	1977/82 CAG
1. Telecommunications Test Equipment o Centralized Test Consoles o CB/Land Mobile o Analog Line Impairment o Microwave o Digital	$1.2	11%
2. General Purpose Test Equipment o Signal Sources o Counters o Signal Analyzers o Recorders o Voltmeters o Power Supplies	$1.5	9%
3. Computer Aided Manufacturing (ATE) o Component Testers o Subsystem Testers o System Testers	$0.2	14%
4. Computer Aided Engineering (MDA/CAD) o Software Development System o Documentation Drafting System	$0.2	29%
5. Semiconductors o Discrete Devices o Memories o Microprocessors	$6.3	15%
6. Small and Dedicated EDP o Intelligent Terminals o Dedicated Microcomputers o Small Dedicated Minicomputers o Small Business Computers	$5.0	25%
7. General Purpose Minicomputers o General Purpose Microcomputers o General Purpose Minicomputers o Mainframes, peripherals, software, support	$3.5	29%
8. Computer Mainframes and Memories o Commercial and Scientific o Medium to Very Large Computers o Mainframes, Software Support, Non-Intelligent Peripherals and Add-On Memories	$13.0	11%

9.	Telecommunications Equipment (U.S. Only)	$8.5	12%
10.	Medical Instruments	$0.2	12%
11.	Analytical Instruments o Spectroscopy o Electron Microscopes o Chromatography o Analyzers	$1.3	14%
12.	Other o T.V. Test o Data Loggers o GPIB Controllers o Logic Probes	$0.2	18%

EXHIBIT 2: COMMON THREADS AMONG SELECTED SIGNAL AND DATA PROCESSING INDUSTRIES

COMMON THREADS:

1. Driven by semiconductor performance/cost push
2. Products that:
   - o Acquire Data
   - o Process Data
   - o Display Data
   - o Operate Under Instructions

DIFFERENCES:

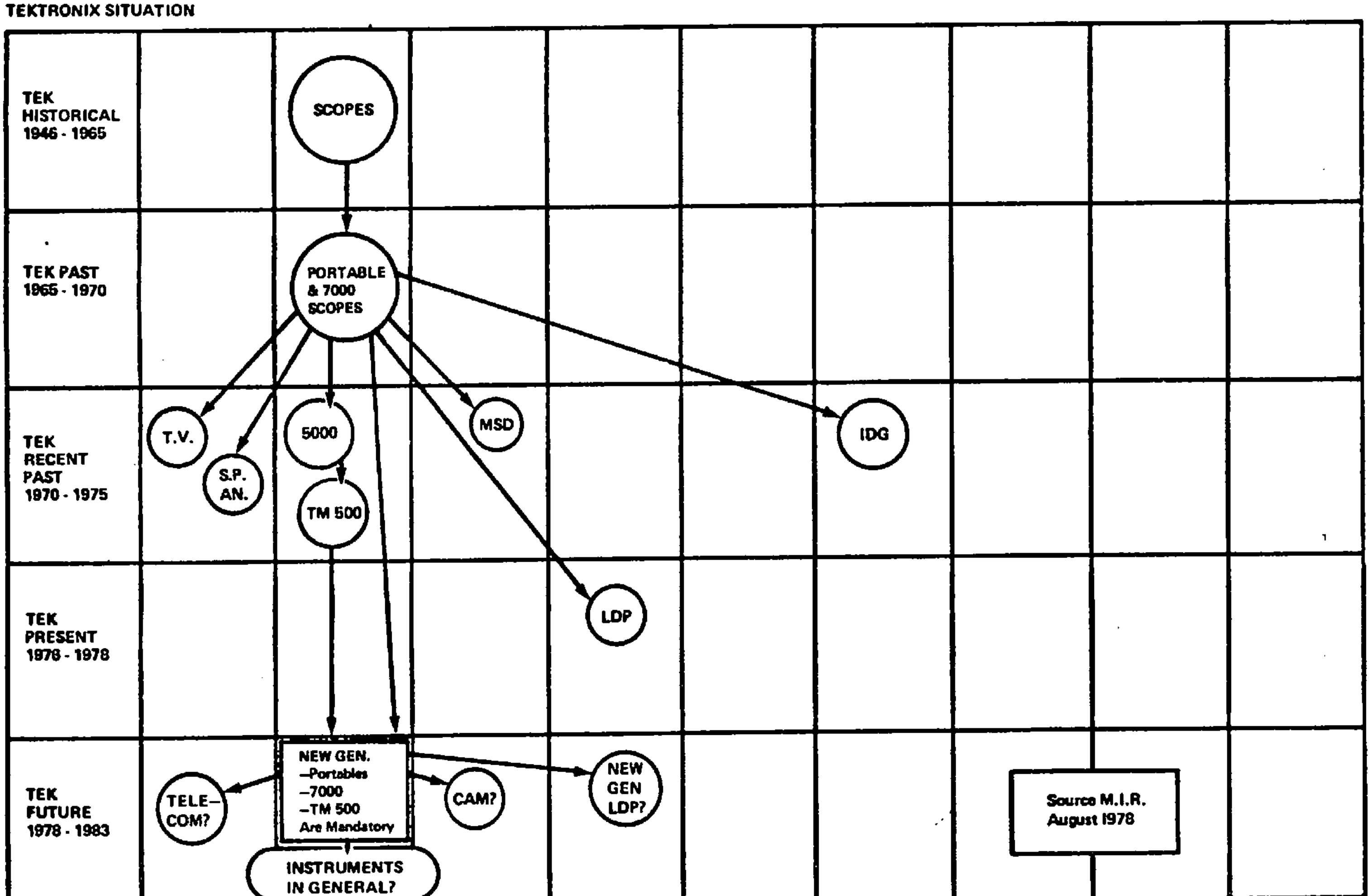
1. Product applications
2. Mechanical packaging
3. Users
4. Competitors

INDUSTRY	HOW ADJACENT INDUSTRIES ARE RELATED
Telecommunications Test Equipment	
	Telecommunications Test Equipment is general purpose test equipment dedicated to specific applications.
General Purpose Test Equipment	
	GPTE instruments can be seen as components of a Computer Aided Manufacturing system with a controller at the center.
Computer Aided Manufacturing (ATE)	
	CAM systems test semiconductor systems and components; CAE systems develop semiconductor applications.
Computer Aided Engineering (MDA/CAD)	
	MDAs are essential to the sales of microprocessors.
Semiconductor	
	VLSI means a system on a chip...to the point that semiconductor manufacturers are beginning to take the system design function away from the Dedicated EDP industry.
Dedicated EDP	
	Larger bit structures and larger and cheaper memories make general purpose, flexible microcomputers and minicomputers practical as replacements for dedicated EDP products. Thus the Dedicated EDP industry is being redefined.
General Purpose Minicomputer	
	The increasing power and complexity of semiconductors and the increasing capabilities of minicomputer networks are blurring the traditional computer definitions even as all categories drift upwards in performance/cost. Incidentally, the semiconductor companies participate in virtually all computer industry categories by providing add-on memories.
Computer Mainframes and Memories	
	Large telecommunications switches are really computers in all but name. Further overlap between the computer and telecom industries occurs as AT&T begins providing point of sale terminals in Seattle trials; networks with computers as centerpieces depend upon cheap, effective communications which means computer firms have a stake in events in the telecommunications industry.
Telecommunications Equipment	

COMPETETIVE ANALYSIS OVERVIEW

	INSTRUMENTS ← DOWNSTREAM APPLICATIONS				SEMICON–DUCTOR COMPONENTS	DOWNSTREAM APPLICATIONS → EDP			
INDUSTRY	TELECOM–MUNICATIONS TEST EQUIP.	GEN. PURPOSE TEST EQUIP.	COMPUTER–AIDED MFG. (ATE)	COMPUTER–AIDED ENGINEERING (MDA/CAD)	SEMICON–DUCTOR	DEDICATED EDP	GEN. PURPOSE MINICOMPUTER	COMPUTER MAINFRAME	TELECOM–MUNICATIONS EQUIPMENT
INDUSTRY RELATION–SHIPS	DEDICATED GPTE–LIKE INSTRUMENTS FOR COMMUN–ICATIONS SERVICE	GEN. PURPOSE INSTRUMENTS FOR ELEC–TRONIC & EDP RESEARCH, DESIGN, MFG.	INSTRUMENT SYSTEMS FOR S/C AND S/C SYSTEMS MFG.	INSTRUMENT SYSTEMS FOR S/C AND S/C SYSTEMS DESIGN	A KEY COM–PONENT OF EDP & INSTR. PRODUCTS	SMALL, DEDICATED SYSTEMS ON A CHIP	MEDIUM CPU'S, MEDIUM MEMORY	LARGE CPU'S, LARGE MEMORY	DEDICATED COMPUTERS
SIZE: 1977 CAG: 1977-1982	$1.2 B 11 %	$1.5 B 9 %	$0.2 B 14 %	$0.2 B 29 %	$6.3 B 15 %	$5.0 B 25 %	$3.5 B 29 %	$13.0 B 11 %	$8.5 B 12 %

TEKTRONIX SITUATION



CURRENT COMPETETIVE SITUATION

	TELECOM. TEST EQUIP.	GEN. PURPOSE TEST EQUIP.	COMPUTER-AIDED MFG.	COMPUTER-AIDED ENGINEERING	SEMICONDUCTOR	DEDICATED EDP	GEN. PURPOSE MINICOMPUTER	COMPUTER MAINFRAME	TELECOM. EQUIPMENT
KEY COMPETITORS	H.P.	H.P.	H.P. →	- - - - -	← H.P.	H.P.	H.P.	H.P. →	- - - - -
	PHILIPS	PHILIPS →			PHILIPS	PHILIPS	PHILIPS →		← PHILIPS
		GOULD	——						
				← INTEL	INTEL	INTEL →		← INTEL	
				← T.I.	T.I.	T. I.	T.I.		
		GENRAD	GENRAD						
		FLUKE	FLUKE						
						← DEC	DEC	DEC	
						IBM	IBM	IBM	IBM
									AT&T
	W.E.								

EXHIBIT 4: RELATIVE SIZES OF KEY PARTICIPANTS
SIGNAL AND DATA PROCESSING INDUSTRIES
1977 FY SALES IN BILLIONS OF DOLLARS

	1977 SALES	RELATIVE SIZES
Tektronix	$ 0.5 Billion	1.0
Hewlett-Packard	1.4	2.8
North American Philips	1.9	3.8
Philips N.V.	13.7	27.4
Fluke	0.06	0.1
Genrad	0.07	0.1
Gould	1.7	3.4
Intel	0.3	0.6
Texas Instruments	2.0	4.0
Digital Equipment Corporation	1.1	2.2
International Business Machines	18.1	36.2
Western Electric	7.0	14.0
American Telephone and Telegraph	$ 36.5	73.0

INDUSTRY OVERVIEW: SEMICONDUCTORS

1.0 INDUSTRY STRUCTURE AND KEY TRENDS

History

Excerpt from "Microelectronics" by Robert Noyce, Scientific American, September 1977:

"It is not an exaggeration to say that most of the tecnological achievements of the past decade have depended on microelectronics. Small and reliable sensing and control devices are the essential elements in the complex systems that have landed men on the moon and explored Mars, not to speak of their similar role in the intercontinental weapons that dominate world politics. Microelectronic devices are also the essence of new products ranging from communications satellites to hand-held calculators and digital watches. Somewhat subtler, but perhaps eventually more significant, is the effect of microelectronics on the computer. The capacity of the computer for storing, processing and displaying information has been greatly enhanced. Moreover, for many purposes the computer is being dispersed to the sites where it is operated or where its output is applied: to the "smart" typewriter or instrument or industrial control device.

"The microelectronics revolution is far from having run its course. We are still learning how to exploit the potential of the integrated circuit by developing new theories and designing new circuits whose performance may yet be improved by another order of magnitude. And we are only slowly perceiving the intellectual and social implications of the personal computer, which will give the individual access to vast stores of information and the ability to learn from it, add to it and communicate with others concerning it."

Special Characteristics

- Costs and the Pace of Change: With each doubling of accumulated experience, unit costs in constant dollars have declined 28 percent. While this is a typical rate for any industry, unusual is the pace of events: a doubling of unit volume nearly every year since 1959. This pace has been due to unprecedented market acceptance of the products: annual usage in terms of individual electronic functions has increased 2000 times in the past 17 years. Each new application has expanded volume which has lowered costs which has opened new markets. If these price changes over the past 15 years had been matched by the auto industry, one could buy a car today for $2.50.

  Costs of a device to achieve a given task are decreased in four major ways: 1) unit costs decline due to learning curve effects; 2) more functions can be placed on each device; 3) performance of each device is increasing, such as greater speed, better reliability, and lower power consumption; and 4) devices are becoming more complex, often combining on a single device logic, memory, input capabilities, processing, and display formatting and drive; in only slightly over ten years products have gone from single transistors to one-chip computers.

  It is important to appreciate the pace of the industry and the associated volatility. The industry involves a high technology. Breakthroughs in high technology depend on a relatively few, especially capable people. These people can leave an established firm and redefine an industry in a short period of time. This industry volatility then attracts even more capable people while their importance leads participating firms to seek them out. More capable people then leads to an even greater rate of change. Many people and companies have been ruined in this rapid pace, and adaptation to the pace keeps industry profits low and tends to undermine any basic strength that a single company may have. As a result, competitive advantages in this industry have tended to be short-lived, and rapid change appears to be a basic feature of this industry rather than a temporary phenomenon.

Are there limits to these developments? Not for a long time. Even the most powerful circuits of today are only barely comparable to the complexity of biological systems, such as the DNA molecule.

- Social Implications: More than the rapid rate of cost declines make this industry historically unique. The products of this industry represent a qualitative change in human capabilities, particularly in terms of the ability to acquire, process, organize, and utilize vast quantities of information. Previous industrial revolutions, in retrospect, have altered man's physical capabilities, whereas this industrial revolution directly alters his mental capabilities. An article in a recent issue of Time (20 February, 1978) even proposed straight-facedly the eventual development of a new kind of intelligent life made of silicon.

- Competition: This is a specially competitive industry, with large numbers of competitors and a continual influx of new products and markets. It is an unusual industry in that the largest producer of devices does not offer them for sale at all in the form of components (IBM). It is, at the same time, also unusual in that the next largest competitors will sell to anyone (Intel, Mostek, Motorola, and the like).

So at one end there is IBM (1977 sales of $18 billion) keeping the world computer industry locked-up with its superior technology, and at the other end there are the Intels (1977 sales of $0.3 billion) keeping an incredible array of other industries (ranging from instruments to automobiles) in deep disarray as it single-mindedly pursues volume, experience, and market share in components.

2.0 PRODUCTS

The semiconductor industry produces:

- integrated circuits
- discrete devices
- optoelectronic devices.

Integrated Circuits

An integrated circuit is a single chip made principally from silicon and artificially induced impurities that has more than one electrical device on it. Electrical devices include transistors, diodes, resistors, and capacitors. Integrated circuits may perform either digital or analog electronic functions and may be based on a wide variety of basic technologies.

Integrated circuits may be subdivided into four major types:

- memories, which store information in digital form and which consist of memory sites and addressing circuits; types of memories include random access memories (RAMSs), read-only memories (ROMs), and other variants, including the mythical write-only memory (WOMs).

- microprocessors, which can perform arithmetic on numbers and make basic log decisions (if such-and-such, then this-and-that); microprocessors require external support circuits to provide timing, program memory, random-access memory, interfaces for input and output, and other ancillary functions; microprocessors contain a decode and control unit to interpret instructions stored elsewhere, an arithmetic and logic unit to perform arithmetic and logic operations, registers which serve as readily available memory for data frequently manipulated, accumulators which are special registors for holding interim results, address buffers to supply the control memory with the address from which to fetch the next instruction, and input-out buffers to read instructions or data into the microprocessor or to send them out.

- peripheral devices, which support microprocessors.

- microcomputers, which combine on a single chip all memory, processing, and ancillary support functions to constitute a self-contained computer system.

Discrete Devices

Discrete devices are products such as transistors, diodes, and switching devices. There is a wide diversity of applications which has led to the development of a wide diversity of types of discrete devices, numbering in the tens of thousands, which create an accompanying diversity in manufacturing and design approaches.

Optoelectronic Devices

These devices, such as light-emitting-diodes (LEDs), are used in display and communications applications. An example of a display application is a digital watch read-out, and an example of a communications application is a signal source for a fiber optics telephone line.

In general semiconductor products can be categorized as:

- custom products, specifically designed with a particular application in mind;
- standard products, which are adapted to a particular application with a special instruction set (software)
- commodities, which is a semiconductor that has been universally accepted and is produced in high volume by more than one manufacturer, typically at low cost and with low margins.

PRODUCT TRENDS

Microprocessors

The new 16-bit microprocessors are powerful enough to be compared with traditional mini and mainframe CPUs. This involves semiconductor houses in the design of more complex systems and opens up new market areas as performance/cost ratios jump upwards (again). In this new world software assumes a greater importance (for example, one-half of the investment in Intel's new 16-bit microprocessor was in software and documentation). Software is important both because 16-bit microprocessors are economical only because standard designs can easily be altered to suit particular applications through use of software and because these new devices are so complex that only with higher level software and easily understood documentation is it feasible for end-users to apply them to their needs.

The larger word size of 16-bit microprocessors also makes direct data base management easier which has implications for producers of dedicated EDP products. In general, the greater power and software support makes 16-bit microprocessors more attractive as flexible building blocks for OEM's and will usher in a new "shotgun" era of specialized applications built upon these common building blocks.

For the foreseeable future, then, microprocessor products will continue to be characterized by ever increasing diversity, high technology, rapidly changing technology, short life cycles, and more functions per chip.

Memories

Ever improving memory performance/cost ratios, partly due to some new device types (such as bubble memories), along with improving A-D converters, mean ever increasing numbers of memory applications. The major limiting factor may be time. . . the time it takes for product designers first to understand the new possibilities and then to apply them.

New areas of applications include instruments, consumer goods, automobiles, office equipment, communications equipment, terminals, and controllers. In some cases semiconductors will displace other forms of memory such as tapes and disks and in other cases the applications will be totally new.

3.0 MARKETS

Customer Groups

Semiconductors are components. Although the largest producers of these components, such as IBM and DEC, are fully integrated companies selling directly to end users, most semiconductor companies sell to other manufacturers that design, assemble, and market the end products. Thus, the vast majority of semiconductors are sold to other industrial manufacturing corporations rather than used internally.

Semiconductors find their greatest use in five separate types of product/markets:

- instruments, including general purpose test equipment, analytical instruments, telecommunications test equipment, computer aided engineering, and medical instruments.
- electronic data processing, including dedicated EDP, minicomputers, computers, and telecommunications equipment.
- controllers, including process control and current switches.
- consumer products, including radios, televisions, cameras, watches, automobiles, calculators and appliances.
- government and military products, including guidance systems, special purpose test equipment, and battlefield equipment including night vision devices and personnel sensors.

The types of devices sold into each of these markets are similar, and manufacturers rarely specialize in a single market. The characteristics of each of these markets are very different, however. For example, instruments are sold to industrial users who are interested in manufacturing, designing, or servicing products other than instruments; EDP products are sold to end users in a wide variety of industries that are both manufacturing and service in nature; consumer products are sold directly to nonindustrial end-users for noncommercial applications; and government and military products are sold to government personnel for uses unique to governments. Thus, although the products may be similar, the distribution channels, relative concern for various product features including price, reliability, and performance, the level of sophistication required, and the service and application support requirements of the various types of customers vary so widely as to make each area a unique industry.

Although semiconductors will increasingly move toward standard designs with applications performed in software, it is expected that the user industries will become even more rather than less distinct in terms of the marketing and product packaging approaches needed to reach each separate group of customers. When, for example, you can literally talk to your washing machine through a microprocessor speech recognizer/ sythesizer, the instruments used to test the washing machine will be specific rather than general purpose in nature and reach the service technician through specialized channels of distribution.

Distribution

Semiconductor devices are sold and distributed in three basic ways:

- Through a direct sales force, with shipment from the company.
- Through a representative organization with shipment from the company.

- o Through a distributor with shipment from its own stocks.

Historically, semiconductor companies have preferred to market directly whenever possible. However, a direct sales force cannot marekt economically to smaller users or in areas where sales volumes are low so that direct selling represents a large fixed cost. In general, distributors try to do a good job for the manufacturers because having access to advanced products is important to them and because associated with sales of semiconductors is a large volume of related components and instruments.

WORLDWIDE SEMICONDUCTOR BILLINGS
OF U.S.-BASED COMPANIES
IN MILLIONS OF DOLLARS U.S.

	1976	1977	First 6 Months of 1978	1978E
To US OEM Customers	1817	2032	1123	
To US Distributors	474	540	336	
Total US Bookings	2291	2572	1459	
To Western Europe	756	885	560	
To Japan	168	164	108	
To R.O.W.	219	236	124	
Total International	1143	1285	792	
Total World	3434	3857	2251	4700

Percent Changes in
Worldwide Semiconductor Billings

1977	1978E
+12.3%	+21.7%

Source: Semiconductor Industry Association, Wema, Morgan Stanley

Worldwide Market Sizes in Millions of Dollars

	1977	1980	Compound Annual Growth Rate
Electronic Games	670	$1,125	19%
Semiconductor Content	55	111	26%
Microprocessors			
Industrial control	107	170	17%
Business Equipment	74	92	8%
Telecommunications	12	30	36%
Computer	68	178	38%
Consumer	15	32	29%
Military/Government	5	20	59%
	281	522	23%
Memories			
RAM			
Dynamic	264	369	12%
Static	79	129	18%
ROM	103	160	16%
EPROM	61	104	19%
EAROM	5	11	30%
CCD	8	71	107%
Shift Register	38	22	-20%
Total MOS	558	866	16%

Source: Dataquest

4.0 COMPETITION

The semiconductor industry has always been intensely competitive and should remain so in the foreseeable future. The effects of this competition are to make the industry aggressive, to make it readily adaptive to any change or competitive advantage, and to lower profit margins.

More than 100 companies in the United States make semiconductor products of one kind or another. Although many of these companies produce only specialized products or manufacture limited lines for their parent companies, more than 70 companies actively compete in the mainstream of the industry. In addition to these U.S. companies, more than 30 European companies and 10 Japanese companies are actively competing in the world market.

In any given semiconductor market segment, there are usually many competitors from which a buyer may choose. Although the large number of companies will almost surely be reduced in the future, they can exist at present because of the wide range of products in the industry. A company can specialize in a given area and have a particular advantage in manufacturing a few products. Although any competitive advantage in a product line is temporary, the diversity of products is sufficient to allow all companies in the industry to be competitive in at least some areas.

New products are continually being developed by the industry at a very high rate. Since a new product, by definition, does not have established suppliers, the company producing it can gain a short-term advantage. Thus, many small companies compete effectively in the semiconductor industry by continually advancing the state-of-the-art technology. The same advantage of new products also applies to new markets created by these products. Nevertheless, since market share and the resulting volume production is extremely important in the industry, particularly as markets become mature, competition is intense for market share. This situation leads to recurrent price competition which can be extremely severe.

Another reason for the large number of competitors in the industry and the severity of competition is that barriers to entry into the semiconductor industry have, in the past, been relatively low. Although such barriers as start-up costs, technology, and the cost of obtaining a competitive market share are rising, they nevertheless remain low in comparison with many other industries. Between 1968 and 1971, more than 30 new companies were formed in the United States to compete in the semiconductor industry. Despite declining semiconductor demand in 1970 and 1971, at least 80 percent of these companies survived in one form or another and some, such as Intel, have been eminently successful.

A corollary to the low barriers of entry to the semiconductor industry is the lack of any artifical market or manufacturing barriers that might serve to lessen competition, such as government regulation, price controls or supports, or union policies.

6.0 MANUFACTURING

The central focus in manufacturing in the semiconductor industry is the fabrication of the semiconductor device from an extremely thin, raw silicon wafer, which is about three inches in diameter. This process entails hundreds of individual manufacturing steps, each requiring complex technology and high precision. The manufacture of the semiconductor device can be divided into three major operations--wafer fabrication, testing, and assembly.

In the semiconductor industry, all manufacturing steps are usually performed by one company. As a result, the industry is structurally simple. Differences occur from company to company, however, in the amount of integration of support functions. Integration includes fabrication of the package in which the devices are assembled, manufacture of the semiconductor wafers on which the devices are made, manufacture of the masks involved in the photolithographic process, and other functions. Larger companies, such as Texas Instruments, operate on this level of integration. Smaller companies, in general, do not perform these manufacturing functions.

The unified manufacturing structures of the industry--from wafer to final product--results from the close interrelationship of the technology of the various manufacturing steps. It is not likely that this structure will change in the future.

In the past, vertical integration from component to end-user product has rarely played a role in the structure of the industry. Notable exceptions have been the Delco Division of General Motors, IBM, and Western Electric. There has been a gradual trend toward vertical integration, which has been highly visible, because of calculators and digital watches. However, the separation of semiconductor manufacturing and end-product manufacturing still prevails in the majority of manufacturers. This is because the semiconductors required for most products require a greater diversity in semiconductor manufacturing than a single semiconductor facility can offer.

Production Trends

Automation of semiconductor/microprocessor manufacturing is increasing in the semiconductor industry with several important future consequences. The rapid wage inflation in Asian countries combined with the development of new automation techniques will lead to less overseas hand assembly. Thus, more production will be performed within each geographic consuming marketplace. As a result, the industry will slowly become less labor-intensive with higher fixed costs, greater manufacturing barriers to new entrants, and a washing-out of underfinanced companies.

COMPUTER INDUSTRY OVERVIEW

1. <u>Industry Structure & Basic Trends</u>

One computer industry executive has suggested that "If we compare the automotive and computer industries over the last 30 years, we fnd that if there had been similar progress in the auto industry as there was in the computer industry in coming from the gigantic Eniac computer system (developed at the University of Pennsylvania's Moore School of Engineering in the 1940's) to the modern microcomputers, then the auto industry would today be able to offer us a Rolls-Royce for $2.50 with an EPA gas rating of 2,000,000 miles per gallon." This trend is continuing. Indeed, the driving facts of the computer industry as a whole are clear:

- o Semiconductor costs are coming down.
- o Semiconductor performance is steadily rising.
- o Communication costs are not dropping.

These facts have led, in turn, to a number of competitive, design and marketing trends that are, increasingly changing the structure of the industry:

- o Cheap semiconductor memory heightens the importance of software as larger, more complex, more specialized applications become economically possible.
- o Larger microprocessors CPU's allow minicomputers to rival in power the mainframe computers of only a few years ago; some large "minicomputers" equal in power small "computers".
- o The continuing drop in semiconductor costs have reduced the value of hardware in absolute terms, which forces computer companies to look towards new applications.

- The major area of growth is data handling, not scientific data processing.

- Unchanging communications costs are making central, large computers fed by remote terminals less attractive than distributed processing networks.

- Semiconductor expertise is widely available so even small companies can produce plug-compatible products.

- U.S. firms are being increasingly vigorously challenged by German and Japanese competitors.

These trends are occurring in a very concentrated industry: IBM's revenues approached 50 percent and the top seven firms accounted for 78.5 percent of total U.S. computer industry revenues in 1977. IBM's domination of the computer industry means that IBM's response to the above factors will inevitably shape the industry.

2. IBM's Response

As benefits its massive size, IBM has responded in a multitude of ways to these trends. (For a more complete treatment of IBM see the separate article in Vol. I.) IBM is increasingly:

- Looking to The Office for growth by tying together data processing and communications with products ranging from typewriters to PBX's. This heightens the importance of two areas of IBM strength: (1) specialized terminals, and (2) the ability to tie diverse elements together into a system.

- Looking to The Decentralized Work Station for growth (the lab, shop, store, bank. . . . .i.e., distributed data entry and distributed data processing). Connected with this effort, IBM has attempted to (1) make it difficult for non-IBM terminals to tie into an IBM system, (2) use "building blocks" to achieve manufacturing economies of scale, and (3) provide upward "migration" paths for its customers.

- Emphasizing software (one-half of R&D budget) and selling complete solutions. Prices have been unbundled.
- Redesigning key computer elements in order to better protect the software (by putting the software into microcode).
- Looking for ways to cut communications costs.
- Pressing forward in marketing practices.
- Developing denser VLSI for the long-term.
- Contracting with Intel for 303X memories in order to bring down the backlog (over three years, which is dangerous and tempts Seimens/ Fujitsu).

These strategies will have the effect of dictating the nature of the changes yet to come in the industry, for, as was implied above, IBM and the computer industry as a whole tend to move in lock step together. Not all goes IBM's way, however. In addition to a governmental anti-trust lawsuit that has been in process since 1969, IBM faces vigorous competition from a host of competitors that is at least, occasionally painful, if not truly dangerous.

3. Competitor Strategies

IBM's competitors try either to emulate IBM's strategies or to specialize in specific segments of the computer marketplace.

Burroughs has always had a very loyal base of users, and a computing system that set it apart from the other suppliers. During the past year it has been announcing many new generation computers and just in April 1978, brought out the latest versions of its 6800 series, complete with the most sophisticated memory electronics being used at the time. More than 20 percent of its business is with banks, almost as much is with computer service bureaus, and an additional 10 percent is represented by state and local government installations.

Control Data got its start with supercomputers and still concentrates its EDP business on very large, scientifically oriented accounts. Some 70 percent of its computer base is installed at educational or federal government sites, or with service bureaus. Many of these are its own. Between its Cybernet operations and the Service Bureau Co. operations it received from IBM in settlement of a lawsuit from the late 1960's, CDC does more than $300 million in computer service business. It is also a major factor in peripherals, both selling to the IBM marketplace and operating joint ventures with NCR and Honeywell. And CDC has begun to produce a computer for competition in the IBM-compatible marketplace.

Honeywell from its origins has tried to compete with IBM on a broad basis. So when it acquired the General Electric computer business in 1970, it began to use the GE 600/6000 architecture as an approach to larger computer systems. An outgrowth of this--the Level 66 and 68 Distributed Processing Systems--forms the basis for Honeywell's current competition with IBM's new 303X line. Honeywell is no longer in control of the French computer operation it acquired along with the GE base, and during the last year has been positioning itself for the 1980's. It recently acquired Incoterm so that it could satisfy specific demands for application-oriented terminals such as those required in banking, finance, manufacturing, and airline reservation systems. It has reoriented its marketing thrust to focus on distributed systems and small stand-alone business uses.

NCR in many ways has been forced to develop computers to support its more traditional lines of business--and during the last few years has been applying its computer technology to terminals such as cash registers and bank teller stations. One-third of NCR's computer business is concentrated in wholesale, retail, and banking. The company has developed specialized hardware/software packages for applications such as hotel reservations and medical services. And because of its customer base, it is bringing computer power to smaller companies in the distribution industries. As a result, its total computer-related revenues for 1977 were almost $2 billion, second only to IBM's.

Sperry Univac traditionally has emphasized larger mainframes and government business. . .and its installed base reflects this. About 30 percent of its computers are in various government installations. Otherwise, its customers are distributed across the board in fairly normal fashion. Having absorbed the RCA computer base it picked up in the early 1970's, Univac recently has made some moves directed toward broadening its computer activities. With the purchase of a disk drive manufacturer in the mid-1970's, Univac got an entry into the IBM plug-compatible peripheral market as well as a source of disk drives for its own computers. Last year it bought Varian and about $35 million worth of minicomputer business, and launched its BC-7 computer for small business. In the general purpose area, Univac has introduced several models of its 1100 series computer and competes with IBM at most levels, offering more performance at equivalent prices.

In general, the major growth of all these "other" mainframers is from within their own bases--growing with the customer--and from new users. The competitive "wins" from IBM are more or less balanced by losses. The most significant competition among the mainframers comes at the entry level for new users and when sophisticated computer users go out for bids and benchmark tests on new applications they plan to implement. If some degree of standardization comes to the computer industry, this sort of business could increase in volume.

There will be additional pressure on these "other" companies. Over the next few years, a growing number of new companies will begin to offer hardware replacements for IBM computers. This immediately makes the IBM base harder to chip away at; users who are going to move are likely to move to hardware that is compatible.

In addition, the threat of one or more companies beginning to manufacture hardware replacements for Burroughs, Honeywell, Univac, etc., cannot be overlooked. The amount of equipment installed by these mainframers is large enough to make an attractive target.

The Target: IBM

Within the IBM base itself, there are additional forces chipping away. For years, plug-compatible peripheral manufacturers--companies such as Memorex, CDC, Storage Technology, Intel and National Semiconductor--have made disk drives, tape drives, printers, and additional memory for IBM System/ 360's and 370's. These companies shipped over $500 million worth of IBM-compatible peripherals last year, and have gained, collectively, market shares of 15 percent to 35 percent of the IBM-type equipment with which they compete.

A newer and potentially more powerful force arrived in the mid-1970's, intent on replacing the heart of IBM's computer systems: the processor and main memory. Since often these plug-compatible processors would be surrounded by plug-compatible peripherals, all that remained of IBM in the system would be the software--the instructions that tell the electronic equipment how to operate and perform specific user tasks.

This marketing ploy is possible because, today, IBM operating systems (control software) are in the public domain and thus "free." Anyone who buys an IBM computer gets a copy, so the instructions are available for use in the compatible processors.

In addition to other mainframe producers and manufacturers of IBM compatible equipment, IBM is receiving substantial competition from makers of minicomputers and microprocessor based systems. These latter two segments of the computer industry have become industries in their own right and are discussed at length in separate reports in Volume I of the M.I.R. Annual Report. But, in aggregate, it is clear that competition in the computer industry is fierce and can have only an accelerating effect on the pace of change.

4. Some Future Implications

In discussing the probable directions that computer technology will take as it moves into the 1980's, C.W. Spangle, President, Honeywell Information System, states:

> The computer industry continues to offer improved product performance with each announcement. . .bucking the inflationary trend. It is a dynamic business with a relatively short lead time from the product development stage to the marketplace; it remains capital intensive--requiring massive outlays for research and development and investment in rental assets. These characteristics will continue into the 1980's and beyond, even as the marketplace and needs of users change substantially. Systems of the 1980's will feature:
>
> - Very high performance and more cost-effective hardware technologies;
> - Hierarchies of storage devices that are faster and have larger capacity;
> - Utility grade system availability;
> - Support of large distributed data bases;
> - Standardized communications links.
>
> In short, the comprehensive system architecture for the 1980's must be flexible enough to accommodate widely differing requirements.

But the competitive nature of the industry can only increase; one tends to wonder what characteristics will typify the firms that survive in the future. Paul C. Ely, Jr., Vice President and General Manager, Hewlett-Packard Computer Group addresses this issue:

> Competition among mainframe makers, small-computer manufacturers, local specialists, and other third parties will be keen, but the final

decision on whose services to purchase, in taking advantage of the new possibilities in computer technology, will rarely be on the basis of who has the most advanced hardware, nor even the best price-performance ratio, although advanced performance and good value are important considerations.

The final decision will continue to be made, I think, with heavy consideration for the reliability of the supplier's products and services, and for the ease with which the supplier makes it possible for the user to adopt the new capabilities that are offered.

This does not mean the large mainframe supplier will always win, or that the small-computer maker has the edge, or that the local supplier has little change of success. On the contrary, the small house near the customer may well develop the best reputation for local service and equipment reliability. In the coming shakeout, suppliers of all sizes, will remain in the running. The determiner will not be the glamor of their offerings, though, but the quality of their demonstrated service.

INDUSTRY OVERVIEW: MINICOMPUTERS

1. Industry Structure & Key Trends

In the less than 25 years since its inception, the computer industry has experienced tremendous growth, until, with $30 billion in revenues in 1975, it has become one of the most important segments of the world economy. One of the primary contributors to this high rate of growth has been the minicomputer segment, which in the last decade has become an industry in its own right. The minicomputer industry can be viewed as consisting of three levels of participants: (1) primary minicomputer participants; (2) secondary minicomputer related participants, and (3) general purpose minicomputer competitive participants. Primary minicomputer dependent participants include:

- o General purpose minicomputer manufacturers.
- o Hardware-oriented third party participants, i.e.
  - OEM's, systems integrators, systems software house.
  - End users of equipment.

Minicomputer related secondary participants include:

- o The suppliers of semiconductors, memories, power supplies.
- o Independent peripheral equipment suppliers.
- o Service related firms such as software, maintenance and consulting concerns serving the primary market structure.

General purpose minicomputer competitive participants include a wide variety of firms competing for the minicomputer end-user market:

- Suppliers of programmable controllers, microprocessors, small and medium-sized EDP computers, accounting machines, remote terminals, intelligent and batch terminals, programmable calculator manufacturers, etc.

- Computational services such as timesharing, remote batch services and interactive remote batch service suppliers.

Where minicomputers once filled a need left unanswered by mainframe suppliers, higher power/price ratios are blurring the traditional product application distinctions between minicomputers and other computational products such as microprocessors and large mainframe computers. The result of this trend is that the industry will experience continuing change as minicomputer manufacturers attempt to maintain their historically high growth rates.

Thus, the 1975-1980 period is expected to be distinguished by an increasing emphasis on software and end-user support, more powerful systems, and direct competition with medium--and large scale--EDP computer suppliers. Recent announcements have shown an increasing emphasis on 32-bit word length machines and sophisticated software systems. The distributed processing concept is allowing networks of minicomputers to perform tasks previously accomplished only by large mainframes when possible at all. This concept clearly thrusts the minicomputer suppliers into direct competition with IBM and other large and relatively well capitalized mainframe suppliers. The success of the minicomputer suppliers will be related closely to their ability to finance the software required to implement the distributed processing concept. The eventual outcome of the impending confrontation is by no means clear. The one clear conclusion is that the worlds of large mainframes, microprocessors, and minicomputers are merging and eventually will be one and the same.

2. Products: Types and Trends

Like the computer industry in general, the product offerings in the minicomputer industry fall into four general categories: mainframes, peripherals, software, and support. Several product trends within the minicomputer industry are becoming increasingly important:

- Minicomputers in networks now rival mainframe computers in power.

- The declining value of semiconductors increases the value of software in the final system, so software becomes a crucial selling element in the systems. (General purpose minicomputer CPU and memory costs as a percent of minicomputer direct costs: 1977--42 percent, 1982--20 percent).

- 32-bit word lengths allow direct data base management.

- A full-line of products is increasingly important in order to allow customers to migrate upward.

3. Markets: Segments, Distribution Patterns

The market for minicomputers can be segmented by customers, geographical patterns and end-user applications.

The overwhelming preponderance of mini-computers are being shipped to business. Potential customers within the business sector can be separated into three categories:

- Very small companies (annual sales of $100,000 to $1 million with 4 to 25 employees)--over 13 million potential users.

- Small companies (annual sales of $1 million to $25 million, 25 to 100 employees)--about 285,000 potential users.

- Large companies (over $25 million in annual sales, more than 1,000 employees)--about 25,000 potential users.

These three different business sectors have very different equipment requirements. The very small businessman will need low priced systems, with packaged software and low maintenance and training costs. The small businessman will require somewhat more mass storage, typically more than one terminal, a fairly fast low cost printer, and more customized software. Large companies are likely to be using several computers, dispersed geographically. They will have a sophisticated data processing department that can make knowledgeable price comparisons. More and more, they will require communications capabilities and software networking packages. They will be uninterested in applications software, but will require service at all geographic locations.

Geographical Segmentation

The need for a wide geographical dispersion of manufacturers' customer service organizations stems from the fact that the minicomputer marketplace is becoming increasingly international in scope. Indeed, one of the most striking statistics pertaining to the industry is that over 40 percent of the revenues of U.S. minicomputer suppliers result from export shipments. This figure includes both the systems that are exported directly and those that are eventually exported by the Third party participants (TPP's) such as hardware OEM's and software houses.

End-User Application Segmentation

Perhaps the most critical market segmentation for analyzing the minicomputer market is end-user application. Minicomputer applications can be separated into ten major segments:

- Business Data Processing: Most rapidly growing application (34 percent in value annually) with high end minicomputers playing the largest tole. Value of this segment in 1980: $509.5 million.

- Communications: applications include both data and telephone communications. Minicomputer manufacturers here encounter AT&T and IBM occupying positions of strength. Probably room for aggressive minicomputer companies: sales 1975--$84.5 million: 1980--$152.4 million.

- Design and Drafting (CAD) Multiple applications including Computer Aided Design Sales 1975--$27 million; 1980--$277 million for a growth rate of 59 percent annually.

- EDP support: remote patch terminals, processing terminals, shared processor data entry, and peripheral control accounted for $100 million in 1975, $334.7 million in 1980.

- Industrial Automation: Many applications reaching maturity and being displaced by microprocessors: growth expected at 10.5 percent annually; 1975--$195.4 million to $332.1 million in 1980.

- Instruction: fund constraints will promote timesharing applications: 1975--$27.4 million to grow to $69.2 million by 1980.

- Laboratory and Computational: subsegments are (1) instrument automation, (2) laboratory automation, (3) experiment monitoring, and (4) scientific computation. Growth 11.1 percent to $310 million in 1980.

- Specialized Data Acquisition and Control: transportation, environmental monitoring, simulators, and military and weapons control. 18.5 percent growth annually from $80.3 in 1975 to $187.6 million in 1980.

- Specialized Data and Word Processing: major applications include point of sale systems, banking terminals and word processing. First two applications dominated by large mainframes (IBM). Word processing appears best minicomputer opportunity. 20 percent annual growth to $56.8 million in 1980.

- Other: Wide variety of applications including an increasing personal/consumer market. Estimated market size by 1980--$239 million.

Distribution

Distribution of minicomputers, both in the U.S. and Internationally, is being accomplished increasingly by means of a direct sales effort on the part ofthe manufacturer. However, in the earlier phases of industry development, the third party participant (TTP) was the primary distribution channel used, and TTP's still play a major role in the industry. This role has been decreasing because of the growing sophistication of minicomputer manufacturer marketing capabilities and because of the rising importance of general EDP minicomputer applications (1970--64 percent of minicomputer sales were through TTPs, 1975--39 percent of sales were through TTPs with other 61 percent sold directly to end-users).

In summary, the minicomputer market will grow overall but will experience most of its growth at the expense of the larger mainframe companies while losing some low level applications to microprocessors. The role of third parties in securing general purpose minicomputer sales is decreasing (although not for dedicated application); thus the efforts of minicomputer manufacturers to develop general minicomputer system applications that meet end user requirements are becoming increasingly important.

4. Competitors, and Market Shares

The major minicomputer manufacturers are, to the extent of their resources, putting increased emphasis on software and broad product-line offerings to meet end-user requirements. A recent event that may have a substantial impact on the industry is IBM's 1978 entry into the minicomputer market. Exhibit #1 shows that IBM's system 1 should capture a 4 percent market share in 1978. Digital Equipment Corporation remains the dominant firm in the industry with a 33.8 percent market share, followed by Data General (17.5 percent), H.P. (6.7 percent) and Interdata (4.1 percent). The top five firms should account for 66.1 percent of minicomputer system shipments in 1978.

5. Finance and Conclusion

Like the rest of U.S. Industry, the minicomputer suppliers are faced with a severe shortage of capital for future expansion. Most are too small to obtain favorable treatment from the investment community. The continued growth of the industry combined with increased competitive pressures will exert severe demands on suppliers in terms of working capital and capital expenditures, with few having sufficient earning to generate the necessary capital internally. Thus, the major uncertainty associated with the industry may well relate to the source of capital. Unless stock market conditions change drastically, or the OTC market once again becomes the haven for the small investor, or unless the capital gains tax is reduced, merger and acquisition may be the only route open for some suppliers.

EXHIBIT #1

MINICOMPUTERS TO BE ACQUIRED IN 1978
BY SURVEY RESPONDENTS*

COMPANY	QUANTITY	1978 PERCENT SHARE
Digital	10,063	33.8
Data General	5,193	17.5
H-P	1,979	6.7
Interdata	1,217	4.1
IBM	1,200	4.0
Computer Auto.	1,045	3.5
Gen. Auto	768	2.6
Texas Instr.	692	2.3
Honeywell	543	1.8
Microdata	438	1.5
Modcomp	403	1.4
Varian	385	1.3

Total Units--29,734

Total Dollar Value--867,630

*Dataquest/Mini-Microsystems Annual Survey Data Based on 11,915 Responses.

INDUSTRY OVERVIEW: INSTRUMENTS

INTRODUCTION

Following is a brief review of significant trends in the instruments industry. Volume two and three of this series provide a more definitive analysis.

PRODUCT TRENDS

1. Lower cost LSI/VLSI and increasingly scarce engineering resources are driving product developments in several directions:

   o Small, low cost, low margin, high volume products like hand-held DMMs. These products are expanding the vista for T & M products by virtue of their small size and lower price.

   o Equipment that does repetitive measurements without operator assistance. More and more, this category of equipment gives answers to the user rather than just a series of symptoms or measurements. This allows engineers and other scarce labor to work in more productive areas.

   o Stand-alone instruments with gradually improving price/performance ratios that are designed for a service or laboratory environment. Information supplied by the equipment is used directly by the operator rather than by another electronic device. Instruments are designed for a fairly narrow category of measurements, although the measurement breadth may be increasing.

2. GPIB is another potent driving force (due to both customer needs and aggressive HP promotion). GPIB underlies a trend toward "systems" which grab and process data and then display data in uniform and usable forms. This equipment is also enlarging the market for instruments by enabling "unsophisticated" users to perform technical tasks.

3. Increasing numbers of users are finding "low-cost" instruments suitable for R & D and service applications.

4. There is a vast audience that feels comfortable with a computer terminal or a hand held calculator and BASIC or FORTRAN. Over time, such users may gradually begin to make measurements in new ways, perhaps using "instruments" more as signal acquisition devices than as stand-alone devices.

5. The fastest rates of industry growth will be in the "low-cost" and systems categories. General purpose test equipment sales overall will grow at a 9 percent rate. Although the growth rates are higher in the "low-cost" and systems segments, the magnitudes of these segments are still small compared to GPTE.

MARKETING/SALES/SERVICE

- "Low-cost" instruments increasing are marketed by wide retail-like distribution networks. There are more price sensitive buyers compared to upper-end purchasers for these products. Manufacturing cost is a primary profit leverage tool. The importance of manufacturing and retailing may spread upwards into the higher price products as the industry and its products mature.

- "Systems" means the connecting of possibly disparate units. So, intregration, turnkey support, and service take on more importance to the buyer and the user - who may be different people. Debate surrounds where the integration should occur:

Should it be designed and built into the products "at the factory" (Tek), or should integration take place in the field (HP)?

- Although direct selling is now economical for stand-alone lab equipment (due both to the prices and volumes involved), in general, instruments are coming up in complexity and down in price, with many instruments gravitating towards the $1,000-$4,000 price range. Products in this range are too complex to sell through catalogs and too cheap to sell through F.E.s. As a result there are some distribution problems to face... walk-in showrooms? Retail outlets? Radio and TV ads? More sophisticated distributors?

INDUSTRY OVERVIEW: OSCILLOSCOPES

INTRODUCTION

Since Tektronix is a primary force in the oscilloscopes industry, to describe the industry would cover material in Volumes following. Accordingly, the following represents a basic situation overview.

SITUATION

The oscilloscope industry may be nearing the end of its second long period of stability and quiet (although rapid) growth. The first such period started after World War II and continued into the 1960's. The second long period occurred with Tektronix' decisive turning back of a challenge by HP in 1967 - 1970, and an industry shakeout in 1970 - 71 due to a severe recession in electronics.

The driving force for a new period is semiconductors, both as devices to be measured and as devices to do the measuring.

DEVICES TO BE MEASURED

Semiconductors are becoming the primary device of interest in the electronics industry. They are different from preceeding devices in that they operate digitally and more slowly. While they will continue to operate digitally, their speed is picking up to the point that optimization around higher performance levels may gradually become necessary.

Another key feature of semiconductors is their operating voltages. Up to now operation at 5 volts has been common, but new devices will operate at much lower voltages, which creates a need for ever better probes operating with greater sensitivities and higher impedances.

Semiconductors are also getting more complex, truly systems on a chip. Not only are physical probe connections important, but also sorting out the data will become an increasingly crucial task.

Finally, semiconductors are basically a different type of device to measure as compared to analog devices because of the relatively greater importance of timing issues rather than waveform or signal amplitude issues.

DEVICES WITH WHICH TO MEASURE

Advances in A-D converters alter the economics and performance of oscilloscopes by making possible new and digitally oriented techniques for signal acquisition. With a signal acquired in digital form, use of semiconductors for processing and storing the signal becomes relatively easy and desirable from a user's standpoint. In fact, at lower speeds, signal processing features made possible by semiconductors already seem to be selling factors in some products.

Advances in displays also has implications for oscilloscopes. Although it seems impossible to conceive of a faster or "better" display than a CRT, use of fast A-D converters and storage of a signal in digital form means that cheap, television-like monitors are all that are needed to display the signal in a pseudo-analog or digital format. Alternately, flat panel displays, while not expected until 1980 in significant quantities (in televisions), may impact oscilloscope packaging and perhaps measurement approaches for field applications.

HOW OTHERS SEE OSCILLOSCOPES:

> HP's view: "For most of their existence oscilloscopes have been used to study those waveform parameters that can be determined from the shape of the traces displayed, like noise on analog control lines, ramp linearity, and amplifier response. But with the tremendous growth of digital systems and techniques, the emphasis has shifted to time related parameters."

(The 9800 desk top calculators, the 1000 series minicomputers, and a planned line of hand-held calculator/controllers are seen as the control nuclei of systems in which "instruments" are distributed processing devices.)

HP is reported to have centered its oscilloscope R & D efforts on the achievement of high speed A-D conversion.

Intel's view: "We (have) recognized that the design of electronic equipment was changing and introduced what could be the equivalent of the oscilloscope for digital systems, namely the Intellec design aid."

Minicomputer manufacturers' view: (Once the signal is acquired, use a device coupler and have a minicomputer analyze, format, and display the signal.)

Prime Data's view: "Oscilloscopes are a basic instrument and will grow and mature into a replacement market despite alternate measurement methods" (computer self-diagnostics, logic analyzers, digital service instruments).

Gould's view: (The key is signal acquisition, so we will use our waveform digitizing expertise to capture and then analyze and display signals. Over time we will get better and faster at it.)

Philip's view: (The key is understanding what customers want, namely reliability. So we will provide me-too products with crisp traces, solid switches, metal frames, sober colors, and then dominate Germany, then Europe, then U.S., focus on large accounts and avoid Tektronix expertise in lab areas.)

Hameg's view: (The proportion of proprietary components in low-end oscilloscopes is low, and the associated electrical engineering issues are well defined. So we will focus on assemby, tight control of costs, and me-too engineering.)

INDUSTRY OVERVIEW: TELECOMMUNICATIONS TEST EQUIPMENT

INTRODUCTION

The Telecommunication Test Equipment industry is a $1.2 billion (1977 worldwide) industry related to the larger $60 billion telecommunications equipment industry.

U.S. sales account for about one-half of the total market, but this percentage will decline to about 44 percent by 1987 due to more rapid growth in the international markets. Overall, the industry will grow slowly and steadily at a rate of about 8.8 percent per year.

In more normal times this industry would not be discussed in a report such as this because the natural assumption would be that in the U.S., at least, Western Electric would have this business entirely for its own. But maybe not.

PRODUCTS

The products of the telecommunications test equipment industry include centralized test consoles, analog line impairment instruments, digital bit error rate testers, spectrum analyzers, pattern/function generators, microwave test equipment, and transmission test sets. These products are similar in nature to general purpose test equipment except dedicated to and optimized for particular applications. The products are used in the maintenance and installation of telephone and data communication networks.

INDUSTRY STRUCTURE AND KEY TRENDS

It is necessary to understand the intense battle being waged in the telecommunications equipment industry to understand the situation in the related telecommunications test equipment industry.

The main thing that is happening to the telecommunications equipment industry is technology: fiber optics and satellites are jostling to obsolete conventional wire links; computers are replacing mechanical and electromechanical switches; digital transmission of signals is replacing analog transmissions; and new consumer and banking services, such as electronic funds transfer, are being tied in with conventional communications networks. Of special interest to the telecommunications test industry is the equation-computer equals switches, for computer service is a mainstay of the General Purpose Test Equipment industry.

Fueling this technology turmoil are large sums of money: IBM is spending $900 million on R&D in 1977 and AT&T is spending $600 million. Sums being spent outside these two companies by other computer, minicomputer, and semiconductor firms and by foreign government consortiums on technology related to this field must be of a similar size.

Both AT&T and IBM are giant firms with a high competence in technology. AT&T and Western Electric are about 2.4 times the size of IBM, but that advantage is overweighed by another critical variable: cash. Although AT&T earns from 27 to 30 percent pretax on its revenues, it is still not enough, because earnings are not the same thing as cash, and cash is what AT&T needs to replace its equipment quickly enough to head off competition from IBM in the form of satellite-based communications networks. AT&T depreciates its equipment on a 40-year schedule, while IBM depreciates its equipment over five years. Since AT&T earns "only" 8 percent on its capital, it is constrained from installing advanced equipment as fast as is necessary. IBM may show lower profits with its faster depreciation, but it then has much more cash to spend on capital equipment.

The result of all this turmoil is some unique market openings and even some thinking of the unthinkable: AT&T forced to sell Western Electric for the cash necessary to bring it into the new era? Unbundling of AT&T costs and charges due to regulatory issues raised by IBM?

Meanwhile, the structure of the telecommunications test equipment industry, in the light of the above development, seeems increasingly open. Basically, the competitors consist of Western Electric (with sales of $260M in 1977 and a market share of 44 percent) and a large assortment of small and specialized firms. The next largest competitor is HP with sales in this industry of $47M and an 8 percent market share, followed by Scientific Atlanta with a 3 percent market share, and more than 100 other firms sharing $246M and 45 percent of the market.

This fragmented market structure did not happen by accident but is the result of the influence of Western Electric. The small firms involved are typically vulnerable with low levels of sales support and specialized areas of technological competence. As the influence of Western Electric becomes less decisive, the telecommunications test equipment industry may be due for restructuring.

COMPETITOR OVERVIEW: JOHN FLUKE MANUFACTURING COMPANY

INTRODUCION

Fluke designs and manufactures electronic test and measurement instruments and systems.

PRODUCT STRATEGIES

Fluke enters T & M areas through the engineering of a lower-cost alternative. An exception to this strategy is data loggers where they performed a technological leap-frog to become the market leader. Fluke is the leader now in DMMs, number two in frequency synthesizers, and strong in counters and in programmable, high voltage power supplies. HP has countered Fluke moves strongly with mixed results so far.

Fluke has recently been advertising for CRT engineers and is expected to go into the manufacture of controllers.

MARKETING/MANAGEMENT STRATEGIES

Fluke has just completed purchasing its U.S. distributors, more than a year in advance of its own schedule. Fluke is internally organized into business units whose definitions seem cumbersome to outsiders but which seem to be effective in practice.

MANUFACTURING STRATEGIES

A key skill of Fluke so far has been choosing their projects well and sticking to a low cost approach. Fluke buys a fair amount of components, most importantly ICs from Intersil and Siliconix (the designs for which were developed jointly on a non-exclusive basis). Fluke is building an IC facility. The new Fluke manufacturing facility has been successful in increasing productivity significantly, and their business unit structure, although cumbersome appearing to outsiders, appears to be working out.

PERFORMANCE

Recent performance has been startling:

Year:	1974	1975	1976	1977	1978
Sales:	33.4M	41.9M	49.2M	60.0M	74M

COMPETITOR OVERVIEW: GOULD, including ADVANCE, BIOMATION, STATHAM

"The Product Development Company"

INTRODUCTION

Gould is a $1.2 billion (1977) company which makes electrical products (motors, generators, torpedoes), electronic products (principally thin metal foils for circuit boards and digital instruments including waveform digitizers, oscilloscopes, recorders, DVMs, counters, pulse generators, and medical products), battery products (principally auto batteries), and industrial products (battery answered industrial trucks) that are based on key and related technologies in electronics, electrochemistry, electromechanics, and metallurgy.

As an acquisitions minded company (acquisitions supply half of its growth) Gould may be interested in acquiring instrument firms (six in the last seven years) only as a way of improving its price/earnings ratio.

But Gould is not a conglomerate, and so closely reasoned and decisive have been its other acquisitions (15 plus three mergers since 1967), numerous internal resource allocations (resulting in an internal 12 percent compound annual growth rate over the last ten years. . . .for an overall growth rate of 23 percent per year for ten years to a present size of $1.2 billion), and firm insistence on continued growth of any business it holds (six have been sold since 1967) that Gould deserves a second look.

There is room for reasoned debate, and Gould only threatens Tek now in a few areas (logic analyzers), but their actions do seem to suggest a coherent strategy to become a leading manufacturer of instruments. If so, factors such as their command of some key technologies, their cash sources invulnerable to easy counterattack (i.e., auto batteries), and their able management make them a worthy competitor.

PRODUCT STRATEGY

Gould's slogan, "the product development company", seems apt. Gould is product oriented in the sense of a relative emphasis on innovative design to lead the company into new areas and maintain growth in sales and earnings.

Gould's instrument products are clustered around low frequency measurement needs, particularly in the mechanical and medical market segments. Gould has a history of producing excellent analog oscilloscopic chart recorders, and signal conditioners, and, in the U.K., sells low frequency oscilloscopes with some success.

Recently, principally through acquisitions, Gould has gained control of over half of the small ($17 million in 1977) but rapidly growing (42 percent per year since 1972) waveform digitizer market. This digital expertise is also related to its benchtop IC tester and logic analyzer products.

These various strengths in low frequency measurements and digital products recently combined in an innovative logic analyzer product. This "Digital Testing Oscilloscope" can operate as a go/no-go comparison tester, as a logic analyzer, and, by constructing a psuedo-analog waveform from its digital memory, as a storage oscilloscope. The DTO-1 is billed as "the first oscilloscope-like instrument designed to test and troubleshoot digital systems. It performs automatic tests, as well as manual trouble-shooting procedures, not only on digital but also on related analog circuitry."

Some observers feel that with oscilloscopic recorders (basically oscilloscopes without CRTs), some basic offerings of oscilloscopes in the U.K., and a new logic analyzer, Gould is in a good position for a major effort in the low frequency oscilloscope market in the U.S.

Gould's overall product strategy may have a fatal flaw, however, in the form of its strong commitment to electric vehicles. Gould has overwhelming battery exepertise, but long-term success means overcoming the combined forces of the auto industry, the oil companies, and alternate forms of fuel, including alcohol.

MARKETING STRATEGY

Published statements and corporate actions suggest that Gould sees the instrument industry as a relatively fragmented one where small firms can thrive while growing strong by carefully defining their niches and positioning in areas of rapid growth.

These published statements conflict somewhat with insider statements that Gould has virtually no market research function at the corporate level and only a small effort in the Divisions. The resolution, perhaps, of an apparent inconsistency of market niche strategy with a truncated marketing staff, lies in Gould's practice of bringing innovative but sometimes flawed products quickly to market. Gould then learns from its customers in a direct way and modifies its products accordingly.

MANAGEMENT STRATEGY

Gould's management approach stresses thorough planning, quarterly reviews with decisive action following, annual education in industry trends as well as company procedures, and dramatic "pay for performance" (35 recent millionaires). High priorities are placed on meeting targets for earnings, developing new products, and reducing manufacturing costs steadily. The emphasis on setting and meeting goals in financial terms has allowed an organization that is both "tight" in terms of accountability and decentralized in organizational form.

Gould is not a relaxed place to work. The top managers are financial types, and they do run the firm by the numbers. Gould's public relations efforts strongly assert that they are more than a holding company, but the primary interest in the financial numbers suggest otherwise.

Just below the top levels many of the key managers seem to be engineers, according to available information. This suggests that in the Divisions the current product orientation will continue. The marketing expertise that does exist is apparently concentrated in the Gould Labs.

MANUFACTURING STRATEGY

In relative terms, Gould sees itself less as a manufacturer than as a product and financially oriented firm. Accordingly, Gould often buys components used for assembling its products rather than emphasizing a vertically integrated approach.

ENGINEERING/TECHNOLOGY STRATEGIES

Product development takes place in the various Gould divisions, while basic research takes place in a central facility, Gould Labs. Gould Labs is in the process of doubling in size during 1978 to a size of perhaps 350 or more people. It is divided into two separate groups, an Energy Lab (batteries) and an Electronics Lab.

Gould Labs are oriented toward new products, not improvements in existing products. It seems the one area with Gould that can be said to be market driven, in that it looks for good markets and asks itself what can be produced for that market using the basic technology available.

Published statements about Gould's engineering approach to instruments suggest that Gould sees special possibilities in microprocessors. To Gould, microprocessors make possible and desirable a strategy of developing standardized products which can then be targeted to specific applications through use of software.

Specific areas of Gould strengths are A-D conversion at 100 MHz, digital storage, use of IEEE interfaces, digital and analog displays, and use of microprocessors for internal controls.

COMPETITOR OVERVIEW: HEWLETT-PACKARD

INTRODUCTION

HP designs, manufactures, and sells signal and data processing computers and instruments of advanced design and high quality. Areas of focus include commercial data processing, manufacturing applications of instruments and computers, and "traditional" test and measurement task. 1978 is the year when computers become larger than instruments for HP.

Hewlett-Packard is the largest test equipment supplier in the world and leads in most instrument markets. HP dominates instruments, but over half of HP's overall sales come from areas where they are not the leader. Strengths include finances, vertical integration, technology, distribution, worldwide scope, and extraordinary management. Weaknesses include strains due to fast growth, geographical dispersion, and the sheer pace of VLSI events which affect them directly. HP has lined up against three especially strong competitors: Digital Equipment Corporation, Texas Instruments, and Tektronix; and HP is in the path of at least two others: IBM and Intel.

HP is exceptionally strong in a financial sense, so their ability to fund high growth rates is excellent. They rarely compete on a price setting basis, except to achieve specific objectives such as a particular military contract. HP prefers instead to compete with a flood of quality, high-performance products often utilizing state-of-the-art technology.

HP is a truly international company with important design and manufacturing sites in Germany, France, and the U.K.

PRODUCT STRATEGY

HP product strategy includes emphasis on networks centered around a controller or mainframe with instruments and terminals viewed as distributed processors and peripherals.

While HP has extensive software capabilities, customized point-of-use applications of HP computers usually depend upon outsiders: OEMS and software houses. By contrast, HP performs its own point-of-use applications of instruments in networks using a special force applications engineers in the field.

With request to tying together instruments into networks, HP seems strongly adverse to solving all application problems in the factory. HP prefers its factory types to optimize their hardware in terms of quality and performance while meeting specified interface requirements. Because there is no "grand scheme" of integration at the factory, the field applications of instruments often take in a "messy" appearance, but their salesmen can sell the bits and pieces of equipment in virtually any configuration to almost any manager or engineer at any level in practically any business, engineering group, or educational establishment in the world.

To make this field applications approach work in instruments, HP is well along in appointing applications specialists in every sales office and has implemented a four level pricing scheme based upon the differing levels of support that a customer might need.

In general, Hewlett-Packard products may be described as broad in range, deep in performance, innovative in nature, and excellent in quality.

MARKETING STRATEGY

HP sells its products, with some exceptions, directly to users through its own world-wide sales force, with the exception of Japan where it has a 50 percent joint-owned venture (YHP). It's worldwide sales subsidiaries are not autonomous, but rather they report back directly to the Product Divisions. Although HP conducts aggressive price campaigns in specific countries (such as the U.K.) in order to achieve specific objectives, in general HP is a price leader that prefers to keep prices high. Rather than pioneering new areas (although calculators are an exception) HP prefers to go after other people's markets with innovative products (minicomputers are typical).

Major competitors are: DEC (minis, IBM (business oriented computers), GE (medical), TI (calculators), Wavetek (fcn. gen.), Tek (scopes), Perken-Elmer (analytical), Fluke (DMMs), Gould (osc. recorders).

MANAGEMENT

Current corporate concerns per President John Young, EVP Bob Boniface, VP & GM Instruments Bill Terry, Instrument Engineering Manager Al Bagley (source: Measure, an HP employee communication, F/March 1978):

1a. Top priority is reorganization to reflect the effects of digital technology on all lines and to move from a divisional to a strategic orientation. (Young)

1b. "Our businesses are different, but not fundamentally different." (Terry)

1c. Corporate Marketing is to work with product groups to develop strategies. (Boniface)

1d. Processing of data is 'where the action is' in instruments, and it is hard to imagine an instrument that couldn't use a microprocessor. (Bagley)

2. Add and manage people, particularly at the supervisory level. (Young)

3. Better control of spending. . .meeting profit targets. (Young)

4. Greater use of VLSI in Products. (Young)

5. Reducing IC costs. (Young)

6. Government regulations. (Boniface)

7. Better management information systems. (Boniface)

8. Quality control. (Boniface)

9. New manufacturing sites overseas. (Boniface)

Special instrument group concerns:

1. Generating new products is seen as the key to success.

2. More interdependence of products, ICs, R&D, sales force.

3. Keep the bureaucracy from becoming inward looking.

HP is a geographically decentralized company with plants spread from Corvallis to Malaysia, New Jersey to Grenoble. HP is organized into four product groups (Instruments, Computers, Medical, and Analytical Instruments). Each product group is further subdivided into product divisions (40 division of which 11 are Instrument Group divisions).

MANUFACTURING STRATEGY

Manufacturing is divisionalized, with an important emphasis placed on reducing costs. Divisions can build their own components or order common parts from central manufacturing. An effort is made to use common parts where possible.

ENGINEERING/R&D STRATEGY

HP is technology driven, and they invest heavily into new and innovative technologies.

FINANCIAL STRATEGY

HP funds growth internally and carries no debt. HP places a great emphasis on selling stock to employees.

COMPETITOR OVERVIEW: INTEL

INTRODUCTION

Intel manufactures semiconductor memories, microprocessors, and electronic equipment with a high semiconductor content. Sales and profits in 1977 were up 25 percent to $383 million and $32 million.

Intel in many ways is still an entrepreneurial firm with extremely capable managers at the helm. Intel is aggressive, usually first to market with advanced products, operated at a fast pace, and determined to broaden its business base "to serve new markets for integrated electronics created through technology."

PRODUCT STRATEGY

Intel is now trailing T.I. and Mostek in semiconductor memory devices due to pricing pressures, delivery problems with 16K RAMs, and entry of EPROM competitors. Intel is unlikely to try to regain memory leadership but rather will pursue microprocessors and mircoprocessor related products (where they dominate with perhaps a 70 percent market share) and memory boards (where there is a greater vertical value-added). High priority products are single board computers (14 new types in 1977), MDAs (where profits are higher than microprocessors and Intel enjoys a commanding market share), memory systems, and control devices. A multiprocessor architecture is being emphasized for the single board computers, which minimizes the helpfulness of ICE devices. Meanwhile MDA people are reportedly becoming closely involved in microprocessor design, in order to improve ease of single chip applications.

Intel recently signed a $52 million agreement to supply IBM with add-on memory to help IBM work down a three year backlog for 303X computers. Intel and IBM are negotiating a follow-on contract. Intel will probably maintain this link for three to five years and then move on when margins begin to decline.

A strong emphasis in the product development effort is placed on ease of use in the forms of advanced software, thorough documentation, and provision of supporting products, such as design aides.

Intel seems to be avoiding the auto market for fear that the products will almost instantly become commodities. Intel does seem to be expanding into telecommunication peripherals and bubble memories.

MARKETING STRATEGIES

Intel sells both directly and through distributors. Direct sales of semiconductors are to OEM customers, such as IBM, and in target areas in Europe and Japan. A portion of the direct sales force works closely with distributors, who perform well for Intel in order to maintain contact with the technology leader and because of the ancillary product sales that go with semiconductors (resistors, capacitors, power supplies and the like).

Intel avoids price competition, relying instead on technological advances. Intel will withdraw from a market as soon as margins suffer.

Europe is a target of a current special marketing effort.

MANAGEMENT

Intel faces strong competition on all fronts, strains due to growth and geographic dispersion, and some morale problems. Intel management is tough and performance oriented, but there is no reason to believe that they have any magic answers to the inevitable problems caused by size and diversity.

Management skills include instrumentation--some key managers have previously worked at Hewlett-Packard. Intel has made few mistakes in entering the instruments market with their Microprocessor Development Systems.

MANUFACTURING

Intel does not have the virtually total manufacturing orientation of Mosek and T.I., but it still relies on high volumes and scale economics as crucial elements of its strategies. Products are assembled in Southeast Asia. Basic manufacturing (as well as engineering and marketing) facilities are being established in the Portland area to supplement its Bay Area plants.

Current technological interests include CMOS and SOS (acquired from RCA) and bubble memories. There is also a strong emphasis on developing in-house software expertise (apparently Intel is beginning to develop software before hardware on advanced projects; the chief architect for the 8086 has a software background). There seems to be a relaxation of interest in GaAs with Intel feeling that its new high speed HMOS process introduced in 1977 has a lot of growth left.

ENGINEERING/TECHNOLOGY STRATEGIES

Intel employs high technology, principally silicon-based, in state-of-the-art products.

FINANCIAL STRATEGIES

Microprocessors now represent more than a third of corporate revenues. Corporate sales may rise 20 percent a year through the early 1980's with industry growth at a faster rate (perhaps 30 percent for microprocessors and 25 percent for memories). Intel invested $4.5 million in plant and equipment in 1977 while maintaining no debt. Intel plans on self-financing its growth and maintaining its strong cash position. Pretax margins in 1977 were maintained at close to 1976 levels despite rapid price declines in many product areas. Intel has 8,100 employees, and 38 percent of sales are overseas.

COMPETITOR OVERVIEW: PHILIPS N.V. AND NORTH AMERICAN PHILIPS

INTRODUCTION

Philips N.V. is a #13.7 billion (1977) firm based in the Netherlands which manufactures nearly a million different products ranging from light bulbs to toasters to computers.

North American Philips is a $1.9 billion (1977) company operating primarily in the U.S. and is 60 percent owned by the U.S. Philips Trust. North American Philips produces products ranging from mobile homes to integrated circuits.

After acquiring Phy Unicam, Philips N.V. could and does claim that it is the oldest test and measurement instrument company in the world. . . .founded in 1896, which is one year before Marconi invented the wireless telegraph. Philips has been strong in specifically oscilloscopes since before World War II, although immediately after the war they gave other areas higher priorities.

Philips N.V. is an international company, not a Dutch company. They are noted for their staying power: they think in terms of the broad sweep of decades and how to remain viable in the midst of wars and world calamities. In general, Philips is slow to market but persistent and powerful once they are there. They have a consumer products focus. They are much more than a holding company, for they can conceive and execute coherent strategies on a worldwide basis.

PRODUCT STRATEGY

Recently Philips announced for delivery in 1980 a flat panel television set with a picture in three-dimensions. Despite this announcement and other similarly startling products, in general Philips, particularly in the Test and Measurement areas, is more known for its reliable, me-too, and easy to use products than for high technology products. Their product lines are pruned with a carefully controlled breadth and depth.

Philips test equipment is oriented towards high volume, medium to low price areas. Philips usually meets competition head-on rather than resorting to product or application niches.

MARKETING STRATEGY

As a company, Philips is long-term oriented and persistent. In the few product areas, such as mainframe computers in Europe, where they have retreated, they have done so only after substantial losses far beyond what most companies would have tolerated.

Perhaps because they are at heart a consumer goods firm, and perhaps because of its orientation to decades of time, Philips shows no hesitation about purchasing world market share with slim margins, high volumes, me-too products, aggressive marketing, and manufacturing economies. They seem willing to pursue this strategy even in industries, such as instruments, that seem far removed from consumer goods.

Philips tailors their marketing strategies to each country and prices products selectively by country to achieve local goals. They prefer to pick off new countries one at a time. In the U.S. in instruments they are currently engaged in trying to buy market share on a price basis.

Philips uses both distributors and direct sales forces to sell Test and Measurement equipment. They have a major account focus, particularly in the U.S., and are capable of aggressive discounting to achieve targets in a particular country are area.

Test and Measurement sales of Philips N.V. are estimated at $70 to 75 million internally (1977) and $70 to 75 million externally (of which perhaps 10 percent was in the U.S.). Oscilloscope sales in 1977 may have been about $23 to 26 million in 1977 of which perhaps $6 million represented sales in the U.S. In 1976 Philips may have had a 17 percent share in portables in Europe and a 25 percent market share in low cost scopes.

Philips' oscilloscopes are designed with an apparently sophisticated regard for customer purchase behavior, almost as if scopes were another consumer good to Philips. Selling strategies in the U.S. are executed by North American Philips.

Philip's world efforts in instruments are aided by the overall company sales organization which operates in 60 countries. About 63 percent of Philip's sales are in Europe, and 17 percent are in North America (1977).

MANAGEMENT

Philips N.V. is organized into five major divisions (until 1977 there were 13 divisions): Lighting and Battery (9 percent of sales), Home Electronics for Sound and Vision (30 percent), Domestic Appliances and Personal Care Products (10 percent), Products and Systems for Professional Applications (24 percent), Industrial Supplies (17 percent). (In its Annual Report Philips also reports revenues from Miscellaneous Activities (10 percent). Philips also has (records and tapes).

Philips has a consensus form of governance which outsiders often have a difficult time understanding. For example, a typical organization will have chains of command along finance, engineering, and marketing lines; but it is unclear who is responsible for the general management of what we would call a business unit.

In any case, Philips employees are generally hired for life, so there is apparently time for its managers to learn its complex but effective management culture.

Although turnover at the very top appears to be low (and key senior positions seem held mostly by Dutch), young managers get tested early and effectively and find their careers dependent upon the results they achieve. This managerial testing against results depends upon the presence of goals, and the Central Group of Philips seems as able to provide strong strategic directions as they are able to act decisively to see that the middle managers work successfully for the goals that have been set.

Although Philips can develop strategies that lead to internally generated growth, Philip's appears to prefer to grow through acquisitions. These acquisitions are often bold and imaginative, and acquired companies such as Signetics and Magnavox often do much better under their new owners.

Although management strength is characteristic of Philips, their return on sales in 1977 was only 2.2 percent and return on equity was 6.1 percent. These returns need to be seen in the light of Philips long-term orientation, the effect of their growth through acquisitions policy, and the fact that their accounting conventions seem to understate earnings.

North American Philips is organized into four principal product groups: electrical/electronic (lighting, electronic controls, components); professional (communications, data, medical); consumer (Magnavox TV, Norelco personal care and home applications); and drugs and chemicals. Philips Test and Measuring Instruments is a subsidiary of North American Philips.

North American Philips grows principally by acquisitions and joint ventures (Magnavox and Signetics). North American Philips executives the Philips sales strategy in the U.S. by targeting on major accounts and stressing reliability, lower prices, advertising, and human engineering. They are perhaps best known for their mobile teams of experienced salespeople and their willingness to negotiate prices.

MANUFACTURING STRATEGIES

Wherever possible Philips manufactures in the countries in which they sell. By manufacturing at least some of their line locally, they can act as a national in each country, which is often to their distinct advantage. Overall, Philips manufacturing strategies are oriented towards high volumes and vertical integration.

TECHNOLOGY STRATEGIES

Although Philips Labs conducts research in advanced areas, in practice Philips products tend to employ medium or well-proven technology. One exception is in the area of human engineering, which is a large and well-funded function and which allows Philips to offer products, including instruments, which are state-of-the-art in terms of ease of use.

FINANCIAL STRATEGY

In general Philips is a conservative company whose enormous size creates an awesome financial potential. This potential is reduced in practice by the facts that its consensus of governance at the top makes it very hard for its managers to treat one area as a cash cow in order to fund opportunities in another area.

AMERICAN TELEPHONE & TELEGRAPH (WESTERN ELECTRIC)

INTRODUCTION

AT&T, with $40 billion in revenues and over $5 billion in profits for 1978, dominates one of the largest industries in America, telecommunications. Highly integrated, most equipment is developed by Bell Laboratories (with a yearly budget of $666 million) and manufactured by Western Electric. The $8 billion in captive sales to AT&T revenue comes from common carrier (voice) (communication) operations, but AT&T faces a loss of revenue to:

- FCC actions allowing increased competition in specialized common carrier services and business and consumer telephone interconnect equipment. Competitors have, for the most part, been aiming at "cream-skimming" by offering only selected, high margin services.
- Anti-trust action threatening to force divestiture of Western Electric. This could also be a major threat to Bell Labs.
- A leveling of growth in telephone common carrier operations.

About 10 percent of AT&T's revenues come from data communications, which is a rapidly expanding market. Bell is seeking a monopoly position in the market for transfer of information (without transformation), and is also pushing into data manipulation (imaging and computing) which places it in direct competition with the large computer mainframe companies.

AT&T faces a major hurdle if it is forced to apply accounting practices designed for the utility industry to its new competitive ventures.

AT&T's management is dedicated to a 'religion' of the best possible service to the public. It is conservative and hardworking, with a high reliance upon management controls and standards. Recently there has been a shift from an engineering/service orientation to a market-oriented perspective forced by new competition:

- o Major accounts are individually managed and are being centralized.

- o Marketing/planning is being organized around major market segments.

DIGITAL EQUIPMENT CORPORATION

Introduction & Strategic Overview

Digital Equipment Corporation (DEC) is the leading world supplier of small computers. From modest beginnings as a logic module supplier, revenue has grown to $1,059 million in fiscal 1977 and should approach $1.5 billion in fiscal 1978. Approximately 80 percent of the company's revenue is estimated to be derived from small computer-related products.

DEC has established a worldwide manufacturing, sales, and service capability which has allowed it to achieve a leading position in nearly all countries where it sells its products. Products range from the 12-bit PDP-811, through the 16 bit PDP-11, 18-bit XVM, 32-bit VAX, and 36-bit DEC 20, to the large-scale DEC 10. In addition to DEC's dominance of the small computer market, the DEC 10 and its predecessor, the PDP-10 are widely used in the time-sharing business as well as by engineering and commercial DP end-users.

DEC has developed substantial in-house manufacturing capabilities which include semiconductor production facilities, manufacture of a wide variety of peripheral devices, and, of course, its computer mainframes. Research and development expenditures have been maintained at a high level, approximately 8 to 10 percent of total revenue over the past five fiscal years. A significant portion of these R&D expenditures is for software products such as the DECNET computer network operating system.

Originally concentrating on the OEM market for its small computers, today DEC is placing increasing emphasis on meeting the product, service, and support requirements of end-users. Particular emphasis is being placed on commercial EDP users who are actively implementing stand-alone and distributed computer systems to augment or replace large central DP facilities. In 1976 and 1977, DEC undertook a major facilities expansion and appears currently well-positioned to maintain its leadership position in the small computer market.

DEC's product and marketing strategies for the future can be summarized as follows:

- DEC's future revenue growth will come more from its "mainframe" lines, VAX and DECSYSTEM-20, services and peripherals.

- Their future product startegy will attempt to improve DEC's "commercial image" via three main lines:

  1. VAX-11/780;

  2. DECSYSTEM-20; and

  3. an LSI version of the 11/34.

- The first-time end-user market will continue to be penetrated through distributors and retail outlets (the first opened July 31, 1978, at the Mall of New Hampshire near Boston).

- The corporation is changing from its earlier product oriented groups to an industry specialized structure, and its targeted markets will include:

  1. manufacturing

  2. services (e.g., ADP, etc.)

  3. insurance, and

  4. distribution

- In order to succeed in distributed processing, Digital must correct the software incompatibilities between its many product lines. DNA/DECnet, common command languages and data types are the primary techniques being implemented to improve this situation.

- DEC will gradually unbundle its software and services over the next five years.

- DEC's chief challenge is: how to hire, train, and make productive the thousands of new professionals required to support its 40 percent annual growth rate.

Industry Trends That Affect DEC's Strategies

DEC is operating against a background of rapid industry-wide change. Differentiation between the microcomputer, minicomputer, mainframe, and data communication industries is becoming increasingly more difficult:

- Minicomputer firms are horizontally migrating into traditional mainframe markets.

- Minicomputer and semiconductor firms alike are entering IBM plug-compatible mainframe markets.

- Mainframe firms, in turn, are developing and marketing minicomputers to protect their markets from trends toward distributed processing, and to reduce the cost of mainframes. IBM poses a formidable challenge to Digital's leadership in minicomputer markets.

- Mainframe and minicomputer firms alike are vertically integrating into semiconductor development and manufacture to gain critical microcomputer expertise, and to protect themselves from the onslaught of semiconductor firms that choose to build computers. (National Semiconductor claims that a full IBM 370/158 processor could be confined to a single chip by 1985.

- IBM and AT&T will have a major confrontation in the future when both offer new data communications services and when computer and communications technologies become inseparable. Cheap communications will alter in some way not yet definable the market for minicomputers in distributed processing networks.

Product Strategies

In response to these changes, Digital has embarked on three major product developments to support its competitiveness and growth: (1) a 32-bit minicomputer called the VAX-11/780, (2) a computer networking approach called Digital Network Architecture (DNA), and (3) a family of medium-scale mainframes called DECSYSTEM-20.

VAX-11/780

The VAX-11/780 is DEC's first 32-bit supermini system and represents a commitment that will provide substantial impetus to the marketability of 32-bit superminis. It offers substantially more processing potential that the PDP-11/70 (presently Digital's largest 16-bit minicomputer) at prices ranging from only 30 percent at the low end to 15 percent more at the high end for comparably configured PDP-11/70's. The VAX-11/780 offers Fortran processing capabilities competitive with those offered by vastly higher-priced systems, such as the IBM3031, Honeywell level 66/DPS-1, etc. However, due to an intentional slowdown on developing software (to avoid impacting its PDP-11 and DECsystem-20 lines of computers), the business processing potential of the VAX-11/780 remains underdeveloped. However, as hardware prices erode and the Japanese threat to the established U.S. EDP industry intensifies, software will become vital to Digital's future. These trends will force DEC to spend substantial amounts to develop software functionality for the VAX-11/780 and to pursue direct marketing to end-users.

DNA

Digital introduced Digital Network Architecture (DNA) in April 1975, as an approach to computer networking. It comprises:

- Digital Data Communications Message Protocol (DDCMP), a bit oriented message format with transmission recovery and packet switching provisions.

- DECnet, a collection of modular operating system extensions that are easily installed to facilitate information exchanges between Digital's minicomputers and mainframes arranged in complex communications networks.

DECnet software can be employed to coordinate message traffic and control functions with a wide range of network types, including host-independent distributed computing networks and host-dependent terminal and resource sharing networks.

DECSYSTEM-20

Although mainframe sales and services constitute only about 20 to 25 percent of Digital's total revenues, they could contribute substantially more in the future, especially as a result of the DECsystem-20 announcement in February 1978. The 2020, a low-end member of the DECsystem-20 family, is acclaimed by Digital to be the "World's Lowest Cost Mainframe," competing head-on with small-scale mainframes, such as the IBM 370/115, the Honeywell L66/DPS, and the Burroughs B17/1800. Capable of supporting two mature operating systems and a broad range of application software already in existence, the 2020 could open vast new markets for Digital.

Higher levels of processing power are offered by the other members of DEC's 20 family: the 2040, the 2050, and the 2060. DEC's product strategy, therefore, has been to meet its competition head-on with often uniquely designed hardware and software offered at extremely competitive prices.

Marketing Strategies

In 1977, Digital commanded a 41 percent share of the minicomputer market and was mounting a substantial challenge in mainframes. Several marketing elements have contributed to this success. One of the keystones of Digital's marketing strategy is offering products with among the best price/performance ratios available.

Using IBM products as an example, Digital offers:

- o The 2020 at IBM System/3 and 370/115 prices but with 370/125 and 138 performance.

- The 2040 at IBM 370/115 and 125 prices but with 370/138 and 148 performance.

- The 2050/60 at IBM 370/138 and 148 prices but with 370/158 and 3031 performance.

Thus, with mainframe product offerings ranging in (full system) price from $150,000 to $1,000,000, DEC has become a thorn in the side of mainframe suppliers.

Another factor that DEC management considers central to their marketing strategy is their effort to provide extensive field support. To support this policy DEC pays its salesmen salaries with the result that they go after small customers and sell the most appropriate product, rather than the product that generates the best commission. Perhaps as a result of this salary arrangement, one major DEC customer has commented that "DEC's salesmen are very aggressive and stop by once or twice a week to make sure equipment is working all right and fill any sudden requests".

The needs of the very small businessman have traditionally been ignored by minicomputer suppliers. However, DEC opened a small business system retail outlet near Boston in July 1978, with the intention of making inexpensive packaged systems and extensive support readily available to this customer segment. This latest development underlies some of the reasons for DEC's 40 percent annual growth rate: superior price/performance offerings and extensive efforts to address the needs of a broad array of customers.

<u>Management Styles & Capabilities</u>

Some industry experts and DEC customers worry that the company has grown so fast that it will be hard-pressed to keep up with changing demands. One facit of this potential problem is that DEC has a decentralized management organization that encourages competition among its 13 product and marketing groups for sales and internal resources. This had led to inefficiencies such as two new computer products occasionally priced about the same. This can cause some customer confusion, and may mean there were duplicate development efforts, as scientists design computers for a certain price range. DEC's recent growth spurt also has brought it some less sophisticated customers who expect additional technical assistance and service. Citicorp's Citibank subsidiary, which has about $20 million of DEC equipment, is pleased with DEC's "very reliable" computers but complains that DEC seems to employ only technically oriented types who are unable to get "involved in our strategy"; they "want a little more handholding". DEC has reacted to these pressures to the extent of reorganizing for centralized long-term planning. However, it remains to be seen whether DEC can hire, train, and employ productively sufficient numbers of new employees to service its rapidly growing customer base and thereby insure its continued growth at historical levels.

CUSTOMER OVERVIEW: INTERNATIONAL BUSINESS MACHINES CORPORATION

INTRODUCTION:

IBM is the eighth largest firm in America. In 1977 IBM sales were $18.1 billion, profits were $2.7 billion, the number of employees was 310,000 and its five-year growth rate had been 13.3 percent per year. IBM has over $6 billion in cash and short-term securities and spent $1.1 billion on research activities in 1977.

In 1977 data processing products accounted for about 81 percent of IBM sales. IBM's core business, with about 34 percent of data processing sales, is general purpose computer mainframes. About 47 percent of data processing sales in 1977 were peripherals and terminals, a proportion that is rising as customers demand readier access to data and as mainframe prices keep falling due to technology advances. In 1977 minicomputer revenues accounted for 5 percent of total data processing sales, software products and services accounted for 9 percent, and media and supplies accounted for 5 percent. About 50 percent of all sales are outside the U.S.

IBM is being sued by the government on antitrust charges. But while the government may influence prices and policies, nobody, apparently, can stop customers from demanding to be allowed to buy. In 1977 IBM's backlog grew 86 percent. In any event the Justice Department suit is already an anachronism because so rapid is the computer industry changing that the conditions referred to in the suit are no longer relevant.

IBM's competitive position is holding steady or improving slightly. In 1976 IBM computer sales rose 32 percent versus an industry rise of 23 percent, while in 1977 IBM computer sales rose 16 percent versus an industry rise of 18 percent. Analysis by a respected consulting firm, Arthur D. Little, suggests that over the next four years IBM's market share in the general purpose computer market will rise from 65 percent to about 72 percent. In 1977 IBM's data processing revenues (all categories) accounted for about half of all data processing sales worldwide.

IBM's high market shares are generally viewed with ambivalence by outsiders. . .partly because our prejudice against large companies conflicts so directly with our desires for the technologies and economics that only large companies can provide and partly because IBM is facing intense and determined competition in every segment of its business (due to changes such as trends towards distributed processing, increased customer sophistication and efforts by foreign governments.)

Meanwhile, IBM profits are growing faster than sales, and as an increasing proportion of sales are software rather than machinery, profits will rise further since software is more profitable than hardware. Productivity is increasing although somewhat lower than in recent years (58,500 $/ employee in 1977, up 5 percent).

Rather than become complacent with success, during 1977 IBM introduced a series of more cost-effective computers, slashed prices on existing lines, reduced memory prices by one third, and announced a variety of other hardware and software products.

IBM apparently relishes a good fight. IBM is directly taking on one American government protected monopoly, AT&T; threatening another, the Post Office; and IBM may become the first company ever to win against the combined efforts of Japanese industry and the Japanese government itself, even though the Japanese have now combined with the Germans in an all-out stop IBM effort. Meanwhile, IBM has decided directly to challenge giant firms such as Xerox, Digital Equipment Corporation, and Hewlett-Packard on their home ground.

IBM's continued growth will affect us all. Because of IBM you may not have to commute to work in a few years, universities in their present form may become obsolete, your picnics will be planned with greater confidence about the weather, the cost of gasoline may start coming down, and you will not be able to overdraft your checking account anymore. Time magazine estimates that already every American is connected with a computer transaction at least ten times every day. (In Russia the average person is involved with a computer transaction about once every six months.)

One of the reasons for these miracles is the development of new technology. The current backlog on one product, the 303X, represents four times the processing power of all of the computers ever shipped by IBM.

An example of IBM's technology is their ability to fabricate metal lines on semiconductor crystals that are only 80 angstroms wide. IBM believes that soon their scientists will be able to fabricate lines only 29 angstroms wide. By comparison, the typical atomic spacing in metals is about 4 angstroms.

But not everything IBM touches turns to gold. In a recent effort to develop a "Future Systems" generation of computers IBM spent about $40 million on software development alone--only to have to admit failure. (This loss needs to be seen in the light of the more than $500 million IBM makes per year in interest and appreciation on its cash reserves and U.S. Treasury bonds.)

All of these facts about IBM have appeared in published materials--magazine articles, annual reports, and the like. All of the following analysis is similarly built upon published documents. But it should be said that authors of these materials readily admit that their observations are based only upon observable actions that IBM has taken. In fact, few seem to know how IBM is run and can say little about why IBM is so successful. IBM seems to be run rationally, but how this has occurred no one can say.

2.0 PRODUCTS AND PRODUCT STRATEGY

IBM products include data processing machines and systems, office products such as electric typewriters, copiers, educational materials, and related supplies and services. These products handle data: the sorting, processing, organizing, and displaying of information.

IBM products may be divided into the categories of:

- Computer
- Minicomputers
- Office products
- Communications
- Educational materials; other

2.1 COMPUTERS

The core business of International Business Machines is general purpose computers. . .computers costing more than $250,000 that perform centralized functions such as payroll, sales records, inventory, personnel records, and large scale or time-shared scientific computations.

The category "computer" includes products such as:

- Mainframes and central processing units
- Memories and bulk storage devices
- Terminals
- Software and logic

The most important things to know about the general purpose computer business are:

1. The central hardware element of computers is semiconductors, and the cost of semiconductors is dropping rapidly even as performance is improving dramatically.

2. By and large, the latest advances in semiconductors are available to all companies because of the role of the semiconductor companies.

3. Software is becoming more important as cheaper memory costs make more complex and/or specialized applications feasible.

4. Data handling is becoming more important than computation, because data handling is what large users of computers are really most interested in doing.

5. Communications costs are not dropping, even though communications are essential to any large scale application of computers.

6. Information processing is increasingly seen by foreign countries as essential to a complex society, as a potential source of jobs, and as an industry that will grow rapidly for many more decades even as traditional manufacturing industries begin to languish.

These trends are havng the following impacts on IBM:

1. The drops in semiconductor costs are reducing the value of IBM products in absolute terms.

2. The wide availability of semiconductor expertise allows even relatively small companies to produce advanced products that mimic or enhance the performance of individual elements of IBM computer systems. These products fall into two overall categories: "plug compatible peripherals" (including cpu's, memories, and terminals) and "minicomputers" (that can substitute for IBM computers in many applications).

3. Not only plug-compatible modules are being copied, but also entire IBM computers, often able to operate on IBM software; these computers are being produced by firms such as Amdahl (partly owned by Fujitsu), Itel (Hitachi) and a German-Japanese consortium of Siemens and Fujitsu.

4. The increasing importance, cost, and complexity of software gives large firms, such as IBM, a market advantage

5. The fact that communications costs are not dropping along with steadily improving product performance is fueling an explosive growth of minicomputers as it becomes cheaper to perform jobs locally than to communicate with large general purpose computers.

6. Foreign governments acting independently or through major national firms are providing increased competition to IBM.

Since semiconductor costs are dropping, the value of IBM products is declining as well. So, in order to maintain growth in sales and profits, IBM is looking for new business areas outside computers. Its primary areas of emphasis are:

- The Office, where administrative functions are performed.
- The Decentralized Work Station, where products are designed, manufactured, sold or paid for: the lab, shop, store and bank.

Since semiconductor expertise is widely available, IBM is looking for ways to defend its core businesses. Its primary defenses are:

- Redesign computer elements to make them more difficult to copy (put software in microcode); cut prices selectively to turn back specific competitors.
- Use advanced technology to improve computer performance and make them more difficult to copy.

- Emphasize software.
- Provide large amounts of memory as a standard part of attractive new product offerings (such as 303X) in order to undercut the plug-compatible memory suppliers.

Since software is becoming increasingly more important, and since IBM has software expertise, and since memory costs are dropping fast which makes more complex applications possible, and since economics of scale apply to software development:

- IBM takes as a marketing approach the urging of complete solutions on customers rather than selling hardware and letting customers develop applications expertise.

Since communications costs are not dropping, and since communications with central processors are essential to sales of general purpose computers, and since communications are essential to IBM's targeted new business areas of the Office and The Decentralized Work Station:

- IBM is looking for ways to cut communications costs, principally by setting up a national network of ground stations linked with synchronic earth orbit satellites.

Since foreign competition is increasingly keen, IBM proposing fairer and more rational U.S. tax policies, although it does not propose direct government subsidies.

This section set out to discuss computer products only. It quickly led outwards to terminals, minicomputers, communications, and even foregn governments. These relationships are inherent to the industry.

Historically IBM has lagged in introducing new products, perhaps because of:

- Management difficulties in translating technology into hardware.
- An historical policy of renting rather than selling machines.
- A commitment to a batch and central site product orientation.

This situation has changed, and IBM is now aggressively introducing new products.

2.2 MINICOMPUTERS

A major thrust against IBM is minicomputer manufacturers - minicomputers now perform tasks that much larger computers used to perform. IBM has responded with a full-line of minicomputers:

- Series/1--a competitive entry into the traditional minicomputer market; IBM now offers attractive software and peripherals.

- System/34--the System/34 is an updated System/32 and is for the multi-user (up to 8 on-line work stations; up to 72 stations can be connected) performing small scale, general purpose EDP; the new System/34 signals an IBM determination to become a major force in distributed processing.

- System/3--a small computer able to use advanced disk storage systems; able to perform financial transaction and information handling services for small banks.

2.3 OTHER PRODUCTS; SUMMARY

Other products are discussed briefly in the context of market segment analyses.

Following is a summary of IBM organization and products:

IBM CORPORATE ORGANIZATION

Board of Directors

Corporate Office

Corporate Staff

Research Division

Real Estate and Construction Division

DP Product Group	DP Marketing Group	General Business Group	Americas/ Far East Corp.	Europe/ Mid-East/ Afr. Corp.
General Products Division	Data Processing Division	GBG/ International Division		
System Comms. Division	Federal Systems Divison	General Systems Divison		
System Products Division	Field Engrg. Divison	Info. Records Division		
Data Systems Division		Office Products Division		

Group	Division	Products
Data Processing Product Group	General Products	High performance storage systems
Data Processing Product Group	System Communications	Communications equipment, SNA, terminal systems
Data Processing Product Group	System Products	Intermediate range computer products
Data Prcessing Product Group	Data Systems Divison	Large, complex, high performance computer products
General Business Group	General Systems	Low & medium priced information-handling systems (word processors, minicomputers, small computers)
General Business Group	Information Records	Magnetic tape, disk packs, business forms
General Business	Office Products	Base Line Products: typewriters, dictation
		Advanced Rental Products: mag card typewriters, copiers
		Document Printers
Data Processing Product Group	Data Processing	Sales of large systems
Data Processing Marketing Group	Federal Systems	Special systems for federal government and military; some R&D
Data Processing Marketing Group	Field Engineering	Maintenance and support company - and worldwide
Other	Research	Basic research
	Real Estate	Plant and equipment

3.0 MARKETING STRATEGY

Key market segments for IBM are:

- o The computer room
- o Work stations (data entry/data communications)
- o Office products
- o Satellite communications

3.1 THE COMPUTER ROOM

The Computer Room is where central data processing and computation occurs. Examples: payroll, sales records, inventory, personnel records.

The Computer Room basically contains a central processing unit (cpu) and associated memory. Peripherals such as disc and tape drives, plug-compatible memories, printers, and non-intelligent terminals are also considered part of the Computer Room.

This market is often called the general purpose computer market and is usually considered as separate from the "distributed data processing market."

A more complete analysis of the Computer Room would recognize at least three distinct segments: medium computers (selling for $250,000 to $1 million), large computers (selling for $1 million to $2 million, and giant computers (over $2 million).

The Computer Room is where IBM is the safest. Here is where IBM's world market share is 67 percent and rising. Here is where IBM has recently announced a $3.5 million dollar product so popular that one customer ordered 85 and over 2,000 formal letters of intent to buy were received within two months of announcement (there is now a three-year backlog).

The Computer Room is also where IBM, without particular fanfare, recently cut prices on its basic models 30 percent, sending billion dollar companies such as Burroughs, Honeywell, NCR, and Control Data into panic price-cutting reactions which dropped their stock prices drastically--in half in several cases.

The basic fact about what is happening in the Computer Room is the continuing drop in prices of semiconductor circuits--circuits similar to those used in the now ubiquitous hand-held calculator. These circuits comprise the logic and memory portions of all computers. It is this on-going drop in costs that make the IBM story so interesting, because as these costs drop, IBM's traditional business ares decline in value. As a result, IBM is on the prowl for new businesses in new areas.

There area basically two kinds of companies competing for business in the Computer Room. One kind of company is the broad-line mainframe company. These firms offer a full line of products that perform in ways similar to IBM's general purpose computer products. Another kind of company is the plug-compatible peripherals companies. These firms look for special situations and try to pick off "small" chunks of IBM business in hit and run raids.

There are five principle mainframe computer competitors: Honeywell, Burroughs, Sperry Univac, Control Data, and NCR. As interesting as their stories are, only a few brief comments will be made here about them. All of these companies have sales of $2 billion or more. All are relatively secure, with R&D budgets enabling them to generate new products that are competitive with IBM. They are secure because in the general purpose computer business customers are loyal.

All would be peace here but for the "mosquitoes"--the plug compatible peripheral companies--and the "icebergs"--the Japanese mainframe companies receiving massive support from the Japanese government.

The "mosquitoes" include companies such as Amdahl, Intel, Memorex, Four-Phase, Telex, STC, and Varian. These firms offer products that can substitute for individual parts of a large IBM system. Products include tape drives, disk files, terminals, add-on memories, and control processing units themselves. In fact, it is now possible to replace an entire IBM installation piece by piece without reprogramming the software instructions.

Although the plug-compatible firms share only about $1.5 billion in sales as compared to the $6 billion or so shared by the five general purpose competitors, these competitors offer the greater threat because they skim off high profit business and are highly focused and thus extremely competent competitors. The plug-compatible products are often dramatically cheaper than IBM products because they cost less to develop: they use IBM software and they are second-round copy products.

An exception to the "follower" pattern is the add-on memory market where firms such as National Semiconductor, Intel, Intersil, and others can apply semiconductor, expertise developed in other market areas. In fact, firms such as Intel seem to be technical leaders in terms of products on the market, although further turmoil seems to be ahead when denser circuits and another round of new technologies (V-MOS, SOS, GaAs) hit the market.

The competitive threat offered by the Japanese firms is more head-on in nature and derives from a recognition by the Japanese government that computers are essential to modern society. This Japanese threat is discussed separately in a following section.

IBM'S COMPETITIVE RESPONSES IN THE COMPUTER ROOM

IBM is moving aggressively against the three armies of computer room competitors arrayed against it (the mainframes, the plug-compatibles, and the Japanese). Here is a list of recent and planned moves:

1. Has introduced a new product at the new high end of the price/performance spectrum, the 3033, which is half again as powerful as the previous top-end model yet costs no more.

2. Has dropped prices 30 percent on its existing family of general purpose computers, the "370 family".

3. Has made some moves (under coincidental governmental pressure) to charge separately for software and hardware. Further moves will hurt plug-compatible firms, for "free" software has been a major reason for the price advantages of plug-compatible firms.

4. Embody the instructions (microcodes) used to carry out elemental operations (such as moving information from one register to another) in hardware rather than software and move selected functions into peripheral equipment.

Under these circumstances proprietary or patent rights to the hardware and the distribution of key operations into peripherals would sharply increase the development costs of plug-compatible peripheral manufacturers.

5. Enhance the price/performance of existing products with add-on innovations such as bubble memories and use of multiprocessing modes that would link two central processing units.

6. Develop for the large computers specialized processing units tailored for the separate tasks of data handling, computation and input/output.

7. Utilize strengths in election beam lithography to make denser VLSI circuits.

8. Continue to press forward the state-of-the-art in marketing capabilities. For example, documents revealed in a recent antitrust case showed that IBM already can analyze sudden moves by competitors, prepare new marketing plans, present new purchase agreements to thousands of customers, and implement a new pricing structure. . . all in two weeks.

3.2 THE DECENTRALIZED WORK STATION (DATA ENTRY/DATA COMMUNICATION)

The "Decentralized Work Station" is where products get designed, manufactured, sold, and paid for: the lab, shop, store and bank. Each of these tasks are utilizing increasing amounts of local computation as many engineering tasks get automated; as quality control, production scheduling, shop floor control, and inventory handling tasks are computer-aided; as stores experiment with point of sale (POS) terminals to check out coded goods, track inventories, and verify customer credit; and as stores and banks begin to transfer funds electronically (EFT).

Each of these applications--lab, shop, store, and bank--is a separate market with unique situations, needs, and cost of competitors. These markets are tied together by a common concept--distributed processing--and by a comparible product approach--minicomputers or intelligent terminals at local rather than central sites.

It is beyond the scope of this report fully to review the distributed processing market situations. In brief, distributed processing is a relatively new market for IBM, because it is a departure from the Computer Room concept. As a generalization, IBM has been reluctant to enter the market because IBM has felt that the market exists only because of the high cost of communications--otherwise most users would use terminals communicating with computers rather than local minicomputers. IBM has traditionally felt that minicomputers inherently limit the growth of data processing because their limited capacities block customers from exploring new applications. IBM seems recently to have changed its mind.

The distributed processing market is currently dominated by the Digital Equipment Corporation--with 1976 sales of $736 million, the Hewlett-Packard Corporation with 1976 minicomputer sales of about $400 million, and the Data General Corporation with 1976 sales of $161 million. These minicomputer firms are enjoying fabulous growth rates ranging from a five-year annual rate of 34 percent per year for DEC to 50 percent per year for Data General.

IDC, a prominent industry consulting firm, estimates 1976 minicomputer market size as about $2 billion with growth to $5 billion by 1981.

The minicomputer makers generally sell their small computers with a minimum of programming and other support. These products are used by a diverse group of customers for a wide variety of applications. The pace of product innovation has been rapid, and cost declines have been as stunning as the market growth rates.

As individual product costs decline, minicomputer manufacturers have begun to emphasize software support, usually of a generalized nature. To expand the range of applicatons, the minicomputer firms have also been tieing together their products into networks that can handle more complex jobs. Hewlett-Packard has been a particular leader in network systems as it simultaneously targets on business and instrument network applications.

IBM's strategy in distributed processing has two basic elements. The first element is to increase the attractiveness of using ever-cheaper, ever-more powerful general purpose computers as centerpieces of networks of newly designed "intelligent terminals." The second element of its strategy is to sell a stripped down minicomputer, called Series I, to directly compete with minicomputers produced by the competition. These overall strategies are detailed below.

<u>Summary of IBM Strategy in Distributed Processing</u>

1. Try to lock up the terminals business by designing distributed processing systems dependent on IBM central mainframes, that use specialized IBM communications processors, and that require the use of proprietary software in order to function. These courses of action make it difficult for non-IBM terminals to be used in an IBM system.

2. Try to gain production cost advantages by designing "building block systems" that use common elements for diverse applications such as insurance, banking, medical, education, supermarket, retail stores and factory data collection. These common elements would include standard microprocessors and input/output devices that could be modified for each specialized task by use of microcodes and software.

3. Make it easy for customers using terminals to evolve up to more powerful computer-based systems. This trade-up potential would help the initial sale, become a source of future revenue, and tie users to IBM products.

4. Develop and introduce new lines of terminals embodying the latest in technology (in the past IBM has played a follower role in terminals). Recent terminal products feature: plasma displays, inkjet printers, touch-sensitive screens, greater use of advanced LSI circuits and microprogramming techniques, emphasis on data privacy and security, and low-cost maintenance through use of replacement modules and design emphasis on reliability.

5. By providing price incentives, try to get customers to purchase older models of terminals rather than continuing to lease them; this will minimize the negative impact of new products replacing older products. A related strategy is to introduce new products that will enhance the performance of existing products out on lease.

6. Modify IBM's existing approach to network design so that tasks such as data entry, formatting and file updating are less dependent on the central processor. This is important to customers in situations where local operations must continue even though the central computer breaks down.

7. Orient marketing efforts toward large distributed processing tasks where minicomputer networks are less competitive than networks using intelligent terminals and large central data files. Although minicomputer networks can handle situations where local tasks are independent and do not need access to data held in many other locations, a centralized approach to data files is advantageous for large companies trying to pool inventory (for example manufacturers, distributors, and retail chains) or that need either to share information among many locations or provide for access to information from many locations (for example, insurance companies). By contrast, applications such as motel chains, EFTS, and consumer banking are more suited to minicomputer networks because their decentralized units have little need for large scale computations and need to communicate only with other units whose address is known.

   The rapidly dropping costs of large memories, the rapidly rising costs of the complicated software needed to make complicated mini-computer networks perform, the complex management problems of controlling and standardizing networks of stand-alone minicomputers and the capability of centralized systems to handle large, complex tasks all make the IBM distributed processing approach competitive with decentralized minicomputer networks. The markets aimed at (scientific and business data processing and POS and banking) now account for about 35 percent of the present minicomputer industry.

8. Introduce a minicomputer that will directly compete on even terms with existing lines of minicomputers. The new product, Series I, is initially aimed at medium to high volume, sophisticated end user markets. It is priced comparably to products offered by other firms in the same market, principally DEC, Hewlett-Packard, and Data General. While initially volume discounts are not offered, the worldwide service and support network does appeal to volume purchasers.

While IBM enters the distributed processing and minicomputer markets "from the top," it should be noted in passing that semiconductor firms such as Texas Instruments, National Semiconductor, Intel, and Zilog and several minicomputer firms such as Computer Automation, are keeping the industry in turmoil by challenging the low price end of the market with "microcomputers." These products sell for under $1,000 and are being used in analytical instruments, machine tool controls, laboratory instruments and communications terminals (all applications previously handled only by minicomputers). The market segments consisting of terminals/ peripheral controllers, industrial automation, and communications now consist of about 40 percent of the minicomputer market and are variously predicted to grow to anywhere from $500 million in 1977 to $1 billion by 1980.

3.3 THE OFFICE

In the words of the noted computer industry observer, Frederick Withington, "The 1980's could be very interesting if IBM pulls off its plans to automate the office."

Each factory employee is now supported by $25,000 to $30,000 worth of capital equipment. But each office employee is supported by only $6,000 to $7,000 worth of capital equipment.

Traditionally, the factory has been the object of intense efforts aimed at improving productivity. Traditionally, the office has continued its clerical and administrative routines in patterns only slightly changed from those set early in this century.

These are the essential tasks performed in offices:

Dictation and composing and text
Typing (word processing)
Editing of text

Copying of text
Communication of text (mail and facsimiles)
Filing of text and documents
Entering of data into central files
Retrieval of data from central files
Making calculations based upon data available
Communicating orally and visually with others, individually and in groups

To IBM the most important administrative elements of these tasks can be summed up by the terms:

Data processing
Communications

What is special about the office is the close relationship of these two tasks, data processing and communications.

Up to now, IBM has approached the office with products designed for individual tasks:

Typewriters
Word processors
Copiers
Minicomputers for local record keeping
General purpose computers for centeral data files
Facsimile machines

Now IBM wants to tie these individual products together. There are two main problems:

Software--required to make it easy to use computers for routine tasks such as filing.

Communications--for such tasks as electronic mail, facsimile transmissions, and automated conferencing.

IBM recently installed on a test basis in a large corporation an electronic mail system that consists of a keyboard and CRT display placed on the desk of each executive. To send a letter, the executive types it, edits it on the screen, enters the address and pushes a "send" button. The recipient's terminal holds the letter in memory until it is convenient for the recipient to request a copy of the latest mail. The system also holds updated calendars for each user so that meetings can be set up quickly and efficiently.

Future systems would make it similarly easy to send graphs and pictures (facsimiles) and to retrieve information from data banks about, for example, inventory, prices, and the like and to include a small camera so that television conferences become routine. At that point, the location of individual offices become less important and the need physically to travel to work every day declines.

The future of office automation depends very little on the development of new hardware, and only slightly more on new software. The key element is the cost of communications, which, in a sense, is the essence of the office. An analogy may be made with how humans themselves are constructed: humans have very poor "computational" capabilities but very large memories and excellent communications skills. Similarly, the essence of the IBM approach is 1) to get users to add to their systems large memory capacities, so that complex tasks may be attempted, and 2) to make communications easier and cheaper. In fact, from the IBM point of view, there is very little difference anymore between what is traditionally called "data processing" (the formatting of information) and what is called "communications" (the formatting and transmission of information).

3.4 SATELLITE COMMUNICATIONS

IBM recently joined with the Comsat and Aetna Life and Casualty companies to form the Satellite Business Systems Company.

By the early 1980's the Satellite Business Systems Company expects to have three satellites providing low-cost communications among 500 earth stations, each the size of a two-car garage sitting on top of the buildings of the major corporations in America.

What's exciting is that companies will now be able to transmit to and from their distant subsidiaries at a cost for each link of about one-third of present long distance telephone calls.

Suddenly it becomes possible for central offices to know much more about what is happening in the field: sales, production, inventory, currency fluctuations, personnel changes, and the like.

One company, Texaco, wants to use the system to evaluate instantly the 10 million bits of information that a seismic survey generates each second. At present helicopters ferry loads of computer tapes from remote locations to central computers, a process which takes many days. With satellites the information can be processed at once and instructions given as to where instruments should next be placed. Texaco is so excited that it plans on a complete reorganization in order to take advantage of the new possibilities.

Cheap communications mean computers can be tied together to take advantage of spare capacity and to make larger and more complex jobs, such as weather analysis, feasible. Cheap communications mean offices may be tied together with data links that reduce the need for mail, telephones, and airline travel to conferences. One IBM Vice President has said, "We hope and dream the S.B.S. will be gasoline on the fires of growth."

But it is not easy to fight AT&T on its home ground. Even though the federal government has approved the entry of S.B.S. into the communications business and has forbidden AT&T from entering the data processing business, AT&T has already planned a counterattack: forbidden from data processing by the federal government, it is busily going from state to state for permission to offer point of sale, electronic funds transfer, credit verification, and electronic mail systems within each state.

(The largest pilot project is in Seattle in cooperation with Seattle-First National Bank.)

Other services that Bell would like to supply are remote control of home appliances, text transmission to home televisions, picturephones (assuming the greater capacity of fiber optics), call forwarding, and speed dialing of frequently used numbers.

The major advantage IBM currently enjoys in the communications market is AT&T's own accounting system, originally set up 60 years ago and that has only recently deleted provisions for expense items such as horse-shoeing and livery stable charges. High-speed communications require new, specialized equipment to handle the digitally coded messages. At present, for example, there are about 200,000 PBX's and 123,000 facsimile transceivers in existence. They are all virtually obsolete now, but AT&T still depreciates this equipment over a 20 to 40 year period. The total worth of the entire network is valued at $76 billion, but this is, of course, misleading for the network still employs just about every switching technology ever invented. Since AT&T is regulated to earn only about eight percent on capital, its slow depreciation appears as an artifically low expense charge before profits, which means it looks like it is making more money than it is. Under these circumstances, AT&T is in a politically poor position to go to its regulators and ask for massive increases in its rates in order to fund new equipment.

The AT&T accounting situation is further complicated by the fact that its long distance rates now generate about 40 percent profit, which is partially used to subsidize local service. Raising rates for local service may be necessary but not popular politically, particularly since long distance calls are cheaper because that is where much of the state-of-the-art equipment such as microware, multipath cables, and advanced switching systems, were installed instead of in local office to local office switching.

Actually, IBM has no direct interest in winning against AT&T. IBM wants cheap communications, so if AT&T wins the battle with IBM to provide cheap communications, then IBM wins as well. Thus, AT&T, in some senses, is already in a lose-lose situation while IBM, at least for now, is in a win-win situation.

3.5 COMPETITION: A SPECIAL REPORT ON JAPAN

For a full discussin of IBM's competition please see the computer industry section.

This section focuses on the Japanese challenge.

Statement of the Semiconductor Industry Association (1977):

> The worldwide electronics market will exceed $90 billion in calendar 1977. Underlying this business is a $6 billion semiconductor market. The semiconductor technology is the determinant technology fueling the growth of electronics and, most important, controlling the rate of change in computer and communications products. It is thus the seminal technology of the electronics age. The country which excels in it will hold the key to future worldwide industrial and military leadership.
>
> The U.S.-based semiconductor industry has been a leader in the world market for semiconductors (currently more than $4 billion of worldwide semiconductor consumption is produced by U.S.-based companies). Technological capability has been the basis for this leadership. This technological capability and the attendant leading role in world markets for semiconductors and perhaps more important the resultant leadership of U.S. computer manufacturers (based on the technological superiority of the semiconductor components used in their equipment) is being challenged by the Japanese in an atmosphere created by them of decidedly unfree trade.
>
> Although there are many factors in this unfair trade in Japan, the overwhelmingly important factor is that of government coordination

and subsidy of the Japanese semiconductor industry in its attack upon the world semiconductor market.

That attack involves the assembly of five Japanese companies, Nippon Electric Corporation, Tokyo Shibaura Electric Ltd. (Toshiba), Hitachi Ltd., Fujitsu Ltd., and Mitsubishi Electric Corporation under the direction of the Ministry of International Trade and Industry in a joint development program of advanced semiconductor devices.

This development program is financed by the Japanese government in excess of $250 million. This large government subsidy is granted in spite of the fact that all of the prior listed companies are billion-dollar-electronics corporations.

The U.S. semiconductor industry believes very strongly in free trade. However, this present Japanese cartel represents a large departure from that concept. Our industry is no longer competing with industrial companies but indeed is competing with a Japanese cartel under the direction and financial support of the Japanese government.

In no way can the U.S. semiconductor industry or the U.S. electronics industry allow this situation to continue.

We must and we will find a means to return this critical industry to an environment of free trade.

We are seeking our Government's advice and cooperation in resolving this problem.

Many inudstry observers are impressed with the potential Japanese threat to IBM's positions, but notes shortcomings in large scale systems programming capability. Other observers note Japanese weaknesses in the area of satellite communications, projected to be important in the sale of large computers in the future, although still others note the Japanese lead in the area of fiber optics--which is an attractive alternative to satellites over distances shorter than a continent. Virtually all observers in print agree that Japanese semiconductor technology is impressive and poses a long-term threat to virtually all U.S. companies in the semiconductor, minicomputer, and computer markets.

> "The basic problem is that we're not competing in the normal way here--we're competing with the Japanese government. We think the Japanese VLSI effort is enormous - something in the neighborhood of $500 million to $1.5 billion over a five-year period, spread out over many companies and in government-sponsored programs, but all focused on the same objective: advanced VLSI components and powerful computers. We regard it as a very serious issue", W. J. Corrigan, President of Fauchuld Camera and Instrument Company as quoted by Electronics.

> "Steel, automobiles, and television have been the chief money-earners for Japan until now. But no one can expect these products to continue carrying the load. They are nearing market saturation, and developing countries are catching up. We have to think about how to leap ahead, and the electronics industry is one that Japan should think about developing. The computer industry is the future moneyearner in Japan."--Tsukasa Sakai, director of the Electronics Policy Division of Japan's powerful Ministry of International Trade and Industry.

> "Our best estimate now is that they are spending $1.25 billion over four years on this program. And, the government has caused these companies to come together in a way that would violate our anti-trust laws."--
>
> E. F. Kvamme, G.M., Semiconductor Division, National Semiconductor.

Available information about Japanese technology is sketchy. The primary source for what follows is a recent issue of Electronics magazine devoted to "The Gathering Wave of Japanese Technology" and "The Japanese Challenge in Semiconductors" in Business Week.

Electronics noted a two-pronged approach:

1. Immediate penetration of existing markets for small RAM's and microprocessors of standard and conventional design; the penetration would be based upon production efficiencies and price cutting; (Dataquest estimates the Japanese now have 25 percent of the world market for semiconductors. . .up from 20 percent in 1975).

2. Massive funding of basic semiconductor research to bring to the market by 1980 basically new devices more advanced than U.S. designs.

The Japanese efforts at developing basically new semiconductor devices deserves close attention, according to Electronics. Five multi-billion dollar electronics firms are pooling with the Japanese government large research budgets and the best available talent for an all-out effort. Since Japanese consumer exports, such as televisions and cars, are running into increasingly stiff quota and tariff barriers, the data processing area is viewed as one of national importance.

Although the amounts of money the Japanese are spending on VLSI research are less than total U.S. efforts, Japanese productivity is likely to be higher than U.S. productivity since:

1. Basic research results will be shared among firms, whereas in the U.S. each firm competes individually.

2. Japanese engineering salaries are lower than in the U.S. and 50 to 60 hour work weeks are the norm among Japanese engineers; Japanese officials estimate Japanese productivity in circuit design as 2.5 times American productivity.

3. The Japanese VLSI research effort is being viewed as one of high national priority, which taps strong currents of dedication and nationalism among design engineers.

4. There is a large Japanese home market for the latest devices; the Japanese telephone company is a particularly large user of advanced equipment, while in the U.S. AT&T buys internally only and has strong internal disincentives (its accounting procedures, for example) to using advanced technology on a large scale; also, for reasons of historical protectionism, Japanese computer manufacturers control 75 percent of their home market.

5. The Japanese VLSI effort is focused on specific goals and devices types.

In summary, here is the essence of the Japanese VLSI approach:

1. Develop new device types with higher speed and/or lower power consumption--double-diffused-MOS (D-MOS), V-notch-MOS (V-MOS), CCD, bubble memories, molybdenum gates, fine-pattern silicon gates, and complimentary-MOS (C-MOS).

2. Develop new fabrication techniques: electron-beam lithography is receiving high priority and offers the possibility of cheaper lithographic costs per chip, higher yields, and denser circuits.

3. Concentrate initially on semiconductor memories, rather than microprocessors, since they require virtually no marketing or service support and customers are sophisticated enough to appreciate and use the latest in technology.

4. Develop IBM compatible computers that are "followers" in concept, that use IBM software, and that feature advanced technology for superior performance.

5. Develop minicomputers for individual rather than network applications that will be sold on price and performance rather than on software or networking capabilities.

3.6 SUMMARY

IBM's overall marketing strategy may be summarized in the following five statements:

1. IBM designs and sells comprehensive integrated solutions to customer problems.

2. IBM gives their customers the capacity to do more than they want to do in the knowledge that the customers eventually expand their activities. For example, they will sell a business a simple bookkeeping system while offering them the possibility of doing sophisticated sales analysis.

3. IBM customers see all components of a solution bundled into a package and offered at a single price, although recently--partially in response to government pressure and partially because it is in their own best interests--IBM has begun to distinguish software and hardware prices.

4. IBM salesmen know so much about a customer's business that they can design a truly relevant answer to the customer's problem. Sales training for IBM computer salesmen is thorough and lasts about 18 months.

5. IBM marketing efforts are directed particularly toward high-level executives who can envision the ways totally new systems will benefit the business.

4.0 TECHNOLOGY

Excerpt from The Economist, 13 August 1977:

"The main emphasis throughout IBM's R&D is on making computers that are smaller, cheaper and faster--but that means reaching back into pure science. In designing circuits, IBM is fabricating devices smaller than the wavelength of light, i.e., one-hundredth the width of a human hair and one-tenth the width of the lines on an existing integrated circuit. It has been studying the behavior of individual atoms on the surface of a material. It has had to invent new types of microscopes to study these phenomena; and a new type of supervacuum chamber, which approaches the emptiness of outer space.

IBM makes known to the public only a fraction of its R&D effort, but that small part of the total covers a breathtaking range of technology. For example:

- The storage of computer information in three dimensions, instead of just on the surface of a circuit, by freezing acoustic waves into a material, so that they come out backwards when you want to retrieve the information.

- Ink-jet printers. Special ink, contianing iron filings, is fired from a nozzle, and breaks into drops. A magnet changes the direction of the ink, and forms the letters in what is going to be an extremely rapid method of printing.

- Laser transfer printing of microfilm, making it easy to update microfilm records.

- Photography by electrochromism, in which the photograph can be erased.

- Robots that perform extremely complex manual tasks. Computer programmes for packing toys in a box are harder to write than programmes to play chess. IBM is developing such programmes, in the hope of creating new computer applications in automation.

- Data communications are another key to the expansion of computer applications. Data can be split into electronic packets, so that thousands of calls can be sent at once. IBM is studying the most efficient way of transmitting and switching these packets, using its own satellites.

- Josephson junctions. These circuits, using superconducting metals, do sums 100 times faster than ordinary ICs. IBM's research into suitable superconductors is taking it into such exotic fields as organic metals."

US GOVERNMENT MARKETING AT TEKTRONIX
Based upon a presentation by
Duane Bowans, Government Marketing

Last year the Federal Government was the single largest employer in the country. Its size and complexity has lead to the formation at Tek of a group devoted to Government Marketing.

Tektronix views its government-related sales as to three groups:

1. The Department of Defense:

   Army, Navy, Marine Corps, and Air Force

2. The Civilian Agencies:

   Department of Transportation (including the FAA); HEW; CIA; etc.

3. Major Prime Contractors:

   Hughes, Boeing, Rockwell, Lockheed, Northrop, McDonnell Douglas, etc.

The last category, the prime contractors, may come as a surprise. The reason that prime contractors are approached in a manner similar to the federal government is that they follow purchasing procedures similar to the government's when working on major government projects. The net result is that when the Prime Contractor sells the government a major system or piece of equipment (such as a Trident submarine), the equipment that the Prime specifies to maintain that system (such as three 465's) automatically goes along with the sale.

What are common purchasing traits that set the government apart? Referring to Exhibits 1 and 2, the Government Marketing department concentrates on those procurements (purchases) that are centrally managed and that are associated with major systems that prime contractors sell to the government. Basically there are three major types of procurements:

1. CENTRAL PROCUREMENTS - where a central agency asks for bids on a large number of specified products; this bid may include both a guaranteed purchase of a specified number of units and provision for an open contract so more can be purchased at a specified price. These central purchases,

particularly the large, highly visible ones, are extremely competitive, with companies frantic to cut prices.

2. CENTRAL AUTHORIZATION LISTS - lists of approved products that any governmental agency or contractor may buy at a special government price.

3. LOGISTICS LISTS - lists that specify what electronic test equipment accompanies each major system....like, two oscilloscopes and four probes go with each nuclear submarine.

Now that we know something about the field upon which the game is played, how is government marketing organized and how do they approach selling to the government? Referring to Exhibit 3, there is a central government marketing organization in Beaverton with four account managers in the field (Army, Navy, Air Force and the Civilian Agencies). Each account manager has people working for him in specialty areas.

Not so long ago we used to pick up on government procurements when they were tacked up on bid boards at the various procurement centers. And, we used to catch up on the contractors when their contracts were announced in the newspapers or when they started deliveries. Now the name of the game is to move our influence to as early a stage in the process as possible.

Exhibits 4 and 5 outline our strategy for central sales. The government procurement cycle moves through predictable stages: concept, validation of concept, development of specifications, and finally actual procurement. We try to get involved in the process as early as we can.

The surface level of effort is "Test and Measurement and Diagnostic Equipment management" (TMDE), which means getting our products on central authorization lists and keeping them on these lists. The best way to do this is to influence technical and purchase specifications as early as possible. We want the specifications to match existing or planned Tek products as closely as possible, and we want the government to buy in ways that we are suited to handling.

An example concerns quality control specifications. Often times procurement officers build into their purchases a requirement that the supplier test their products before shipment. If we aren't there with the right information, the procurement officer could unknowingly write in a requirement that we buy $50,000 worth of test equipment of limited usefulness in order to land one small sale. But on the other hand, if we get them to specify test equipment that we already have, then not only do we not have to buy that equipment, but also all of our competitors will have to buy equipment similar to ours in order to make the sale....which could push up their costs, and similarly their prices, which makes them uncompetitive. By working closely with design engineers, providing information in a close and ongoing manner over a period of many years can Tek achieve a high success rate.

Another influence point is the logisticians who work for both government agencies and prime contractors. These are people who specify what test equipment automatically goes along with each major piece of equipment--say, two oscilloscopes automatically go with each major weapons system. In order to get their attention we have to be genuinely helpful to them, providing analysis and information. This requires expertise and team effort on Tek's part. Once the equipment is specified, Tek automatically gets the business over the life of the contract--unless another piece of equipment is found to be an improvement on the original specification.

Marketing to the government has provided four excellent examples of how Tek instruments are used to solve "real life problems." These examples, on the following pages, have been chosen as representative of both the varied uses of Tek instruments, and to give a flavor for the selling task faced by our sales force.

LOGIC ANALYZER APPLICATIONS IN THE FAA

The Federal Aviation Agency (FAA) operates twenty Air Traffic Control Centers around the United States. As the volume of air traffic has increased, the problem of managing the crowded airways has necessitated the use of computers.

It does not take too much imagination to visualize the situation that develops if one of the computers on which the FAA is depending for automatic air traffic monitoring goes out of service. Normally other backup computer systems or manual operation is used in place of the computer while it is down. However, the need is evident for test equipment that can diagnose the computer malfunction so that it can be repaired and restored to operation with a minimum amount of downtime.

Computers process data that is in digital (binary) format. Special test equipment is needed for service applications in the digital domain. The equipment must be able to display, simultaneously, the data on all parallel data lines in a system; it must be able to remember a portion of the data so that it can be analyzed for errors; and it must be able to display the digital data in a format that will enable a service technician quickly to analyze the computer logic pattern and solve the problem.

To perform its computer service and maintenance tasks the FAA has purchased a package consisting of a Type 7704A oscilloscope mainframe, a Type 7D01F logic analyzer plug-in, a Type DF1 digital format plug-in, and a Type 7D10 digital delay plug-in, all mounted on a Model 3 scope cart. This instrument package is being used at the 20 air traffic control centers for local servicing, at the National Airway Facility Engineering Center (NAFEC), in Maryland, and at the Aeronautical Academy in Oklahoma City. In addition, the FAA has purchased LA501W logic analyzers in TM504 mainframes for each of the eleven regional offices throughout the U.S. These portable units are sent with specialists to air traffic control centers to solve computer problems that cannot be solved by the local technician.

There are three reasons why Tektronix equipment was chosen over that available from competitors:

1. Key people at the National Airway Facility Engineering Center (NAFEC), the Air Traffic Control Center at Dallas-Ft. Worth, and at the Aeronautical Academy were exposed to the Tek products and given the opportunity to

evaluate them. These people liked the superior method of acquiring signals via the digital probe arrangement, and the ability of the equipment to manipulate data being analyzed in a more meaningful way, so they recommended the instruments for purchase.

2. Demonstrations were given at key air traffic control centers.

3. Tektronix agreed to give special logic analyzer training sessions for FAA personnel. This, along with the Tektronix field service organization, convinced the FAA that Tektronix supports their products.

The sales program was initiated in June, 1976, and culminated in orders at the end of August. The training sessions were given to FAA personnel in May, 1977. While the order concluded this sales program, its success will result in more sales programs with the FAA in the future.

SITETEST APPLICATIONS IN THE ARMY

The U.S. Army has many requirements for test, measurement and diagnostic equipment (TMDE). This equipment is used for maintaining and servicing communication systems, maintaining navigational aids, digital maintenance for computers and peripheral equipment, and oscilloscope calibration.

The many different measurement tasks have led to a wide proliferation of general purpose test equipment (GPTE). Tektronix has been able to reduce the equipment proliferation by introducing a group of test equipment called SITETEST.

SITETEST is the name given to a traveling test and measurement system consisting of a TM515 Traveler Mainframe and as many as five discrete test and measurement functions in a single rugged instrument suitable for mobile test applications. SITETEST is particularly useful for tasks in which mobility and multiple functions are necessary. Simply by plugging in the appropriate modules, the TM515 may be configured for such diverse capabilities as low frequency or high frequency testing, calibration, digital troubleshooting, etc. The TM515 is small enough to fit under a seat in most commercial aircraft and, with a typical complement of TM500 plug-in modules, weighs approximately 30 pounds. Outstanding operational economy for the SITETEST system is achieved through a combination of the above features, the very low power requirements, and the modest initial cost per test station. SITETEST has also been selected for use by the U.S. Army Mobile Maintenance Contact Teams, with the addition of the conventional six-wide TM506 benchtop mainframe, for use in fixed location maintenance shops.

The success of the SITETEST program was a result of a concerted effort to convince Army TMDE managers within the user commands that SITETEST would be a benefit not only in decreasing the proliferation of test equipment, but in increasing productivity.

Important sales activities took place at Army Electronic Command Headquaters at Ft. Huachuca, Arizona. SITETEST requirements were also generated by a series of demonstrations given on a trip to various Army installations in Europe, Hawaii, Korea and Japan.

Since its introduction in 1975, SITETEST has become an important part of Tek's sales to the Army. No large centralized procurements have resulted, but small individual orders have continued to increase in number.

TYPE 577 MOD 515E CURVE TRACER APPLICATIONS IN THE NAVY

The transducer of an active sonar set used on Navy ships and submarines produces the "ping" sound which is a familiar part of any naval saga. The electronic device that drives the transducer is a silicon controlled rectifier (SCR). Any degredation of the SCR will result in a degradation of the whole sonar system.

Ships, submarines and shore stations which work on active sonar sets are required to have test equipment that can measure the electrical parameters of the SCR.

The Navy designed and built a special test set called the AN/USM-304. This piece of equipment gave basically on-off information and required a conversation chart to translate meter readings into SCR performance.

Tektronix' bench-top semiconductor testers display the electrical parameters of semiconductor devices on an oscilloscope CRT. They work by applying varying loads, voltages or currents to the leads of the semiconductor under test and simultaneously displaying the response of the device. It is then possible to determine how the semiconductor will behave in a circuit.

The type 577 Curve Tracer has plug-in fixtures that allow various types of semiconductor devices to be tested. A special fixture was designed to accommodate the different types of SCRs used by the Navy in sonar applications. This complete instrument was given the number 577 Mod 515E.

For adoption Tektronix had to demonstrate it to key Navy personnel and supply sample instruments for testing by the Navy.

Navy users purchase their electronic test equipment from a document, which is similar to a catalog, called military standard (MIL STD) 1364.

The AN/USM-304 was the only instrument listed in MIL STD 1364B and previous editions as the "standard" silicon rectifier test set. As a result of the Tektronix sales effort, the Navy was convinced that we could provide a product that would do a better job than the AN/USM-304 and would represent a superior value. The type 577 Mod 515E was approved for MIL STD 1364C, the 1974-75 issue of the standard.

In October, 1974, the Navy designated the Tektronix 577 Mod 515E as the "substitute standard" SCR test set to be purchased in lieu of the AN/USM-304. The immediate result was that Litton of Pascagoula purchased 577 Mod 515E's to outfit DD963 destroyers on contract with the Navy. Since that time, sales of the instrument have increased substantially as copies of the updated version of MIL STD 1364C became available to Navy users.

APPLICATIONS OF THE 1502 IN THE AIR FORCE

The advance of modern avionics (aircraft electronics) has led to a mushrooming of the number of cables needed to interconnect the various sub-systems. During operation or maintenance of the aircraft, the cables are prone to damage as a result of vibration, environmental extremes, mishandling, shifting equipment and numerous other reasons. Many different types of cable failures can occur. The protective jacket and underlying conductor can become frayed, the cable could be crushed, the conductor could be shorted, or most severely, the cable could be cut.

The problem of identifying and locating electrical cable faults in aircraft has plagued aircraft maintenance personnel in the Air Force for a long time. Tight spaces and complicated cable routing in aircraft make the problem of troubleshooting cables a tough one. If a cable is replaced and it is not defective, the mistake is doubly expensive because usually other aircraft components must be removed before the cable can be taken out.

As a result, a need existed for a small, lightweight instrument that could be used in tight places to check electrical cables. In addition to its small size, the instrument had to be able to withstand the hostile environment oftentimes found on aircraft flightlines. To minimize the time to repair or replace a defective cable, the instrument had to be able to indicate the location of the cable fault as well as identify the type of cable failure.

The Tektronix 1502 was designed for just such an application. It is lightweight, portable, battery operated, moisture proof, and designed for rugged field operation. The technique it employs for detecting cable faults is called Time Domain Reflectometry. This works similarly to radar or sonar in which a signal is sent out from a transmitter to an object being detected, and the distance to the object is determined by the time it takes for the signal to get to the object and bounce back.

The 1502 operates by transmitting electrical pulses into a cable being tested. As the pulses travel down the cable, they are reflected by discontinuities. The time required for the reflections to return determines the distance to the fault location. Different types of cable faults, such as a crushed cable or one with broken conductors, reflect or absorb the electrical pulses differently. The 1502 has a CRT which displays the reflected signal, so the type of cable fault can be determined by analyzing the shape of the reflected pulses on the CRT.

Several demonstrations were conducted on a variety of aircraft to convince the Air Force to purchase the 1502. An example was the demonstration held at Carswell Air Force Base in September, 1975. The 1502 was used to test electrical cables in B-52 fuel quantity indicating systems, which had accounted for innumerable maintenance problems and an incalculable expendature of manhours. The demonstration was an unqualified success. Later field tests showed that an average savings of four manhours per maintenance task was realized by using the 1502 in fuel quantity system troubleshooting. Other demonstrations were made on F-15 fighters, T-37 amd T-38 trainers, and C-5A transports to test communication and navigation system cables as well as fuel quantity indicating cables. The result of the demonstrations was that the Air Force agreed to conduct a field test of the 1502 in actual service applications aboard aircraft and in ground based instrument, radio and radar shops. The conclusion of the study was that a significant savings in maintenance time could be obtained using the 1502. As a direct result of the study, a large quantity of 1502s were procured by the Air Force.

Since that time, sales of the 1502 have expanded considerably as the instrument has been employed in more and more military locations.

EXHIBIT 1

HOW THE GOVERNMENT MARKET SPENDS ITS DOLLARS WITH TEKTRONIX, INC.

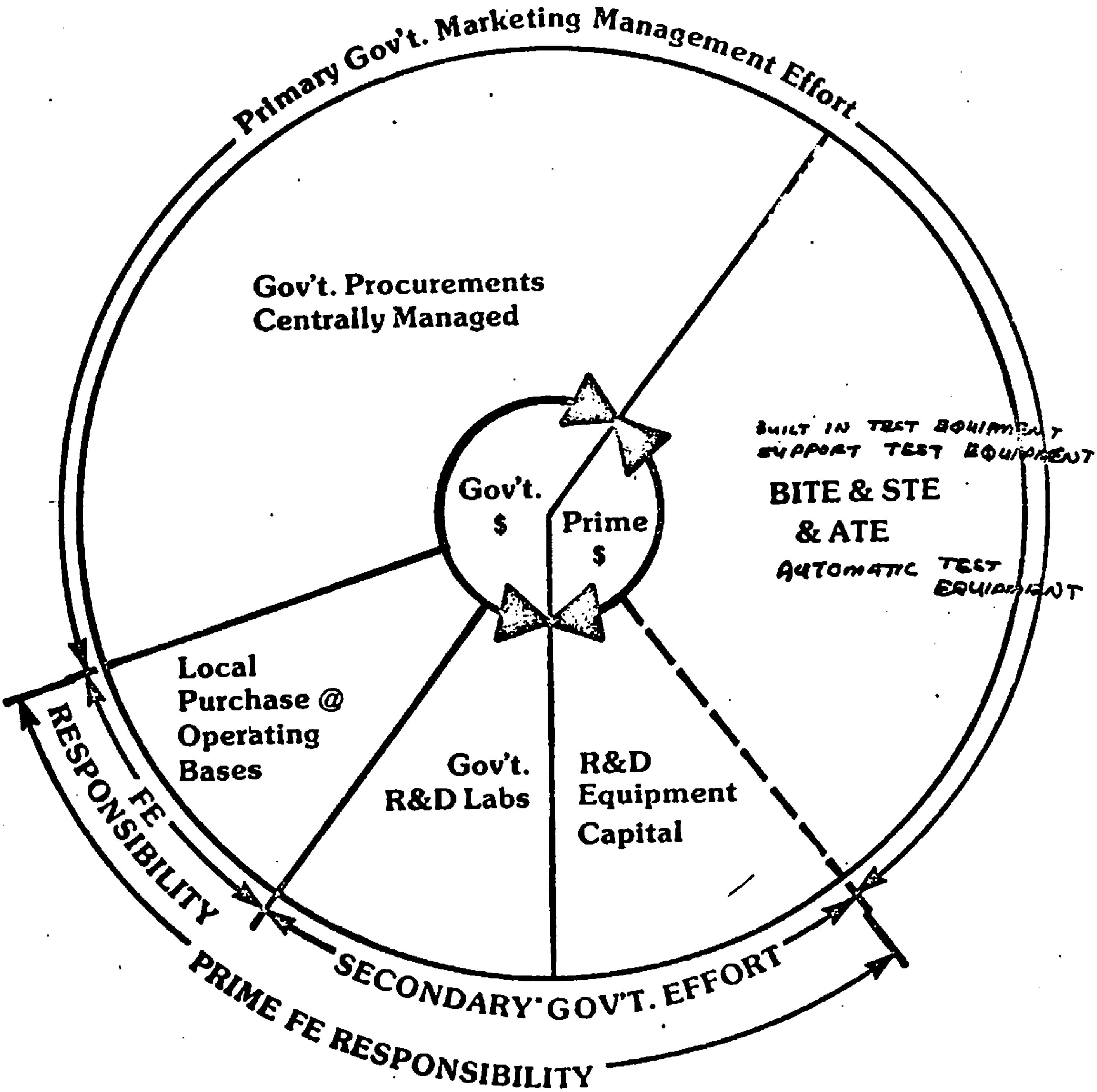


Exhibit 2A

CHARACTERISTICS OF GOVERNMENT SALES PROGRAMS

DIRECT GOVERNMENT

R & D LABS -- ONE-ON-ONE SELLING.

ENGINEERS DECIDE AND BUY WHAT THEY WANT.

SHORT TIME FRAME

F. E. SELLS HERE LIKE TO COMMERCIAL CUSTOMERS

GSA USED FREQUENTLY

Exhibit 2B

DIRECT GOVERNMENT

OPERATING BASES -- USE LOCAL DOLLARS

LOW TOTAL VOLUME.

ONESY - TWOSY BUYS.

WILL USUALLY BUY WHAT IS AUTHORIZED ON A T.A.

F.E. MUST SEE THESE OPPORTUNITIES PER CHARACTERISTICS OF THE LOCAL BASE

Exhibit 2C

DIRECT GOVERNMENT

CENTRALLY MANAGED BUYS --

PREFERRED ITEMS LISTS.

IMDE MANAGERS.

MULTIPLE INFLUENCE POINTS

SPECIFICATION PREPARATION.

PROCUREMENT PACKAGE PREPARATION.

PROVISIONING REQUIREMENTS.

TECHNICAL DATA REQUIREMENTS.

MORE COMPETITION

BEING SELECT SOURCE REQUIRES MORE FINESS.

HIGH DOLLAR VOLUME.

Exhibit 2D

PRIMES

CAPITAL EQUIPMENT---SAME AS DIRECT GOVERNMENT R & D LABS

BITE (BUILT-IN-TEST EQUIPMENT)
STE (SUPPORT TEST EQUIPMENT) --

REQUIRED HIGH COORDINATION MULTIPLE LOCATION PROGRAM.

NORMALLY INVOLVES SEVERAL CONTRACTORS AND GOVERNMENT AGENCIES AND LOCATIONS.

GOVERNMENT PROJECT MANAGER IS KEY.

PIL IMPACTS PRIME RECOMMENDATIONS.

HIGHLY PROGRAM MANAGEMENT ORIENTED.

REQUIRES CONTACT AT PRIME IN PROJECT MANAGEMENT AND LOGISTICS AREAS.

GOOD OVERVIEW (FLOODLIGHT) OF TOTAL PRIME ACTIVITY NEEDED.

GOVERNMENT ACCOUNT SIMILARITIES

1. SIMILAR PUBLIC LAWS APPLY TO THE SPENDING OF TAXPAYERS' MONEY.

   A. FEDERAL PROCUREMENT REGULATIONS.

   B. ASPR

   C. SOCIO-ECONOMIC
      1. LABOR SET-ASIDES.

      2. SMALL BUSINESS SET ASIDES.

      3. EEO COMPLIANCE.

      4. EPA REQUIREMENTS

      5. BUY AMERICAN

   D. RENEGOTIATION ACT.

Exhibit 2F

GOVERNMENT ACCOUNT SIMILARITIES

2. COMMON UTILIZATION OF PROCUREMENT TECHNIQUES SUCH AS GSA---

3. COMMON UTILIZATION OF SPECIFICATIONS AND STANDARDS

4. COMMON SUPPLY MANAGEMENT AND CLASSIFICATION SYSTEMS.

5. COMMON LOGISTICS LANGUAGE

6. COMMON PAYING AGENT - U. S. TREASURY

7. COMMON BUDGET / PLANNING CYCLE

Exhibit 3

GOVERNMENT MARKETING - T & M

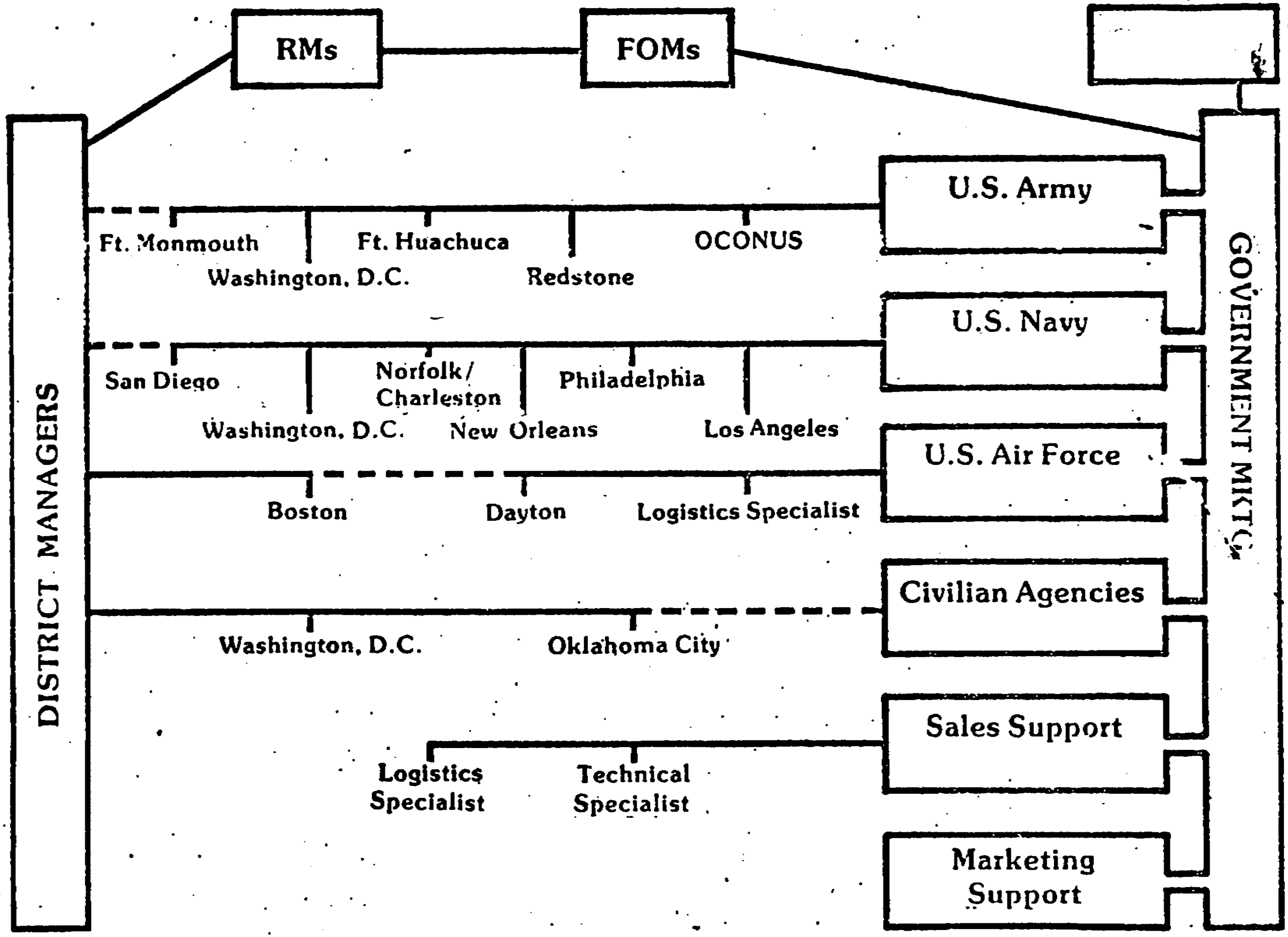


EXHIBIT 4

KEY STRATEGY FOR INCREASING TEK MARKET SHARE

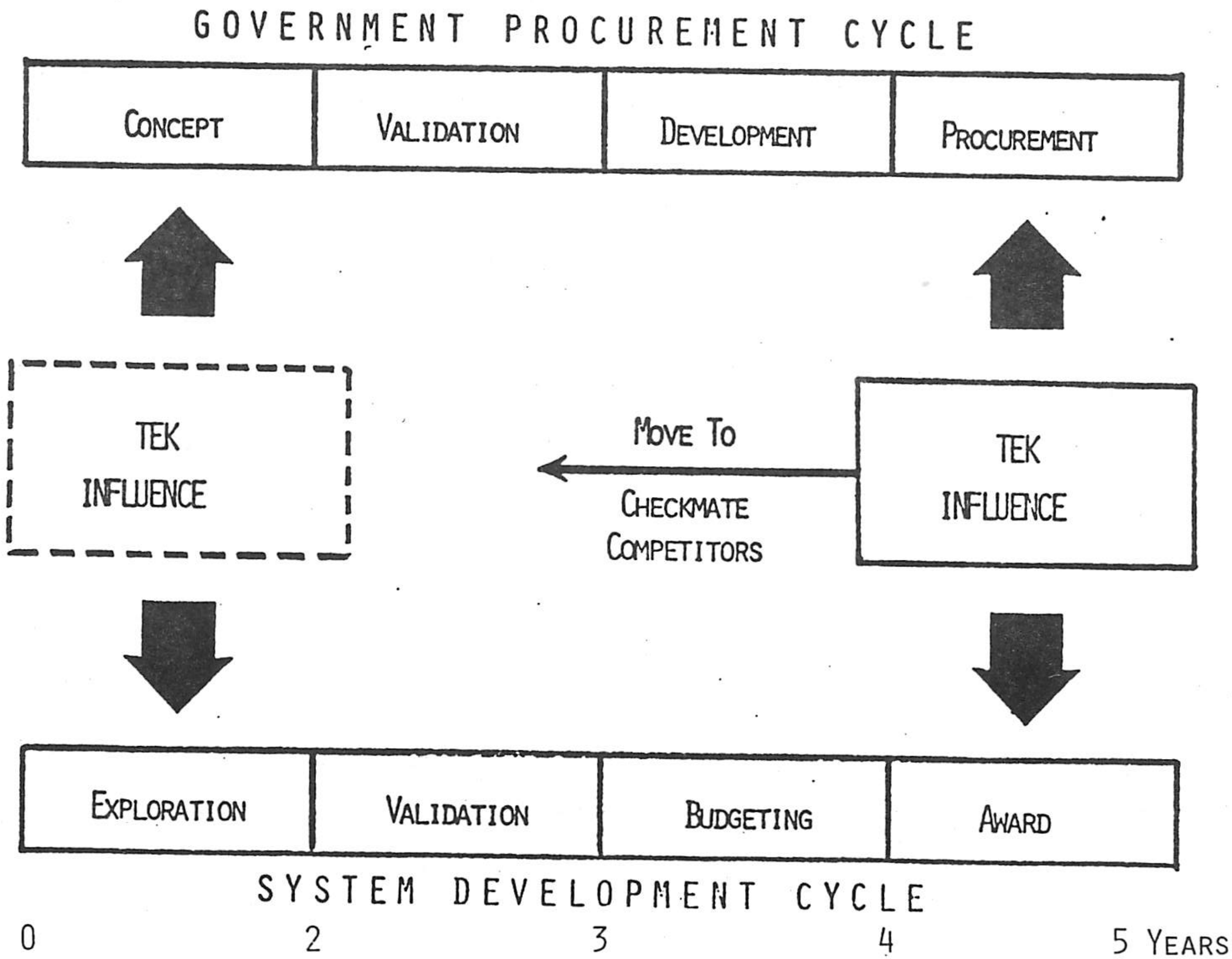


Exhibit 5

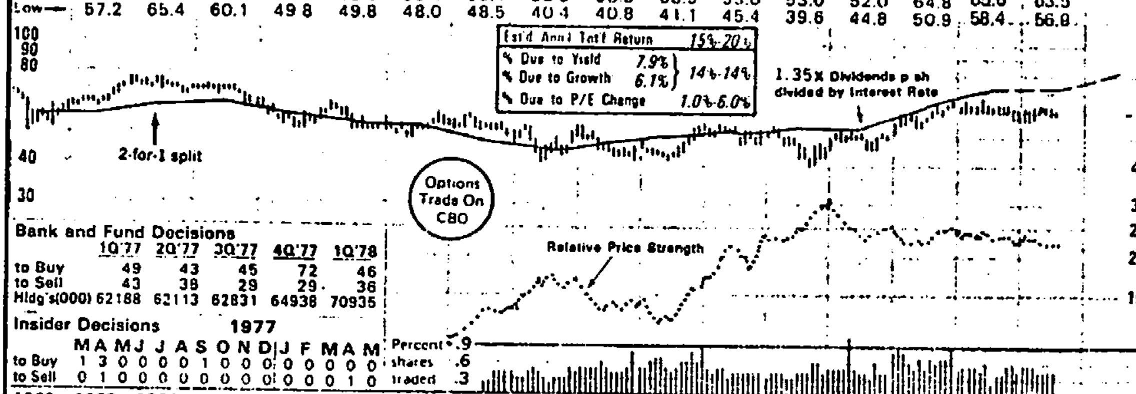
INFLUENCE

- CENTRAL AUTHORIZATION LISTS SO THAT TEK PRODUCTS
  ARE SPECIFIED
  STAY SPECIFIED
  REPLACE UNAUTHORIZED PRODUCTS
  (TMDE MANAGEMENT)
- TECHNICAL SPECIFICATIONS AND PURCHASE DESCRIPTIONS IN FORMULATIVE STAGE
- PROCUREMENT METHODS TO SUIT OUR CIRCUMSTANCES
- DATA, PROVISIONING & TEST REQUIREMENTS TO SUIT OUR PURPOSES
- LOGISTICIANS IN GOVT. & PRIMES BY MAKING THEIR JOB EASIER
- PRIME CONTRACTORS BY RAISING OUR LEVEL OF CONTACT FROM ENGINEERING TO
  PROJECT MANAGERS
  TMDE MANAGERS
  MARKETING MANAGERS
  LOGISTICS MANAGERS
- TEK DEVELOPMENT BY INCREASING OUR CONTACTS AND EARLY AWARENESS OF OPPORTUNITIES AT CONTRACTOR LOCATIONS
- PROGRAMS INVOLVING SYSTEMS DEVELOPMENT BY CENTRALLY COORDINATING EFFORTS AT CONTRACTOR LOCATIONS
- USING COMMANDS BY CONTINUAL TRAINING, APPLICATIONS ASSISTANCE, & SERVICE

AMERICAN TELEPHONE NYSE-T

RECENT PRICE 61 | P/E RATIO 8.0 (Norm 11.0; Trail'g 8.4) | DIV'D YIELD 7.9% (Norm 6.2%; Trail'g 7.2%) | 754

High: 70.7 75.0 70.5 63.5 62.8 58.4 58.1 53.9 53.9 63.5 55.0 53.0 52.0 64.8 65.6 63.5
Low: 57.2 65.4 60.1 49.8 49.8 48.0 48.5 40.4 40.8 41.1 45.4 39.6 44.8 50.9 58.4 56.8



Est'd Ann'l Tot'l Return	15%-20%
% Due to Yield	7.9%
% Due to Growth	6.1% (14%-14%)
% Due to P/E Change	1.0%-6.0%

TIMELINESS (Relative Price Performance Next 12 Mos) **4** Below Average

SAFETY (Scale 1 Highest to 5 Lowest) **1** Highest

BETA .75

Aug. 4, 1978 Value Line

Bank and Fund Decisions

	1Q'77	2Q'77	3Q'77	4Q'77	1Q'78
to Buy	49	43	45	72	46
to Sell	43	38	29	29	36
Hldg's(000)	62188	62113	62831	64938	70935

Insider Decisions 1977

	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
to Buy	1	3	0	0	0	0	0	1	0	0	0	0	0	0	0
to Sell	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0

Percent shares traded .9 .6 .3

1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	© Arnold Bernhard & Co., Inc.	81-83E
18.47	19.55	19.73	20.88	22.50	24.04	25.67	28.55	30.87	33.70	37.75	42.37	46.76	49.75	54.03	56.35	***60.90***	***65.35***	(A) Revenues per sh	***75.35***
5.36	5.74	5.99	6.46	6.96	7.39	7.63	8.22	8.60	9.02	9.80	10.96	11.84	12.03	13.31	14.52	***16.15***	***17.00***	"Cash Flow" per sh	***19.25***
2.86	3.03	3.21	3.41	3.69	3.79	3.75	4.00	3.99	3.99	4.34	4.98	5.27	5.13	6.05	6.97	***7.65***	***7.95***	(B) Earnings per sh	***8.85***
1.80	1.80	2.00	2.05	2.20	2.25	2.40	2.45	2.60	2.60	2.70	2.87	3.24	3.40	3.80	4.20	***4.60***	***5.10***	(C) Div'ds Decl'd per sh ■	***5.70***
6.28	6.43	6.73	7.40	7.77	7.96	8.63	10.14	12.88	13.12	14.99	16.35	17.54	16.07	16.05	17.44	***19.10***	***17.50***	Cap'l Spending per sh	***20.00***
31.52	33.19	35.42	37.05	37.88	39.76	40.61	42.08	43.33	44.67	46.32	48.29	50.16	51.43	53.43	55.94	***59.25***	***62.20***	(D) Tangible Book Value sh	***72.00***
486.20	489.46	522.39	529.84	539.42	541.19	549.26	549.26	549.27	549.31	553.71	555.28	559.76	582.02	607.41	647.63	***670.00***	***685.00***	(E) Common Shs Outst'g	***730.00***
20.4	20.8	21.7	19.6	15.1	14.5	13.8	13.3	11.7	11.6	10.4	10.1	8.8	9.4	9.4	8.9	Bold figures	are VL estimates	Avg Ann'l P/E Ratio	***11.0***
3.1%	2.9%	2.9%	3.1%	4.0%	4.1%	4.6%	4.6%	5.6%	5.7%	6.0%	5.7%	7.0%	7.0%	6.7%	6.8%			Avg Ann'l Div'd Yield	***5.9%***
						14100	15684	16955	18511	20904	23527	26174	28957	32816	36495	***40800***	***44750***	(A) Revenues ($mill)	***55000***
						2051.8	2198.7	2189.4	2239.7	2532.1	2946.7	3170.0	3147.7	3829.2	4543.9	***5200***	***5500***	Net Profit ($mill)	***6575***
						48.8%	46.7%	41.1%	38.9%	39.1%	39.4%	39.6%	40.3%	40.6%	38.8%	***39.5%***	***40.0%***	Income Tax Rate	***39.5%***
						14.6%	14.0%	12.9%	12.1%	12.1%	12.5%	12.1%	10.9%	11.7%	12.5%	***12.7%***	***12.3%***	Net Profit Margin	***12.0%***
						35.9%	37.3%	42.6%	44.5%	46.0%	46.6%	48.0%	48.5%	47.2%	45.1%	***45.5%***	***44.5%***	Long-Term Debt Ratio	***43.5%***
						64.1%	62.7%	57.4%	52.6%	50.2%	48.1%	47.1%	46.9%	48.6%	51.9%	***53.0%***	***54.0%***	Common Equity Ratio	***55.5%***
						35377	37538	42343	47638	52110	56991	61122	65561	68844	72137	***77500***	***81500***	Total Capital ($mill)	***97000***
						34755	38009	42550	47197	52600	58568	64935	70442	75922	82398	***85000***	***90000***	Net Plant ($mill)	***10500***
						6.6%	6.8%	6.3%	5.9%	6.2%	6.6%	6.7%	6.4%	7.2%	7.9%	***8.0%***	***7.5%***	% Earned Total Cap'l	***7.5%***
						9.1%	9.3%	9.0%	8.5%	9.0%	9.7%	10.0%	9.3%	10.5%	11.5%	***12.5%***	***12.0%***	% Earned Net Worth	***12.0%***
						9.1%	9.3%	9.0%	8.7%	9.1%	10.0%	10.2%	9.5%	10.8%	11.7%	***12.5%***	***12.5%***	% Earned Comm Equity	***12.0%***
						3.3%	3.6%	3.1%	3.0%	3.4%	4.2%	3.9%	3.2%	4.0%	4.6%	***5.0%***	***4.5%***	% Retained to Comm Eq	***4.3%***
						64%	61%	65%	66%	64%	61%	64%	69%	65%	62%	***62%***	***65%***	% All Div'ds to Net Prof	***65%***

CAPITAL STRUCTURE as of 3/31/78
Total Debt $35.8 bill. **Due in 5 Yrs** $5.7 bill.
LT Debt $32.4 bill. **LT Interest** $2.2 bill.
(LT interest earned: 4.3 x)

Leases, Uncapitalized Annual rentals $846.0 mill.

Pension Liability $560 mill. in '77 vs $684 mill. in '76

Pfd Stock $2.2 bill. **Pfd Div'd** $169.5 mill.
Incl. 11.8 mill. shs. $4 pfd. conv. into 1.05 comm. shs.; 10 mill. shs. $3.64 pfd.; 10.0 mill. shs. $3.74 pfd. All $50 par, cum.

Common Stock 652,884,000 shares

CURRENT POSITION ($mill.)	1976	1977	3/31/78
Cash Assets	1806.7	1717.3	1278.6
Other	4638.2	5301.4	5298.7
Current Assets	6444.9	7018.7	6577.3
Accts Payable	2520.4	2860.5	2204.7
Debt Due	2471.2	3248.7	3365.3
Other	3187.7	3386.8	3970.9
Current Liab'ties	8179.3	9496.0	9540.9
Fixed Chg. Cov.	300%	329%	378%

ANNUAL RATES of change (per sh)	Past 10 Yrs	Past 5 Yrs	Est '75-'77 to '81-'83
Revenues	9.0%	9.5%	*6.0%*
"Cash Flow"	6.5%	8.0%	*6.5%*
Earnings	5.0%	8.0%	*6.5%*
Dividends	6.0%	7.5%	*7.0%*
Book Value	3.5%	3.5%	*5.5%*

Fiscal Year Ends	QUARTERLY REVENUES ($ mill.)(A) Feb. 28	May 31	Aug. 31	Nov. 30	Full Fiscal Year
1975	6694	7117	7300	7503	28614
1976	7678	8119	8309	8432	32538
1977	8558	8976	9151	9427	36112
1978	9674	10143	***10483***	***10500***	***40800***
1979	***10600***	***11000***	***11500***	***11650***	***44750***

Fiscal Year Ends	EARNINGS PER SHARE (A) Feb. 28	May 31	Aug. 31	Nov. 30	(B) Full Fiscal Year
1975	1.15	1.34	1.36	1.25	5.10
1976	1.33	1.51	1.60	1.61	6.05
1977	1.55	1.80	1.82	1.71	6.88
1978	1.80	1.92	***2.00***	***1.93***	***7.65***
1979	***1.95***	***1.95***	***2.00***	***2.05***	***7.95***

Cal-endar	QUARTERLY DIVIDENDS PAID ■ Mar. 31	June 30	Sept. 30	Dec. 31	(C) Full Year
1974	.77	.77	.77	.85	3.16
1975	.85	.85	.85	.85	3.40
1976	.85	.95	.95	.95	3.70
1977	.95	1.05	1.05	1.05	4.10
1978	1.05	1.15	1.15		

BUSINESS: The American Telephone & Telegraph Co. and its subsidiaries provide telephone and related communications services throughout U.S. Serves 128.5 million telephones. 99% capable of direct dialing; transmits 506 million conversations a day. Local service accounts for about 47% of revenues. Western Electric makes most telephone equipment for the system, contributes about 11% of net income. Bell Labs undertake research and development. Has .95 million employees. 2.9 mill. shareholders. Labor costs: 57% of revs. '77 deprec. rate: 5.0%. Chrmn.: J. DeButts. Pres.: C. Brown. Inc.: New York. Address: 195 Broadway, New York, N.Y. 10007.

AT&T offers a compound average total annual return of at least 13% a year. In the final analysis, the rate of growth of share earnings (and dividends) is a function of the rate of return allowed by regulators and how cheaply new equity capital can be raised. (To a lesser extent, it is also a function of the growth of business since this dictates the amount of added funds needed upon which the return is earned.) In 1975, when the economy slumped, inflation escalated, and interest rates climbed, local rate commissions were persuaded to grant rate hikes. Since then, the economy has improved enough to send profits fairly racing ahead, pushing the rate of return with it. The higher return, alone, is enough to cause regulators to close the rate hike spigot once again, but a new budget-mindedness led by Californians seems to be giving the spigot an extra twist. If, in addition, interest rates edge lower over the coming 3 to 5 years, a further decline in allowable rates of return from this year's level is likely. But despite the prospects of a slow rate of growth ahead, even if we assume (1) that long-term interest rates will not fall during the next 3 to 5 years, and (2) that the interest rate-adjusted dividend multiple will not recover from its present level, AT&T still offers a compound average return from yield and from appreciation of at least 13% a year, not bad from an equity of this caliber, particularly when one considers that the return could be half again as large if interest rates fall and the "multiple" rises.

The use of the phone is soaring. Contrary to forecasts—both those of the phone company and outsiders as well—phone usage continued to climb faster than the general economy in the second quarter. Toll message volume (in units) gained an average of 12.9% in the three months ended May, following a gain of 13.2% in the prior quarter. Dollar volume, excluding rate hikes, pushed upward at a 10.5% clip in the latest period and 10.4% in the prior frame, in contrast to an 8.4% rise for all of 1977. As yet, the tempo gives no sign of abating. The correlation between telephone growth and the economy has been so persistent over the past, however, that we have continued to allow for a decline in phone usage in the second half in our 1978 estimates.

A.S.L./j.h.k.

(A) Calendar years. Qtrly reports are based on 12-month period ending Nov. 30. (B) Based on avg shs. outst'g. Excl. 8¢ extra in '73. Est'd '77 replacem't egs.: $4.35/sh Egs rep't mid-Sept. (C) Next div'd meet'g about Aug. 16. Goes ex about Aug. 24. Div'd paym't dates: Jan 3, Apr. 1, July 1, Oct. 1. Plus rights for conv. pfd. shs. in '71. ■ Div'd reinvest. plan av'ble (5% discount). (D) Excl. intangibles. In '77, $1.84/sh. (E) In mill. adj. for stk. splits & div'ds.

Company's Financial Strength	A++
Stock's Price Stability	100
Price Growth Persistence	75
Earnings Predictability	95

DIGITAL EQUIP. NYSE-DEC

RECENT PRICE **51** | P/E RATIO **14.1** (Norm 26.0 / Trail'g 15.2) | DIV'D YIELD **Nil** (Norm Nil / Trail'g Nil) | 1088

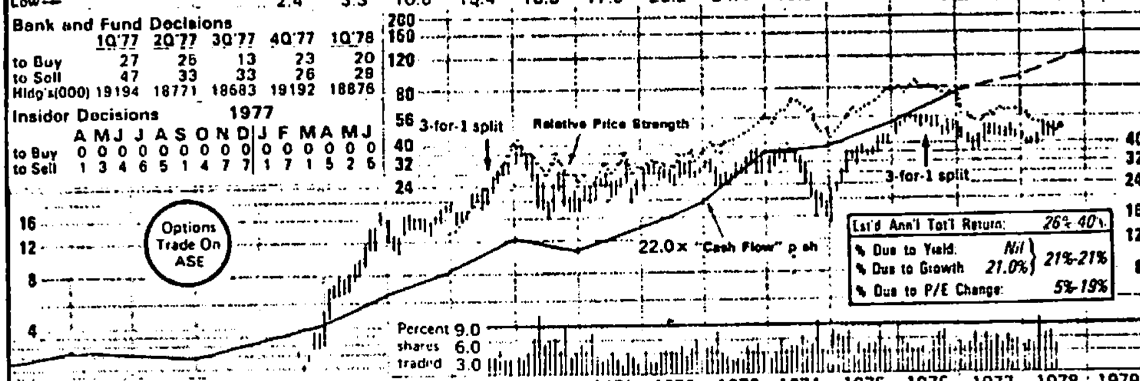
	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
High	3.9	17.3	19.9	34.3	41.3	34.3	34.2	39.8	40.9	47.0	60.8	54.0	64.9
Low	2.4	3.3	10.6	15.4	18.3	17.5	23.2	24.4	16.3	15.1	45.2	36.6	38.5

Bank and Fund Decisions

	1Q'77	2Q'77	3Q'77	4Q'77	1Q'78
to Buy	27	25	13	23	20
to Sell	47	33	33	26	28
Hldg's(000)	19194	18771	18683	19192	18876

Insider Decisions 1977

	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
to Buy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
to Sell	1	3	4	6	5	1	4	7	7	1	7	1	5	2	6



Est'd Ann'l Tot'l Return:	26%-40%
% Due to Yield: Nil / % Due to Growth 21.0%	21%-21%
% Due to P/E Change:	5%-19%

TIMELINESS 3 Average (Relative Price Performance Next 12 Mos.)

SAFETY 3 Average (Scale 1 Highest to 5 Lowest)

BETA 1.30

Aug. 18, 1978 Value Line

© Arnold Bernhard & Co., Inc.

1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979		81-83E
.28	.43	.47	.65	.95	1.49	2.18	3.18	4.67	4.78	6.04	7.99	11.79	14.80	18.96	26.96	*36.20*	*44.80*(A)	Revenues per sh	*69.80*
.04	.06	.05	.04	.11	.20	.29	.38	.56	.44	.66	.95	1.59	1.74	2.46	3.49	*4.70*	*5.60*	"Cash Flow" per sh	*8.55*
.04	.05	.04	.03	.08	.17	.26	.34	.50	.35	.50	.72	1.27	1.28	1.98	2.78	3.40	*4.10*(B)	Earnings per sh	*8.75*
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*Nil*	Div'ds Decl'd per sh	*.60*
--	--	.02	.03	.05	.03	.07	.11	.51	.40	.72	.80	1.40	1.27	1.40	3.65	*4.60*	*3.30*	Cap'l Spending per sh	*7.00*
.06	.12	.15	.19	.26	.60	.86	1.64	2.63	4.10	4.67	6.73	9.49	10.94	15.61	18.73	*22.55*	*27.10*	Tangible Book Value sh	*49.55*
23.00	23.00	23.00	23.22	24.08	26.19	26.34	27.65	29.02	30.72	31.03	33.24	35.80	36.07	38.83	39.26	*39.70*	*40.20*(C)	Common Shs Outst'g	*44.40*
--	--	--	--	--	27.7	49.5	50.5	57.5	63.9	53.2	41.1	26.9	20.6	24.3	17.6	13.2		Avg Ann'l P/E Ratio	*26.0*
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--		Avg Ann'l Div'd Yield	*.3%*

CAPITAL STRUCTURE as of 12/31/77
Total Debt *$352 mill.* Due in 5 Yrs *$15 mill.*
LT Debt $341.0 mill. LT Interest *$19 mill.*
Incl. $250 mill. 4 1/2% debs. (due 2002) callable 104.50, ea. conv. into 17.54 com. shs.
Incl. $6.1 mill. 7.2% capitalized leases.
(LT interest earned: *13 x*; coverage of total interest: *12 x*) (30% of Cap'l)

Leases, Uncapitalized Rentals $18 mill.

Pension Liability None in '77 or '76
Pfd Stock None

Common Stock 39,512,948 shares
(42.9 mill. primary shs.) (70% of Cap'l)

1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979		81-83E
57.3	87.9	135.4	146.9	187.6	265.5	421.9	533.8	736.3	1058.6	1436.6	*1800*(A)	Revenues ($mill)	*3100*
23.3%	20.6%	20.8%	14.3%	16.1%	17.0%	18.4%	17.2%	18.9%	19.5%	*19.0%*	*18.5%*	Operating Margin	*18.0%*
.7	1.2	1.9	2.9	5.1	8.0	12.4	16.9	22.0	28.5	*44.0*	*60.0*	Depreciation ($mill)	*80.0*
6.9	9.3	14.4	10.6	15.3	23.5	44.4	46.0	73.4	108.5	142.2	*180*	Net Profit ($mill)	*300*
47.0%	45.2%	43.5%	41.1%	39.0%	36.8%	32.9%	37.5%	38.5%	38.5%	37.5%	*37.0%*	Income Tax Rate	*36.0%*
12.0%	10.6%	10.6%	7.2%	8.2%	8.9%	10.5%	8.6%	10.0%	10.3%	9.9%	*10.0%*	Net Profit Margin	*9.7%*
19.8	40.5	56.1	96.1	87.2	152.7	238.7	333.2	499.0	574.1	*850*	*950*	Working Cap'l ($mill)	*1800*
--	--	--	--	--	--	10.6	85.2	91.4	90.6	*335*	*350*	Long-Term Debt ($mill)	*400*
22.7	45.3	76.3	125.9	144.8	223.5	339.6	394.4	606.1	735.5	*895*	*1090*	Net Worth ($mill)	*2200*
30.2%	20.6%	18.9%	8.4%	10.6%	10.5%	12.8%	10.1%	11.1%	13.6%	*12.0%*	*13.0%*	% Earned Total Cap'l	*11.5%*
30.2%	20.6%	18.9%	8.4%	10.6%	10.5%	13.1%	11.7%	12.1%	14.8%	*16.0%*	*16.5%*	% Earned Net Worth	*13.5%*
30.2%	20.6%	18.9%	8.4%	10.6%	10.5%	13.1%	11.7%	12.1%	14.8%	*16.0%*	*16.5%*	% Retained to Comm Eq	*12.6%*
--	--	--	--	--	--	--	--	--	--	--	*Nil*	% All Div'ds to Net Prof	*9%*

CURRENT POSITION ($mill.)	1976	1977	12/31/77
Cash Assets	201.3	88.2	212.1
Receivables	219.3	323.1	349.6
Inventory (FIFO)	218.8	375.0	441.5
Other	8.7	18.7	26.5
Current Assets	648.1	805.0	1029.7
Accts Payable	47.1	60.6	*61.0*
Debt Due	5.4	28.6	*11.0*
Other	96.6	141.7	136.9
Current Liab.	149.1	230.9	208.9

ANNUAL RATES of change (per sh)	Past 10 Yrs	Past 5 Yrs	Est '75-'77 to '81-'83
Revenues	35.0%	31.5%	*21.5%*
'Cash Flow'	36.5%	36.0%	*20.5%*
Earnings	35.5%	35.0%	*21.0%*
Dividends	—	—	*NMF*
Book Value	45.5%	32.0%	*21.0%*

Fiscal Year Ends	QUARTERLY REVENUES ($ mill.) (A) Sept. 30	Dec. 31	Mar. 31	June 30	Full Fiscal Year
1975	111.8	126.8	134.6	160.6	533.8
1976	140.5	172.6	191.2	232.0	736.3
1977	204.5	241.0	282.7	330.4	1058.6
1978	302.6	346.6	374.8	412.6	1436.6
1979	*360*	*430*	*470*	*540*	*1800*

Fiscal Year Ends	EARNINGS PER SHARE (A) Sept. 30	Dec. 31	Mar. 31	June 30	Full Fiscal (B) Year
1975	.21	.27	.32	.48	1.28
1976	.32	.45	.51	.70	1.96
1977	.43	.58	.72	1.05	2.78
1978	.66	.78	.87	1.09	3.40
1979	*.70*	*.95*	*1.05*	*1.40*	*4.10*

Calendar	QUARTERLY DIVIDENDS PAID Mar. 31	June 30	Sept. 30	Dec. 31	Full Year
1974					
1975	NO CASH DIVIDENDS BEING PAID				
1976					
1977					
1978					

BUSINESS: Digital Equipment Corporation is the leading manufacturer of small digital computers (minicomputers). Ranks second to IBM in overall computer systems, with 8%-10% of industry shipments. Also makes and sells digital circuit modules, tape handling and disc memory equipment, visual display units. Service income comprises 20% of revenue; foreign business, 36%; U.S. Government, 5%. R&D equals 8% of revenue; payroll costs, estimated 40%. '77 deprec. rate: 8.1%. Has 38,000 employees; 22,700 shareholders. Directors control 8% of stock. President: K.H. Olsen. Inc.: Massachusetts. Address: 146 Main St., Maynard, Mass. 01754.

Digital's profit growth will be slower for a while. Gains aren't coming as easily for the Number Two company in computers as they came when the business was less prominent. Increasingly, Digital Equipment is having to share with other contenders—large and small—part of the minicomputer market that it pioneered. Sales are still climbing at a 25% annual rate—superior progress by most standards. But it's not up to the pace being reported by some smaller competitors. Moreover, it's costing more to bring in this business. So, even though earnings are still ahead, the profit margin is down.

It's a different ballgame for DEC. Until recently, minicomputers virtually sold themselves to data processing professionals—mostly the system suppliers dubbed "OEMs" in the trade—able to apply minis at a cost advantage versus general purpose computers. But Digital no longer has this business sewed up, partly because long deliveries drove some OEMs to other suppliers. Besides that, the competition is now going direct to users, with minis that are more powerful and much easier to use than before.

Management is changing the lineup. The company hasn't lagged technically, by any means. But it will realign itself to compete more effectively in the evolving market framework. Each of 17 market/product lines will move into one of three new groups. These groups are market oriented, which means DEC will mount a more unified campaign in specific fast-growing application areas, such as small business systems.

Digital isn't expanding facilities much this year. The major additions to plant and work force in fiscal 1978 can turn out enough hardware to meet growth objectives for the year ahead. The emphasis, instead, is on adding power in the marketplace. The organizational realignment won't contribute any immediate punch. But some 400 more sales engineers will. They'll have a number of hot new items to offer, like the high-performance VAX 11/780 mini and the low-cost DEC System-2020 mainframe that doesn't need air conditioning. We think this effort will cushion some of the impact of the expected slowdown in general business.

E.B.S. /g.a.h.

(A) Fiscal yr. ends about June 30 of cal yr.
(B) Based on avg. primary shs. outst'g.
Earn'gs rep't due late Oct. Est'd '78 replacem't earn'gs. $3.70/sh.
(C) In mill., adj. for stock splits & div'ds

Company's Financial Strength	A+
Stock's Price Stability	50
Price Growth Persistence	100
Earnings Predictability	65

GOULD INC. NYSE-GLD

RECENT PRICE 33 | P/E RATIO 8.0 (Norm 11.6, Trail'g 8.4) | DIV'D YIELD 4.8% (Norm 3.2%, Trail'g 4.1%)

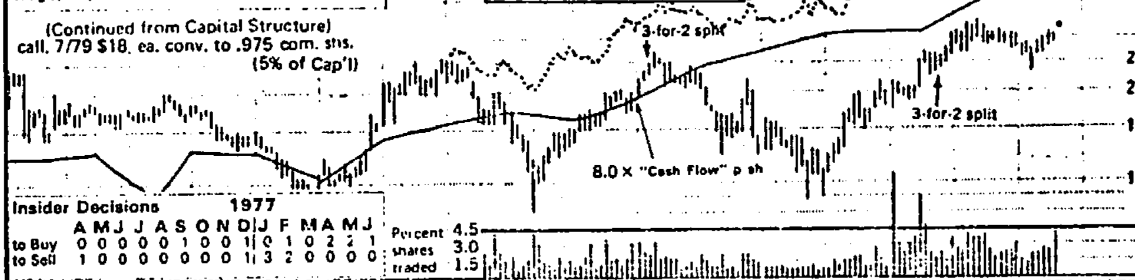
High	16.9	19.8	19.2	14.9	17.0	28.0	25.7	17.1	20.5	27.2	23.0	16.5	21.7	31.1	35.5	33.0
Low	15.1	16.0	12.9	8.7	8.5	15.7	15.5	8.1	13.6	19.5	12.3	8.7	10.7	17.6	27.3	23.8

Bank and Fund Decisions

	1Q'77	2Q'77	3Q'77	4Q'77	1Q'78
to Buy	12	8	7	7	1
to Sell	7	7	12	10	6
Hldg's(000)	2937	2962	3010	2910	3129

Est'd Ann'l Tot'l Return		19%-30%
% Due to Yield	4.8%	17%-17%
% Due to Growth	12.2%	
% Due to P/E Change		2.0%-13%

(Continued from Capital Structure) call. 7/79 $18. ea. conv. to .975 com. shs. (5% of Cap'l)



TIMELINESS 3 Average (Relative Price Performance Next 12 Mos)

SAFETY 3 Average (Scale 1 Highest to 5 Lowest)

BETA 1.00

Aug. 18, 1978 Value Line

Insider Decisions 1977

	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
to Buy	0	0	0	0	0	1	0	0	1	0	1	0	2	2	1
to Sell	1	0	0	0	0	0	0	0	1	3	2	0	0	0	0

Percent shares traded 4.5 / 3.0 / 1.5

© Arnold Bernhard & Co., Inc. | 81-83E

1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	© Arnold Bernhard & Co., Inc.	81-83E
22.82	23.55	22.26	26.30	27.89	29.41	32.25	32.08	30.85	30.82	37.37	48.89	57.40	58.37	53.68	66.48	**72.50**	**75.05**	(A)Sales per sh	105.45
1.60	1.59	1.15	1.69	1.60	1.32	1.74	1.98	2.16	2.06	2.46	2.98	3.45	3.90	4.02	5.17	**5.75**	**6.20**	"Cash Flow" per sh	8.30
1.11	1.04	.64	1.20	1.05	.72	1.08	1.20	1.40	1.29	1.55	1.89	2.34	2.56	3.31	3.72	**4.15**	**4.55**	(B)Earnings per sh	6.25
.53	.58	.58	.60	.62	.62	.62	.78	.47	.62	.63	.65	.70	.77	.95	1.24	**1.48**	**1.65**	(C)Div'ds Decl'd per sh ■	2.25
.61	.75	.46	.99	.79	.93	1.12	1.23	1.35	2.12	2.42	2.51	2.16	2.39	2.32	2.38	**4.25**	**3.50**	Cap'l Spending per sh	3.65
10.36	10.83	10.89	11.49	11.92	12.01	12.03	8.84	9.28	9.93	11.39	12.71	13.16	13.55	18.00	20.10	**22.75**	**25.65**	(D)Tangible Book Value sh	36.85
3.91	3.91	3.91	3.91	3.91	3.91	3.85	10.69	11.02	11.10	12.61	12.67	12.89	13.24	22.83	24.36	**26.20**	**26.25**	Common Shs Outst'g	27.50
19.3	16.0	26.4	14.6	13.3	14.5	13.5	18.7	10.8	11.3	13.7	10.4	6.4	5.0	7.3	8.2	Bold figures	are VL estimates	Avg Ann'l P/E Ratio	11.5
2.5%	3.5%	3.4%	3.4%	4.5%	6.0%	4.3%	3.5%	3.1%	4.3%	3.0%	3.3%	4.7%	6.0%	3.9%	4.1%			Avg Ann'l Div'd Yield	3.1%

CAPITAL STRUCTURE as of 12/31/77
Total Debt $254.4 mill. Due in 5 Yrs $75.8 mill.
LT Debt $224.3 mill. LT Interest $20.1 mill.
Incl. $16.6 mill. 5% sub. debs. ('87) call. 102.50, ea. conv. to 39.86 com. shs.
Incl. $15.6 mill. capitalized leases. (LT interest earned: 8.9 x; coverage of total interest: 7.0 x) (27% of Cap'l)
Leases, Uncapitalized Annual rentals, $14.4 mill.
Pension Liability $25.2 mill. vs $14.2 mill. in '76
Pfd Stock $41.7 mill. Pfd Div'd $4.1 mill.
200,000 shs. $7.50 cum. pfd.
1,808,605 shs. $1.35 cum. pfd. ($12 liq. val.)
(Continued on Chart)
Common Stock 24,360,302 shares (24.4 mill. primary shs.) (68% of Cap'l)

1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979		81-83E
124.0	342.8	340.0	342.2	471.3	619.5	739.7	772.9	1225.4	1619.6	**1900**	**2075**	(A)Sales ($mill)	2900
8.8%	12.0%	12.1%	10.7%	9.6%	10.3%	11.0%	10.7%	12.4%	13.4%	**14.0%**	**13.5%**	Operating Margin	14.0%
2.5	8.3	8.5	8.6	11.6	13.9	14.8	18.4	29.8	36.3	**38.0**	**42.0**	Depreciation ($mill)	55.0
4.2	12.9	15.3	14.3	19.5	23.9	30.4	37.1	66.0	93.6	**113**	**120**	Net Profit ($mill)	175
47.1%	50.8%	48.7%	45.5%	38.8%	44.8%	45.5%	38.2%	36.9%	40.6%	**44.0%**	**44.0%**	Income Tax Rate	44.0%
3.4%	3.8%	4.5%	4.2%	4.1%	3.9%	4.1%	4.8%	5.4%	5.8%	**6.0%**	**5.8%**	Net Profit Margin	6.0%
37.0	56.6	90.3	80.3	111.0	140.1	165.3	166.2	384.2	368.8	**420**	**445**	Working Cap'l ($mill)	650
15.0	38.4	66.5	65.3	92.7	115.8	121.7	160.6	242.9	224.3	**280**	**270**	Long-Term Debt ($mill)	450
46.3	146.0	154.2	162.6	196.6	216.0	244.9	299.1	534.7	611.9	**685**	**760**	Net Worth ($mill)	1050
7.4%	7.5%	8.1%	7.2%	7.8%	8.5%	9.8%	9.5%	9.9%	12.4%	**12.5%**	**13.0%**	% Earned Total Cap'l	13.0%
9.1%	8.8%	10.0%	8.8%	9.9%	11.1%	12.4%	12.4%	12.4%	15.3%	**16.5%**	**16.0%**	% Earned Net Worth	16.5%
3.8%	3.7%	6.6%	4.6%	6.2%	7.3%	9.3%	9.1%	8.7%	10.5%	**11.0%**	**11.0%**	% Retained to Comm Eq	11.0%
58%	58%	33%	48%	38%	34%	32%	37%	35%	36%	**36%**	**37%**	% All Div'ds to Net Prof	36%

CURRENT POSITION ($mill.)	1975	1976	12/31/77
Cash Assets	8.1	10.2	14.7
Receivables	131.2	226.7	251.0
Inventory (FIFO)	161.0	321.5	345.6
Other	21.9	50.3	35.8
Current Assets	323.2	608.7	647.1
Accts Payable	94.0	187.3	221.1
Debt Due	56.1	20.0	30.2
Other	6.9	17.2	27.0
Current Liab.	157.0	224.5	278.3

ANNUAL RATES of change (per sh)	Past 10 Yrs	Past 5 Yrs	Est '75-'77 to '81-'83
Sales	8.0%	12.5%	*10.0%*
"Cash Flow"	11.0%	14.5%	*11.5%*
Earnings	12.5%	17.5%	*11.5%*
Dividends	5.0%	11.5%	*14.5%*
Book Value	4.0%	11.0%	*13.5%*

Cal-endar	QUARTERLY SALES ($ mill.) Mar. 31	June 30	Sept. 30	Dec. 31	(A) Full Year
1975	182.8	177.7	177.1	198.2	735.8
1976	203.9	311.9	346.8	362.8	1225.4
1977	377.4	405.9	402.9	433.4	1619.6
1978	440.1	471.9	*480*	*508*	*1900*
1979	*500*	*520*	*520*	*535*	*2075*

Cal-endar	EARNINGS PER SHARE Mar. 31	June 30	Sept. 30	Dec. 31	(A)(B) Full Year
1975	.65	.67	.63	.72	2.67
1976	.79	.82	.79	.91	3.31
1977	.85	.96	.91	1.00	3.72
1978	.94	1.10	*1.05*	*1.06*	*4.15*
1979	*1.05*	*1.15*	*1.15*	*1.20*	*4.55*

Cal-endar	QUARTERLY DIVIDENDS PAID Mar. 31	June 30	Sept. 30	Dec. 31	(C) Full ■Year
1974	.183	.183	.183	.183	.733
1975	.20	.20	.20	.20	.80
1976	.227	.227	.25	.25	.953
1977	.28	.28	.34	.34	1.24
1978	.34	.34			

BUSINESS: Gould Incorporated develops and manufactures a wide variety of electrical and electronic products for sale to both original equipm't mfrs. and to the replacement market. Foreign business provides 12% of sales, 10% of pretax profits. Acquired companies include Century Electric, Allied Control, Statham Instruments, Chesapeake Instrument, I-T-E Imperial, Hoffman Electronics. Payroll costs, 31% of sales: R&D, 4.3%. '77 deprec. rate: 6.9%. Has 37,127 empls.: 25,462 com. stkhldrs., 2,700 pfd. Directors control about 15% of com. stock. Chrmn.: W.T. Ylvisaker. Pres.: D.T. Carroll. Inc.: Del. Address: 10 Gould Center, Rolling Meadows, Illinois 60008.

Gould's thirst for acquisitions has been quenched—temporarily. In just the past three years, the company had made a half dozen major acquisitions and a number of smaller ones. Even though the number of outstanding shares has more than doubled over the past half decade—as a result of the brisk takeover activity—sales per share have advanced 12.5% yearly. Over the same period, share earnings posted a 17.5% average annual gain. This year, Gould is passing acquisitions by in anticipation of an economic slowdown in 1979. But activity will likely pick up again soon. The company wants to boost its sales to the military and to replacement markets so that together they'll bring in to 50% of its yearly total. Currently, about 30% of annual revenues are derived from these two markets.

The emphasis this year is on plant expansion and R&D. Gould has budgeted a record $112 million for new equipment purchases and a 14% increase in brick and mortar. Product development outlays are soaring to new highs, too—$79 million. We expect that the increase in spending will require an infusion of long-term debt. Still, Gould's debt will likely tally to less than 30% of total capital. That's a five percentage point improvement in just three years. And that's the reason why we've raised Gould's Financial Strength rating a notch to B++, Superior. **This company's sales and share earnings are apt to advance steadily out to 1981-83.** We're looking for a 17% yearly revenue increase in 1978. And about a 10% gain, on average, in future years. A big share of the gain will likely come from an increase in battery sales. The company is introducing a host of new products in this business line from tiny batteries for calculators and watches to long-life batteries designed for the electric autos. Moreover, we think that share profits will grow even faster than sales, as new plant and equipment increases productivity and widens operating margins. . . . GLD shares are a good pick for their handsome estimated total return out to 1981-83. *R.B./m.e.h.*

Restated Sales (and Pretax Profit Margins Before Interest) by Business Line

	1975	1976*	1977*	1978
Electrical	349.9(3.6%)	591.3(8.5%)	823.2(11.5%)	*980(11.0%)*
Battery	205.3(10.4%)	251.3(9.9%)	330.1(10.8%)	*400(10.0%)*
Industrial	180.6(25.9%)	334.9(16.1%)	413.1(17.0%)	*540(17.0%)*
Company Total	735.8(10.9%)	1177.5(13.1%)	1566.4(14.4%)	*1900(12.0%)*

*Excluding sales & earnings of discontinued operations.

(A) Prior to '76, fiscal year ended June 30; prior to '69, Apr. 30. All q'trly figs are for calendar yrs. (B) Based on avg primary shs. Earn'gs rep't due late Oct. Est'd '77 replacem't earnings $2.40/sh. (C) Next div'd meet'g about Nov 6. Goes ex about Aug. 25. Div'd payment dates about Mar. 15, June 15, Sept. 15, Dec 15. ■Div'd reinvestment plan available. (D) Excl. intangibles. In '77: $80.7 mill., $3.31/sh.

Company's Financial Strength	B++
Stock's Price Stability	55
Price Growth Persistence	95
Earnings Predictability	35

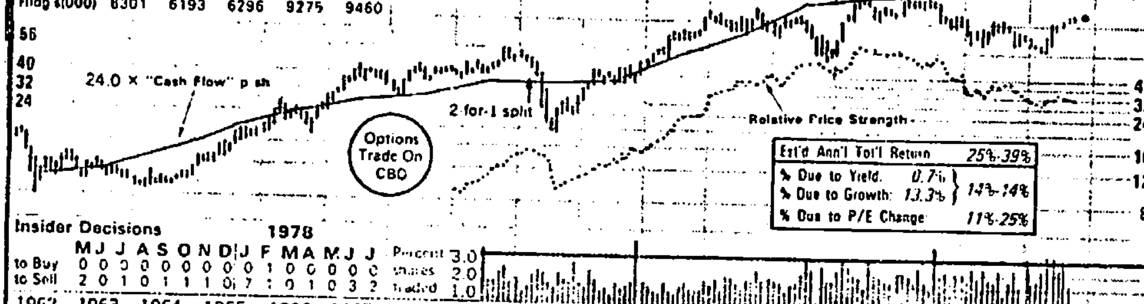
HEWLETT-PACKARD NYSE-HWP

RECENT PRICE **67** | P/E RATIO **15.0** (Norm 30.0; Trail'g 18.7) | DIV'D YIELD **0.7%** (Norm 0.3%; Trail'g 2.9%)

High	13.6	11.7	19.5	27.9	44.9	45.7	57.3	55.3	49.6	88.4	100.6	92.3	120.5	117.8	87.5	92.8
Low	9.3	8.5	11.3	17.6	24.4	29.6	37.6	19.4	29.5	45.5	71.0	52.0	56.4	80.0	68.1	61.8

Bank and Fund Decisions

	2Q'77	3Q'77	4Q'77	1Q'78	2Q'78
to Buy	13	7	17	16	14
to Sell	8	5	7	10	10
Hldg's(000)	6301	6193	6296	9275	9460



TIMELINESS (Relative Price Performance Next 12 Mos.) **3** Average

SAFETY (Scale 1 Highest to 5 Lowest) **3** Average

BETA 1.25

Insider Decisions

	M	J	J	A	S	O	N	D	J (1978)	F	M	A	M	J	J
to Buy	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
to Sell	2	0	1	0	1	1	1	0	7	1	0	1	0	3	2

Oct. 6, 1978 Value Line

1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979		81-83E
5.05	5.17	5.45	6.75	8.27	9.79	10.70	12.80	13.54	14.41	18.11	24.66	32.38	35.50	39.71	47.75	**58.30**	**68.65**	(A) Sales per sh	**95.65**
.42	.44	.55	.75	.95	1.12	1.21	1.45	1.44	1.46	2.04	2.75	4.23	4.30	4.65	5.94	**6.90**	**8.15**	"Cash Flow" per sh	**11.60**
.31	.30	.39	.56	.71	.81	.83	1.01	.90	.88	1.40	1.89	3.08	3.02	3.24	4.27	**4.95**	**6.00**	(B) Earnings per sh	**8.20**
--	--	--	.10	.10	.10	.10	.10	.20	.20	.20	.20	.20	.25	.30	.40	**.50**	**.60**	(C) Div'ds Decl'd per sh	**1.25**
.10	.21	.32	.41	.76	.80	.63	1.08	1.02	.74	1.47	3.03	3.16	2.39	3.69	4.06	**5.20**	**5.90**	Cap'l Spending per sh	**4.80**
2.00	2.39	2.85	3.06	3.77	4.63	5.59	6.72	7.74	8.88	10.68	12.92	16.63	20.23	24.08	28.86	**32.95**	**37.55**	(D) Tangible Book Value sh	**54.00**
21.60	22.42	22.90	24.26	24.60	24.86	25.13	25.30	25.65	26.04	26.45	26.82	27.30	27.64	28.00	28.48	**28.90**	**29.50**	(E) Common Shs Outst'g	**31.00**
44.8	37.2	24.5	25.1	30.7	42.4	45.3	43.6	40.7	43.2	46.6	44.5	25.3	29.6	31.9	18.3	Bold figures		Avg Ann'l P/E Ratio	**30.0**
--	--	--	.7%	.5%	.3%	.3%	.2%	.6%	.5%	.3%	.2%	.3%	.3%	.3%	.5%	are VL estimates		Avg Ann'l Div'd Yield	**0.5%**

CAPITAL STRUCTURE as of 4/30/78
Total Debt $105.2 mill. **Due in 5 Yrs** NA
LT Debt $10.6 mill. **LT Interest** $1.0 mill.
(1% of Cap'l)

Leases, Uncapitalized Annual rentals $17.5 mill.

Pension Liability None in '77 vs None in '76
Pfd Stock None **Pfd Div'd** None

Common Stock 28,479,000 shares on 10/31/77 (99% of Cap'l)

1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979		81-83E
268.8	323.8	347.3	375.1	479.1	661.3	884.1	981.2	1111.7	1360.0	**1685**	**2025**	Sales ($mill)	**2965**
18.5%	19.7%	15.9%	15.1%	17.7%	16.7%	19.9%	18.1%	17.3%	19.6%	**19.0%**	**19.5%**	Operating Margin	**19.0%**
9.5	11.1	13.7	15.3	16.8	22.9	31.5	35.3	39.5	47.6	**56.0**	**66.0**	Depreciation ($mill)	**105**
20.8	25.6	23.1	22.8	37.3	50.8	84.0	83.6	90.8	121.5	**143**	**175**	Net Profit ($mill)	**255**
51.5%	53.0%	49.5%	47.3%	46.7%	46.3%	41.8%	43.7%	43.5%	47.0%	**48.5%**	**48.0%**	Income Tax Rate	**46.5%**
7.8%	7.9%	6.7%	6.1%	7.8%	7.7%	9.5%	8.5%	8.2%	8.9%	**8.5%**	**8.6%**	Net Profit Margin	**8.6%**
76.3	89.3	104.6	133.7	166.8	174.4	237.3	320.1	374.1	460.0	**505**	**565**	Working Cap'l ($mill)	**995**
1.2	.9	1.0	1.3	1.9	2.2	2.9	4.9	7.6	12.1	**13.0**	**15.0**	Long-Term Debt ($mill)	**24.0**
142.8	172.3	200.5	232.9	283.7	349.2	457.7	561.0	676.9	824.4	**955**	**1110**	Net Worth ($mill)	**1675**
14.5%	14.8%	11.5%	9.7%	13.1%	14.5%	18.2%	14.8%	13.3%	14.6%	**15.0%**	**15.5%**	% Earned Total Cap'l	**15.0%**
14.6%	14.9%	11.5%	9.8%	13.1%	14.5%	18.4%	14.9%	13.4%	14.7%	**15.0%**	**15.5%**	% Earned Net Worth	**15.0%**
12.8%	13.4%	9.0%	7.6%	11.3%	13.0%	17.2%	13.7%	12.2%	13.4%	**13.5%**	**14.0%**	% Retained to Comm Eq	**13.0%**
12%	10%	22%	23%	14%	11%	6%	8%	9%	9%	**10%**	**10%**	% All Div'ds to Net Prof	**15%**

CURRENT POSITION ($mill.)	1976	1977	7/31/78
Cash Assets	106.8	172.8	174.3
Receivables	234.3	272.4	311.2
Inventory (Avg Cst)	237.9	278.8	333.4
Other	17.8	27.9	46.2
Current Assets	596.8	751.9	865.1
Accts Payable	31.9	45.9	196.1
Debt Due	58.4	46.9	90.5
Other	132.4	199.1	69.2
Current Liab'ties	222.7	291.9	355.8

ANNUAL RATES of change (per sh)	Past 10 Yrs	Past 5 Yrs	Est '75-'77 to '81-'83
Sales	17.5%	21.5%	*15.0%*
'Cash Flow'	18.0%	24.5%	*15.0%*
Earnings	17.5%	27.0%	*15.0%*
Dividends	12.0%	9.5%	*25.0%*
Book Value	20.5%	22.0%	*14.0%*

Fiscal Year Ends	QUARTERLY SALES ($ mill.) Jan. 31	Apr. 30	July 31	Oct. 31	(A) Full Fiscal Year
1975	212.0	248.4	245.9	274.9	981.2
1976	235.6	279.8	277.5	318.8	1111.7
1977	298.3	341.5	341.1	379.1	1360.0
1978	368.2	415.2	428.1	***473.5***	***1665***
1979	***470***	***485***	***520***	***550***	***2025***

Fiscal Year Ends	EARNINGS PER SHARE Jan. 31	Apr. 30	July 31	Oct. 31	(A) Full Fiscal (B) Year
1975	.67	.87	.73	.75	3.02
1976	.54	.86	.65	1.19	3.24
1977	.93	1.13	1.07	1.14	4.27
1978	1.14	1.23	1.14	***1.44***	***4.95***
1979	***1.40***	***1.50***	***1.45***	***1.65***	***6.00***

Cal-endar	QUARTERLY DIVIDENDS PAID Mar. 31	June 30	Sept. 30	Dec. 31	(C) Full Year
1974	--	.10	--	.10	.20
1975	--	.10	--	.15	.25
1976	--	.15	--	.15	.30
1977	--	.20	--	.20	40
1978	--	.20	.15	.15	

BUSINESS: Hewlett-Packard Company is a major designer and manufacturer of precision electronic equipment for measurement, analysis & computation. Major product categories: test & measuring instruments & systems; computers & computer systems; electronic calculators; medical electronic equipment & instrumentation for chemical analysis. Also mfrs. solid-state components, primarily for in-house use. Gov't business: 17% of sales; foreign: 46%; R&D: 9.2%. '77 deprec. rate: 8.2%; Employs 35,100; has 17,000 stockholders. Insiders own 56% of stock. Chrmn.: D. Packard. Pres.: J.A. Young. Inc.: Cal. Address: 1501 Page Mill Rd., Palo Alto, Cal. 94304.

Electronic Data Products is becoming H-P's main business group. During the third quarter, two new offerings strengthened H-P's position in the high and low end of the business systems market. The new HP 3000 series III is an advanced on-line business transaction processing system. It has four times the capacity and twice the speed of its predecessors; and it's in the same price range: $115,000 to $175,000. For those with a tighter budget, the Super Accounting Machine 250, which sells for under $25,000, is one of the lowest priced data base management systems available. It is aimed at the fastest growing segment of the minicomputer market: small companies and divisions of large corporations. Two more systems are due, which will round out this year's line-up. Marketed under the Amigo name, these middle-of-the-line computers will be heavy users of H-P's latest advance: silicon-on-sapphire (SOS) circuitry. SOS allows computers to operate at considerably higher speeds than more conventional technology.

Other areas are also doing well. Although more sensitive to general economic conditions than the Electronic Data Products Group, the Test and Measurements sector, we think, will continue making good gains through 1979. Major new product introductions include microprocessor diagnostics and digital oscilliscopes. Analytical Instrumentation, H-P's fastest growing group, has been quite sucessful with its gas chromatography/mass spectrometer line.

We project a superior total return over the next 3 to 5 years. The Test and Measurement area is maturing. Even so, we expect that H-P's emphasis on Electronic Data Products will allow the company to maintain an above average earnings growth rate. By 1981-83, we think that H-P's price-earnings multiple will be closer to its historical norm. Over the next twelve months, however, don't expect these shares to outpace the market averages.

E.L. /w.m.

Restated Sales (and Pretax Margins) by Business Line

	1975	1976	1977	1978
Test & Meas	444.5 (17.8%)	487.3 (17.3%)	577.4 (19.6%)	*705 (18.5%)*
Electronic Data	386.8 (13.2%)	447.1 (11.8%)	571.7 (15.3%)	*715 (16.0%)*
Medical	96.4 (12.3%)	119.4 (14.7%)	134.9 (13.4%)	*160 (13.8%)*
Analytical	53.5 (12.5%)	57.8 (10.6%)	78.0 (13.9%)	*105 (14.0%)*
Company Total	981.2 (15.1%)	1111.6 (14.4%)	1360.0 (16.9%)	*1685 (16.7%)*

(A) Fiscal yr. ends Oct. 31.
(B) Based on avg. shs outst'g. Excl. extraord. gains '71, 4¢, '72, 5¢. Next earn'gs report due mid-Nov. Est'd '77 replacement earnings $3.40/sh.
(C) Next div'd meeting about Feb. 21. Goes ex about Oct. 13. Div'd paym't dates: Apr. 14, July 14, Oct. 16.
(D) Excl. intangibles. In '77: $2.4 mill., 8¢/sh.
(E) In mill., adj. for stock splits & div'ds.

Company's Financial Strength	A
Stock's Price Stability	70
Price Growth Persistence	90
Earnings Predictability	70

INTEL OTC-INTC

RECENT PRICE **58** | P/E RATIO **18.7** (Norm 29.0 / Trail'g 21.7) | DIV'D YIELD **Nil** (Norm Nil / Trail'g Nil)

Bank and Fund Decisions

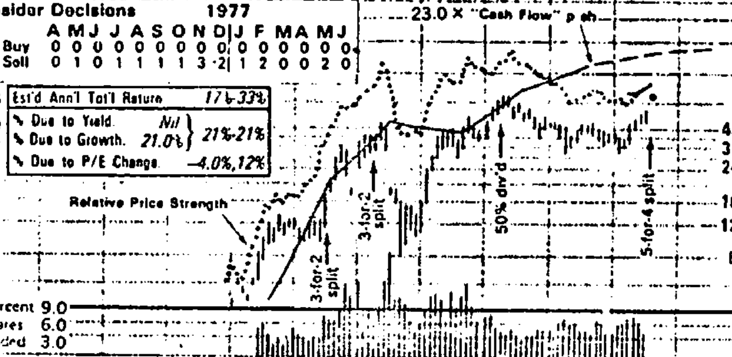
	1Q'77	2Q'77	3Q'77	4Q'77	1Q'78
to Buy	13	10	11	7	10
to Sell	20	18	8	10	9
Hld's(000)	4419	4396	4341	4469	4875

High	13.0	33.6	44.8	47.0	62.0	45.6	58.5
Low	4.2	9.6	8.2	11.1	36.6	30.0	30.9

Insider Decisions 1977

	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
to Buy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
to Sell	0	1	0	1	1	1	1	3	2	1	2	0	0	2	0

Est'd Ann'l Tot'l Return 17%-33%
- Due to Yield Nil
- Due to Growth 21.0% } 21%-21%
- Due to P/E Change -4.0%,12%



TIMELINESS **2** Above Average (Relative Price Performance Next 12 Mos.)

SAFETY **4** Below Average (Scale 1 Highest to 5 Lowest)

BETA 1.60

Aug. 18, 1978 Value Line

Intel was incorporated in California on July 18, 1968. On October 13, 1971, the company made an underwritten public offering of 350,000 shares, which were sold at $11.75 by an underwriting syndicate led by C.E. Unterberg, Towbin Company. In July 1972, Microma Inc., a watch manufacturer, was acquired.

Intel has pioneered in segments of the memory and microprocessor fields. Most of the assembly work is done at factories in Southeast Asia. The packaged circuits are shipped to California for testing and distribution. Since microprocessors are finding applications in a great variety of fields, Intel's list of customers is growing rapidly. Its 8080 microprocessor has already achieved the status of a standard product.

1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	© Arnold Bernhard & Co. Inc.	81-83E
--	--	--	.84	2.01	5.64	11.32	11.12	17.89	21.91	***27.80***	***32.75***	Sales per sh	***57.66***
--	--	--	d.03	.20	.92	1.97	1.72	2.75	3.69	***4.45***	***5.05***	"Cash Flow" per sh	***7.85***
--	--	--	d.05	.17	.75	1.58	1.25	1.90	2.38	***3.10***	***3.60***(A)	Earnings per sh	***6.05***
--	--	--	--	--	--	--	--	--	--	***Nil***	***Nil***	Div'ds Decl'd per sh	***Nil***
--	--	--	.08	.18	.78	1.08	.91	2.54	3.48	***3.40***	***3.60***	Cap'l Spending per sh	***4.00***
--	--	--	1.23	1.53	2.40	4.28	6.03	8.66	11.55	***15.40***	***19.65***	Tangible Book Value sh	***34.70***
--	--	--	10.97	11.41	11.64	11.88	12.30	12.64	12.90	***13.30***	***13.75***(B)	Common Shs Outst'g	***14.40***
--	--	--	--	48.5	23.1	15.8	26.3	26.5	16.3	Bold figures		Avg Ann'l P/E Ratio	***24.0***
--	--	--	--	--	--	--	--	--	--	are VL estimates		Avg Ann'l Div'd Yield	***Nil***
--	--	--	9.2	23.0	65.6	134.5	136.8	226.0	282.5	***370***	***450***	Sales ($mill)	***830***
--	--	--	NMF	17.2%	30.6%	32.9%	27.9%	27.0%	28.0%	***27.5%***	***27.0%***	Operating Margin	***25.0%***
--	--	--	.2	.4	1.5	3.6	4.9	9.5	15.8	***18.0***	***20.0***	Depreciation ($mill)	***28.0***
--	--	--	d.5	2.0	9.2	19.8	16.3	25.2	31.7	***41.0***	***49.5***	Net Profit ($mill)	***87.0***
--	--	--	--	51.2%	51.9%	51.4%	51.0%	51.0%	49.8%	***49.5%***	***47.5%***	Income Tax Rate	***45.5%***
--	--	--	NMF	8.6%	14.0%	14.7%	11.9%	11.2%	11.2%	***11.0%***	***11.0%***	Net Profit Margin	***10.5%***
--	--	--	9.7	12.0	16.5	32.6	52.7	68.8	81.4	***105***	***128***	Working Cap'l ($mill)	***230***
--	--	--	--	--	--	--	--	--	--	***Nil***	***Nil***	Long-Term Debt ($mill)	***Nil***
--	--	--	13.5	17.4	27.9	50.8	74.2	109.5	148.9	***205***	***270***	Net Worth ($mill)	***600***
--	--	--	NMF	11.4%	33.0%	38.9%	21.9%	23.0%	21.3%	***20.0%***	***18.5%***	% Earned Total Cap'l	***17.5%***
--	--	--	NMF	11.4%	33.0%	38.9%	21.9%	23.0%	21.3%	***20.0%***	***18.5%***	% Earned Net Worth	***17.5%***
--	--	--	NMF	11.4%	33.0%	38.9%	21.9%	23.0%	21.3%	***20.0%***	***18.5%***	% Retained to Comm Eq	***17.5%***
--	--	--	--	--	--	--	--	--	--	***Nil***	***Nil***	% All Div'ds to Net Prof	***Nil***

CAPITAL STRUCTURE as of 6/30/78

Total Debt None Due in 5 Yrs. None

LT Debt None LT Interest None

Leases, Uncapitalized Annual rentals $1.5 mill.

Pension Liability None in '77 vs None in '76

Pfd Stock None Pfd Div'd None

Common Stock 12,897,400 shares as of 12/31/77 (13.25 mill. primary shares) (100% of Cap'l) (adj. for 5-for-4 split)

CURRENT POSITION ($mill.)	1976	1977	6/30/78
Cash Assets	26.4	39.5	8.4
Receivables	44.3	56.5	77.2
Inventory (FIFO)	27.5	33.6	46.1
Other	7.3	11.5	17.3
Current Assets	105.5	141.1	149.0
Accts Payable	9.4	12.4	*18.0*
Other	12.4	47.3	*58.6*
Current Liab.	36.7	59.7	76.6

ANNUAL RATES of change (per sh)	Past 10 Yrs	Past 5 Yrs	Est '75-'77 to '81-'83
Sales	—	64.0%	*22.5%*
"Cash Flow"	—	99.5%	*19.5%*
Earnings	—	99.0%	*22.0%*
Dividends	—	—	—
Book Value	—	45.0%	*21.0%*

Calendar	QUARTERLY SALES ($ mill.) Mar. 31	June 30	Sept. 30	Dec. 31	Full Year
1975	30.3	31.5	34.7	40.3	136.8
1976	45.5	50.6	61.9	68.0	226.0
1977	65.7	69.2	73.3	74.3	282.5
1978	80.3	93.7	***95.0***	***101***	***370***
1979	***95.0***	***110***	***115***	***130***	***450***

Calendar	EARNINGS PER SHARE Mar. 31	June 30	Sept. 30	Dec. 31	(A) Full Year
1975	.29	.28	.34	.34	1.25
1976	.38	.42	.50	.60	1.90
1977	.55	.60	.58	.65	2.38
1978	.66	.78	***.80***	***.86***	***3.10***
1979	***.75***	***.90***	***.90***	***1.05***	***3.60***

Calendar	QUARTERLY DIVIDENDS PAID Mar. 31	June 30	Sept. 30	Dec. 31	Full Year
1974					
1975	NO CASH DIVIDENDS BEING PAID				
1976					
1977					
1978					

BUSINESS: Intel Corp. designs, develops, manufactures, and markets products based on the integration of complex electronic functions on a small chip or semiconductor material (LSI components). Estimated 1977 sales mix: memory components, 40%; microcomputers, 35%; memory systems, 25%. Overseas sales about 35% of total. Research & development about 10% of sales. Employee costs, about 35% of sales. Depreciation rate in '77, 14.3%. Has about 9,274 employees; 7,624 shareholders. Insiders own about 36% of stock. Chairman: Robert N. Noyce. President: Gordon E. Moore. Inc.: California. Address: 3065 Bowers Ave., Santa Clara, California 95051.

Business is brisk. Demand for most of Intel's products is strong—especially for random access memories (RAMs). Intel is one of a few companies that offer the 16K RAM, the most advanced semiconductor memory component in production quantity. Currently, demand exceeds supply, and manufacturers are selling all they can make. The company is continuing to expand production capacity as quickly as possible in order to meet customer requirements, but order lead times for some products are stretching out. This is inducing customers to place orders sooner, which is contributing to the abnormally high level of bookings. The company expects the unusually high ratio of orders to shipments will subside, but growth should continue with more modest order levels. We expect shipments to be up about 30% this year. Share-earnings are likely to post a similar gain. The stock is a timely commitment for risk-oriented investors.

IBM placed an order for $25 million worth of Intel's memory system modules. Intel will deliver the modules, which use its high-speed 4K RAM, over the next 15 months. Such a large order will put more of a strain on production capacity. Intel's expansion programs are proceeding on schedule, though, and the company expects to be able to fulfill its agreement with IBM without putting any hardship on its other customers. Two buildings in Oregon will be completed in the next few months, and Intel plans to start construction on two sites in Arizona later this year. Employment has been increased 15% since the first of the year.

Competition is intensifying. Intel concentrates on two very attractive markets—semiconductor memories and microprocessors. More companies are seeking to carve a niche in these lucrative businesses, however. The increasing competition is causing intense price pressure, resulting in slimmer margins and a lower rate of return on capital for Intel. We expect this trend to persist over the next 3 to 5 years, especially as competition from the Japanese picks up.

The shares are still attractive for the long term. We expect company growth will average about 20% a year through 1981-83. Share profits are likely to reach $6.05 by then. If the market capitalizes those earnings at the stock's P/E norm of 29.0, the price of the stock would quadruple in just 3 to 5 years.

W.J.S. /c.l.s.

(A) Primary earnings per share. Excludes extraordinary gains: '72, 18¢; '73, 14¢.

Earnings report due mid-Oct. Est'd '77 replacement earnings: $2.15/sh.

(B) In millions, adjusted for stock splits and dividends.

Company's Financial Strength	B++
Stock's Price Stability	10
Price Growth Persistence	95
Earnings Predictability	35

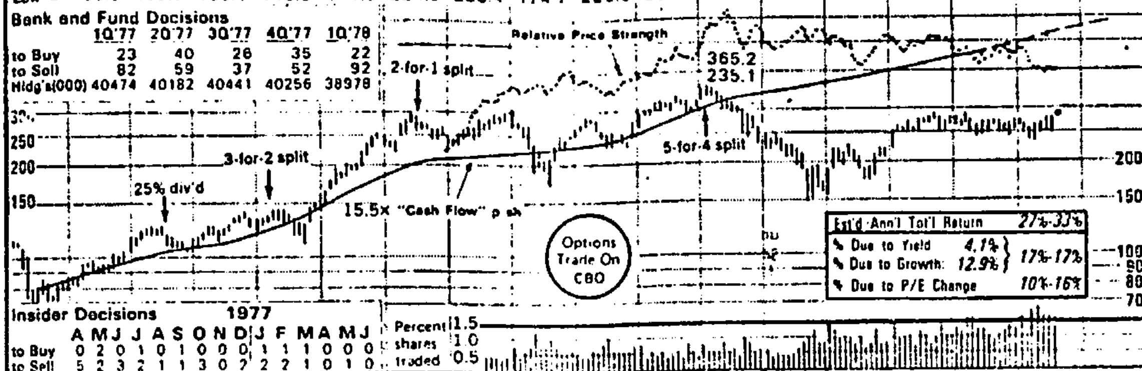
INT'L BUSINESS MACH. NYSE-IBM

RECENT PRICE 289 | P/E RATIO 14.2 (Norm 26.0; Trail'g 16.4) | DIV'D YIELD 4.1% (Norm 2.2%; Trail'g 3.9%) | 994

High	106.1	128.6	142.9	150.6	259.2	300.0	255.0	393.6	292.6	341.4	254.0	227.4	288.5	286.1	295.0
Low	80.0	105.7	105.1	113.0	141.5	224.0	233.4	174.7	226.6	265.4	160.5	167.3	223.4	244.5	234.8

Bank and Fund Decisions

	1Q'77	2Q'77	3Q'77	4Q'77	1Q'78
to Buy	23	40	26	35	22
to Sell	82	59	37	52	92
Hldg's(000)	40474	40182	40441	40256	38978



853 (+195%) | 697 (+140%) | Target Price Range | 1980 | 1981 | 1982 | 1983

Est'd Ann'l Tot'l Return	27%-33%
% Due to Yield 4.1%	17%-17%
% Due to Growth 12.9%	
% Due to P/E Change	10%-16%

TIMELINESS (Relative Price Performance Next 12 Mos.) **3** Average

SAFETY (Scale 1 Highest to 5 Lowest) **1** Highest

BETA 1.00

Aug. 18, 1978 Value Line

Insider Decisions 1977

	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
to Buy	0	2	0	1	0	1	0	0	0	1	1	1	0	0	0
to Sell	5	2	3	2	1	1	3	0	2	2	2	1	0	1	0

1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	© Arnold Bernhard & Co., Inc.	81-83E
19.38	21.31	24.04	26.38	30.44	36.10	48.78	50.63	52.59	57.29	65.52	74.93	85.49	96.34	108.19	122.96	**139.25**	**155.95**	Revenues per sh	**221.85**
5.27	5.98	6.75	7.39	8.38	10.86	13.08	13.67	14.55	15.37	17.70	20.70	23.02	24.49	27.31	30.69	**33.90**	**38.15**	"Cash Flow" per sh	**53.00**
2.28	2.71	3.20	3.52	3.77	4.64	6.17	6.57	7.14	7.50	8.82	10.79	12.47	13.35	15.94	18.30	**20.30**	**23.00**	(A) Earnings per sh	**31.00**
.62	.88	1.24	1.56	1.68	1.74	2.08	2.88	3.84	4.16	4.32	4.48	5.56	6.50	8.00	10.00	**11.52**	**12.90**	(B) Div'ds Decl'd per sh ■	**17.30**
3.84	4.27	5.16	8.28	10.85	9.88	7.67	11.03	14.37	12.25	11.04	14.02	18.75	15.33	15.77	21.71	**24.00**	**27.00**	Cap'l Spending per sh	**42.00**
12.26	14.39	16.62	18.95	23.76	27.31	32.36	37.12	41.52	45.99	52.00	60.06	68.19	76.18	84.60	88.44	**97.60**	**109.85**	Tangible Book Value sh	**166.20**
133.06	133.61	134.76	135.44	139.52	140.29	141.21	142.15	143.23	144.42	145.50	146.71	148.26	149.84	150.69	147.47	**146.50**	**147.50**	(C) Common Shs Outst'g	**151.00**
38.6	34.6	36.5	35.8	35.8	43.5	42.3	40.4	33.0	34.4	35.5	28.5	16.5	15.3	16.6	14.5	Bold figures		Avg Ann'l P/E Ratio	**25.0**
.7%	.9%	1.1%	1.2%	1.2%	.9%	.8%	1.1%	1.6%	1.6%	1.4%	1.5%	2.7%	3.2%	3.0%	3.8%	are VL estimates		Avg Ann'l Div'd Yield	**2.2%**

CAPITAL STRUCTURE as of 3/31/78

Total Debt *$440 mill.* Due in 5 Yrs. *$300 mill.*
LT Debt $251.7 mill. LT Interest *$16.7 mill.*
(2% of Cap'l)

Leases, Uncapitalized Annual rentals $208 mill.

Pension Liability $295 mill. '77 vs $161 mill. '76
Pfd Stock None

Common Stock 145,830,124 shares as of 5/31/78
(98% of Cap'l)

1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979		81-83E
6888.5	7197.3	7504.0	8273.6	9532.6	10993	12675	14437	16304	18133	**20400**	**23000**	Revenues ($mill)	**33500**
41.0%	40.7%	39.3%	37.7%	37.9%	38.5%	37.4%	35.4%	35.5%	35.6%	**35.0%**	**35.0%**	Operating Margin	**34.5%**
975.2	1008.6	1056.3	1140.7	1296.6	1460.8	1575.0	1680.0	1717.0	1806.0	**2000**	**2250**	Depreciation ($mill)	**3300**
871.5	933.9	1017.5	1078.9	1279.3	1575.5	1837.6	1989.9	2398.1	2719.4	**2970**	**3380**	Net Profit ($mill)	**4700**
53.3%	52.8%	49.4%	47.5%	47.3%	46.5%	46.5%	46.5%	46.9%	46.6%	**46.5%**	**45.5%**	Income Tax Rate	**44.0%**
12.7%	13.0%	13.6%	13.0%	13.4%	14.3%	14.5%	13.8%	14.7%	15.0%	**14.6%**	**14.7%**	Net Profit Margin	**14.0%**
1770.1	1814.1	1512.0	1860.7	2562.5	3274.9	3800.1	4751.8	5838.1	5287.2	**5500**	**6200**	Working Cap'l ($mill)	**8500**
545.1	554.8	572.9	676.2	772.9	652.2	335.8	295.1	275.1	255.8	**300**	**350**	Long-Term Debt ($mill)	**800**
4569.1	5277.0	5947.1	6642.4	7565.9	8812.0	10110	11416	12749	13042	**14300**	**16200**	Net Worth ($mill)	**25100**
17.3%	16.3%	15.9%	15.0%	15.7%	16.9%	17.7%	17.1%	18.5%	20.5%	**20.0%**	**20.5%**	% Earned Total Cap'l	**18.0%**
19.1%	17.7%	17.1%	16.2%	16.9%	17.9%	18.2%	17.4%	18.8%	20.9%	**20.5%**	**21.0%**	% Earned Net Worth	**18.0%**
12.7%	10.0%	7.9%	7.2%	8.6%	10.5%	10.1%	8.9%	9.4%	9.4%	**9.0%**	**9.0%**	% Retained to Comm Eq	**8.0%**
34%	44%	54%	55%	49%	42%	45%	49%	50%	55%	**57%**	**56%**	% All Div'ds to Net Prof	**56%**

CURRENT POSITION ($mill.)	1976	1977	3/31/78
Cash Assets	6156.2	5406.6	4916.0
Receivables	2626.0	3104.3	3427.4
Inventory (Avg Cst)	769.7	993.6	988.6
Other	368.4	568.2	720.7
Current Assets	9920.3	10072.7	10052.7
Accts Payable	2582.6	3146.8	*3436.0*
Debt Due	115.9	172.4	*188.3*
Other	1383.7	1466.3	*1600.8*
Current Liab'ties	4082.2	4785.5	5225.1

ANNUAL RATES of change (per sh)	Past 10 Yrs	Past 5 Yrs	Est '75-'77 to '81-'83
Revenues	13.0%	13.5%	*12.5%*
"Cash Flow"	12.0%	11.5%	*11.5%*
Earnings	15.0%	15.0%	*12.0%*
Dividends	17.5%	14.5%	*13.0%*
Book Value	13.0%	11.5%	*13.0%*

Calendar	QUARTERLY REVENUES ($ mill.) Mar. 31	June 30	Sept. 30	Dec. 31	Full Year
1975	3272	3496	3600	4069	14437
1976	3815	4013	3957	4519	16304
1977	4090	4419	4586	5038	18133
1978	4432	4921	*5247*	*5800*	*20400*
1979	*5200*	*5600*	*5700*	*6500*	*23000*

Calendar	EARNINGS PER SHARE Mar. 31	June 30	Sept. 30	Dec. 31	(A) Full Year
1975	2.95	3.14	3.32	3.94	13.35
1976	3.63	3.94	3.90	4.47	15.94
1977	3.82	4.44	4.66	5.38	18.30
1978	4.01	4.73	*5.36*	*6.20*	*20.30*
1979	*5.00*	*5.60*	*5.80*	*6.60*	*23.00*

Calendar	QUARTERLY DIVIDENDS PAID Mar. 31	June 30	Sept. 30	Dec. 31	(B) Full ■Year
1974	1.28	1.28	1.50	1.50	5.56
1975	1.50	1.50	1.75	1.75	6.50
1976	1.75	1.75	2.25	2.25	8.00
1977	2.50	2.50	2.50	2.50	10.00
1978	2.88	2.88	2.88		

BUSINESS: International Business Machines Corp. is the largest supplier of data processing equipment (82% of revenues). Has about 45%-60% of computer systems market. Makes typewriters, dictating machines, copiers. Owns Science Research Associates (education materials). Service and rental provide 61% of gross income; outright sales, 39%. Foreign business accounts for 50% of revs., 45% of earnings. R&D costs equal 6.3% of revs., est'd payroll, 35%. '77 deprec. rate: 10.6%. Has 310,150 employees, 584,000 shareholders. Directors control 0.3% of stock. Chairman: F.T. Cary. President: J.R. Opel. Incorporated: New York. Address: Armonk, New York 10504.

The news from IBM will be getting better. Earnings growth more in line with the historic trend for the computer industry leader is about to resume. The resurgence is being fueled by climbing worldwide output of the new 3000 series processors, which we expect will turn the lagging ratio of sales to rental income upward again. These high performance systems have order backlogs extending several years out, a stabilizing factor for IBM if the general economy slows down as expected in 1979.

Memorex hasn't an airtight case against IBM. Round One in the peripherals company's $306 million lawsuit ended with a hung jury, so the judge declared a mistrial. Memorex wants a new jury trial, while IBM would prefer a directed verdict by the court. The prospect of more heavy legal costs for Memorex might help to bring a mutually advantageous settlement. Xerox and IBM, for example, ended their drawn out patent hassle with an agreement for IBM to pay Xerox $25 million and for both companies to license their patents to each other without royalties.

The company is reorganizing for future growth. A new manager with strong marketing background will head IBM's office products division. This will help put emphasis where it's needed to regain lost position in markets for word processing and dictation equipment. In the computer business, a division that made both large and medium-sized systems has been split to provide top level attention to each size class. Meanwhile, a study will look at the advantages of further autonomy for business units.

We modified some reported figures for logical consistency. As in years past, IBM paid its first-quarter dividend on March 10th in 1978. But this dividend was declared in December 1977, one month ahead of the usual January directors' meeting. So, for the first time, the March-quarter dividend appeared on the prior year-end balance sheet as a $423.1 million obligation deductible from net worth. We added the dividend obligation back to net worth to avoid distorted comparisons and ratios.

E.B.S. /l.v.

Revenues (and Gross Profit Margins) by Business Line

	1975	1976	1977	1978
Product Sales	4545.3 (64.1%)	5959.0 (67.1%)	7090.0 (68.2%)	*8200 (68%)*
Rental & Service	9891.2 (62.4%)	10345.0 (62.6%)	11043.0 (63.4%)	*12200 (63%)*
Company Total	14436.5 (63.0%)	16304.0 (64.3%)	18133.0 (65.3%)	*20400 (65%)*

(A) Based on avg. shs. outstanding. Next earn'gs report due mid-Oct. Est'd '77 replacem't earnings: $18.80/sh.

(B) Stock div'd: 2½%, '67. Next div'd meeting about Oct. 24. Goes ex about Nov. 2. Div'd payment dates about Mar. 10, June 10, Sept. 10, Dec. 10. ■Div'd reinvest plan av'ble.

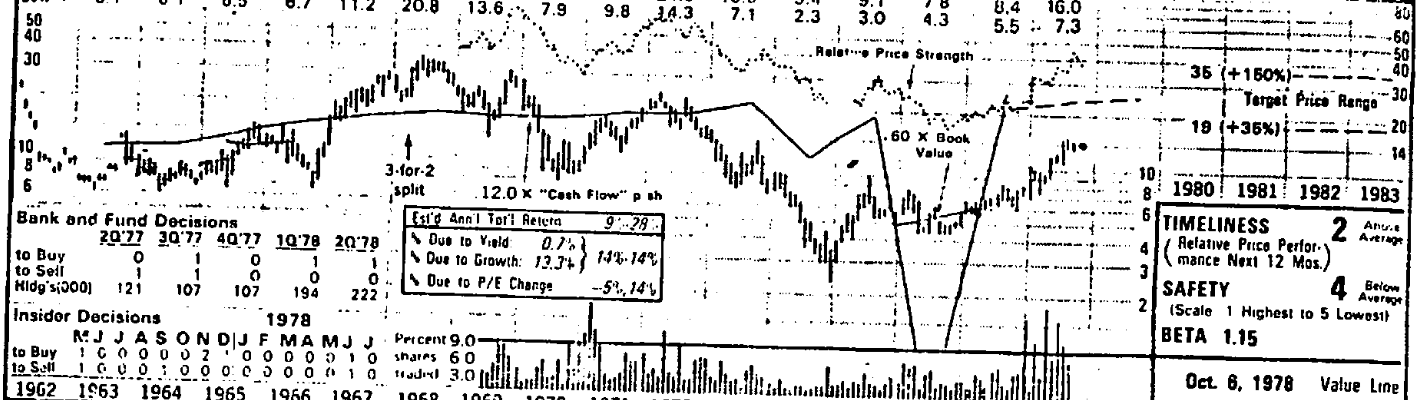
(C) In mill., adj. for stock splits & div'ds.

Company's Financial Strength	A++
Stock's Price Stability	95
Price Growth Persistence	75
Earnings Predictability	100

SYSTRON-DONNER NYSE-SYS

RECENT PRICE **14** | P/E RATIO **10.3** (Norm 13.5; Trail'g 12.6) | DIV'D YIELD **0.7%** (Norm NMF; Trail'g .4%)

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
High	13.1	9.6	15.3	14.5	30.0	38.2	32.4	28.6	20.3	24.8	15.9	9.4	9.1	7.8	8.4	16.0	
Low	6.1	6.1	6.5	6.7	11.2	20.8	13.6	7.9	9.8	14.3	7.1	2.3	3.0	4.3	5.5	7.3	



Est'd Ann'l Tot'l Return	9%-28%
Due to Yield: 0.7%	
Due to Growth: 13.3%	14%-14%
Due to P/E Change	-5%, 14%

Bank and Fund Decisions

	2Q'77	3Q'77	4Q'77	1Q'78	2Q'78
to Buy	0	1	0	1	1
to Sell	1	1	0	0	0
Hldg's(000)	121	107	107	194	222

Insider Decisions

	M	J	J	A	S	O	N	D	J (1978)	F	M	A	M	J	J
to Buy	1	0	0	0	0	0	2		0	0	0	0	0	1	0
to Sell	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0

TIMELINESS (Relative Price Performance Next 12 Mos.) **2** Above Average

SAFETY **4** Below Average (Scale 1 Highest to 5 Lowest)

BETA 1.15

Oct. 6, 1978 Value Line

81-83E

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979		81-83E
	8.04	8.30	9.80	10.24	13.18	18.30	19.69	19.62	20.90	19.30	22.30	25.92	29.20	34.06	30.62	32.84	*38.10*	*40.00* (A)	Sales per sh	*58.35*
	.80	.90	.88	.91	1.10	1.43	1.54	1.44	1.47	1.29	1.58	1.75	.93	1.59	d.27	1.69	*1.90*	*2.25*	"Cash Flow" per sh	*2.95*
	.61	.66	.63	.67	.83	1.01	1.20	1.05	.82	.70	.95	1.12	.24	.84	d.94	.92	1.11	*1.40* (B)	Earnings per sh	*2.00*
	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*.10* (C)	Div'ds Decl'd per sh	*.25*
	--	--	--	--	--	.80	.73	1.24	.44	.35	.49	.72	.79	.70	.60	.83	*.80*	*1.40*	Cap'l Spending per sh	*1.10*
	3.17	3.76	3.72	4.31	5.24	5.58	6.57	6.83	7.35	7.87	8.20	9.30	9.77	10.78	9.87	10.84	*12.00*	*12.60*	(D) Tangible Book Value sh	*17.45*
	.88	.88	.96	.98	.99	1.27	1.47	1.50	1.54	1.61	1.69	1.69	1.69	1.69	1.69	1.69	*1.70*	*1.80*	(E) Common Shs Outst'g	*1.80*
	31.0	11.8	13.6	12.2	14.3	14.7	22.2	24.3	24.2	18.4	19.9	11.7	32.9	5.5	--	6.2	8.3		Avg Ann'l P/E Ratio	*13.5*
	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--		Avg Ann'l Div'd Yield	*.9%*

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979		81-83E
	28.9	29.5	32.2	31.1	37.7	43.8	49.4	57.6	51.8	55.5	64.8	*72.0* (A)	Sales ($mill)	*105*
	13.2%	14.1%	12.7%	11.9%	12.5%	12.1%	10.8%	8.2%	NMF	8.8%	*9.0%*	*9.5%*	Operating Margin	*9.0%*
	.5	.6	1.0	1.0	1.1	1.1	1.2	1.3	1.1	1.3	*1.4*	*1.5*	Depreciation ($mill)	*1.7*
	1.7	1.6	1.3	1.1	1.6	1.9	.4	1.4	d1.6	1.6	2.0	*2.5*	Net Profit ($mill)	*3.8*
	46.9%	52.1%	50.6%	49.3%	51.5%	49.1%	48.1%	47.0%	--	47.8%	*43.0%*	*43.0%*	Income Tax Rate	*43.0%*
	6.0%	5.4%	4.0%	3.5%	4.2%	4.3%	.8%	2.5%	NMF	2.8%	3.0%	*3.5%*	Net Profit Margin	*3.4%*
	6.5	7.7	8.1	9.0	11.2	12.8	19.9	21.4	19.7	21.5	*24.0*	*25.5*	Working Cap'l ($mill)	*36.0*
	.8	2.9	2.1	1.5	1.9	1.9	8.0	8.0	8.0	8.0	*8.0*	*8.0*	Long-Term Debt ($mill)	*10.0*
	10.5	11.8	12.6	14.2	16.0	17.8	18.2	19.5	17.9	19.4	*21.5*	*24.0*	Net Worth ($mill)	*32.5*
	15.4%	11.5%	9.2%	7.2%	9.3%	10.1%	2.0%	6.5%	NMF	7.0%	*8.0%*	*9.0%*	% Earned Total Cap'l	*10.0%*
	16.4%	13.6%	10.2%	7.8%	10.0%	10.6%	2.2%	7.3%	NMF	8.0%	*9.0%*	*10.5%*	% Earned Net Worth	*11.0%*
	16.4%	13.6%	10.2%	7.8%	10.0%	10.6%	2.2%	7.3%	NMF	8.0%	*9.0%*	*9.5%*	% Retained to Comm Eq	*9.5%*
	--	--	--	--	--	--	--	--	--	--	--	*7%*	% All Div'ds to Net Prof	*13%*

CAPITAL STRUCTURE as of 4/30/78

Total Debt $9.4 mill. Due in 5 Yrs $4.4 mill.
LT Debt $8.0 mill. LT Interest $.7 mill.
(LT interest earned: *6.3 x*; coverage of total interest: *5.1 x*) (28% of Cap'l)

Leases, Uncapitalized Annual rentals $0.9 mill.

Pension Liability None in '77 vs None in '76

Pfd Stock None **Pfd Div'd** None

Common Stock *1,701,000* shares (72% of Cap'l) as of 9/13/78

CURRENT POSITION ($mill.)	1976	1977	4/30/78
Cash Assets	.1	2.6	1.8
Receivables	10.7	11.7	13.9
Inventory (FIFO)	13.8	14.4	14.8
Other	2.3	.7	.7
Current Assets	26.9	29.4	31.2
Accts Payable	2.3	2.2	3.2
Debt Due	1.9	1.7	1.4
Other	3.0	4.0	3.6
Current Liab'ties	7.2	7.9	8.2

ANNUAL RATES of change (per sh)	Past 10 Yrs	Past 5 Yrs	Est '75-'77 to '81-'83
Sales	9.0%	9.5%	*10.5%*
'Cash Flow'	-1.5%	-7.0%	*19.5%*
Earnings	-10.5%	-20.0%	*NMF*
Dividends	—	—	*NMF*
Book Value	7.5%	6.0%	*9.0%*

Fiscal Year Ends	QUARTERLY SALES ($ mill.) Oct. 31	Jan. 31	Apr. 30	July 31	(A) Full Fiscal Year
1975	13.1	14.6	14.4	15.5	57.6
1976	13.9	13.1	11.8	13.0	51.8
1977	13.2	13.1	14.5	14.7	55.5
1978	14.1	16.3	16.8	17.6	64.8
1979	*17.0*	*18.0*	*18.5*	*18.5*	*72.0*

Fiscal Year Ends	EARNINGS PER SHARE Oct. 31	Jan. 31	Apr. 30	July 31	(A) Full Fiscal (B) Year
1975	.20	.25	.26	.13	.84
1976	.14	.02	d1.25	.15	d.94
1977	.19	.20	.25	.28	.92
1978	.23	.25	.28	.35	1.11
1979	*.29*	*.36*	*.36*	*.39*	*1.40*

Cal-endar	QUARTERLY DIVIDENDS PAID Mar. 31	June 30	Sept. 30	Dec. 31	(C) Full Year
1974					
1975	NO CASH DIVIDENDS PAID BEFORE 1978				
1976					
1977					
1978	--	--	--	05	

BUSINESS: Systron-Donner makes electronic instruments for test and measurement. Products have applications in communications, computers, electronics and general industry. Transducers (sensing devices) measure motion, temperature, pressure, account for approximately 50% of sales. Markets include R&D, aerospace, transportation and weather. Government agencies account for 38% of sales. Foreign vol. 22%. R&D: 4.6% of sales. Has 1,870 empls. Wage costs: est'd 30% of sales. '77 deprec. rate: 9.9%. Has 3,301 shrhldrs. Directors own 3.5% of stk. Chrmn.: G.H. Bruns, Jr. Pres. & C.E.O.: G.P. Ward. Inc.: Cal. Address: 1 Systron Drive, Concord, Cal. 94520.

Earnings appear headed for new highs in fiscal 1979. Systron entered its new year with a backlog of $37.4 million, 28% higher than they were a year earlier. Systron's results should also benefit from a continuing high level of government aerospace spending, greater penetration of the test and measurement device market, and increased systems business, a high margin activity. With earnings in a solid uptrend, S-D shares are expected to outleg the market averages in the year ahead.

Systron has ambitious profit goals. The company is aiming for a 14% to 18% pre tax profit margin on its commercial and industrial lines and a somewhat lower return, we estimate 12% to 15%, on its aerospace operations. President Ward, who took office nearly a year ago, has made a number of management and marketing changes. But we would want to see several quarters of rising pretax margins before we're convinced that S-D's margins are headed significantly higher and that any improvement is permanent. But investors should note that Systron shares have good 3- to 5-year appreciation potential even if margins do not rise substantially from current levels.

Systron's fire detection systems are in strong demand. American Airlines bought 30 fire/overheat detection systems (at $18,000 per unit) for its DC-10s. Several other airlines with roughly 300 DC-10 aircraft are considering a similar move. And Systron hasn't neglected the general aviation market. It signed a $360,000 contract with Beech Aircraft for installation of their systems on its Queen Air and Twin Bonanza lines. Follow-on purchases might bring the total Beech contract to approximately $1 million.

The U.S. Government is Systron's best customer. In the mid-1960s, as much as 90% of S-D's revenues came from the government. Since the company found commercial applications for its aerospace technology, the ratio in recent years has ranged between 35% to 45%. (In fiscal 1978 it was 38%.) Government business, we believe, will provide an element of stability to Systron's future results, while the commercial applications offer the possibility of growth. *J.H.K. /a.s.l.*

(A) Fiscal yr. ends July 31 of cal. yr. (B) Based on primary shs. outstanding. Earn'gs rep't due late Nov. Excl. extraord. gain: '78, 6¢/sh. Est'd '78 replacem't earnings 80¢/sh. (C) Next div'd meeting about Mar. 13. Goes ex about Mar. 19. Div'd payment date Oct. 23. (D) Excl. intangibles. In '77: $1.1 mill., 65¢/sh. (E) In mill., adj. for stock splits & div'ds.

Company's Financial Strength	C+
Stock's Price Stability	15
Price Growth Persistence	5
Earnings Predictability	10

TEXAS INSTRUMENTS NYSE-TXN

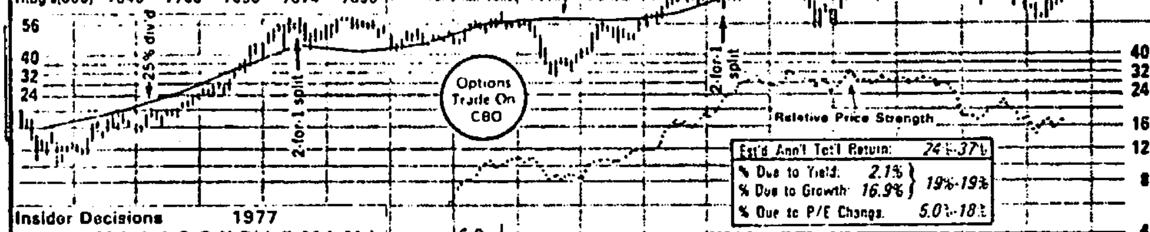
RECENT PRICE **89** | P/E RATIO **14.6** (Norm 24.0, Trail'g 12.0) | DIV'D YIELD **2.1%** (Norm 1.0%, Trail'g 1.8%)

High	19.5	23.8	49.1	69.9	72.4	57.5	70.1	67.3	64.5	95.0	138.9	115.8	119.4	129.8	102.3	92.3
Low	11.4	15.1	23.4	40.9	49.8	43.1	47.4	30.7	39.8	58.7	74.4	58.8	61.0	93.1	68.6	61.4

301 (+240%) — Target Price Range — 201 (+126%)

Bank and Fund Decisions

	1Q'77	2Q'77	3Q'77	4Q'77	1Q'78
to Buy	13	16	4	16	9
to Sell	20	21	20	11	10
Hldg's(000)	7846	7760	7690	7874	7858



Est'd Ann'l Tot'l Return:	24%-37%
% Due to Yield:	2.1%
% Due to Growth:	16.9% (19%-19%)
% Due to P/E Change:	5.0%-18%

1980	1981	1982	1983

TIMELINESS 3 Average (Relative Price Performance Next 12 Mos.)

SAFETY 3 Average (Scale 1 Highest to 5 Lowest)

BETA 1.20

Insider Decisions 1977

	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
to Buy	0	1	0	0	0	0	0	0	2	1	0	0	1	0	0
to Sell	0	6	1	4	1	0	0	3	7	1	0	0	3	1	4

Percent shares traded 6.0 / 4.0 / 2.0

Aug. 18, 1978 Value Line

1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979		81-83E
12.19	13.84	16.30	21.57	26.87	26.13	30.68	37.69	37.50	34.58	42.55	56.54	68.76	59.66	72.58	89.70	**107.60**	**119.55**	Sales per sh	**173.90**
1.05	1.27	1.60	2.18	2.94	2.77	3.11	3.77	3.84	3.81	4.32	6.28	7.73	6.74	8.07	9.85	**11.45**	**12.80**	"Cash Flow" per sh	**20.00**
.43	.61	.90	1.23	1.57	1.05	1.21	1.52	1.36	1.53	2.17	3.67	3.92	2.71	4.25	5.11	**6.00**	**6.50**	(A) Earnings per sh	**10.45**
.12	.16	.26	.25	.28	.38	.40	.40	.40	.40	.42	.62	1.00	1.00	1.08	1.41	**1.76**	**2.00**	(B) Div'ds Decl'd per sh	**3.00**
.54	.96	1.16	2.20	3.34	2.41	2.21	3.90	1.97	1.54	2.15	5.48	6.46	2.86	5.97	8.73	**12.00**	**9.00**	Cap'l Spending per sh	**13.50**
4.33	4.90	5.54	6.55	10.06	10.76	11.59	12.76	13.74	14.87	16.67	20.62	23.67	25.53	28.89	30.62	**37.40**	**41.95**	Tangible Book Value sh	**64.35**
19.74	19.98	20.10	20.23	21.60	21.75	21.88	22.07	22.07	22.10	22.18	22.77	22.87	22.93	22.85	22.81	**23.00**	**23.00**	(C) Common Shs Outst'g	**23.00**
34.6	25.5	21.6	25.5	35.1	57.6	41.8	39.1	32.8	35.2	36.8	27.4	22.1	35.0	26.8	16.4	Bold figures		Avg Ann'l P/E Ratio	**24.0**
.8%	1.0%	1.4%	.8%	.5%	6%	.8%	.7%	.9%	.8%	.5%	.6%	1.2%	1.1%	1.0%	1.7%	are VL estimates		Avg Ann'l Div'd Yield	**1.1%**
						671.2	831.8	827.6	764.3	943.7	1287.3	1572.5	1367.6	1658.6	2046.5	**2475**	**2750**	Sales ($mill)	**4000**
						13.6%	13.4%	13.2%	14.4%	13.9%	15.9%	16.3%	15.1%	15.1%	15.6%	**15.0%**	**14.5%**	Operating Margin	**15.5%**
						41.7	49.7	54.8	50.5	47.7	59.8	87.3	92.3	87.0	108.1	**125**	**145**	Depreciation ($mill)	**220**
						26.3	33.5	29.9	33.7	48.0	83.2	89.6	62.1	97.4	116.6	**138**	**149**	Net Profit ($mill)	**240**
						47.7%	44.4%	42.6%	43.3%	43.2%	42.8%	45.0%	46.4%	45.3%	44.7%	**45.5%**	**43.5%**	Income Tax Rate	**42.0%**
						3.9%	4.0%	3.6%	4.4%	5.1%	6.5%	5.7%	4.5%	5.9%	5.7%	**5.6%**	**5.4%**	Net Profit Margin	**6.0%**
						157.2	189.3	211.0	261.4	282.1	307.0	314.4	360.8	364.8	348.3	**445**	**490**	Working Cap'l ($mill)	**680**
						52.9	94.6	86.8	94.8	71.4	67.7	72.8	47.5	38.2	29.7	**46.0**	**25.0**	Long-Term Debt ($mill)	**15.0**
						253.5	281.6	303.2	328.7	369.6	469.3	541.4	585.3	660.2	744.6	**860**	**985**	Net Worth ($mill)	**1480**
						9.0%	9.6%	8.3%	8.7%	11.4%	15.9%	15.0%	10.2%	14.2%	15.2%	**15.5%**	**15.0%**	% Earned Total Cap'l	**16.0%**
						10.4%	11.9%	9.9%	10.3%	13.0%	17.7%	16.6%	10.6%	14.8%	15.7%	**16.0%**	**15.5%**	% Earned Net Worth	**16.0%**
						6.9%	8.8%	6.9%	7.6%	10.5%	14.7%	12.3%	6.7%	11.0%	11.3%	**11.5%**	**10.5%**	% Retained to Comm Eq	**11.5%**
						33%	26%	30%	26%	19%	17%	26%	37%	25%	28%	**29%**	**31%**	% All Div'ds to Net Prof	**29%**

CAPITAL STRUCTURE as of 12/31/77
Total Debt $78.9 mill. Due in 5 Yrs. $76.0 mill.
LT Debt $29.7 mill. LT Interest $2.7 mill.
(LT interest earned: 79.1 x; coverage of total interest: 24.0 x) (4% of Cap'l)

Leases, Uncapitalized Annual rentals $8.6 mill.

Pension Liability None vs None in 1976
Pfd Stock None **Pfd Div'd** None

Common Stock 22,814,682 shares (96% of Cap'l)

CURRENT POSITION ($mill.)	1975	1976	12/31/77
Cash Assets	266.6	293.8	257.1
Receivables	245.8	282.3	334.1
Inventory (FIFO)	142.9	197.6	214.3
Other	7.3	9.5	9.4
Current Assets	662.6	783.2	814.9
Accts Payable	172.6	211.7	287.9
Debt Due	46.5	55.3	49.2
Other	82.7	151.4	129.5
Current Liab.	301.6	418.4	466.6

ANNUAL RATES of change (per sh)	Past 10 Yrs	Past 5 Yrs	Est '75-'77 to '81-'83
Sales	11.5%	14.0%	*15.5%*
"Cash Flow"	12.0%	15.5%	*16.5%*
Earnings	12.0%	19.0%	*17.0%*
Dividends	14.5%	23.5%	*17.0%*
Book Value	12.0%	13.5%	*14.5%*

Calendar	QUARTERLY SALES ($ mill.) Mar. 31	June 30	Sept. 30	Dec. 31	Full Year
1975	332.8	330.9	313.0	390.9	1367.6
1976	369.4	392.2	426.1	470.9	1658.6
1977	461.9	493.3	516.6	574.7	2046.5
1978	557.6	614.6	**640**	**662.8**	**2475**
1979	**585**	**650**	**730**	**785**	**2750**

Calendar	EARNINGS PER SHARE Mar. 31	June 30	Sept. 30	Dec. 31	(A) Full Year
1975	.61	.49	.70	.91	2.71
1976	.93	.98	1.06	1.28	4.26
1977	1.20	1.21	1.29	1.41	5.11
1978	1.35	1.50	**1.53**	**1.62**	**6.00**
1979	**1.40**	**1.60**	**1.70**	**1.80**	**6.50**

Calendar	QUARTERLY DIVIDENDS PAID Mar. 31	June 30	Sept. 30	Dec. 31	(B) Full Year
1974	.17	.25	.25	.25	.92
1975	.25	.25	.25	.25	1.00
1976	.25	.25	.25	.25	1.00
1977	.33	.33	.33	.33	1.32
1978	42	.42	42		

BUSINESS: Texas Instruments is engaged in the development, manufacture, and sale of electronic equipment, such as samiconductors, calculators, microprocessors, and watches. Its equipment group fills military orders for missile guidance systems. International sales about 42% of total. Has 44 plants in 18 countries. Employee costs about 40% of sales; research and development, about 4.7%. Deprec. rate in 1977: 15.1%. Has 68,521 employees, 24,438 shareowners. Insiders own 19% of outstanding stock. Pres.: J. Fred Bucy. Chrmn.: Mark Shepherd, Jr. Incorporated: Delaware. Address: 13500 North Central Expressway (P.O. Box 5474), Dallas, Texas 75222.

This year is shaping up well for Texas Instruments. Incoming orders are up sharply across the board; the backlog is up to almost $1.2 billion—equal to about six months of business. We think the company's record backlog and continuing strength in orders insures reasonably strong sales and earnings trends into 1979. Sales will probably rise 20%, and earnings will increase about 17% to $6.00 a share. The stock, as a result, is likely to do at least as well as the market over the next 12 months.

Electronic component sales will be up about 15%. The company's 16K dynamic RAM is in full production. Demand currently exceeds supply, and manufacturers are selling all they can make. Pricing is fairly stable, and TI's margins are widening.

IBM recently awarded TI with an order for 16K RAMs that may amount to $50-$100 million. Volume shipments to IBM should commence by the second half of 1979. Demand for other semiconductor components also is strong, and TI plans to introduce a host of new products over the next year. Among these will be a 64K dynamic RAM, which may be the company's answer to rumors that the Japanese are coming out with a 32K dynamic RAM.

Digital products revenues will climb 25%. This business includes minicomputers, computer terminals and printers, and seismic equipment. Demand for TI's geophysical equipment should continue to rise because oil and gas exploration is likely to remain at high levels. Sales of intelligent terminals (those possessing processing capability) and minicomputers are growing at a rapid rate—in excess of 35% a year. The company's new portable computer terminal uses TI's magnetic bubble memory which allows users to turn the machine off without losing stored data. Demand for this product is strong.

TI's other businesses will score good gains. Geophysical services is also being impacted favorably by the rise in oil and gas exploration. And TI also recently won a large government contract for laser-guided bombs, along with other sizable orders. *W.J.S./m.h.s.*

Restated Sales* (and Pretax Profit Margins) by Business Line

	1975	1976	1977	1978
Elec. Comp.	NA(—)	830(13.4%)	958(12.8%)	*1110(12.5%)*
Digital Prod.	NA(—)	398(7.6%)	559(9.7%)	*715(9.5%)*
Govt. Elec	NA(—)	331(10.0%)	393(9.9%)	*460(10.0%)*
Metallurgical	NA(—)	127(15.7%)	148(14.9%)	*165(15.0%)*
Services	NA(—)	138(1.4%)	175(8.0%)	*220(7.0%)*
Company Total	NA(—)	1828(10.8%)	2233(11.2%)	*2670(11.0%)*

*Before interdivision sales elimination

(A) Based on avg. shs. outstanding. Next earn'gs rep't: late Oct. Est'd '77 replacement earnings: $4.56/sh

(B) Next div'd meeting about Sept. 22. Goes ex div'd about Sept. 29. Approx. div'd payment dates: Jan. 25, Apr. 25, July 25, Oct. 25.

(C) In millions, adjusted for stock splits and dividends.

Company's Financial Strength	A+
Stock's Price Stability	60
Price Growth Persistence	95
Earnings Predictability	80

TEKTRONIX, INC. NYSE-TEK

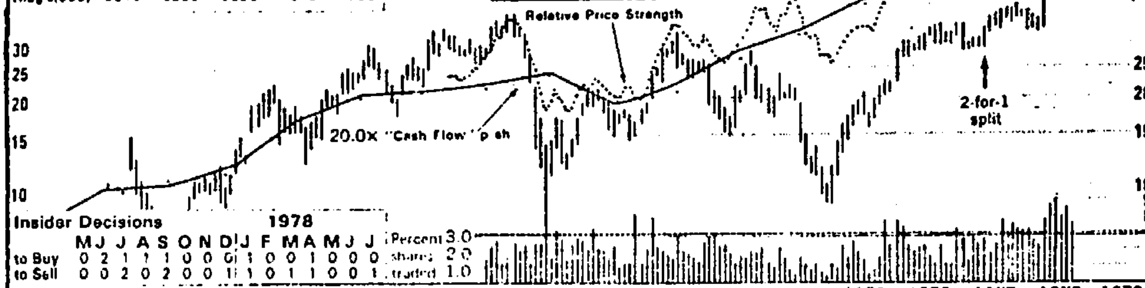
RECENT PRICE **47** | P/E RATIO **13.1** (Norm 21.0; Trail'g 14.2) | DIV'D YIELD **1.4%** (Norm 0.8%; Trail'g 1.1%)

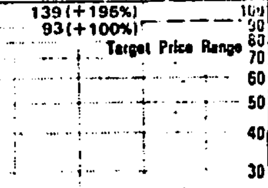
	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
High	11.8	15.0	18.8	22.1	29.9	33.7	37.3	37.5	21.5	32.8	28.4	23.9	22.8	34.5	40.0	50.5	
Low	9.6	6.8	8.5	12.1	14.7	17.5	25.6	9.8	14.0	16.4	15.0	9.1	9.1	22.2	28.3	32.5	

Bank and Fund Decisions

	2Q'77	3Q'77	4Q'77	1Q'78	2Q'78
to Buy	10	16	14	11	13
to Sell	21	23	25	19	24
Hld's(000)	6216	6280	5828	4840	4209

Est'd Ann'l Tot'l Return	21%-34%
% Due to Yield 1.4 / % Due to Growth 16.6	18%-18%
% Due to P/E Change	3%-16%





Insider Decisions

	M	J	J	A	S	O	N	D	J (1978)	F	M	A	M	J	J
to Buy	0	2	1	1	1	0	0	0	1	0	0	1	0	0	0
to Sell	0	0	2	0	2	0	0	1	1	0	1	1	0	0	1

TIMELINESS 3 Average (Relative Price Performance Next 12 Mos)

SAFETY 3 Average (Scale: 1 Highest to 5 Lowest)

BETA 1.25

Oct. 6, 1978 Value Line

1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	© Arnold Bernhard & Co., Inc.	81-83E
3.77	4.41	4.68	5.06	6.37	8.09	8.36	9.20	10.19	8.99	10.10	12.11	15.69	19.28	20.85	25.74	33.43	*39.50*	(A)Sales per sh	*56.45*
.40	.50	.53	.60	.85	1.03	1.05	1.11	1.20	.96	1.09	1.40	1.67	2.07	2.37	3.21	4.03	*4.70*	"Cash Flow" per sh	*6.90*
.29	.36	.39	.46	.69	.84	.84	.88	.88	.58	.67	.96	1.24	1.52	1.72	2.49	3.19	*3.70*	(B)Earnings per sh	*5.50*
--	--	--	--	--	--	--	--	--	--	--	.10	.10	.10	.12	.23	.60	*.64*	(C)Div'ds Decl'd per sh	*.90*
.29	.17	.19	.24	.36	.36	.40	.73	1.03	.37	.30	.43	1.36	1.82	1.07	1.25	2.33	*3.05*	Cap'l Spending per sh	*3.25*
1.56	1.90	2.36	2.75	3.42	4.02	4.92	5.85	6.77	7.29	8.05	9.03	10.05	11.53	13.14	15.51	18.19	*21.10*	(D)Tangible Book Value sh	*32.75*
15.96	15.96	16.15	16.02	15.97	15.94	16.00	16.19	16.22	16.25	16.27	16.37	17.30	17.46	17.58	17.68	17.91	*18.10*	Common Shs Outst'g	*18.60*
--	--	21.7	25.7	24.7	27.3	29.7	32.2	33.5	27.2	28.4	25.1	16.9	9.1	13.5	12.4	11.5		Avg Ann'l P/E Ratio	*21.0*
--	--	--	--	--	--	--	--	--	--	--	.4%	.5%	.7%	.5%	.7%	1.6%		Avg Ann'l Div'd Yield	*.6%*

CAPITAL STRUCTURE as of 5/27/78
Total Debt $51.2 mill. Due in 5 Yrs $47.4 mill.
LT Debt $40.9 mill. LT Interest $3.3 mill.
(LT interest earned: 27.7 x; total interest coverage: 23.6 x) (11% of Cap'l)

Leases, Uncapitalized Annual rentals $5.7 mill.
Pension Liability $1.8 mill. in '78 vs $1.1 mill. in '77
Pfd Stock None Pfd Div'd None

Common Stock 17,912,962 shares (89% of Cap'l)

1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979		81-83E
133.7	148.9	165.2	146.0	164.3	198.2	271.4	336.6	366.6	454.9	598.9	*715*	(A) Sales ($mill)	*1050*
21.4%	19.4%	18.4%	15.3%	15.5%	16.9%	16.9%	18.0%	18.9%	19.6%	18.3%	*18.0%*	Operating Margin	*18.5%*
3.4	3.8	5.2	6.3	6.9	7.3	7.5	9.7	11.6	12.8	15.3	*18.0*	Depreciation ($mill)	*26.0*
13.4	14.1	14.3	9.3	10.8	15.7	21.4	26.3	30.1	44.0	56.9	*66.5*	Net Profit ($mill)	*102*
46.2%	44.2%	42.4%	40.5%	44.8%	44.8%	44.5%	43.8%	45.5%	42.0%	40.8%	*41.0%*	Income Tax Rate	*40.0%*
10.1%	9.5%	8.6%	6.4%	6.6%	7.9%	7.9%	7.8%	8.2%	9.7%	9.5%	*9.3%*	Net Profit Margin	*9.7%*
50.8	57.6	59.9	69.6	83.7	96.7	107.9	153.5	187.9	225.9	250.1	*300*	Working Cap'l ($mill)	*475*
.8	.4	.3	1.7	1.1	.9	.6	29.8	38.6	42.8	40.9	*60.0*	Long-Term Debt ($mill)	*80.0*
81.6	97.5	112.3	122.2	133.9	150.0	175.5	202.3	232.0	274.1	326.7	*383*	Net Worth ($mill)	*610*
16.3%	14.4%	12.7%	7.6%	8.0%	10.4%	12.1%	11.7%	11.7%	14.4%	16.0%	*15.6%*	% Earned Total Cap'l	*15.0%*
16.5%	14.5%	12.7%	7.6%	8.1%	10.5%	12.2%	13.0%	13.0%	16.0%	17.4%	*17.5%*	% Earned Net Worth	*16.5%*
16.5%	14.5%	12.7%	7.6%	8.1%	9.4%	11.2%	12.2%	12.1%	14.6%	14.1%	*14.5%*	% Retained to Comm Eq	*14.0%*
--	--	--	--	--	10%	8%	7%	7%	9%	19%	*17%*	% All Div'ds to Net Prof	*16%*

CURRENT POSITION ($mill.)	1976	1977	5/27/78
Cash Assets	70.4	84.9	66.2
Receivables	70.1	87.3	115.1
Inventory (LIFO)	99.1	118.4	163.5
Other	8.8	9.6	12.9
Current Assets	248.4	310.2	357.7
Accts Payable	15.9	22.1	31.0
Debt Due	3.1	5.4	10.3
Other	41.5	56.8	66.3
Current Liab	60.5	84.3	107.6

ANNUAL RATES of change (per sh)	Past 10 Yrs	Past 5 Yrs	Est '76-'78 to '81-'83
Sales	13.5%	20.5%	*16.5%*
'Cash Flow'	12.5%	23.0%	*16.5%*
Earnings	12.0%	27.5%	*17.5%*
Dividends	--	26.0%	*24.0%*
Book Value	14.0%	14.0%	*16.5%*

Fiscal Year Ends	QUARTERLY SALES ($ mill.) Aug. 31	Nov. 30	Feb. 28	May 31	(A) Full Fiscal Year
1975	72.8	77.2	104.6	82.0	336.6
1976	74.9	82.2	113.8	95.7	366.6
1977	89.5	100.0	140.1	125.3	454.9
1978	120.4	140.3	178.3	159.9	598.9
1979	158.9	*170*	*205*	*181.1*	*715*

Fiscal Year Ends	EARNINGS PER SHARE Aug. 31	Nov. 30	Feb. 28	May 31 (B)	(A) Full Fiscal Year
1975	.31	.30	.52	.39	1.52
1976	.33	.35	.54	.50	1.72
1977	.48	.50	.71	.80	2.49
1978	.67	.76	.93	.83	3.19
1979	.79	*.90*	*1.06*	*.95*	*3.70*

Cal-endar	QUARTERLY DIVIDENDS PAID Mar. 31	June 30	Sept. 30	Dec. 31	(C) Full Year
1974	--	.05	--	.05	.10
1975	--	.05	--	.06	.11
1976	--	.06	--	.075	.14
1977		.15		.24	.39
1978	.12	.12	.12	.16	

BUSINESS: Tektronix, Inc. is the largest manufacturer of CRT oscilloscopes (65% of world market). Sales breakdown by market: industry, 80%; government, 10%; and education, 10%. Manufactures over 700 electronic instruments for display, measurement, and control including storage tubes, computer terminals, electronic calculators, and recorders. R&D: 8.3% of sales. Plants in U.S., Europe, and Japan. Foreign sales: about 36% of total. Labor costs: 48% of sales. '78 deprec. rate: 7.5%. Employs 19,147, has 7,305 stockholders. Insiders own 30% of stock. Chairman: H. Vollum. President: E. Wantland. Inc.: Oregon. Address: P.O. Box 500, Beaverton, Oregon 97077.

Tektronix opened fiscal '79 in high gear. August-quarter sales were up a hefty 32% with shipments strong across the board. Both service (portable) and laboratory (the 7,000 series in particular) instruments sparked the Test and Measurement group to a 29% gain. OEM sales led the Information Display group to a 42% increase. The fly in the ointment: a squeeze on profit margins as the cost of sales rose over 8% from 43.4% to 47%. Main problem: the high cost of training new employees. Tek's head count (mostly in production) has increased by about 27.5% in just one year. In addition, Tek's spectacular sales growth has required the use of outside contractors, more costly than in-house manufacture. Result: a share earnings gain of "only" 18%.

The top and bottom lines should move into more normal balance during the rest of the year. As the learning curve is climbed, profit margins should recover. Thus, while we think the *rate* of sales gain will decrease substantially during the economic slowdown, earnings should moderate at a slower pace. We expect the full fiscal year to balance out to a 16% share earnings gain on about a 19%-20% addition to sales. In 1979 slower capital spending growth probably won't halt Tek's earnings uptrend. The far worse '74 recession didn't.

Tek's Information Display group will start shipping an important new product this month. It's the 4027 terminal. Similar to the 4025, it uses "refreshed displays" (like television, the continuous transmitting of an image while it's being viewed). Text and graphics can be simultaneously "scrolled" (information moved up and off the tube while bringing in new exhibits at the bottom of the screen). The 4027 meets the market demand for color at a competitive price, $8,695. Hues can be selected from a 64-color palette; up to eight are displayed together on the screen. The 4027 is the most important of a number of new products introduced this fall to keep Tek's relatively new Information Display group at the forefront of the fast-moving state of the art in the growing computer graphics market.

This stock is a good bet for the longer pull. Investors in need of high income *shouldn't be* tempted but the higher than average annual total return projected to 1981-83 will interest most others.

R.S.C./m.l.s.

(A) Fiscal yr. ends about May 31 of cal yr. Fiscal yr. is divided into three 12-week periods and one 16-week period. (B) Based on avg. shs. outst'g. Next earn'gs rep't due early Dec. Est'd '78 replacement egs. $3.05/sh. (C) Next div'd meeting about Dec. 5. Goes ex about Dec 17. Div'd payment dates: Jan 16, Apr. 17, July 5, Oct. 16. (D) In millions adjusted for stock splits & div'ds.

Company's Financial Strength	A
Stock's Price Stability	45
Price Growth Persistence	95
Earnings Predictability	65