TEKTRONIX, INC. COMPANY CONFIDENTIAL

APRIL, 1980

TECHNOLOGY report

HARDWARE SOFTWARE FIRMWARE PROCESS ENGINEERING MATERIALS RESEARCH

THE REVERSE FORUM

DIVISION MANAGERS DISCUSS TEK PLANNING PROCESS

CONTENTS

ABOUT THE COVER

Because this month's cover story discusses Tek's decision-making and planning processes, our cover design is based on a *decision tree:* a graphic tool used to sequence decisions and determine an optimum course of action.

Volume 2, No. 4, April 1980. Managing editor: Burgess Laughlin, ext. 8929 (Merlo Road), d.s. 53-077. Editors: Art Andersen and Laura Lane. Cover and graphic design: Joe Yoder. Graphic illustrator: Jackie Miner. Composition editor: Jean Bunker. Published by Technical Publications (part of Technical Communications Services) for the benefit of the Tektronix engineering and scientific community.

Laura Lane edited the Forum 15 articles on pages 3-23.

Why TR?

Technology Report serves two purposes. Long-range, it promotes the flow of technical information among the diverse segments of the Tektronix engineering and scientific community. Short-range, it publicizes current events (new services available and notice of achievements by members of the technical community). □

JANUARY PAPERS AND PRESENTATIONS

While providing recognition for Tektronix engineers and scientists, the presentation of papers and the publication of papers and articles contribute to Tektronix' technological leadership image.

The table below is a list of papers published and presentations given during January 1980.

The Technical Communications Services' (TCS) Engineering Support group's charter is (1) to provide editorial and graphic assistance to Tektronix engineers and scientists for papers and articles presented or published outside Tektronix and (2) to obtain patent and confidentiality reviews as required.

If you plan to submit an abstract, outline, or manuscript to a conference committee or publication editor, take advantage of the services that TCS Engineering Support offers. Call Eleanor McElwee on ext. 8924 (Merlo Road). □

TITLE	AUTHOR	PUBLISHED	PRESENTED
MATERIALS RESEARCH:			
☐ "Positive Dry-Film Photoresist"	Bob Mueller	**AES Abstracts**	American Electroplaters Society
☐ "Recent Advances in Electron Beam Deflection"	Edward F. Ritz, Jr.	**Advances in Electronics and Electron Physics, Vol. 49**	—
SOFTWARE:			
☐ "Managing the Development and Supplementation of a Universal Standard Data System"	Jim Lushina	**The MTM Journal of Methods — Time Measurement, Vol. VI, No. 3**	—

For a copy of a paper or article listed here, photocopy this table, check the appropriate box, and mail to TCS, d.s. 53-077.

NAME _____ D.S. _____

FORUM 15: INTRODUCTION

DIVISION MANAGERS DISCUSS TEK PLANNING PROCESS

A major function of the Engineering Activities Council (EAC) is to provide engineers with a forum in which they can present directly, to multiple levels of management, what they consider to be important in technology. Forum 15 (presented in October 1979) is the second forum which reversed the presentation process: questions from engineers were presented to upper management through the EAC. The four division managers answered those questions and discussed the values, changes, and planning processes at Tektronix today.

Chairpersons for Forum 15 were EAC members Mike Rieger (Signal Processing Research) and Tom Woody (Large Screen DVST Engineering). To accommodate the large number of Tek engineers wanting to attend, there were three presentations of Forum 15.

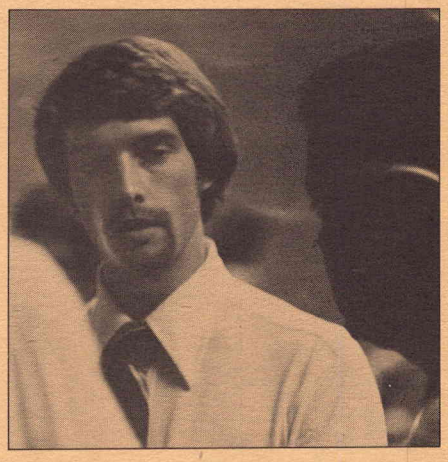
Mike Reiger (Signal Processing Research), cochairperson.

Since Forum 15, there have been some organizational changes at Tek; the following articles reflect the information given in the presentation. Technical Communications Services staff members edited transcripts of the presentation for conciseness, clarity, and technical and financial confidentiality.

PREVIEW

In part one, Larry Sutter (Laboratory Instruments Division manager) introduces Forum 15 and discusses the values behind planning at Tektronix. He explains the importance of market share and the effects of our recent growth, and introduces the business portfolio concept.

In part two, Howard Mikesell (Information Display Division manager) elaborates on the planning structure at Tek and discusses Tektronix' Statement of Corporate Intent, the Statement of Corporate Objectives, the corporate strategic plan, and business and functional plans. Howard also introduces the sector concept.



Tom Woody (Large Screen DVST Engineering), cochairperson.

In part three, Tom Long (Communications Division manager) further explains the sector concept, Tek's organization, and the basis of our business plans. He also discusses product design philosophy, marketing's role (as it relates to engineering), automation in manufacturing, and new technology.

In part four, Jim Towne (Service Instruments Division manager) describes the impact of the concepts discussed in parts one, two, and three. He presents an in-depth discussion of Tek's concepts of change and the values that guide Tektronix' business decisions. □

Bill Walker (executive vice president) welcomed the audience.

PART ONE

LARRY SUTTER ON TEK PLANNING CONCEPTS

INTRODUCTION

Tektronix has changed a lot in the last ten years and even more in the last three. To give you an idea of the kind of change we're experiencing, we thought we'd talk about what the changes are, the principles behind them, and what they mean to all of us.

TEK PLANNING

How did our company change from a single product-line company with 270 million dollars in sales five years ago to an almost one-billion dollar company today with 800 different products? What are the principles and values that drove this change?

Larry Sutter, Laboratory Instruments Division manager.

First, let's start with what we think is the prime driver behind all this change: Tek's planning and ability to plan. Five or six years ago our planning process was very informal; today, it is much more disciplined.

There are three keys to Tek planning, three basic concepts to which Tek subscribes: **market share, growth,** and **business portfolio.** These are three driving forces the corporate group considers in resource allocation and business decisions.

"There are three keys to Tek planning, three basic concepts . . . market share, growth, and business portfolio."

MARKET SHARE

If a company intends to enter a business segment, it ought to plan to lead it. At Tektronix today, we have more opportunities than we can fund, so we want to fund opportunities only in product areas in which we will be the leader. We measure this leadership in terms of **market share.**

We measure market share in two ways: (1) *absolute* market share, your company versus the competitor (having 40% market share means you sell 40% of all the units that go into that market), and (2) *relative* market share, which we think is even more significant.

". . . we want to fund opportunities only in product areas in which we will be the leader."

Relative market share is the ratio of a company to its nearest competitor. If we're the leading supplier and we sell 4,000 units a year and the second place competitor sells 1,000 a year, our relative market share is four. If we are in a second-place position, selling 1,000 units per year, and the leading competitor is selling 2,000, our relative market share is 0.5.

Relative market share is very critical for this reason: In a business where market shares have been stable for some time, the relative accumulated experience of each competitor is virtually interchangeable with its relative market share. Whoever has more experience usually leads the market. The competitor with the leading market share will have the most *accumulated experience* and, thus, should have the lowest costs.

The experience we're talking about is not just in manufacturing, it is accumulated experience in all areas: selling, servicing, manufacturing, testing, design, marketing, research . . . every element of the company.

The Boston Consulting Group has researched, in detail, companies in some 1600 different industries in the U.S. They found that, as the number of units produced increases, the unit cost a company incurs declines. More specifically, the unit cost declines approximately 20% to 30% every time the company doubles its accumulated experience, or the number of units produced (we measure accumulated experience by the number of units produced). What that means is, the second hundred units will cost 20% or 30% less than the first 100 units. Depending on the industry, these units will accumulate at different rates.

Figure 1 is a graph of an 80% slope showing that, for 100 units, the unit cost is a dollar; for 200 units, it's 80 cents; for 400 units, the cost is 64 cents (80% of 80 cents), and so on. Having a large market share enables us to accumulate experience so that we can lower our costs faster than our competitors.

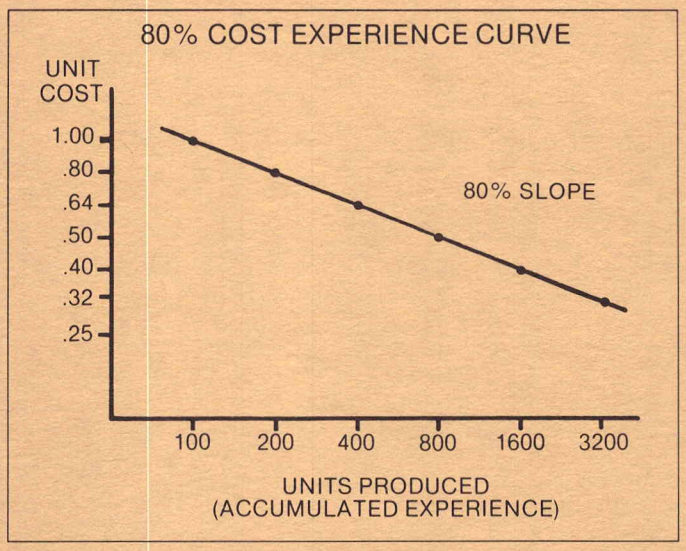


Figure 1. In a typical cost/experience curve, when a company doubles its accumulated experience (measured by the number of units produced), unit cost declines approximately 20% to 30%.

The graph in figure 2 shows three competitors. Competitor A has accumulated 1000 units; competitor B has accumulated 2000 units; and competitor C has accumulated 4000 units. This is at a 70% slope and shows that competitor C, who has a relative market share of 2.0 relative to competitor B, has costs of 50 cents per unit; competitor B's costs are 70 cents; and competitor A, who has only accumulated 1000 units, has a cost of a dollar. If you're in third place trying to go to first place, you're probably starting with total costs at about twice that of the leader. Once you're behind, it's difficult to catch up.

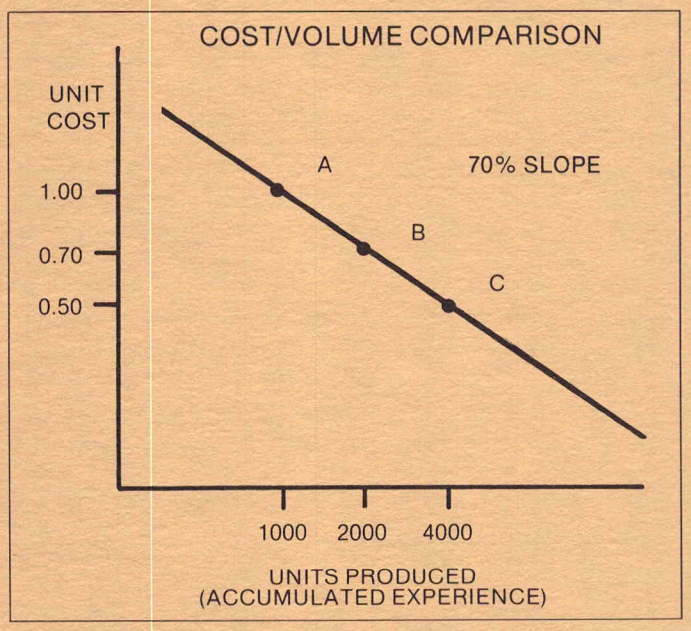


Figure 2. A large market share enables a company to rapidly accumulate experience and thereby lower cost per unit. Here, competitor A has produced only 1000 units and therefore has very little accumulated experience; their costs are twice that of competitor C who has produced four times as many units, thereby accumulating more experience.

Figure 3 further demonstrates the value of accumulating experience using the Ford Model T price experience curve from 1909 to 1916. In seven years, the cost went from approximately $6,000 per unit (in 1958 dollars) down to around $1,000 per unit. The volume had a tremendous influence on the cost and allowed Ford to gain a very strong position early.

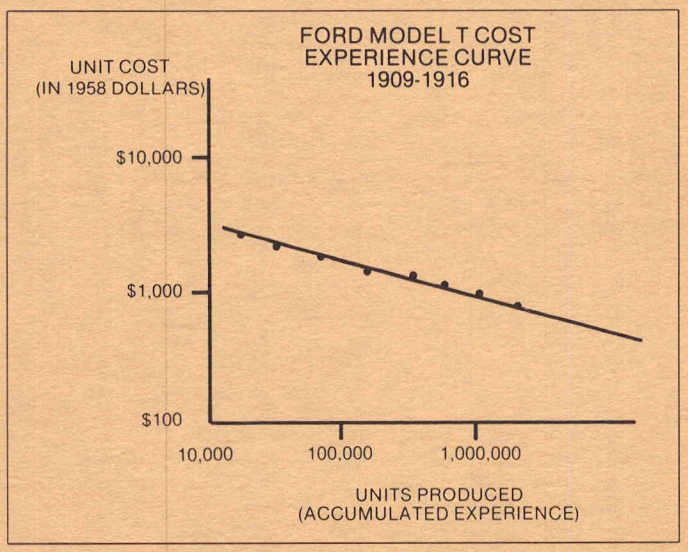


Figure 3. By the time Ford produced the millionth Model T, the cost was about $5,000 less than the cost of the first 10,000 units. This dramatic decrease was due to their increased accumulated experience. Cost decreases as accumulated experience increases.

Figure 4 shows a graph of an industry you're more familiar with — integrated circuits. In this industry, of course, unit volume accumulates a lot faster than in the automobile industry. The curve shows the annual average price data from 1964 through 1968. Volume is in millions of units and price per unit varies from $1.00 to $50.00.

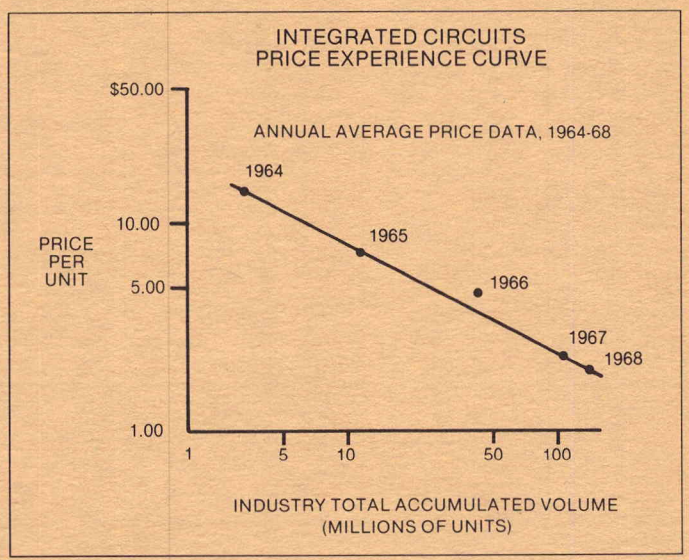


Figure 4. In the IC industry between 1964 and 1968, unit prices dropped dramatically as the industry increased production.

Continued on page 6

You can see that the price per unit for a particular circuit, in 1964, was around $20.00. Four years later, after a hundred million units, the price was around $2.00. That's tremendous leverage.

For companies like Texas Instruments, a prime marketing strategy is to generate a lot of volume early. This strategy accumulates experience and gives an edge on the competition. They can actually afford to sell products at less than cost early in the game.

The polyvinylchloride industry had a curve like the one shown in figure 5; it's not as linear as the one for ICs. What happened in 1955 (the sudden drop in price) was that new competitors came into the market when they saw the large margins that companies were accumulating.

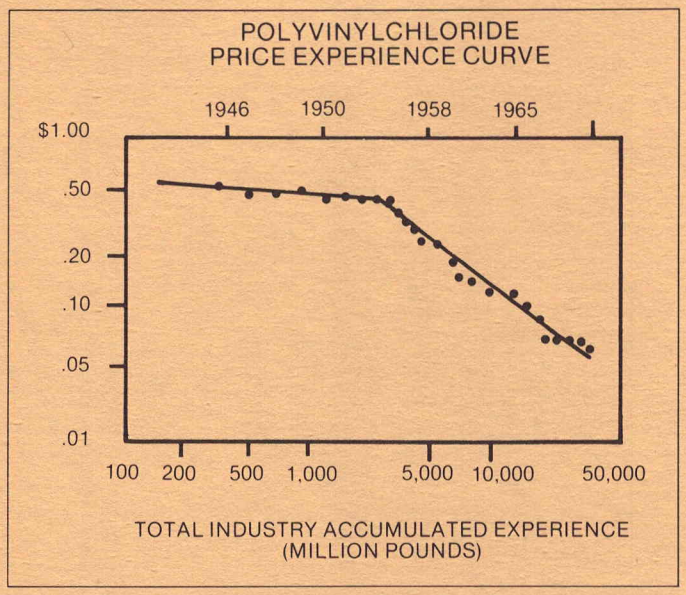


Figure 5. The polyvinylchloride industry experienced a decrease in price to the customer as greater amounts of polyvinylchloride were produced. (Because new competitors entered the polyvinylchloride industry in 1955, price per pound decreased rapidly.)

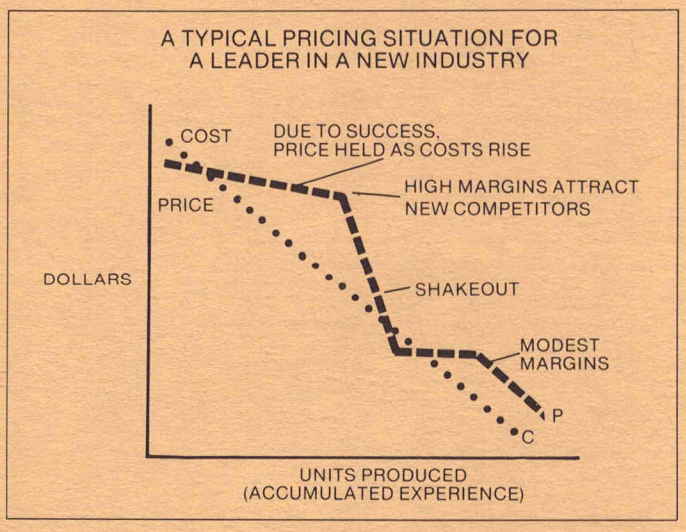


Figure 6. When new competitors enter a market, prices decrease dramatically. Cost decreases as accumulated experience grows.

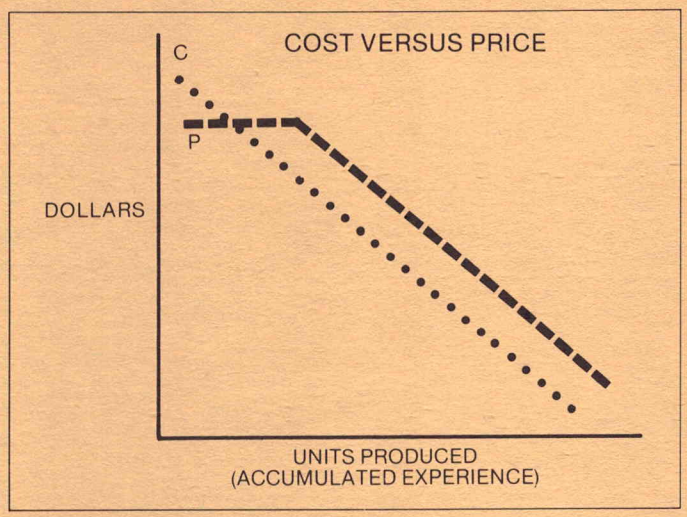


Figure 7. Although a product may start with costs greater than price per unit, costs will decrease as accumulated experience grows. As costs decrease, a company can lower prices *and* offer more value and higher performance.

Figure 6 shows a typical pricing situation for a leader in a new industry. The dotted line shows cost, and the dashed line shows price. Cost would probably be at a curve as shown; price holds fairly flat, then drops a little when larger profit margins attract additional competitors. There would be some price cutting and some shake-out in the market, and the customer's price would take a steep drop.

Some industries and products have the profile shown in figure 7. This is a classic curve and applies to at least one of our business units. Again, the dashed line shows price, and the dotted line shows cost. The price, in nominal dollars, starts off almost flat; in real dollars, the cost decreases. You can make up the difference between decreasing cost and steady price by offering more value and higher performance. This approach to pricing can be a real advantage for sales and has been one of the keys to our success.

So, relative costs are a function of market share. The quicker you gain market share, the better off you are. Figure 8 shows, basically, that if your relative market share is four, you're four times the size of your nearest competitor and your costs are about 64% of theirs. If your relative market share is two, you're twice as large and your costs are about 80% of theirs. If you have parity with a competitor in the

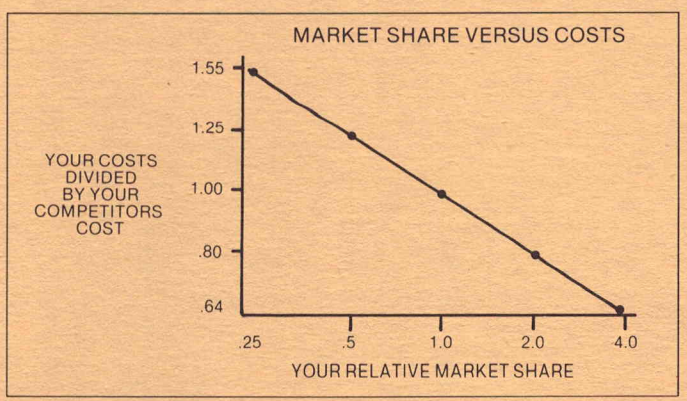


Figure 8. A company's relative market share (RMS) inversely affects its costs relative to its competitor's costs.

market, your costs are about the same. On the problem side, if you are half the size of your nearest competitor, your costs are 25% more.

It's very important to get into the market early and do a good job; hence, at Tektronix, market share is a guiding principle in our planning process.

GROWTH

The second principle is **growth.** What is the effect and value of growth? We recognize that market share will allow us to lower costs more quickly than our competitors. A high-growth market lets us accumulate experience and lower costs more rapidly. Therefore, we can make a larger investment to gain market share.

Markets that are growing quickly produce a return on investment sooner. Figure 9 illustrates that concept. The squares show growth year-by-year in a 30%-growth market area, and the triangles show growth year-by-year in a 5%-growth market area. Basically, what it says is, for accumulating experience, one year of a 30% per year growth business equals about 5 years of a 5% per year business.

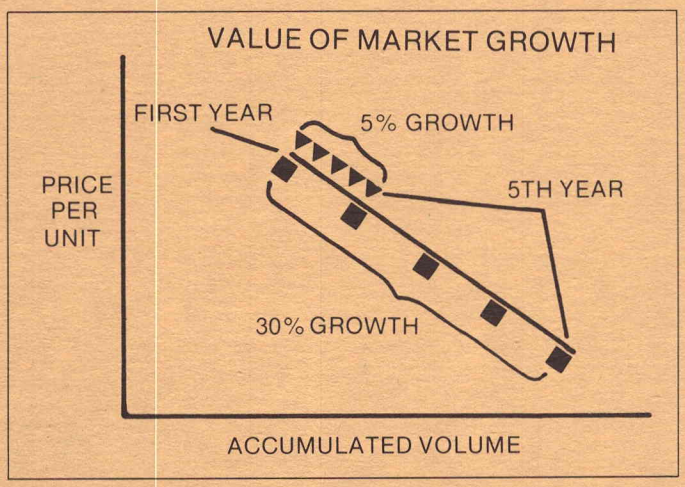


Figure 9. The more quickly a market is growing, the sooner a new company entering that market will achieve a return on investment. This graph shows that for accumulating experience, one year in a 30% growth market will achieve the same return as five years in a 5% growth market will achieve.

So, you have tremendous leverage with rapid growth. If you're trying to decide where to invest, two criteria are market share and how fast the market is growing.

BUSINESS PORTFOLIO

What do we do with those two concepts, market share and growth? Well, we have numerous business units at Tektronix and as we become larger and more diverse, resource allocation decisions become much more difficult and much more critical. How do we manage that?

We approach it with **portfolio management:** A business should yield cash either today or some point in the future. Cash generation is an important consideration when we allocate resources for the five-year business planning process. Our goal for every business is to generate cash.

Each business will become either a leader or a follower; we're either going to be first or we're not going to be first. A diversified company like Tektronix must have the portfolio approach for an overall strategy. Basically, this kind of planning asks: Have we picked the appropriate strategy for each business?

> **"Our business units are pretty much independent in that we can develop an independent strategy for each."**

Our next question is: If we add up all the Tektronix businesses, does the total strategy make sense? They will not all grow at the same rate in their markets. Some generate cash, others use that cash for growth.

The first step in the portfolio approach to management is to define the businesses we're in. We call these distinct entities **business units** — a product or market grouping for which a strategy can be developed independently from other business units. All of our businesses have things in common, but if you are involved in one business unit and find that your planning dramatically impacts another business unit, you may have a problem with your business definition. Our business units are pretty much independent in that we can develop an independent strategy for each.

The second step is to take those businesses and characterize them in terms of market position and growth. We can plot the business units on a chart called the **spot-and-dot chart.** The chart in figure 10 shows market growth on the vertical axis, and relative market share on the horizontal axis.

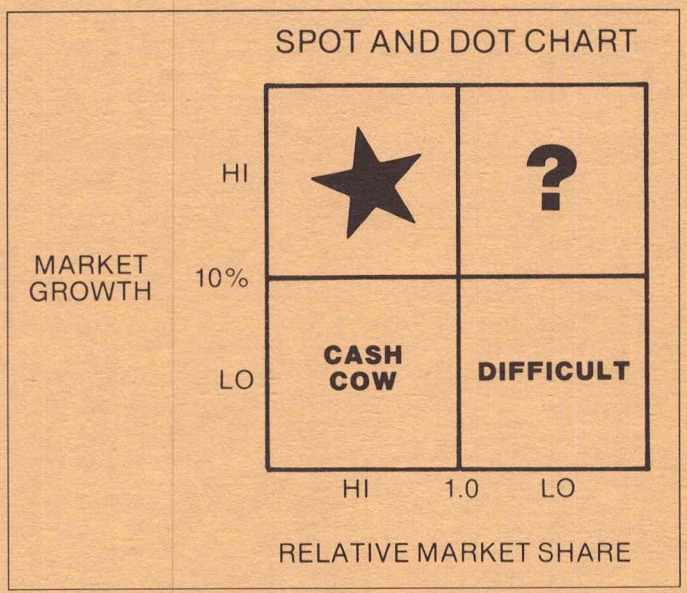


Figure 10. By plotting each business by its market growth and relative market share on a spot-and-dot chart, a company can allocate resources based on what quadrant each business falls into. A new business starts out with a low market share; if the business enters a high-growth market, it is a *question-mark* business; if it enters a low-growth market, it is a *difficult business.* If a business is in a high-growth market, it is a *star business;* if it is in a low-growth market, it is a *cash cow.*

Continued on page 8

Market areas growing faster than 10% per year (high-growth markets) are above the middle horizontal line, and market areas that are growing less than 10% per year (low-growth markets) are below that line. The relative market share axis shows that if you have a business in a position where you're a leader and you have a relative market share of more than one, you're out to the left of the middle vertical bar. If you have a lower position, you're to the right.

Businesses which have a high market share and are generating cash are **stars.** Businesses that are profitable, more mature, and have been around for some time are **cash cows;** businesses that do not have the leading position but are in fast-growth markets are **question-mark** businesses (we have a number of these, as do most companies). Question marks will move to the left and become a star or they will move down and become **difficult** businesses: businesses that have a low market share and are growing slowly. (The Boston Consulting Group uses these terms to classify businesses and we are now using them around Tek.)

If you were to graph businesses on a spot-and-dot chart according to their positions and use circles proportional to the size of those businesses, you would come up with something like figure 11. This does not represent Tektronix, but it is a typical business portfolio.

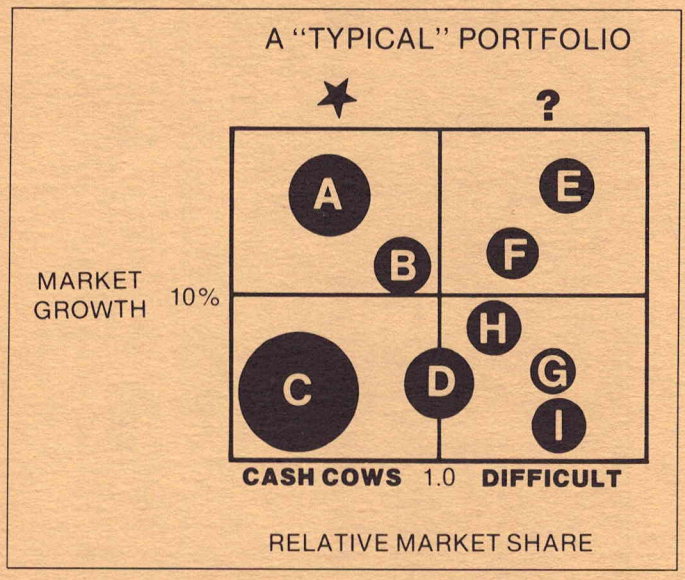


Figure 11. Typically, companies have businesses in all four quadrants of a spot-and-dot chart. Most companies try to move question-mark and difficult businesses to the star and cash-cow quadrants by taking cash from the star and cash-cow businesses and investing in the difficult and question-mark businesses.

Most companies have a couple of businesses that are stars (A and B) and some that are question marks (E and F). Some businesses that were star businesses mature and become cash cows (C). Some businesses are right on the edge of being in a leading or losing position (D). Most corporations will always have difficult businesses.

A spot-and-dot chart is a good starting point in evaluating a portfolio. It's not the whole answer to strategy development, but it's a good way to look at the different options that exist for every business.

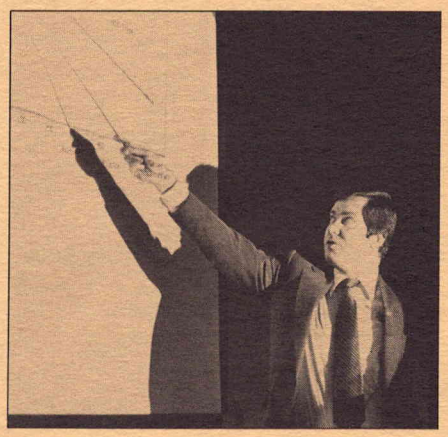
For example, if you are a star business, what are your options? Well, not too many: you can increase your share or give up some share. Hopefully you increase or decrease share purposefully, not unintentionally. You may wish to liquidate some share to generate more cash, but you sure wouldn't want to give up your basic position.

"You can make tremendous jumps in market share through innovation or technological advances."

The cash-cow businesses can maintain their positions or liquidate some market share to generate even more cash. Typically, however, you'd want to stay dominant; you wouldn't want to give up a strong cash position.

Question-mark businesses are hard to work with. You can invest in a question-mark business to produce a star; however, you have to decide if you want to put more cash into that product area to make it a star. If you're starting behind other people, it's more difficult.

You can make tremendous jumps in market share through innovation or technological advances. If you decide not to invest in star status, you can divest or maximize cash, manage it for cash, or redefine the business to make it more viable to the portfolio. If the business is difficult (low market share or low-growth market), you can simply do nothing or you can divest, lose more position to generate some cash, or try to increase share to another quadrant. Once a business drops to the difficult quadrant, unless there is some new force that advances it, you probably will never get it above the 10% line.



Larry Sutter elaborates on figure 1 (shown on page 5).

So, in portfolio management, business unit strategies are either cash-use or cash-generation. With the different business units we have at Tek, we have to make individual judgments about each of them.

IN CONCLUSION

With Tektronix growing as fast as we have in the past few years, planning and resource allocation become much more complex. With all the business units' heavy demand for cash, we have to decide where to make our investments. The principles of market share, growth, and portfolio management aid us in doing that. □

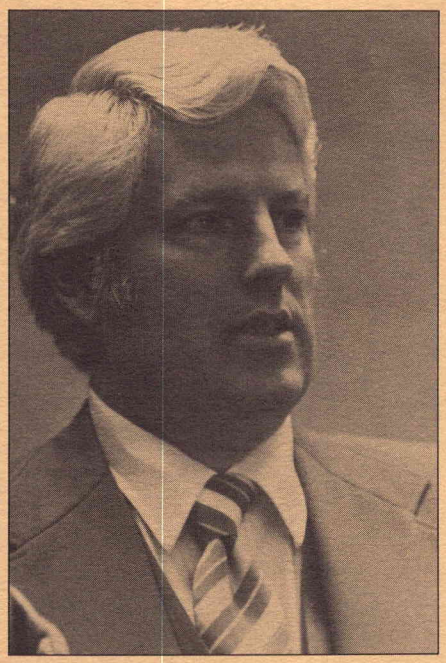
PART TWO

HOWARD MIKESELL ON DOCUMENTS AFFECTING TEK'S PLANNING

INTRODUCTION

I would like to start by reading some questions submitted to the Engineering Activities Council. One asks about new ideas in products: "At the first-line engineering level, we have no visibility of long-, medium-, or short-term marketing strategies; without clear goals, projects often meander for years before getting the ax or become ill-defined products which miss the mark. What can Tektronix do to avoid this situation?"

Other questions for the corporate group were: (1) "What is the optimum rate of growth for Tektronix for sales and for space and personnel?" (2) "How does the corporate group choose these figures?" and (3) "How large does Tek want to get?"



Howard Mikesell, Information Display Division manager.

Those same types of questions were asked at a similar meeting of engineers about 10 years ago. Because engineers are still asking the same kinds of questions, it indicates that some of the things the corporation has accomplished since that meeting haven't had much visibility. I'll try to provide some of that to you here.

I will discuss: the **Statement of Corporate Intent,** the **Corporate Objectives** and their strategic policies, **business and functional plans,** and the **sector planning concept.**

STATEMENT OF CORPORATE INTENT

At Tektronix, we have a document called the **Statement of Corporate Intent.** It attempts to answer the types of questions I just mentioned. How many of you in the room have seen the Statement of Corporate Intent? A very small number, I see — that's unfortunate.

The corporate group wrote the Statement of Corporate Intent in 1974 and it first appeared in **Agenda.** Today, it is in the **Managers' Guidebook.** If you want to read it, I suggest you ask your manager for a copy.

The corporate group developed the Statement of Corporate Intent in response to engineers and marketing people asking questions such as: "What is Tektronix all about?" and "What do we want to become?" They were trying to establish a clearer identity for Tektronix.

We had a book in the late '60s that was three or four inches thick and was called the **Policy Manual.** It covered everything from A to Z. It told you how to do *everything:* how to fill out this form, how to fill out that form, how to think. In 1972, we did away with that document and later replaced it with a much simpler document, the Statement of Corporate Intent. It was two or three pages long and provided guidelines for managers, engineers, and other employees so that they could understand Tektronix' overall purpose. Of course, a document that short didn't last long. Over a period of time, we had to supplement it.

> "... it's customer satisfaction that counts - doing the job for the customer. That's what really keeps us in business."

A brief summary of what is in the Statement of Corporate Intent follows.

In terms of ***obligations to customers,*** we want "to consistently provide unmatched value in the products and service we offer customers." In this area, it's customer satisfaction that counts — doing the job for the customer. That's what really keeps us in business. If we don't satisfy our customers, they won't buy our products, and if we don't sell products, we won't have a business. In other words, improved products is the key to customer satisfaction. This statement also encourages Tektronix employees at all levels to keep the customer foremost in mind.

Continued on page 10

The next statement deals with ***commitment to employees:*** "To recognize the one limitless resource: the individual and collective potential of the human being; and to provide employees with maximum opportunity to exceed their own expectations." Tektronix employees are the most valuable asset we have. We want to match each individual to the job and make sure the goals they have coincide with the corporation's goals.

"Tektronix employees are the most valuable asset we have."

Corporate leadership: "To accept in full the obligations of leadership." We always want to move from strength so we can enhance our leadership position; and Tektronix *does* have many strengths. This statement also points out that we want to be innovative as well as profitable.

The next statement deals with ***profitability:*** "To consider continued profitability a valid measure of contribution." We don't expect all products to have the same level of profitability. Some products are more profitable than others, and some business units are more profitable than others. We want to be profitable over the long-term.

The next area the Statement of Corporate Intent discusses is ***growth:*** "To maintain growth as a means of maintaining and renewing vitality." We don't want to be big just because it's neat to be big. If we're going to be big, we're going to do it well. We want growth to be orderly.

The last subjects are change, field of endeavor, and social responsibility.

Change: "To creatively manage change by organizationally channeling it into the most socially useful and profitable directions."

Field of endeavor: "To focus our effort in the expanding fields of electronic equipment; and to expand that effort only when we can lead from strength and can expect to make a significant contribution."

Social responsibility: "To insure that corporate objectives, wherever possible, enhance the goals of the immediate and larger communities of which we are a part."

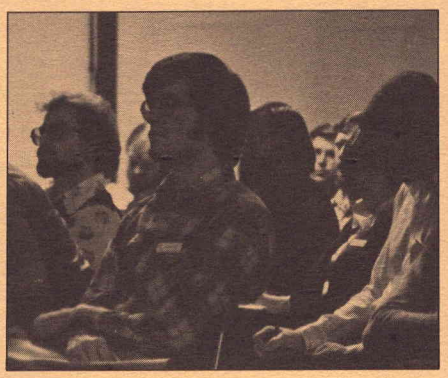
The Statement of Corporate Intent sets the stage for what Tektronix wants to do. I would like to encourage you to take the time to examine your manager's copy of the Statement of Corporate Intent. I think you'll find it relevant to the type of work you're doing.

CORPORATE OBJECTIVES AND STRATEGIC POLICIES

The **Corporate Objectives** answer questions like: *What* do we want to accomplish? How *much* does Tek want to accomplish?

There are seven key result areas that the corporate objectives deal with: market position, innovation, productivity, profitability, physical and financial resources, human resources, and social responsibility.

The key result areas, their objectives, indicators, and goals all give us a basis to judge our direction and performance.



During the Reverse Forum, division managers exposed engineers to business factors that influence product development decisions.

Market Position

For market position, we want to increase our penetration into the growth segments of the electronic equipment market, establishing leadership in the businesses in which we compete.

We want a leadership position because we will then have the best cost position: greatest market share, greatest volume, lowest cost, and greatest profitability. One indicator here is the growth in Tek revenues; relative market share is another.

In addition to the key result area, the indicators and the objectives expressed, we have strategic policies that describe how we're going to achieve those objectives.

Some strategic policies for market standing are: (1) to enter those businesses which offer substantial growth and profitability opportunities; (2) to enter new businesses and markets only when Tek has a clear competitive advantage (this concurs with the Statement of Corporate Intent); (3) to be a price leader in most businesses; (4) to price in such a way as to obtain a high **contribution margin** (net sales less the cost of sales); and (5) to revitalize our businesses continually through application of new technology.

Innovation

In innovation, our objective is to be creative in conceptualizing market opportunities and to lead in technologies critical to their development in order to produce products and services with high value. The indicators are the contribution margin, unit volume, and revenues attributable to new products.

"... (we want) to create a corporate environment that encourages a high level of employee innovation."

New products are the lifeblood of Tektronix. If we don't introduce new products, we won't last very long. The last indicator for this objective is to successfully search out and recognize innovative contributions in all areas of the company.

There are several strategic policies for innovation: (1) to create new businesses through the application of Tektronix technological strengths to obtain a position of initial market leadership (*leadership* and *strengths* are terms that appear often in these documents); (2) to grow primarily through internal development of new businesses; (3) to invest a fixed portion of sales in product engineering and corporate research and development; and (4) to create a corporate environment that encourages a high level of employee innovation.

"... (we want) to provide a platform for productivity improvements by encouraging individual involvement and personal initiative ..."

Productivity

Another key result area is productivity. The objective is to achieve a high yield on the resources employed at Tek. There are five indicators: value added, profit share, asset turnover, how well we employ our people, and manufacturing and labor productivity.

Some strategic policies for increasing productivity are: to increase productivity through investments in new equipment, production methods, management processes, employee training, and new technology; to provide a platform for productivity improvements by encouraging individual involvement and personal initiative; and to utilize common parts wherever possible (that's something we've been trying to do for a long time and I think the company is getting much better at it).

Resources

The next key result area is physical and financial resources. The objective is to ensure that Tek provides and effectively uses the physical and financial resources necessary to support corporate growth. Two indicators are asset turnover and capital structure.

Some strategic policies are: to ensure capacity is available when needed; to be primarily self-financing; and to maintain control over expenditures for facilities, machinery, and equipment through the capital budgeting process.

Profitability

The corporate objective for *profitability* is to generate a sufficiently long-term return on resources employed. The indicators are: a good return on shareholders equity, sales, and invested capital, and good growth in earnings.

Strategic policies include: (1) to manage Tek as a portfolio of businesses maintaining a balance between the fast-growing, cash-using businesses (high-growth areas use, as well as generate, a lot of cash) and slower-growing, cash-generating businesses (those that grow slower don't use as much cash but generate a lot of cash and thereby help finance others); (2) to allocate resources based on corporate strategic decisions; (3) to delegate decision-making; and (4) to monitor the profit planning process.

Human Resources

There are two corporate objectives for human resources. One is to ensure that we have well-trained qualified employees. An indicator is the turnover rate of permanent employees. The second objective is to ensure that each employee has the opportunity to develop his or her potential to the fullest extent possible.

The human resources strategic policies are: to maintain competitive wage ranges; to set high performance requirements; to define the scope and responsibility of every position; and to base promotion on proven performance.

Social Responsibility

For the last key result area, social responsibility, the objective is to ensure that Tek policies and actions advance the well-being and prosperity of the communities of which the company is a part. The indicator is the extent of our participation in significant public affairs; the goal is to achieve at least six such instances annually. Some of the strategic policies are to operate within the spirit as well as the letter of the law, to operate with high ethical standards, and to be an equal opportunity employer.

"... (we want) to ensure that each employee has the opportunity to develop his or her potential to the fullest extent possible."

Summary

The corporate objectives govern, to a great extent, the way we behave in the divisions, the way we manage the business units, the kinds of projects we approve, and the kinds of projects and products we work on. We have a lot of strengths and, if we want to have a leading position in the marketplace, we must carefully select our fields of endeavor. The corporate objectives attempt to guide us in this selection process.

The corporate group's decisions often don't make sense to engineers. An engineer will have a great idea and wonder why the company won't pursue it. It may be because, while it could be an outstanding idea, it might not fit the direction in which Tektronix is moving.

Knowing that these documents (the Statement of Corporate Intent and the Corporate Objectives) do exist is important to you because you can discuss them with your manager. The Statement of Corporate Intent is available from your manager; the Corporate Objectives are available from your division manager.

STRATEGIC PLANS

In addition to the Statement of Corporate Intent and the Corporate Objectives, we have five-year plans. We call these **strategic plans** and we have two types.

For each business unit, we have a **business plan** which describes what the business unit will do during the planning

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interval (generally five years), the objectives they want to attain, and the strategies they will employ to reach those objectives.

At the same time, we have **functional plans:** plans put together by support organizations (such as Central Marketing, Tek Labs, U.S. Sales, and International Sales) to help the divisions attain their strategic objectives. The kinds of things you will find in a five-year plan are the business unit definition, competitor profiles, our strengths, and a segmentation scheme (how we segment our markets).

"(Customers) are buying more than a thing, they're buying an ability to do something."

Another element of the business plan is the market and customer analysis. What do customers want in new products? What are customers actually buying? (They're buying more than a thing, they're buying an ability to do something; the purpose, not the thing, is of importance.)

We look at the growth rates we can expect. Some of our business units are growing very rapidly, some are growing very slowly. We examine the market's stability. Have a lot of new competitors entered the market or is it relatively stable? What are the characteristics of the customers? What are our strengths and weaknesses in the market?

What about our competitors? We need to know not only our customers, but our competitors as well. We spend a lot of time trying to put ourselves in our competitors' position and analyzing Tektronix in relation to them. We want to see how they look at us as their competitors.

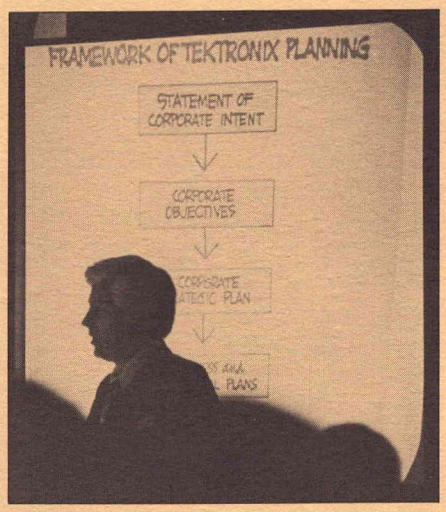
The business plan defines strategic targets and what our strategies are going to be. We try to define the size of a task: what the market is today, how big it is going to be in the future, what the growth will be, what the environment will be, what some of the key variables are, and what the critical hinge points are on which our business is dependent.

What all this implies is a lot of planning, a lot of thinking, and trying to psyche out our competitors' behavior. When we announce new products, how are our competitors likely to react? How are we going to counter what they do?

"... it's that kind of competition - always striving to do better - that helped Tektronix attain the position we hold today."

Years ago whenever we went to a WESCON or an IEEE show in New York, we'd take our latest oscilloscope with all the latest features on it, something which we all were proud of. Our competitors would be there, primarily Hewlett-Packard. They'd come by and look in the booth, look at our new oscilloscope, and go back, depressed, to Palo Alto (which is primarily where they were at the time), and try to develop a new product that would leapfrog the one they just saw at the previous instrument show.

A year later, they'd come back to the show with their new oscilloscope or new product and, of course, we all rushed over to their booth to take a look at what they had developed; and then *we'd* come back depressed. That was a very competitive environment; it was done in good spirit, and it's that kind of competition — always striving to do better — that helped Tektronix attain the position we hold today.



Howard Mikesell outlines his presentation.

We live in a competitive world and, even with the tremendous strengths we have at Tek, we must always strive to stay ahead of our competitors.

THE SECTOR CONCEPT

We have just recently developed a new term at Tektronix called the sector. Since it is a new term, and I know you will be hearing it, I think it's important that you know exactly what a **sector** is: a major area of business focus tying together a number of related business units. This relationship can be a common technology, common customer base, common applications for products, or some similar dimension. The sector concept encourages synergism between individual business units. What we're doing is looking for businesses that have a lot in common.

"We use sectors to size up Tek in terms of ... how we should pit ourselves against the competition ..."

The sector concept identifies central thrusts, provides leadership, and provides the company with a greater sense of direction and order.

Sector strategy is a key piece of the corporate strategy, but when we talk about sectors, don't get it confused with organizational entities such as business units. "Sector" is just a term that we use for planning purposes only; it has nothing to do with organizational structures.

We began using the sector concept last spring, so it is a relatively new term that's not completely polished and is subject to change. We use sectors to size up Tektronix in terms of how we perceive ourselves in a particular market

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PART THREE

TOM LONG ON PLANNING'S IMPACT ON ENGINEERS

INTRODUCTION

In this part of the forum, I will outline how we use sectors and give you an idea of the importance we place on the sector planning concept. I'll also discuss how we look at our competition and just why we divided up into sectors.

SECTORS

By dividing the corporation into sectors, we can compare ourselves with the competition. We're trying to find ways to develop synergy among our businesses, find some threads that run through all of them, and then compare ourselves with the competition and the market. As markets change from year to year, we will take businesses from one sector and put them into another.

We can have a profitable business growing at, say, 20% per year, and, if there is another company that is profitable and growing at 40% or 50% per year, we will have trouble downstream somewhere. From an economic point of view, when the competition's market share becomes significantly greater than ours, we can anticipate difficulties.

Tom Long, Communications Division manager.

We must use the sector concept in a meaningful way; we must not treat it lightly or play games with it. Our endeavor is to put sectors together in a way that enables us to achieve market-share advantage wherever possible.

TEKTRONIX ORGANIZATION

Figure 1 shows the organization as it is today; we only recently reorganized. We used to have an Information Display Group (IDG) and a Test and Measurement Group (T&M). Those have been combined under one manager (Larry Mayhew) as the Operations and Marketing Group and still contains all the divisions and business units.

> "We're trying to find ways to develop synergy among our businesses . . . and then compare ourselves with the competition and the market."

The reason we merged IDG and T&M is because T&M was continuing in the traditional test-and-measurement line; however, at the same time, we started to see more and more involvement of controllers and programmable instruments containing microprocessors.

We assumed IDG was pursuing business applications. They did pursue some of those, but they slowly evolved to preferring to cast their lot with the engineering and scientific world rather than compete with companies like IBM.

So, both T&M and IDG veered from their original courses, leaving the potential for the two group managers to vie for the same resources. Earl Wantland promoted Bill Walker to executive vice-president and gave Operations and Marketing (O&M) to Larry Mayhew with the expectation that a common managerial hierarchy would sort out the resource requirements.

BUSINESS PLANS

The format of Tek business plans are based on a business definition, a market and customer analysis, a competitive analysis, strategic targets, a strategy, and a financial statement. Financial planning requires a lot of projections and it's not always a pleasure to work with — but it is a necessary part of planning.

We look at each business unit as a team. All business units have a business unit manager who manages an engineering manager, a marketing manager, and a manufacturing manager. The focal point of the business decisions is at the business unit level, not at the division, group, or corporate level. The division and group managers evaluate strategy and performance, they do not formulate the strategy.

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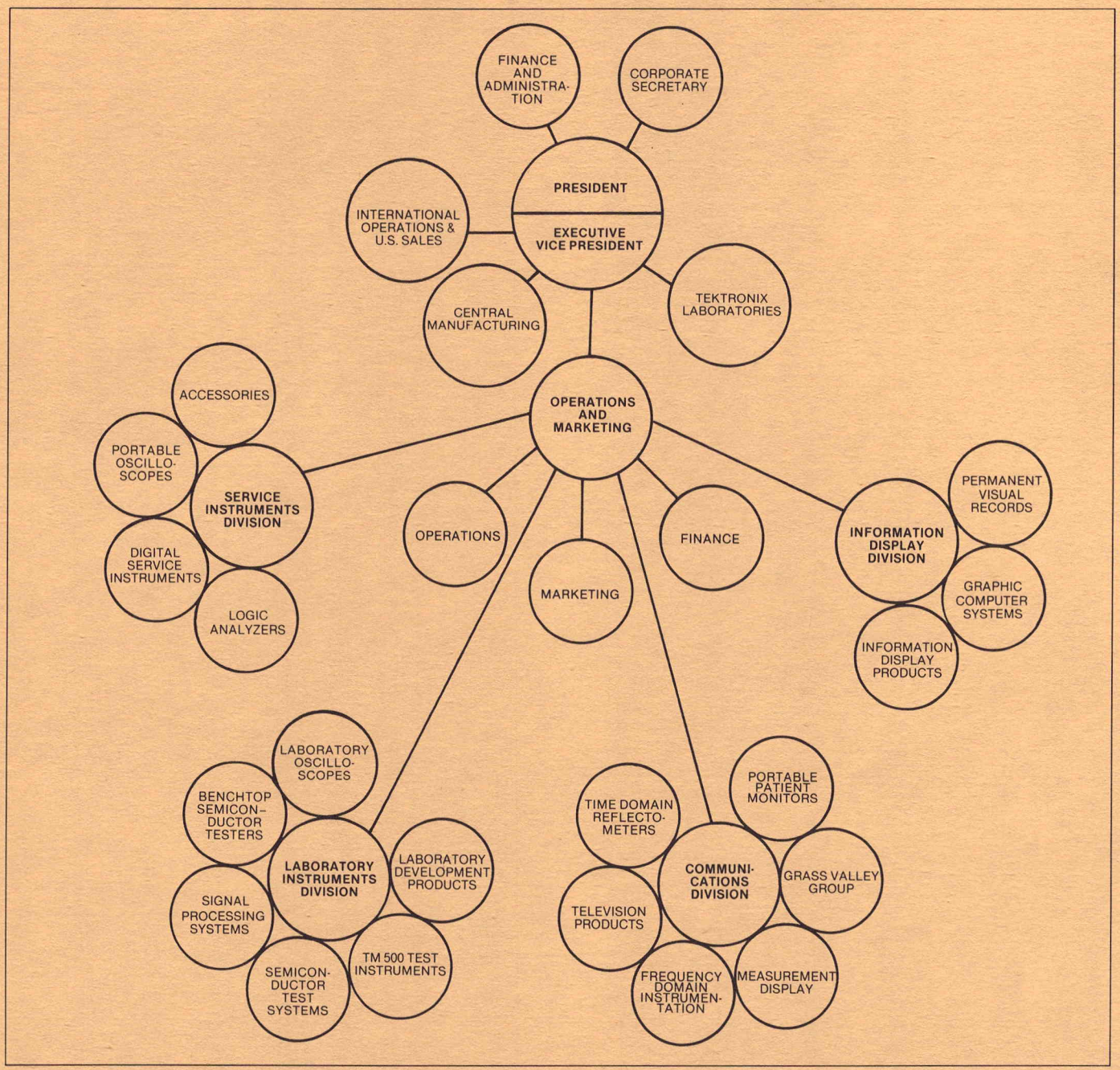

Figure 1. In 1979, the Test and Measurement Group and the Information Display Group merged into one group, Operations and Marketing. Operations and Marketing contains all the divisions and their respective business units. The diagram above describes Tektronix in the fall of 1979.

In other words, the people in each business unit choose the strategic direction the business unit will take. The corporate group or the divisions may decide which businesses we don't want to be in, but once they have decided that, it's up to each business unit to formulate their plans and carry them out.

MARKETING AND ENGINEERING RESPONSIBILITIES

I'd like to delve just a little deeper into business unit planning and talk about marketing and engineering responsibilites inside the business units.

Certainly, marketing has sales-support responsibilites, including creating advertising programs and training programs and defining what markets we're going after. Forecasting is a very important part of that. What is going to be the order rate next year? How fast is the market growing?

Product configuration is another marketing responsibility and involves working with engineering to define what product features to develop to satisfy a given market. This is a responsibility shared by both marketing and engineering.

A few years ago, we brought in a lot of marketing people because we really didn't have a good feel for our marketing needs. At that time, some engineering groups seemed to think that marketing was going to slip a piece of paper under the door on Monday morning telling them what a product needed to be and expect the engineers to just go about developing it — and that's all there would be to it.

Well, I certainly don't think that is even possible. Engineering has got to play a vital role in the marketing function. Engineering has to know what the market is and where it's going and has to develop a sensitivity for what we can do. Without that joint effort, our products won't succeed.

"Engineering has got to play a vital role in the marketing function."

Another engineering responsibility is designing with costs in mind; in fact, in some areas, we must rigidly design to cost.

PORTFOLIOS

Though the other speakers have talked a little bit about product portfolios, let me give you an idea of how we use that concept. In figure 2, we show profitability along the left side (as measured by return on sales), relative market size along the bottom, and the various businesses scattered within the shaded area over the graph. You can see that there is a wide distribution of business units across the chart. Those business units above the 0% profitability line are positive (some of them just barely). This gives you an idea of the different levels of profitability of some of our businesses. As was described before, there's nothing inherently good or bad about each position.

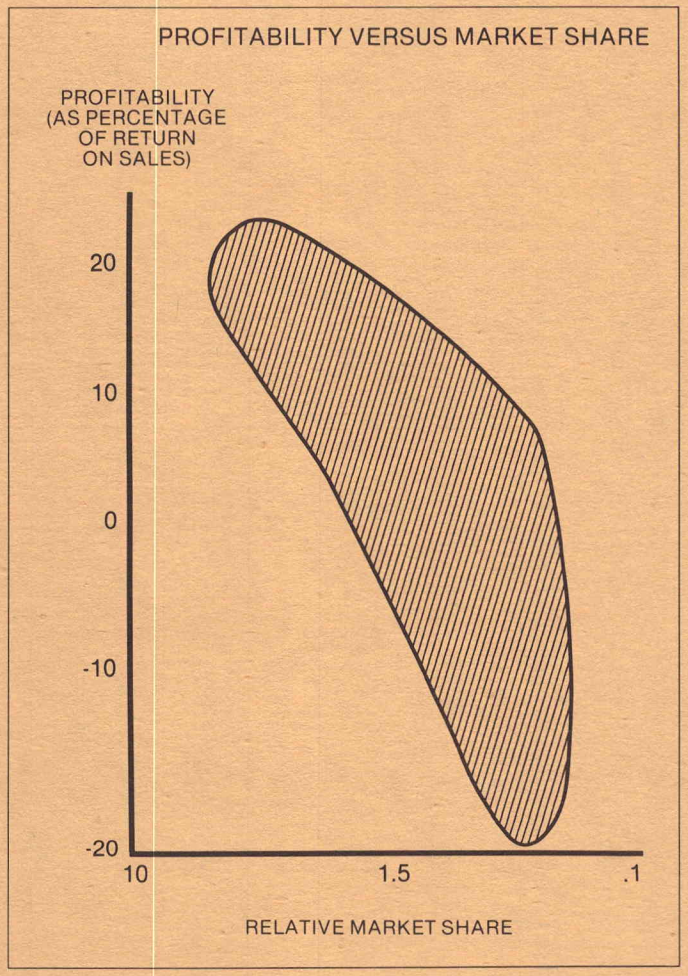

Figure 2. The shaded area above illustrates the range of profitability of our business units. Using the portfolio approach to management, the corporate group uses this information to allocate money from the more profitable businesses to those less profitable but worth developing.

Figure 3 shows engineering dollars as a percentage of net sales spent along the left side and relative market share along the bottom. The shaded area represents the distribution of our business units. Some business units show small market share with a large investment. This shows that some business units use an inordinate amount of engineering dollars in relation to the percentage of net sales. But these are businesses that we're trying to grow. They're growing at fairly rapid rates, many from 30% up to 100% per year. They won't always grow like that. Our intent is to grow them fast — sometimes that takes seven or eight years to do, sometimes longer, and sometimes we never get there and we have to bail out.

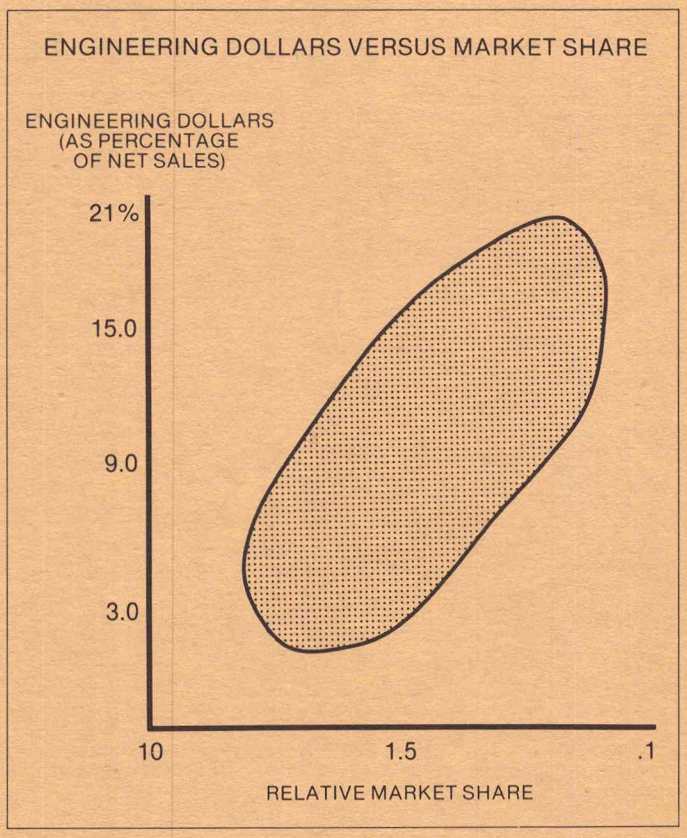

Figure 3. To develop our smaller businesses, the corporate group allocates proportionately more engineering dollars to those businesses with smaller market share. This graph represents engineering dollars as a percentage of net sales.

"... some business units use an inordinate amount of engineering dollars in relation to the percentage of net sales."

Some business units are cash cows. We don't expect these markets to grow rapidly, but they do have significant market share position. We use the cash they generate to finance other businesses to get them into a profitable position.

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PRODUCT DESIGN PHILOSOPHY

In discussing product design philosophy, we must more closely consider:

- diagnostics,
- mechanical packaging,
- compatibility,
- codes and formats, and
- controllers.

Certainly, **diagnostics** heads the list. Instruments are becoming very complex, service problems are increasing, and competent technicians are hard to find. Therefore, diagnostics within the instruments will be more important. You will see more and more pressure to include them.

"Instruments are becoming very complex, service problems are increasing, and competent technicians are hard to find."

Mechanical packaging. We've all heard about the Marlow Butler modular packaging system, we've discussed it and cussed it. However, we *must* have common mechanical packages wherever possible. We cannot afford to introduce thousands of new mechanical parts into the system every year. Any of you who are close to the assembly areas know what happens when one of these mechanical parts doesn't show up on Monday morning: we can't turn out a product line and we may even shut the area down. The result is that we're stopping and starting product lines because we can't get the parts. This problem is due, in part, to the proliferation of mechanical packaging parts. We must contain that proliferation.

Compatibility. As we use the General Purpose Interface Bus (GPIB) more, compatibility is becoming a real issue. We must make sure our products work together.

Codes and Formats. Hewlett-Packard developed the HP Interface Bus, a prototype for the GPIB. We're trying to make a similar contribution through codes and formats — this is the software side of the problem. There's every reason to believe that the IEEE will adopt our proposed codes and formats as a standard — or certainly most of them.

"There's every reason to believe that the IEEE will adopt our proposed (GPIB) codes and formats as a standard . . ."

Controllers. We have to develop a controller strategy. Each business unit cannot develop controllers on their own. If they do, they're going to develop their own software which won't talk to the one across the aisle. So, we gave the job of developing common controllers to IDD with support from LID, SID, and Communications to make sure that as many of the needs for controllers that can be met are met.

AUTOMATION IN MANUFACTURING

Manufacturing will be more of a concern in the next few years, and engineering must be aware of manufacturing concerns. We must use more components that are automatically inserted. We cannot live with boards that only have 20% to 30% of the parts automatically inserted and the rest hand-added. It's very likely that you are going to see additional constraints put on engineering to make sure we can automatically insert components.

We must look at manufacturing as a technology, and we're going to have to look at it from the following points of view: cost containment, control, automation, design constraints, and systems design.

With ever-increasing cost in some of these areas we must take advantage of automation wherever possible. We must have control systems in manufacturing that we don't have today in order to minimize material handling and inventory.

We must link computers to insertion equipment and automatic test equipment to monitor and control the processes throughout the manufacturing line as well as to control inventory and generate reports. In the next three years at Tektronix, the manufacturing area will see more change than any other part of the company.

"In the next three years at Tektronix, the manufacturing area will see more change than any other part of the company."

The Communications Division is the guinea pig for new automation. Within 6 months, you won't recognize the top floor of building 58. If Communications makes automation work successfully, then the other divisions will pick it up. The reason the Communications Division is first in trying automation is that we are smaller than the other divisions and the mistakes won't be as big as they would be in a larger division.

NEW TECHNOLOGY IN PRODUCTS

Microprocessors and software are in all our new products. At this point, however, we don't know how to manage software very well — many of you know that. It's not surprising because we don't have very much experience in this area. We're gaining experience rapidly, though we've made some mistakes. That, however, is the only way we'll be able to learn.

We've done some talking about VLSI (very large-scale integration); it is probably medium-scale integration or even small-scale integration compared to what some other companies are doing. I'm not sure that we can afford large-scale integration in many of our products because of the investment necessary in the chip design. We do not have high enough volume to effectively amortize this cost. We will surely continue to debate VLSI and, from time to time, I'm sure many of you will enter into that debate.

In the next few years, more products will require A-to-D converters. We will use them in virtually every product that we manufacture.

High-speed logic is something the communications and television people particularly need. We want to do real-time — that is, television-rate image processing. If you think for a moment about the 525 lines on your television at home and the 980 points on each line, to do simple things like rotating the picture requires a lot of logic circuitry, and the circuitry has to be fast. It's beyond today's state-of-the-art. You can certainly do it, but the required multiplexing with memory is a nightmare. We're aiming for logic that's fast enough to do that without all the multiplexing. That would open up vast markets to Tektronix generally and the Information Display Division particularly.

"The purpose of wall-to-wall strategy is to . . . lock up customer groups at the design stage and carry them all the way through service."

I'm sure you've heard a lot of talk about wall-to-wall strategy. The purpose of wall-to-wall strategy is to link design, manufacturing, and service, and come up with transportable software at each one of these points so that we can lock up customer groups at the design stage and carry them all the way through service. That is a formidable task and we're spending a lot of time and effort putting strategies together to make it work.

GPIB

We have many GPIB instruments currently under design or development. We have a tremendous need to reduce language problems via codes and formats. We will extend SPS BASIC and use it in many areas. The SPS group has done a lot of good work for handling waveforms and manipulating waveforms — we must take advantage of it. As I mentioned before, our approach to codes and formats has a very good chance of becoming the IEEE standard.

GPIB is now in a few of our products: for example, the 7912 (on the market now), the 1980 (a television instrument), and the 492 Spectrum Analyzer. So, we are doing a lot with GPIB — it's coming slow, but within the next year, Tektronix will be making significant contributions.

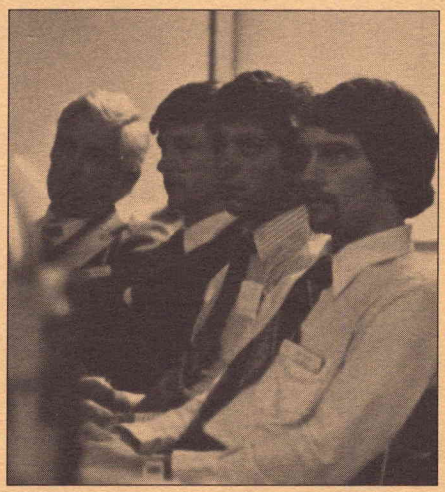
IN CONCLUSION

As we mentioned before, business units are the basis of business planning. We expect them to be successful as independent businesses as measured by market share and profitability. That doesn't mean that everything is going to be profitable tomorrow, but certainly goals are in place so that that possibility improves each year.

We're trying to develop competitive advantages through interdependencies and links. This is coming out of the sector strategies that we talked about. For example, we're trying to get everybody using the Marlow Butler Mechanical Package. Where we can't apply it, we modify it. To stay within that package, we sometimes compromise a little more than we otherwise would.

"We're trying to develop competitive advantages through interdependencies and links."

We will meet our corporate goals if each business unit in our portfolio achieves its worldwide objectives based on market share, cash flow, profitability, growth, development of technology, penetration of key segments, holding off competition, and assisting other business units. □



Tom Woody, Mike Reiger, Jim Towne, and Howard Mikesell listen as Tek business planning is discussed.

Mikesell continued (from page 12)

environment and how we should pit ourselves against the competition in that particular segment.

Sector strategy is a critical element of corporate strategy. It essentially defines the company's product and market directions. Sector strategies, in combination with technology, distribution, manufacturing, and financial strategies, make up our overall corporate strategy.

IN CONCLUSION

To recap, back in 1972, we had our first planning conference where we developed statements on values, purpose, defacto objectives, and so on. We tried again in 1973 and then, in 1974, we produced the Statement of Corporate Intent.

The Statement of Corporate Intent really describes what Tektronix is and what Tektronix wants to be. By understanding the Statement of Corporate Intent, you can see how you, as engineers, fit into the picture.

In 1975, we had a session in which we dealt with a lot of strategic issues and cross-organizational concerns. From that came the Corporate Objectives and strategic policies.

In 1979, we again revised the Corporate Objectives and began using the sector planning concept. You can see that there has been a high degree of change in planning at Tektronix. □

PART FOUR

JIM TOWNE ON CHANGE AT TEK

INTRODUCTION

So far, we've discussed Tek's basic structure, our philosophy of planning, and some of the structure behind our planning processes. I will talk about some basic values and a few perspectives that influence corporate decision-making and planning, and that ought to influence your decision-making.

One of the major reasons Tektronix began to formalize planning (about nine years ago) was that we saw the world changing significantly. To deal with this change, we saw that we needed to plan better than we had in the past.

"... none of us should be frustrated by Tek's not pursuing all of the neat ideas generated around here."

Putting the gist of what you've heard today in context, there are three guidelines for corporate management decisions mentioned in the preceding presentations that I'd like to highlight.

First, none of us should be frustrated by Tek's not pursuing all of the neat ideas generated around here. ***Tektronix will be a conservative company enjoying healthy, relevant growth.*** We're lucky enough to be in a position to discard high-return opportunity proposals; we're taking advantage of even higher-return opportunities.

"Conservative" doesn't mean that we're going to move slowly or operate crudely. It means that we're going to be consistent with that tag line on the Tektronix logo: we are committed to excellence. We are committed to doing things properly and well. Why chase high-risk opportunities when we have so many lower-risk/higher-return opportunities?

Second, ***we will not compromise our objective of excellence in all things.*** There's been some worry in the past few years that, in the face of growth and increased product volume, we might compromise our dedication to quality. It is true that the excitement and challenges of growth can easily distract our attention from quality. During the last three or four months, we have had much dialogue about quality and have realized that we must occasionally remind ourselves about its high priority.

The people who are stuffing boards at the bench, especially some of the employees who have been here for 15 years or so, are saying, "I haven't heard a thing about quality for the last few years. It's been output, output, output." Well, every once in a while something happens to remind you that you'd better re-examine your values or, if your values haven't changed, maybe you'd better re-examine what you've been communicating. I think that, especially during the next two years, you will hear much more about excellence in all things — including management. By the way, the engineering force at Tek has as much or more influence on and responsibility for quality than manufacturing does.

Finally, ***we will be a success for the very long term.*** In general, short-term considerations don't affect top management's decisions as much as the long-term health of the company does. That, of course, is a luxury for management only when the short-term results are looking good.

MORE DECISION-MAKING GUIDELINES

Other guidelines for management decisions include:

- ***Avoid spikes in business because of the downside.***

We often hear frustration from our sales force that sounds like: "Why didn't we go after that 10-million dollar opportunity? It would have only taken 10 engineers and two-and-a-half years, and we probably would have hired 500 people." One reason we don't go after that kind of opportunity is because at completion, we would have had to awkwardly redeploy those 500 people or let them go.

Jim Towne, Service Instruments Division manager.

Tektronix is not in the business of looking for spikes in orders and sales. By its very definition, a spike has a downside. Tektronix looks for healthy, ever-profitable growth. You can assume this value stands behind most of our decisions.

- ***Employees are important stakeholders and we don't intend to lay any off.***

We intend to provide an environment where employees like to come to work, where they have fun, where they are challenged. There's much evidence of how Tektronix

allocates significant resources to implement that particular value. When Earl Wantland took his job as president of the company, one of the first really difficult things he had to do was to lay off 350 light-manufacturing people. I've heard him say twice, with much emotion, that he hated laying off those people and he doesn't intend to allow this company to get into that situation again.

When I was in Corporate Planning, we regularly surveyed top management. One of the things we did was talk to the top guys to find out who they believed they worked for. Now, you could go to other large electronics companies and ask them who the most important people on their list of people to satisfy are, and you would get one kind of list. If you went to a telephone company, you would get a different list. If you went to a local drugstore, you would get an even different list of people.

"... the employee and the customer are the people management wants to satisfy first."

As we asked around Tektronix, the customer and employee continued to be at the top of the list of people that top management tried to satisfy. It was amazing to find that, for the four years I ran the survey, the list was the same year after year. If you went to other large companies, the shareholder, top management, the chairman of the board, or the board of directors would be the people at the top of the list top management tries to satisfy.

I assure you that the same values that came out of those four years of surveying are still prominent at Tektronix: the employee and the customer are the people management wants to satisfy first.

- ***Earl Wantland has an enormous commitment to uninterrupted earnings-per-share growth.***

Ten years ago, earnings-per-share weren't awfully important, but we're almost a billion-dollar company now. At these incredible growth rates, we'll probably be a 5- or 10-billion dollar company before we know it. It's shakey to do any linear extrapolation, but a few years back, it would have been wise to guess that the rate of growth would be 20% or 30% and that we would grow at an exponential rate. Well, in light of becoming a Wall Street company, clearly a worldwide company, our financial performance is critical to the guy who feels like he's sitting in the saddle and trying to make the company perform. Growth in earnings-per-share is one of the key indicators Earl uses to evaluate Tek's performance.

- ***The excellence we are now committed to goes well beyond technical excellence.***

The Tek logo used to state Tek was "committed to technical excellence." In the 1972 Annual Report, Earl was very explicit about our commitment to excellence in *all* areas. He said Tek will become more of a marketing company and more of a financially driven company without compromising its technical strength. It's very difficult to balance all the functions of a big organization so that they all play together. Above all, however, we're committed to excellence in as many places as we can find to be excellent. It's a tough task, but I assure you it's the topic of conversation more than three times a day around here.

- ***We will project an image of ourselves as quietly elegant.***

About a year ago, the 7000 Series generated an advertising campaign to position that product line and get ready for the introduction of the 7104. We were trying to achieve a high degree of awareness among customers and a strong leadership position in the market. Well, how do you do that? One way is to use large, bold letters, fluorescent colors, and stark graphics. At the time, I was division manager of that particular group. We did a great job; we researched it and felt sure that the people who saw that style of ad in a technical magazine wouldn't feel negatively about a company that ran it.

We ran the ad once. Earl quickly pointed out that, whether it was effective or not, there is a position that Tektronix wants to fill in the minds of the world out there: We are a high quality, quietly elegant, soft-spoken, but confident company. Everything that we do in our communications, especially the extremely visual things (such as advertising and graphics), we will do in a way that is consistent with a quietly elegant image. This image describes how we now attempt to position ourselves in ads and pitch ourselves to the world. We won't be doing any more flourescent ads.

- ***We have recently changed our goals from "a" leader to "the" leader.***

I was in marketing for a long time and, like the sales people, I used to get very frustrated. There's a competitive fever you get when you're competing in the marketplace. Something that contributed to the high level of frustration was that we couldn't get the corporate group to say we will be *the* leader in the world. It was adequate to be *a* leader.

How do you know if you are a leader? Well, you have good financial performance, your products are high quality, and the world knows you're really a good company. In the last year, there's been a change — we're giving it all we've got to be *the* leader. We think it's within our grasp.

"Half the people in this company weren't here three-and-a-half years ago."

Determining the leader, however, becomes a semantic issue. For example, if you define the test-and-measurement market one way, we're a little bit larger than HP; if you define it another way, they are larger.

CONCEPTS OF CHANGE

I'm sure you all feel the enormous change that we're undergoing. The period between 1975 and 1985 will be remembered as a time of significant change for Tektronix. Half the people in this company weren't here three-and-a-half years ago. *That* is change. Change, however, is healthy — everything changes.

Continued on page 20

Flexibility, alacrity, and responsiveness to the environment are characteristics we want to instill and maintain in Tek's culture. We don't intend to create a steady-state condition.

Innovation and experimentation will be key parts of management activity. All employees must intelligently deal with innovation and experimentation. However, you folks, as engineers, are the most visible innovators and experimenters; you can expect an equivalent amount of innovation and experimentation from other areas.

Here are some concepts of change that highlight what Tek has experienced and will experience in the 1975-1985 period.

Concept 1: We're experiencing exponential growth. I alluded earlier to the number of employees who are new to Tek. We're not sure that management's experience, dealing with the growth during the last 20 years, is adequate preparation for the next ten years.

All of us make decisions based on our experience. How else do you make decisions other than on your data base, the experience you've had, and how you've made decisions before? If a strategy or decision worked out well before, you will make similar decisions in the future. At Tektronix, we acquired all of our experience during a time when, if we grew 30%, we added 200 people. Now if we grow 30%, we're adding 6,000 people.

The employment office has to grow at the same rate as the absolute number of people we're bringing in. We have more and more competition in our local labor-pool marketplace. Intel isn't making it easy for us, and there are other companies that are coming into this area as well. For example, National Semiconductor, with 2,000 people, will be moving into Vancouver soon. HP will do likewise.

So, in the face of exponential growth, turnover, and adding lots of new people, this is going to be a very challenging period for us.

We take a lot of pride in our value system. Committed to excellence — that's a tough thing to communicate to people who haven't been here for very long. Communicating values is a significant challenge to top management. Very few of us have been here long enough to know what Tek values really mean.

"There's now competition not only for our customer base and key employees, but also for acreage, for pools of labor . . ."

A 10% error in our forecast is going to have an enormous effect now compared to a 10% error a few years back. If we make some bad assumptions, we can negatively impact the community we are in. We have social as well as business responsibilities. We had better make our plans and assumptions properly.

There's now competition not only for our customer base and key employees, but also for acreage, for pools of labor, and even for things like "effluent capability" (getting rid of manufacturing waste products).

If we want to build a plant, we've got to find a small town that will let us do fabrication. There are very few towns in the world that are willing to let us dispose of the acids and chemicals that we use. So, there are many electronic houses like ourselves who are competing to find available sites. Our competitors have the same problems, and that includes the computer companies, the semiconductor manufacturers, and the consumer electronics companies as well as our traditional competitors like HP, Philips, Gould, Fluke, and Schlumberger.

Figure 1 demonstrates what exponential growth means for Tektronix. The graph starts in 1947, when Tektronix started. I can't believe the tremendous growth, but it's what we're dealing with right now.

Concept 2: We are moving from mostly analog stand-alone instruments to digital, systematizable, software-driven products. Right now we have 13 business units that are actively working on GPIB activities. Still, we must penetrate new segments. Our sales are weak in the manufacturing segment of our markets; we aren't selling much into the manufacturing departments of our customers, and that looks like a good opportunity.

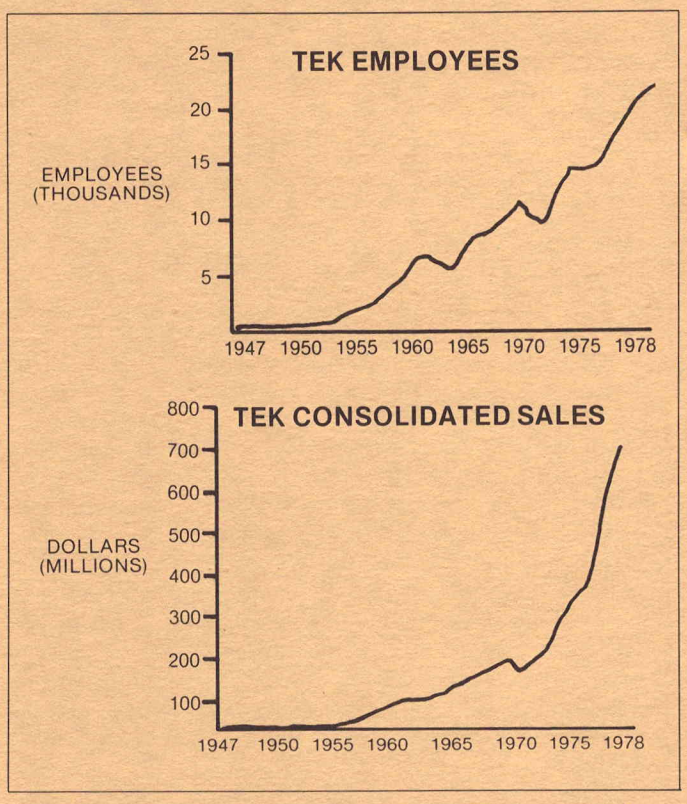


Figure 1. The graphs above demonstrate Tek's growth from 1947 to 1978. The number of employees has grown in direct proportion with our growth in sales.

There are other opportunities that we should grasp. We must develop effective strategies for the marketplace so that our strengths generate product lines that allow us to be more financially successful than our competition.

Most of you who have tried to talk to your managers about source and object languages, object code, and firmware concepts know that many of them are not familiar with software jargon. The instrument world, which we know well, is very different from the systems world. It's tough, especially for top managers, to relate to the kinds of risks they're taking and the nature of the management task for software. This is a significant concern. I believe we are learning quickly, but it is your job to realize we're still learning and to help make opportunities clear, concise, and understandable to management.

"... it is your job to ... help make opportunities clear, concise, and understandable to management."

SPS and STS have been our systems businesses for a long time, and they have been tough businesses for us. We've done very well and are prominent in those areas. If technology leadership is an important goal, SPS and STS have given us that. But we have had a very tough time managing the manufacturing process, generating cash, and doing all the other things that businesses have to do.

How should we handle systems integration? There's a lot of controversy about that. Do we do it here? Do we do it out in the field?

Controller language issues are interesting . . . and difficult. We've got a lot of controllers, and there are a lot of arguments about what kind of languages we want to use. Choosing is very difficult, especially because we, as a company, are trying to shoot at a moving target — a changing software and hardware technology. I believe we are solving this problem effectively now; time will tell.

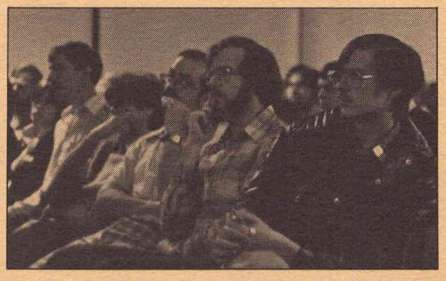
We've discovered that managing software is different from managing hardware. How many people can boast about how well we're managing software right now? It's a tough task . . . we're studying the problem and we're learning. One thing that we can do is spot successful people. We have more and more managers who have managed software problems well. Wim Velsink (director, Tek Labs) brought in some of the world's best software people to advise us on managing software. I assure you it's a subject that top management talks a lot about.

"... we ... are trying to shoot at a moving target - a changing software and hardware technology."

On the other hand, while we're organizing the business units, there are forces that pull in many different directions. Should we centralize software? Probably not, but maybe there are advantages if we do. Big houses like IBM have done a lot of centralization to maintain software homogeneity. It's tough, but it's not an invisible issue — that's the best thing I can say right now.

Concept 3: We're trying to become more marketing oriented. In 1972, the Annual Report said that we're going to become a more marketing-oriented company without diminishing our great technical strength. At that time, we hired a lot of marketing people and brought a lot of people back from the field. But if you examine our history, you will see that we didn't generate many products shortly after that time. Some people have argued that the engineers were saying, "Okay marketing guys, tell us what products we ought to be designing because we understand that's what marketing people are supposed to do." The marketing guys were mostly new to their jobs. For quite a while, the process left us without much product definition and we did not have much technical progress in our products.

Right now I think we have struck a balance: the business plans we recently reviewed are very hardware oriented; marketing people have a better communication link with the manufacturing organization; and engineers feel sufficiently confident to take a position they feel is appropriate for designing a hardware product. It's likely, as we hit the 1980s, that we will be able to integrate the technical perspective with the marketing perspective and make sure we don't implement technologically superior products that don't have marketplaces. We probably won't be implementing many products without having proprietary or technical strength that enables us to make money with it. We must keep our marketing and engineering perspectives in balance.



Over 600 engineers attended the three Forum 15 presentations held in fall 1979.

The company has only recently learned that the sales function and the marketing function of a business are very different. Most people understand that now. We've hired lots of marketing (as opposed to "sales") people during the last few years. We've segmented and strategized very well on paper, but we haven't done very well at taking those concepts to the marketplace. Still, we're far better able to do it today than we were in the past, and we will continue to improve.

Concept 4: We're diversifying our products and our markets. It's interesting to ask people what the first thing is that pops into their minds when you say *Tektronix*. Almost everybody says *oscilloscopes*. In 1969, about 85% of Tek's business was oscilloscope-based, both accessories and scopes. A one-product company is technically, structurally, and financially risky, and management began changing that one-product philosophy. We now have 19 business units, only two of which are oscilloscope-based. We *are* diversifying.

There was a time when we sold primarily to electronic engineers; now, we sell to lots of markets and users, like the people that IDD has sold to and will continue to sell to.

Continued on page 22

We will continue to be diverse and to diversify with lots of new products, and we're investing aggressively in some of our businesses that have a small market share. We're investing heavily in some selected areas and aren't getting much revenue back this year, but don't think that it's out of control. Those things are all planned.

Concept 5: We're trying to develop professional management. Earl Wantland, Bill Walker, Larry Mayhew, and all the group vice-presidents are relatively young compared to top management in other companies like ours. Yet they have a lot of experience at Tek, and they have very strong convictions.

"We don't have the luxuries we once had in being the only electronics firm in the upper lefthand corner of the U.S."

Sometimes its tough to remind ourselves that we're creating a fun place to work while, on the other hand, we've got someone who's playing by somewhat different rules living down the road. We try to be honorable and have high standards that direct our behavior. Yet, there are some other people who are moving out of Silicon Valley, where they really play hardball, and moving into our backyard. We don't have the luxuries we once had in being the only electronics firm in the upper lefthand corner of the U.S. I think we all understand that the game may have changed, but we must be careful not to modify our sense of ethics.

We're going to have to manage with experience curves in mind. You've probably heard of Texas Instruments' plans to drive costs and prices down. Those plans aren't realized by themselves. Costs don't just happen to get lower as accumulated experience doubles. To accumulate experience and thereby lower costs, we have to manage as professional managers.

We should be devoting a high percentage of our time to planning. There must be better planning; we're not bad, we're probably in the 99th percentile of electronics firms as far as planning is concerned. Most companies are amazed at how well we do, but the fact is, we're going to have to do better.

We are going to have to control, innovate, and be efficient.

We cannot tolerate mediocrity.

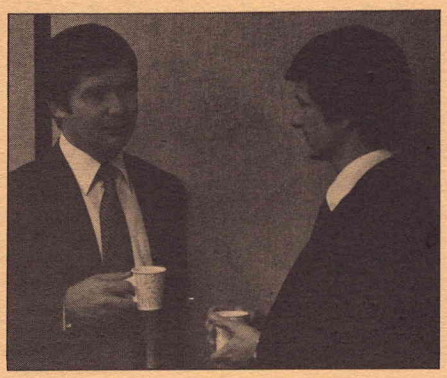
Another change in management perspective is reflected in our relationship with an outside consultant, Walter Mahler. Tektronix was a monolithic, functionally organized company for a long time. Five years ago, we started creating general management jobs, but nobody had training for a general management position. Engineers who became general managers tried to be both engineering and marketing managers. It took a long time for engineers to learn what marketing was all about. Likewise, marketing and sales people had much to learn about engineering management. Today, our expectations are that general managers will understand manufacturing and finance as well as marketing and engineering.

We've invested aggressively in 40 or 50 of the top managers in the company so that they can learn to be general managers. That has been a significant investment. We're now investing in middle management's learning about general management. Walter Mahler is an outside consultant-mentor-teacher whom we've hired to improve our general management capability. Being a good general manager is as critical as being an effective specialist.

Being soft or gentle is not a Tektronix value. Being professional, being sharp, being good (and that may mean being tough) are Tektronix values. We're going to do what it takes to be a good company. Many of us have heard examples of departments at Tektronix where it's rumored that, if you stay around for 90 days, you've got a job for life. That isn't true anymore and I don't believe it ever was; however, we'd better make sure we've cleared our minds of that rumor and all that it implies.

Concept 6: We have changed from a functional to a divisional organizational structure. These days, we focus on results, responsibility, and accountability. Performance is measured monthly and is very visible. There is more emphasis on planning and the use of those plans. We've had many struggles in merging strategic and five-year plans with our one-year operating plans. It's been very difficult.

Each division has worldwide responsibilities, but we don't have worldwide information on cash flow or profitability. Our information system needs work to help us manage some of the activities for which divisions have accountability. The need for coordination and communication has greatly increased.



During a break, Jim Towne and Larry Sutter discuss the forum.

Concept 7: We're using sector planning strategy. Sector is a word we'd never heard in this company before last spring. I'm told Bill Walker said, "I'll tell you how I feel about this company . . . we have *circles* here." (How do you tell someone they're in charge of planning for one of the three circles at Tektronix?) Then we heard that General Electric used the term "sector." Our usage, however, may not perfectly parallel GE's.

The issue that clearly created a need for sectors is that we have 19 business units, each of which we treat as an independent planning unit. If each were saying, "Support groups, here is how you must help me implement my strategy," then we'd be pulling our support groups in 19 (or more) different directions.

So, we're going to try sector planning. It's a conceptual arrangement that we intend to try to validate. It's still at the hypothetical level in terms of whether or not it will be useful. We think it will be. We'll try to cluster business units, pull them together more, and hopefully generate some fruitful results.

"...we decided to be the leader in those sectors, not just a leader."

The corporate group met at Bowman's in April (1979) and we started tackling our problems. At that meeting, we decided to be *the* leader in those sectors, not just *a* leader. It is a new concept that you're going to see much more of in the next few years.

Concept 8: We're financially driven now. As those of you who have been here a while know, there was no budgeting or rigid, formalized, comprehensive financial planning during Tektronix' first 25 years. If you needed something, I'm told, you went and bought it. I wasn't around then, but I was around when the budgeting process was implemented, and I assure you it was a tough implementation.

I try to think about what it must have been like. Sales and profits were there to cover expenses, and it was a nirvana for a lot of folks. But life gets tougher when you have competitors trying to kick you in the shins while you're getting larger, becoming a marketing company, and diversifying your product line. So, we began budgeting and doing more financial planning.

Starting in 1972 we changed dramatically. Some people feel we went to an extreme the first few years. We had quarterly budgets; it was ridiculous. We still don't know many of our real costs, that's not a secret. As an engineer develops a product, you get one figure for product cost, and that number can double or triple by the time you get the product out. It's an estimate and it's the best we've got. We need to work on this problem.

Financial information systems don't match the objectives of our planning process very well. Even though we insist that cash flow is the ultimate measure of a business unit, we can't really tell you what it is.

The shareholder is very important now. Shareholders may be gaining on customers and employees in our list of people most important to this company. Consequently, we're striving for consistent growth in earnings-per-share.

Concept 9: Manufacturing must be a technology. Manufacturing is not a ho-hum area where we dump products and expect people to do just the easy stuff. Manufacturing is where we make our money. We don't make money by managing divisions, and we don't make money by engineering. We make money by building products, getting them to customers, and getting customers to send money back for them. We need to do that in as much a state-of-the-art way as we engineer products or manage the company. Some of us have forgotten that principle over the years.

All divisions have done a lot in terms of automating and improving the manufacturing processes. We are exerting much effort to drive costs down through automation and systemization . . . and we've raised prices. The other thing left to us now is to design the cost out of the product. This subject hasn't received as much attention during the last ten years as engineering, marketing, and financing have.

IN CONCLUSION

One of our primary objectives in this presentation has been to give you a sense of the context and values that guide decisions and actions at Tektronix. The three things that we do know for certain are:

- Tek is becoming bigger and more complex. We can look at the future, but it's difficult to know what's out there. Don't be dissappointed if decisions are reversed here and there. The future is not perfectly predictable. We're working in an unsure world and we have to base our decisions on probabilistic data.

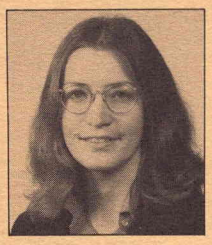
- The more we all understand about each other — our goals, our styles, our problems, our philosophies —the better job we will do helping each other be successful. That's the name of the game. One of the reasons we choose not to be geographically dispersed is that we can take advantage of togetherness.

- Mutual support and interdependent objectives will be the basis for organizational decisions far more in the future than they have in the past. We will expect people to cooperate. We will expect people to use similar protocols, software languages, packaging schemes, and maybe even similar advertising campaigns. We will expect more togetherness than we have in the past. We *must* help each other. □

To accommodate the large number of Tek engineers wanting to attend the Reverse Forum, the EAC sponsored three presentations.

TEK SPS BASIC TOP-DOWN EVALUATION PROCEDURE

AN EFFECTIVE SOFTWARE TEST PROCESS



Cindy McMeekin is a software engineer in Signal Processing Systems Development. She has been at Tektronix for almost two years since receiving her bachelor's and master's in computer science from Purdue.

This article outlines an evaluation procedure we use to test Signal Processing Systems (SPS) BASIC routines for accuracy and adherence to design criteria and programming standards. A **module** (a group of related subroutines such as those that form a command) is the fundamental unit to be tested. With this procedure we test each module and integrate it into the software system before evaluating another module.

Programmers in SPS perform the tests in a top-down fashion, using the levels in a subroutine hierarchy graph to divide the tests into groups. Typically, all subroutines in the ith level are tested before the subroutines in the i + 1st level. To illustrate how we use the top-down procedure, let's assume a set of subroutines in one module are related as in figure 1. In this case we would perform tests on level 1 (subroutine A) in order to evaluate integration of each new module into the system formed by previously tested modules. Next, we would evaluate level-2 subroutines. This process would continue down through each level to the fourth level. Stub subroutines can replace some of the actual subroutines at the next level down when testing all but the lowest-level subroutines. Stubs can be very simple, for example, "exit," "print a message," and "timing loop."

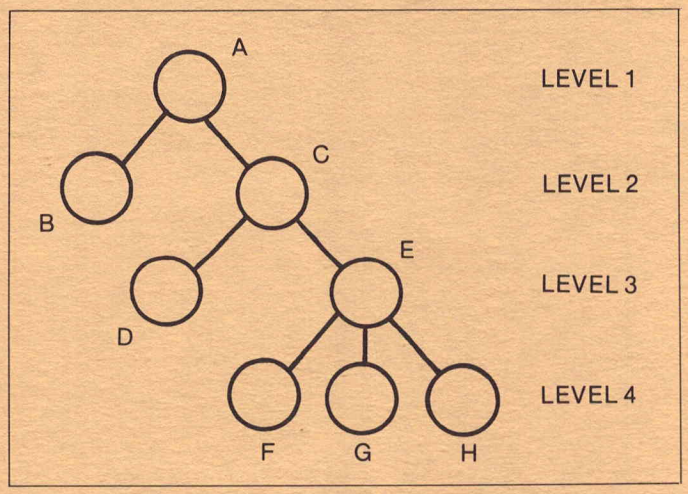


Figure 1. Top-down structure of subroutine in a typical software module.

The function of the specific routine determines the type of stub we would use in a top-down procedure. In the example from figure 1, we would start testing subroutine A with the stubs for B and C; and next test subroutines B and C with stubs for D and E; and proceed to test subroutines D and E with stubs for F, G, and H. Finally, we would integrate subroutines F, G, and H into the module being tested and evaluate the module without stubs. To better isolate errors, we would evaluate subroutines one at a time.

EXPERIENCES USING TOP-DOWN EVALUATION

We used this evaluation system on the extended-memory version of TEK SPS BASIC, which is written in MACRO-11 assembly language that runs on the PDP-11 family of computers. The system is organized into a monitor and more than 150 non-resident commands and drivers, all of which are loaded from a peripheral device when referenced in the user's BASIC program.

To develop an extended-memory version, our group needed only to revise and add to an existing system, TEK SPS BASIC V02-01; therefore, it was not necessary to use stubs during the evaluation.

We tested the monitor with a **C1 measure** (a test set that forces all branches to both branch and drop through to the next statement). For this purpose, we wrote an automatic tester. This tester was simply a non-resident command which set up inputs for a routine, called the routine, checked the outputs against expected outputs, and then documented any discrepancies; however, this tester did not automate the C1 coverage check. Non-resident modules were tested from BASIC programs.

Two areas, boundary conditions and bad syntax, required more attention than one might expect. Boundary conditions, such as negative numbers and extremely large numbers, are often a source of errors in systems programs; therefore, we tested them thoroughly. The second area, bad syntax, includes problems in user programs such as a numeric argument appearing where a string is expected, or an incorrect number of arguments. Because it is important that the software not fail when it confronts the unexpected, this area also required thorough testing.

This top-down evaluation scheme clearly doesn't address some special problem areas. Because the TEK SPS BASIC software is a data-acquisition and instrument-control

Continued on page 26

MAJOR STEPS IN THE TOP-DOWN EVALUATION PROCEDURE

I. Research

1. Become familiar with the design and implementation standards specific to the project.
2. Study system design specifications to become familiar with the system, making sure you understand all the specifications completely.
3. Read the external and internal specifications to understand the overall function of the module being tested and its relation to other modules within the system.
4. Sketch a block diagram, like figure 1, of the relationship of subroutines in the module.
5. For complicated flow-of-control in a subroutine, sketch a control graph and calculate the complexity. Then redesign unnecessarily complex subroutines.

II. Test Specifications

There are three major types of evaluation tests: (1) tests for interactions between subroutines within a module and between a module and the rest of the system, (2) tests which are internal to a subroutine, and (3) hardware-related tests. General tests of type 1 should be performed level-by-level, from the top down to the lowest level; however, if another order makes sense, use it. Evaluation tests are based on external specifications, internal specifications, and program code.

1. Test specifications for system and subroutine interaction.
   a. Determine all possible interactions between the module and the system and then design the tests that exercise all interactions (or at least use a carefully selected subset). Be sure to consider the effects of panic stops, interrupts, error conditions, and power failure.
   b. Design tests to supply data and conditions which exercise the interactions between the module's subroutines.
   c. Design tests to verify all module capabilities and limitations listed in the external specifications.
   d. Design tests to exercise the various forms and ranges of module inputs. If the module is a command in an operating system, verify the various legal-syntax forms including: number, order, range, and types of arguments as well as illegal arguments and keywords.
2. Test specifications internal to a subroutine. This kind of test is performed on each subroutine in a module.
   a. Read the subroutine's code to verify that comments make sense and have reasonable frequency, that programming standards are met, and that the following header information is correct: module name, one-line brief description, detailed description, routines called, calling routines, input, output, possible errors, and resources used.
   b. If necessary, design stubs for the called routines.
   c. Design tests to verify each subroutine's output and returning conditions. Include verification that registers contain the correct values and that values in tables are correctly modified.
   d. Make sure that the preceding test (2c) checks all possible error conditions and exercises all branches in the subroutine being tested.
3. Hardware-Related Tests

   Ideally, you should test TEK SPS BASIC software with all expected hardware configurations. But, running all of the tests outlined in I and II with all hardware configurations is often impractical; therefore, you must use a subset of all possible tests. A typical subset of tests could test a different set of commands on each configuration. When choosing a subset, consider hardware differences that affect different commands. For example, if a command's performance depends on timing and the command must run on a family of computers whose members vary in speed, you must test the command on a representative computer of each performance level.

III. Test Implementation

Because test programs are used to initially evaluate a module's performance and to re-evaluate the module if a modification is required, the program should be easy to use, well documented, and complete.

1. Document exactly what is tested, how it is tested, and how the tester is run.
2. You should code tests in one of two ways:

   Method A. At the beginning of a project, not enough software is coded for a skeleton system to run, even in a top-down implementation. For this case, write the tester and any necessary stubs in the implementation language and link them with the routine to be tested. (We used method A on the first implementation of TEK SPS BASIC, but now we use the method described in B, below.)

   Method B. Farther along in the implementation, the module to be tested can be linked-in and tested using modules which already have been evaluated and integrated into the system. This process is faster with top-down implementation and testing than with a bottom-up implementation.
3. These programs, including stubs, should be archived, documenting exactly what is tested, how it is tested, and how the tester is run.

IV. Test Execution

1. Run the tests.
2. If minor bugs (not caused by design error) are found, fix them and restart the test execution cycle at step one.
3. If a subroutine-level implementation error is found, return the subroutine to the programmer for correction. After correction go back to step one.
4. Inform the project leader about design errors and stop further testing of the module. After the module is redesigned and recoded, go back to step one.
5. After you finish the tests and verify the functions of a module, you can integrate the module into the master copy of the system.
6. Record results of the test in the test log book.

ENGINEER IV PROFILE

RONALD ROBINDER

Ronald Robinder, Materials and Processes Staff, ext. 6643 (Beaverton).

Engineer/Scientists IV's and V's serve as technical resources both inside and outside the company. To increase their visibility to the Tektronix technical community, *Technology Report* publishes profiles of these individuals.

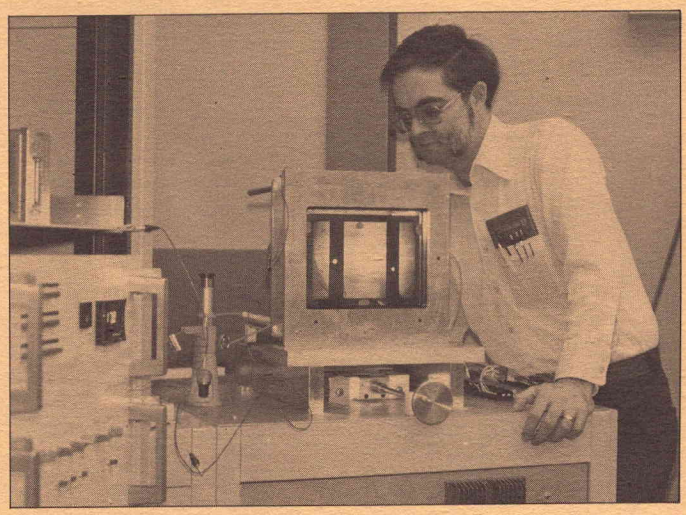
Ron's field is color-display technology. Since rejoining Tektronix five years ago he has sharpened and enlarged the expertise in shadow-mask technology and in special-purpose CRT design that he previously employed at Zenith Radio's Rauland Division and at Raytheon. He also worked at Tek from 1962 to 1965.

Originally from Spokane, Washington, he graduated from Linfield College in McMinnville and received his Ph.d. from Duke University in Durham, North Carolina with a major in Physical Chemistry.

Ron is continuing his investigations in shadow-mask color CRT technology and has a patent application on file in this area, as well as several disclosures.

Other projects have included investigations into the improvement and applications of penetration-color cathode-ray techniques. He presented a paper on the subject: *Two-color Display Tube* at the Electro-Optical Systems Conference in 1967. Penetration-color CRT's use multi-layered phosphors to produce traces of two or more colors which are selected by using different accelerating voltages.

Ron holds four patents on display technology ranging from storage-tube screens through photo-chemistry to contrast-enhancing filters for CRT's. His expertise in color-display technology has been recognized in **Who's Who In The West.** Ron represents Tektronix on the Joint Electron Device Engineering Council (JEDEC) Committee on Phosphors and Optical Characteristics of CRT Screens (JT-31). □



Continued from page 24

system, we use special testing to verify that external events and combinations of external events will not cause the software to fail. It is impossible to test all combinations of all events; therefore, we test only events or combinations which seemed particularly "dangerous" (there is more than a small probability of bad results). Careful design helped minimize the risk of only testing the dangerous subset.

With real-time code, we exercise special care. For example, if a programmer omits an essential software test such as waiting for a peripheral to become ready, overhead from a tester may allow enough time for the peripheral to become ready and the software will run correctly. But when the tester is not linked into the system, the peripheral may not have enough time to become ready and the software will fail.

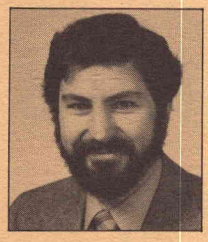
CONCLUSIONS

Top-down evaluation is effective; it assures that all modules are tested to a specific level. Because the tests are systematic, you can uncover subtle bugs and fix them before releasing the software. Earlier releases of TEK SPS BASIC software tested in a similar fashion produced few customer-reported errors.

FOR MORE INFORMATION

For more information, call Cindy McMeekin on ext. 1148 (Walker Road). □

FEEDBACK LOOPS HELP MANUFACTURING MONITOR PRODUCTION QUALITY



Ken Cone manages Information Display Division Test Engineering; he has been with Tektronix for 12 years. His first ATE (automated test equipment) experience was with a team designing a functional circuit-board tester for the TEKTRONIX T4002 Graphic Computer Terminal. Since that time, he has worked in Machine Control Engineering and in IDD Manufacturing Support.

Ken based this article on a presentation he made in Forum 16 (Automated Testing). The Engineering Activities Council sponsors forums to offer engineers and scientists an opportunity to tell Tektronix managers what engineers and scientists consider important in new technology.

Testing in manufacturing is required for two reasons. First, to assure that a product provides the performance that the customer expects, and second to validate and correct the manufacturing process.

This article describes feedback loops around ATE that help solve the problem of process validation and correction.

FEEDBACK LOOPS

To monitor production quality, manufacturing groups can use two feedback loops around circuit board automatic test equipment.

As shown in figure 1, the first loop carries information from the test equipment to board assembly; the second loop carries information from the product assembly and test areas back to the ATE. The information in these loops describes board quality: how many boards failed, and what types of failures there were.

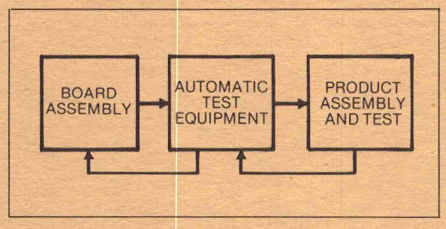


Figure 1. To monitor production quality, Manufacturing can use two feedback loops around automatic test equipment that tests circuit boards.

QUALITY CONTROL

ATE is used in one kind of quality inspection station. Quality control (QC) groups cannot inspect quality into a product; Engineering must design quality in, and Manufacturing must build it in to products. For example, in a 100% QC station at the end of a production line that has no other inspection points, what level of quality will the customer receive? Poor, because 100% test coverage is almost impossible to achieve; therefore, some defects will get by.

Next, consider multiple QC stations at several manufacturing locations. ATE is an important QC tool in manufacturing. Placed at various points, ATE can help assure fault-free boards. Figure 2 summarizes these two approaches to QC.

ATE'S PLACE IN THE TEST PROCESS

Manufacturing uses various forms of testing to detect different types of faults. **In-circuit tests** generally find board assembly problems. **Functional tests** run boards under actual working conditions. **System tests** verify that all boards work together as a product. As figure 3 shows, the trend for error fallout and deletion is generally downward. Error fallout is also overlapping: several different test sequences may detect similar faults (for example, solder shorts). This overlap is expensive.

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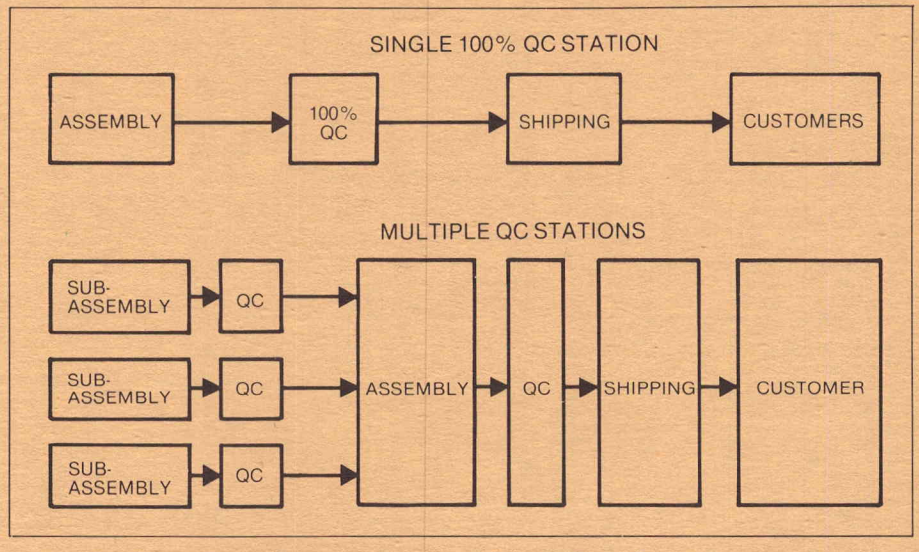


Figure 2. When Manufacturing uses multiple QC stations, the manufacturing process is much more effective than using only one QC station because 100% test coverage is very costly and almost impossible to achieve.

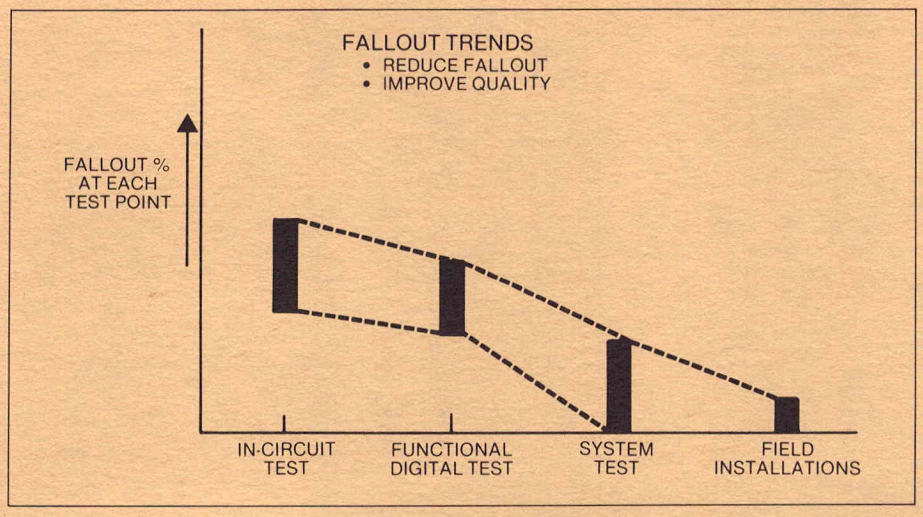


Figure 3. With each succeeding type of testing, the error fallout trend is generally downward and overlapping.

IMPROVING THE MANUFACTURING PROCESS

Now let's go back to examine how we can use ATE to improve the manufacturing process.

Let's look first at in-circuit ATE. By measuring each component on the board individually, in-circuit tests can detect solder shorts, wrong parts, and parts inserted backward. Faults detected at this level of test are found in parallel. The first test pass detects shorts and the second pass detects most other problems. In-circuit ATE can detect several faults in one pass.

DATA

Now let's look at data from one day's ATE operation. Manufacturing detects and fixes faults through a combined effort of the ATE's diagnostic software and the repair person working with a diagnostic procedure. Figure 4 shows data (in pie-chart form) taken from the repair records that accompany each board. Using the data to identify problems provides an excellent way to improve the board assembly process.

The pie-chart, in figure 4, raises several questions. Why does Manufacturing wait until the ATE test to find dirty boards? Why are there wrong parts on the boards? Can Manufacturing correct these problems with a better build procedure? Can Manufacturing correct solder shorts by using an improved CAD algorithm or changing solder temperature?

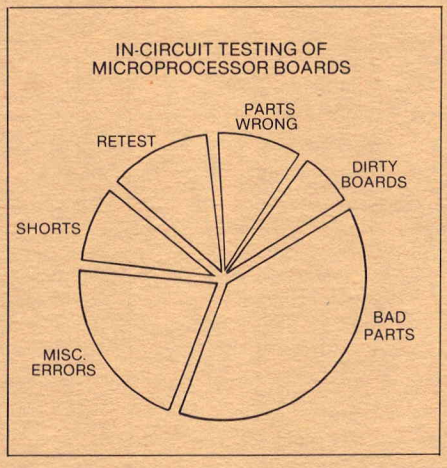


Figure 4. An example of fault data, taken from one day's repair records (the records accompany boards through the manufacturing process).

Attacking these problems on a day-by-day basis can prevent further occurrences of the defects. Also, concentrating on solving the most important problems is the most effective way to eliminate faults. (Miscellaneous errors are usually not important.) Using this pie-chart data enables us to fix the problem and check for follow-up.

MORE FEEDBACK

The next example (in figure 5) of feedback from ATE is data from a Gen Rad functional digital tester. This machine and its software provide power and operating stimulus to the board under test. Tests at the functional-test level should find bad parts and part interaction problems. The functional digital tester finds, one at a time, faults detected at the board level, a more costly process than finding faults in parallel. It is important to find broken runs, shorts, and wrong parts before this stage of board-level testing.

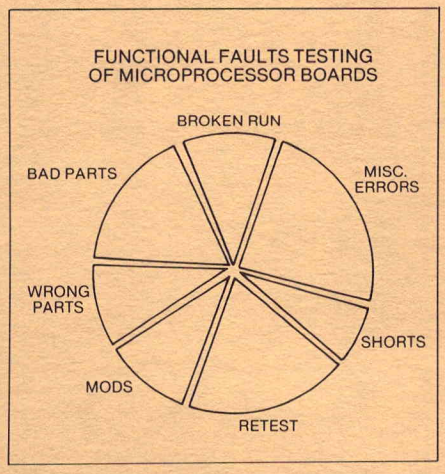


Figure 5. An example of fault data gathered by a functional digital tester.

Manufacturing uses a daily summary of faults (extracted from the repair records) to make more information available for improving the process, enabling us to find defects before board-level tests.

Fixing problems may take the form of training board builders or using better mod implementation procedures.

EFFECTIVENESS

Several factors affect the effectiveness of using ATE in manufacturing feedback loops: (1) tweaking is a continual process; (2) ECB (etched circuit board) departments employ many entry-level people and are capital intensive, requiring ATE, insertion machines, solder flow, and parts handlers; (3) three-shift operation requires training and operations coordination; and (4) process monitoring and control is a continuing requirement.

When problems recur, Manufacturing must use ATE to correct the board assembly process as well as to fix boards.

PRODUCT TEST AREA FEEDBACK

Now let's examine the feedback path from the product test area to ATE test. How can we use data from this area to improve the yield from ATE, and what are the cost trade-offs?

First consider the cost of developing ATE programs. See figure 6. Increasing a test program's fault

coverage to 95% or more of all faults is a very costly process. The last few percentage points represent faults that are difficult to detect because there are no accessible test points.

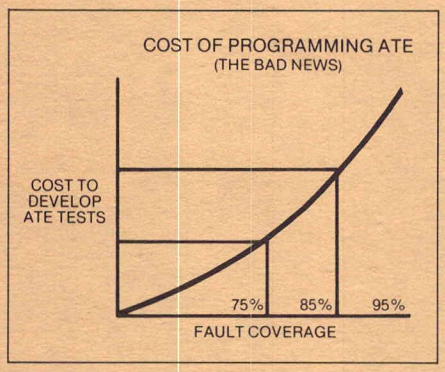


Figure 6. Increasing fault coverage dramatically increases the cost of developing ATE routines.

Now compare costs to the benefits of programs with high fault-coverage. Refer to figure 7. Thoroughly testing individual boards greatly increases the number of units that operate properly in product-level tests.

From a manufacturing manager's viewpoint, the higher the fault coverage, the better.

Here, again, Manufacturing can use data from test technicians to improve the ATE software programs, yielding higher fault-coverage. Refer to figure 8. Typical defects, that could have been detected earlier, are open connections and IC pin defects. (The problem may lie beyond the ATE routine's ability to handle.) In the example in figure 8, Manufacturing installed the product's operating system ROMs (read-only memory units) after ATE testing to maintain close control of the ROM version. We solved the problem by installing the ROMs before functional test and by modifying the program to test the ROMs.

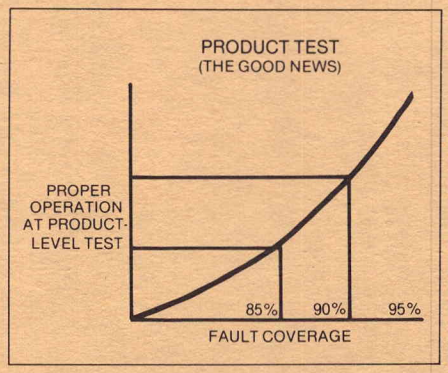


Figure 7. Increasing ATE software fault coverage greatly increases the product turn-on rate at product test time.

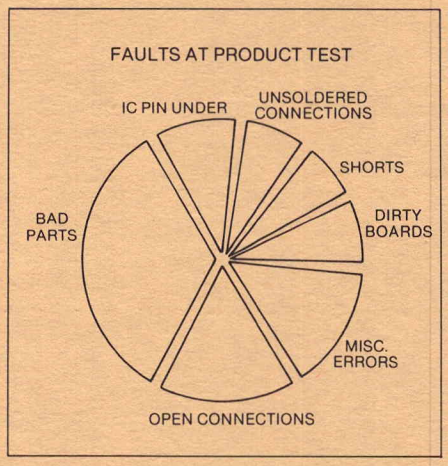


Figure 8. An example of data that test technicians supply after testing finished products.

Again, we used current data from a pie chart to improve the ATE program and also the product level turn-on rate.

CONCLUSIONS

Feedback helps tweak the ECB assembly process. Board building procedures and mod implementation procedures are very important. Data must be real time. Manufacturing must daily collect the data and process it into usable information. The data should also be easily disposable . . . there is no need to keep stacks of printouts around the manufacturing line.

The data is important for process control feedback. To use this feedback most effectively, Manufacturing should first define the feedback loops, then get them working, and finally automate them. Manufacturing should pay special attention to the data source. Incorrect data can cause more harm than good.

FOR MORE INFORMATION

For more information about ATE used in IDD manufacturing, call Ken Cone on ext. 2703 (Wilsonville). □

technical standards

SES CONFERENCE PROCEEDINGS AVAILABLE

The **28th Annual Conference Proceedings of the Standards Engineers Society (SES), 1979** is now available. This year's proceedings cover such topics as paint systems and paints, air quality standards, group technology, parts coding, referenced numbers, metric limits and fits, component standardization, metric laws and practices in international trade, coating materials, and metric fasteners.

This publication contains papers presented by standards people from the Environmental Protection Agency, Westinghouse Electric, Caterpillar Tractor, U.S. Office of Defense and Research Engineering, General Electric, Standards Council of Canada, General Motors, Monsanto Research, Massey-Ferguson, Inc., Carrier Corporation, and others.

You can borrow this book (for one week only) by calling Technical Standards at ext. 241 (Town Center).

NEW STANDARDS

To borrow or order copies of standards, call ext. 241 (Town Center).

NBS-507 — **Special Publication;** Standardization in Support of Development.

MIL-C-81706 — Amendment 5; **Chemical Conversion** Materials for Coating Aluminum and Aluminum Alloys.

MIL-STD-1562B — Lists of Standard **Microcircuits;** (supersedes MIL-STD-1562A).

NEMA LD 3-1975 — **High-Pressure Decorative Laminates,** Revision No. 4. □

NEW MEMBERS JOIN ENGINEERING ACTIVITIES COUNCIL

In February, nine new members joined the Engineering Activities Council. At the same time, other members, who have been with the Council since 1978, left the Council (members serve for about 18 months). The new members are Jerry Jacky, Doug Jones, Lester Larson, Larry Lewis, Hal Philipp, Hans Springer, Bill Stein, Kris Verma, and Al Yielding.

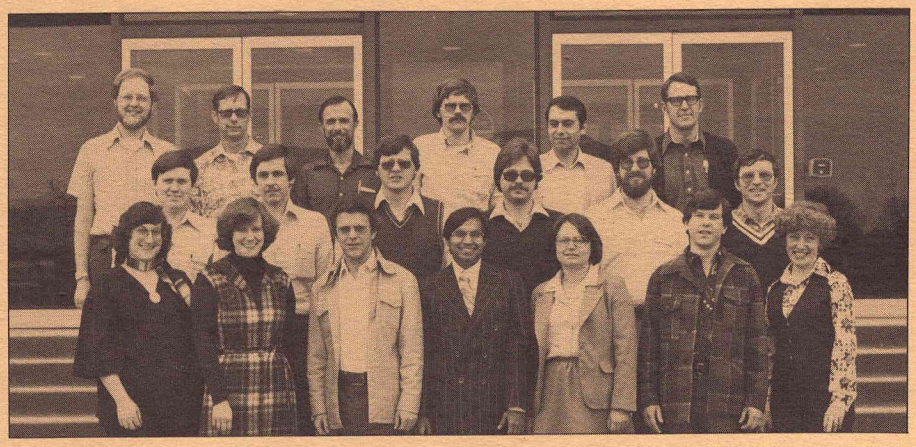
EAC CHARTER

The Council's primary objective is to provide engineers with a forum in which to present directly to management what engineers themselves consider to be important in technology. To meet their charter, the council has sponsored 18 Engineering Forums ("Engineers Talk to Managers").

In each forum, four or five engineers discuss their viewpoints on the problems and progress of new technology. The forum chairpersons are Council members. They select forum speakers from the engineering community. The audience consists of approximately 125 corporate, divisional, and departmental managers. Attendance is limited by the capacity of the auditorium, but material from the Forums is published in **Technology Report** (to add your name to the distribution list, use the coupon in this issue).

FOR MORE INFORMATION

For more information, call an EAC member from your organization. Use table 1 for extensions. □



Engineering Activities Council members: *back row, left to right,* Doug Jones, Al Yielding, Bill Stein, David Kreitlow, John Moore, and Ron Bohlman. *Middle row, left to right,* Wayne Thomas, Jim Zook, Dave Armstrong, Hal Philipp, Larry Lewis, and Lester Larson. *Front row, left to right,* Laura Lane (support), Anita Massey, Hans Springer, Kris Verma, Elske Cordell, David Keith, and Karen Hall (support).

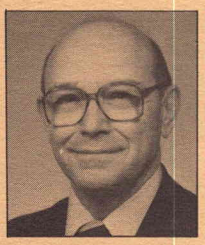
Elske Cordell	CM, Hybrids Ceramics	4760 (B)
Al Yielding	CM, CRT Engineering	6746 (B)
Hal Philipp	Communications, FDI Engineering	7240 (B)
Jim Zook	Communications, TV Engineering	7457 (B)
David Kreitlow	IDD, Copiers, Plotters, and Imaging Systems	3620 (W)
Anita Massey	IDD, Graphic Computing Systems	3114 (W)
John Moore	IDD, Technology Development	3748 (W)
Wayne Thomas	IDD, Measurement Displays	3162 (W)
David Keith	LID, STS	1392 (WR)
Lester Larson	LID, 7000/5000 Engineering	7874 (B)
Larry L. Lewis	LID, TM 500 Engineering	1528 (WR)
Hans Springer	LID, 7000/5000 Engineering	5374 (B)
Dave Armstrong	SID, Advanced Service Instrument Development	4827 (B)
Jim Besemer	SID, DCA Engineering	1929 (WR)
Wayne Kelsoe	SID, Portables Engineering	5245 (B)
Ron Bohlman	Technical Support, CAD Development	221 (TC)
Jerry Jacky	Technical Support, Engineering Support	7830 (B)
Doug Jones	Tek Labs, Component Development	5637 (B)
Cathy Lin-Hendel	Tek Labs, Signal Processing	5629 (B)
Bill Stein	Tek Labs, Component Development	7111 (B)
Kris Verma	Tek Labs, Component Development	5636 (B)
Tom Woody	Tek Labs, Display Devices	7147 (B)

B = Beaverton TC = Town Center W = Wilsonville WR = Walker Road

Table 1. The current Council members are listed here. Call a member from your organization for more information.

ENGINEER IV PROFILE

ROBERT HOLMES



Robert E. Holmes, Hybrid Circuits Engineering, ext. 5822 (Beaverton).

Engineer/Scientists IV's and V's serve as technical resources both inside and outside the company. To increase their visibility to the Tektronix technical community, *Technology Report* will publish a series of profiles of these individuals.

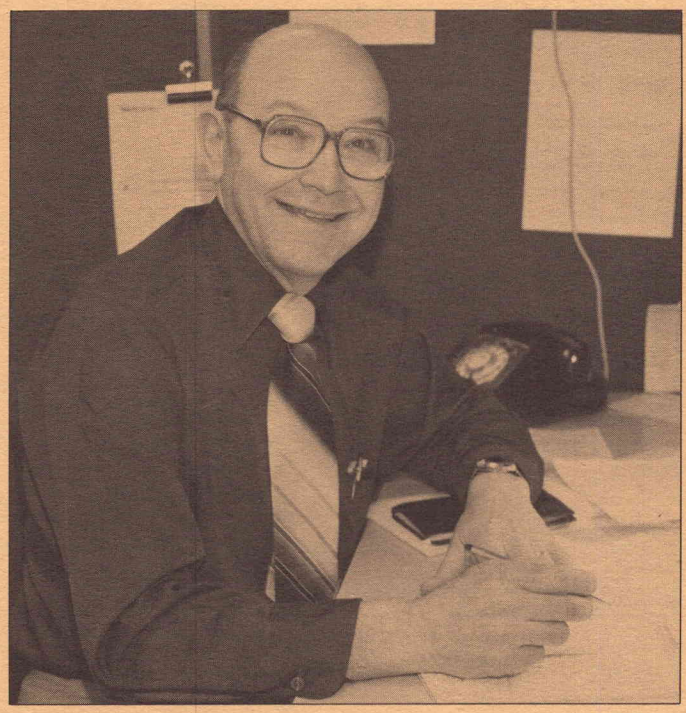
Bob was recently installed as President-Elect of ISHM (International Society for Hybrid Microelectronics). As president he will continue his extensive interaction with hybrid microelectronic professionals in industry and education.

Bob joined Tektronix 12 years ago bringing experience in thin-film and chemical processes gained at Autonetics, Bournes, Hach Chemical, and Dow Corning. His degree is in chemistry from the State University of Iowa.

Presently, Bob is introducing new materials and processes for component development and lending technical support in the field of materials science to engineering projects. This keeps him in touch with Tek people in the processing disciplines.

Major projects in his credits list include: assisting in the manufacturing introduction of the T611 display monitor tube (this tube was used extensively in our early display products), the vacuum-assembled tube, the electroformed mesh for scan-expansion CRT's, and thin films for monolithic circuits and hybrids (by deposition and photo-processing).

Patents to his credit include: one for "Forming Holes and Multilayer Interconnections Through A Dielectric," another for a "Wire Mesh Member Having Intersecting Strands Bonded Together," a third, shared with Bob Zimmerman, for a "Method of Making a Metalized Substrate Having a Thin-Film Barrier Layer," the fourth is for "Laser Trimming of Resistors with Silicon Nitride Passivation."



Bob's papers include: "Localized Doping of Epitaxial Ferrite Films" — **Journal of Applied Physics;** "The Epitaxy of Zinc Sulfide on Tungsten or Molydbenum Substrates" — **Electrochem Technology;** "Thin Film Material and Equipment" — **Electronic Packaging and Production.** □

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INVENTORS SHOULD USE INVENTION RECORD NOTEBOOKS

Patents and Trademarks has retitled the familiar **Engineering Notebook;** it is now the **Invention Record Notebook.** This change re-emphasizes the true purpose of the records kept: documenting new ideas, developments, discoveries and the like — "inventions." Don't use the notebooks for recording routine test data of little or no relevance to any new idea, concept, development, discovery or invention.

To protect an invention you must record the date when it was conceived and the date when it was reduced to practice. It is equally important to identify all contributors to the invention and to describe relevant facts clearly and completely: include relevant sketches, diagrams, test data, and photos. Have two associates who understand the recorded information sign and date every tenth page, identifying the witnessed pages by number.

Invention Record Notebooks are Tektronix property. When you fill a notebook, or terminate, you should leave the notebook with your manager or return it to **Patents and Trademarks,** Y3-121.

Invention Record Notebook entries are confidential — treat them accordingly.

Notebooks are available at the following locations:

Y3	Barbara Wall, ext. 8168
Walker Road	Eleanor Hess, ext. 1168
Wilsonville	Cheri Eckholt, ext. 3986
Beaverton	Kay Smith, ext. 4683

To record possible patentable subject matter while working in a clean room, order a **Clean Room Invention Record Notebook** from Barbara Wall, ext. 8168 (Y3). The standard **Invention Record Notebook** is not suitable for clean room use because it sheds particles of paper. For recording other matter while working in a clean room, order a suitable notebook through Purchasing for this purpose. You may find VWR Scientific's Nalge Lab Notebook #6300-1000 acceptable. □

Scratch Area

GPIB CONSULTING SERVICE

Are you:

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If so, take advantage of the services the Digital Products Coordination Group is offering. For details, contact James Walker, ext. 5165 (Beaverton), d.s. 50-473. □

WANT TO REACH TR READERS?

A continuing feature of **Technology Report** is the *Scratch Area* column. This space is set aside for miscellaneous short notices such as new personnel introductions, calls for information, and calls for papers. To contribute to *Scratch Area,* send your input to **Technology Report,** d.s. 53-077. □

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