0688

RESEARCH AND DEVELOPMENT IN INDUSTRY

2 February 1959

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NOTICE

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INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D. C.

Dr. Lawrence R. Hafstad, Vice President in charge of General Motors Research Staff, was born on 18 June 1904 at Minneapolis, Minnesota. He graduated from the University of Minnesota in 1926 with a B. S. degree in electrical engineering, continued on as a graduate student in physics until 1928 and in 1933 was awarded a doctor of philosophy degree in physics by John Hopkins University. He has worked as an engineer for Northwest Bell Telephone Company, a physicist for the Carnegie Institute of Washington, D. C., director of research of the Applied Physics Laboratory of Johns Hopkins University, executive secretary of the Research and Development Board, OSD, Director of U. S. Atomic Energy Commission's Reactor Development Division, chairman of the Interdepartmental Committee on Scientific Research and Development, and as director of Chase Manhattan Bank's Atomic Energy Division. He shared the American Association for the Advancement of Science Award with M. A. Tuve in 1931 for development of a million volt vacuum tube and also was presented with the Medal of Merit and the British "King's Medal in Defense of Freedom" for his war work, among other awards. He has written many scientific and technical papers, chiefly in the field of physics. He is a fellow of the American Physical Society as well as many other scientific, engineering,and fraternal societies. He holds various trustee, council, and committee memberships, including Ethyl Corporation, Scientific Research Society of America, National Industrial Conference Board, and Atomic Energy Council. He is also a consultant to the Assistant Secretary of Defense for R&D and technical advisor to Syndicat d'Etude de l'Energie Nucleaire (Belgium). This is Dr. Hafstad's seventh lecture at the Industrial College.

RESEARCH AND DEVELOPMENT IN INDUSTRY

2 February 1959

ADMIRAL CLARK: The title of our lecture this morning is "Research and Development in Industry."

As everyone here knows, there are few aspects of industry of equal importance to its growth, to maintaining its competitive situation, and to its ability to meet changing needs, than is research and development.

To discuss this subject this morning, we are fortunate in having a man who has had a most complete and diversified experience in research and development in both business and government. His personal achievements, as well as his managerial skills, have won him recognition and awards in this country as well as abroad.

In addition to his other scientific achievements, he has authored a great many technical papers, he has participated in the work of a great many engineering societies both here and abroad, and he holds trusteeships and memberships on a great number of scientific societies, boards, and councils.

It is a great pleasure for me to welcome back here for his seventh appearance the Vice President in Charge of the General Motors Research Laboratories, Dr. Lawrence R. Hafstad. Dr. Hafstad.

DR. HAFSTAD: Thank you, Admiral, Gentlemen: My talk here, according to the suggested outline that I was given, is supposed to cover these points: The importance of industrial research to technological progress, the question of what is industrial research, how business grows through research and development, how industrial research is organized and managed, what the problem areas are, and what the contributions to national security are.

All of these items are extremely interesting and I could talk at length on nearly all of them, but I think I would be most helpful to you if I would confine my remarks mainly to examples of my own experience and my own impressions, because I have read the paper that you were given here, the paper by Richard R. Nelson, on "Invention, Research, and Development," and I find it excellent. I couldn't write a better paper myself and would be wasting your time if I tried to repeat it or improve upon it.

I think the subject we are going to discuss today actually could be better handled by a question-and-answer session. So, as I run through my presentation, I would invite you to think of questions--the more embarrassing the better--and I will see how I can handle them, because I enjoy the give and take which we ordinarily have in this group and am looking forward to it.

The first item on my list was the importance of research to technical progress, and I can think of no better way of answering that than to read a quote from Sumner Schlicter, the Professor of Economics at Harvard University. He states in a recent article:

"The best way to indicate the significance of technological research for the growth and stability of the economy is to point out that technological research had developed sufficiently by 1937 to make Keynes' theory of employment obsolete on the day of its publication, in spite of invaluable concepts and tools of analysis contained in the work. The reason why his theory of employment itself was out of date on the day of its publication was that Keynes ignored completely the impact of technological research upon the economy. Hence his theory of employment rested upon a theory of consumption and upon a theory of investment that were seriously in error. In addition, Keynes was led to the mistaken practical conclusion that economic progress inevitably creates a cronic deficiency of demand."

I think this is about as convincing a statement as one can make as to the change which has come with respect to our attitude toward research and development. It used to be a sort of incidental activity in the Government and in industry as well. In recent years, over the last several decades, it has become an essential and, I believe, a motivating force in our economy. I will return to that subject later when I will show you some charts.

Let's turn to the question: What is industrial research? The definition I like best is one given by Duer Reeves of the Standard Oil Company of New Jersey: "Industrial research is the effort on the part of management to provide itself with technology for present and future growth."

This is worth thinking about, because I think Reeves is correct in saying that there are many ways whereby management can provide itself with this technology. It doesn't mean that management necessarily has to, or should, set up a long-haired research department.

Management can buy its new technology from another organization; it can hire a lot of consultants; it can support research in universities. There are many ways that management can get its new technology. Setting up its own research and development organization is merely one of the ways of doing this.

So, industrial research, then, is the effort on the part of management to provide itself with new technology for present and future growth. Another way you could express it is to say that it is an organized effort to make inventions. I don't like that quite so well, because, to me, invention always associates itself with patents. Things that are invented are usually patentable, and this more or less restricts you to gadgets of various kinds. Gadgets are the things that you can invent, whereas R&D, in this day and age, often leads to a basic understanding in a new area of technology. The often-used words "know-how" are the important concept here, and this know-how gives the company an advantage, sometimes greater than that which it could get from formal patent arrangements.

Another important characteristic of industrial research is that it must be profitable, and this is often forgotten by writers on the subject. There is so much being written these days about R&D, so much stress on the importance of basic research, that somehow or other it seems to be lost sight of that, as far as industry is concerned, the operation overall must be profitable. And this ties in with another very fundamental thing in our society and in our particular economic system, and that is the basic assumption that the customer is always right. This is quite different from the Russian system. I won't argue here whether it is a proper decision or a proper assumption, but the basic assumption of our industrial economy and the R&D efforts that are a part of it is that the customer is always right.

How does business grow through R&D? I don't think we have to spend too much time on this subject. You are all familiar with the miracle drugs that have stemmed from research, and the companies that have prospered from sponsoring this research. Those of you who watch the stock market know how one drug company after another will have a spurt in the value of its stocks due simply to one or another of the miracle drugs being developed. I don't say "discovered" or "invented" in this case, because development is the correct word. The company chooses a certain area in which to do research and, after a lot of work in this area, usually emerges with a series of products which are effective and marketable.

Other examples of growth due to R&D would be new processes in the petroleum industry or in the petro-chemical industry. A close relation to these is the plastics industry, which has been growing by leaps and bounds. The electronics industry is another one which is closely associated with R&D. Any new development, any device or component which is invented or developed, usually gives the company a real advantage in marketing its product. So the growth tends to follow the R&D, and one gathers from general reading the impression that the only thing he needs to do to make a successful small company or industry is to set up an R&D program. In fact, I have the impression that a lot of R&D departments, or even engineering departments, are seceding from companies and organizing small companies of their own. This is a rough dangerous business, because you have to be good in R&D, but you also have to be good in business and in the financial side if you are going to stay alive. In a period of prosperity this system works fairly well; but when the going gets tough, it will be difficult for many of these small companies to stay alive in the competition.

Another area in which industry grows through R&D is, of course, through government contracts. All of you have seen how small companies, particularly, can thrive and profit by getting a number of government contracts. There is a difference here between small and large industry. Small industry, by and large, is struggling to maintain itself, to keep going. It is very happy to have its salaries paid. If it does so it is a successful company. A big company, by and large, has many other directions in which to make its investments, and it is concerned about the profit rate, which is relatively low on government contracts.

As a result, it is my impression that government contracts work fairly well for subcontractors and component development people; but they are not very attractive or successful from the point of view of a major contractor who has a civilian business to protect. And here you get into a lot of problem areas, which, if there is time, we will discuss later.

Basic to this, I think, is that with modern trends in weapon development it is extremely difficult to separate the R&D and the production phases of an overall activity. In the old days, as many of you know, R&D was one thing; production was another. You did a lot of R&D, developed the gadget, took your time to prove it in, made sure that it was just what was needed in the field, and then the production department took over and the military people would order these things by the millions. Under those conditions the production man could move in and really do a job.

In this day and age, with the weapons we are now developing, the R&D has to follow right along into the production area of the activity. In fact, the devices we now make are so expensive that you don't ordinarily get into volume production, and your production people have to have R&D people sitting right beside them in solving the problems. This gives a whole new set of problems in the production area in getting a weapon from the R&D stage into production. I think one of the reasons that we are having some confusion and difficulty in lead times here--that is, the problem of getting from R&D into operation--is that we have not yet made up our minds or have not yet learned whether we want to use a system where we have R&D in one category of facility and production in another, or whether we want to combine these two and do R&D in the same company and the same organization that is going to do the production.

There are advantages and disadvantages both ways. We'll come back to that one a little later.

I'd now like to show you a number of charts which may reiterate some of the points I have been making.

Chart 1, page 6.--I want to stress the growth of R&D in the United States. Notice the rapid rate of growth on the logarithmic ordinate. This really means, insofar as those lines can be represented by straight lines, that there is an exponential growth in R&D. Those of you who have played with exponentials know that they can't continue indefinitely.

Chart 2, page 7.--Here, just for fun, is the plot of employment in the electrical industry. You will note that we would have the entire working population of the United States working in this field by 1990. I wouldn't bet on it if I were you.

Chart 3, page 8.--Here is an effort to show you the more or less classic distribution of effort in pure science, which is mainly the business of the universities and applied science, which is the business of industries. A few decades ago we were very happy with this arrangement. Particularly due to the impact of developments during World War II and their reflection in the economic society in which we live, however, we came out with a need for something in between these two. This I represent here by the Research Associations, or, if you like, the large governmental laboratories, which sort of fill the gap between the pure research of the universities and the applied research of the industries. Our big government laboratories run all the way from basic science, as you know, to weapon development, and would come in the category of these Research Associations.

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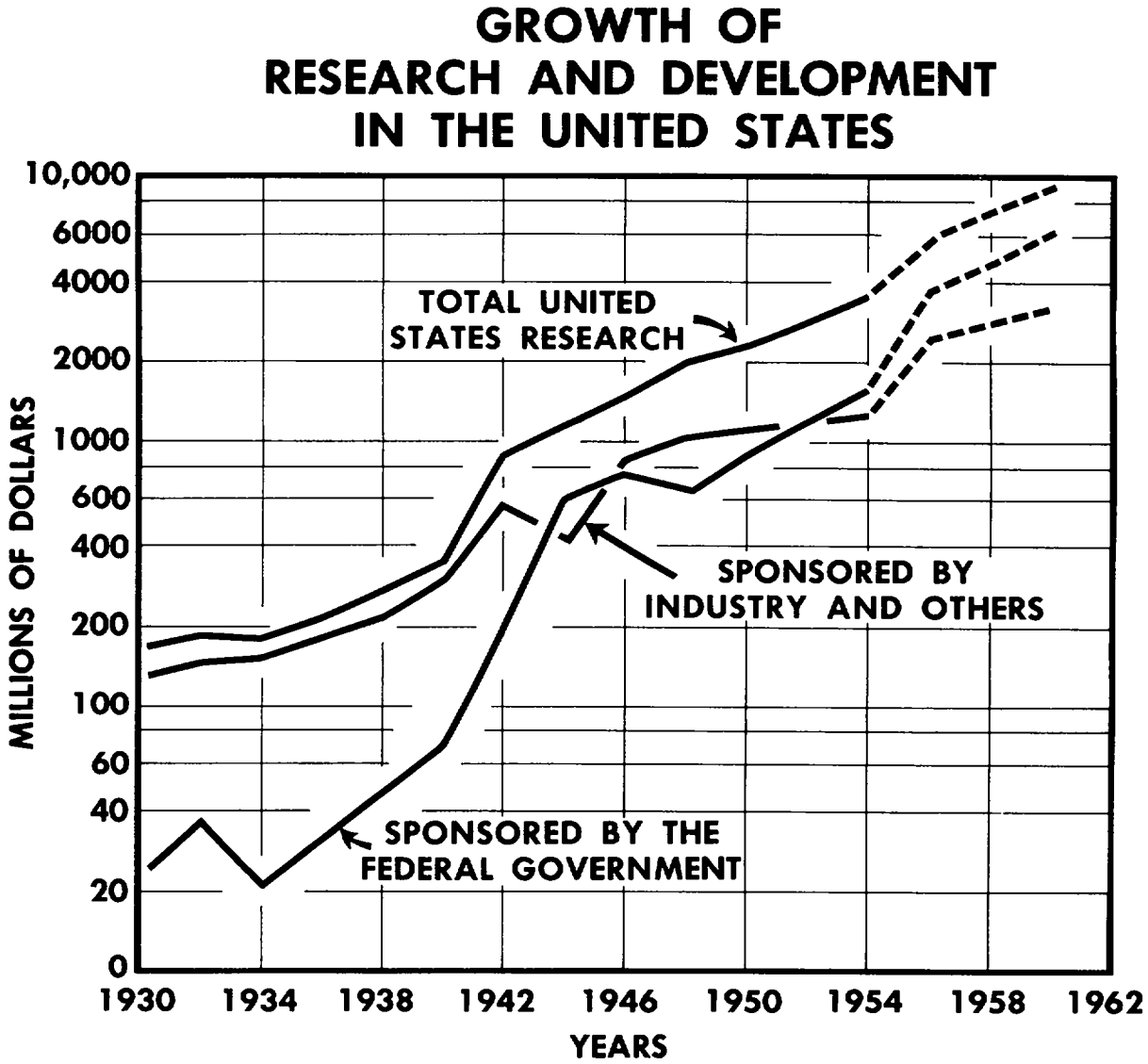
Chart 1


GROWTH OF
RESEARCH AND DEVELOPMENT
IN THE UNITED STATES
10,000
6000
4000
2000
1000
600
400
200
100
60
40
20
0
MILLIONS OF DOLLARS
TOTAL UNITED
STATES RESEARCH
SPONSORED BY
INDUSTRY AND OTHERS
SPONSORED BY THE
FEDERAL GOVERNMENT
1930
1934
1938
1942
1946
1950
1954
1958
1962
YEARS

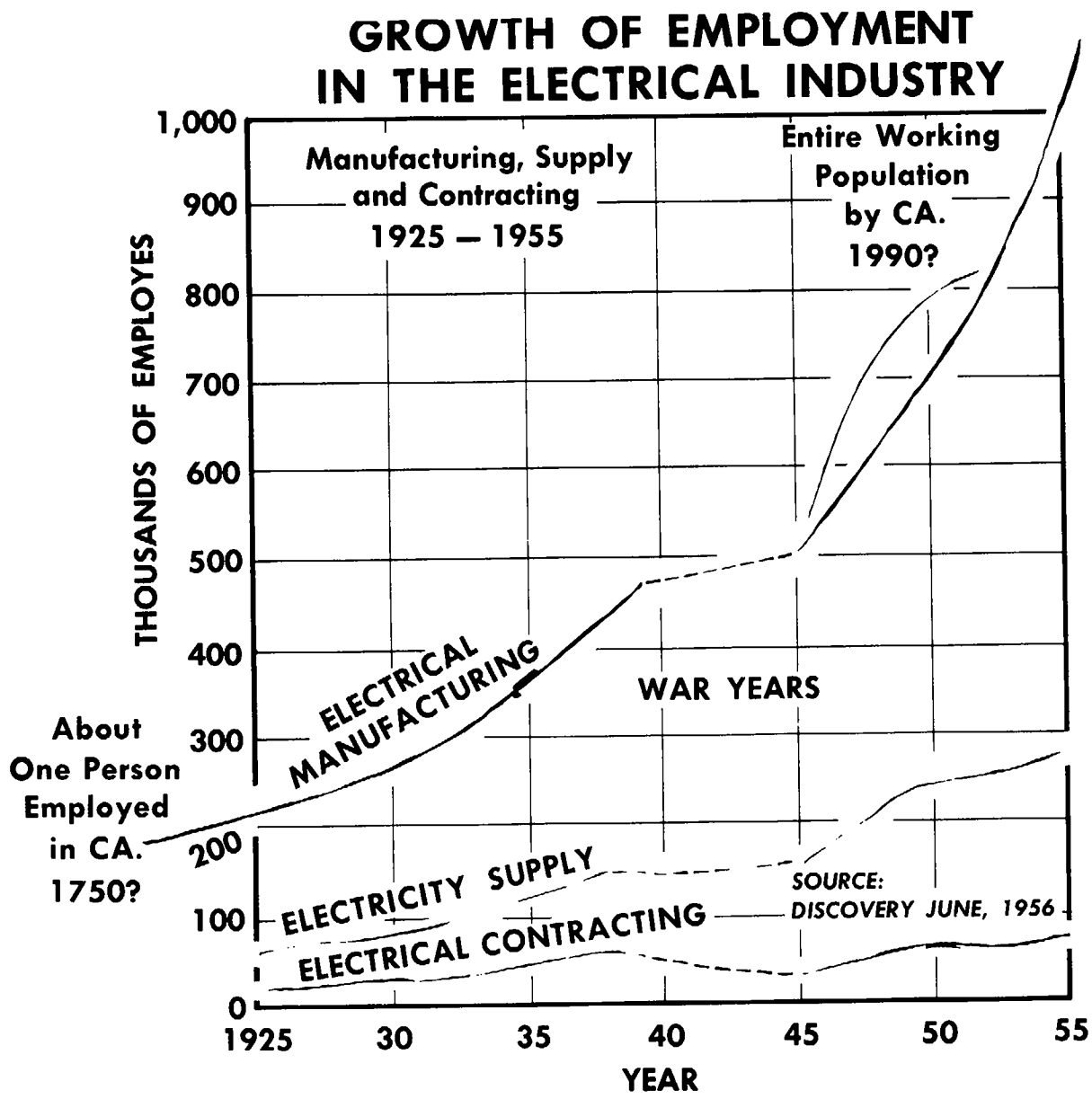

GROWTH OF EMPLOYMENT
IN THE ELECTRICAL INDUSTRY
THOUSANDS OF EMPLOYES
1,000
900
800
700
600
500
400
300
200
100
0
Manufacturing, Supply
and Contracting
1925 — 1955
Entire Working
Population
by CA.
1990?
ELECTRICAL
MANUFACTURING
WAR YEARS
About
One Person
Employed
in CA.
1750?
ELECTRICITY SUPPLY
ELECTRICAL CONTRACTING
SOURCE:
DISCOVERY JUNE, 1956
1925
30
35
40
45
50
55
YEAR

Chart 3

EXTENT AND TYPES OF SCIENTIFIC CONTRIBUTIONS

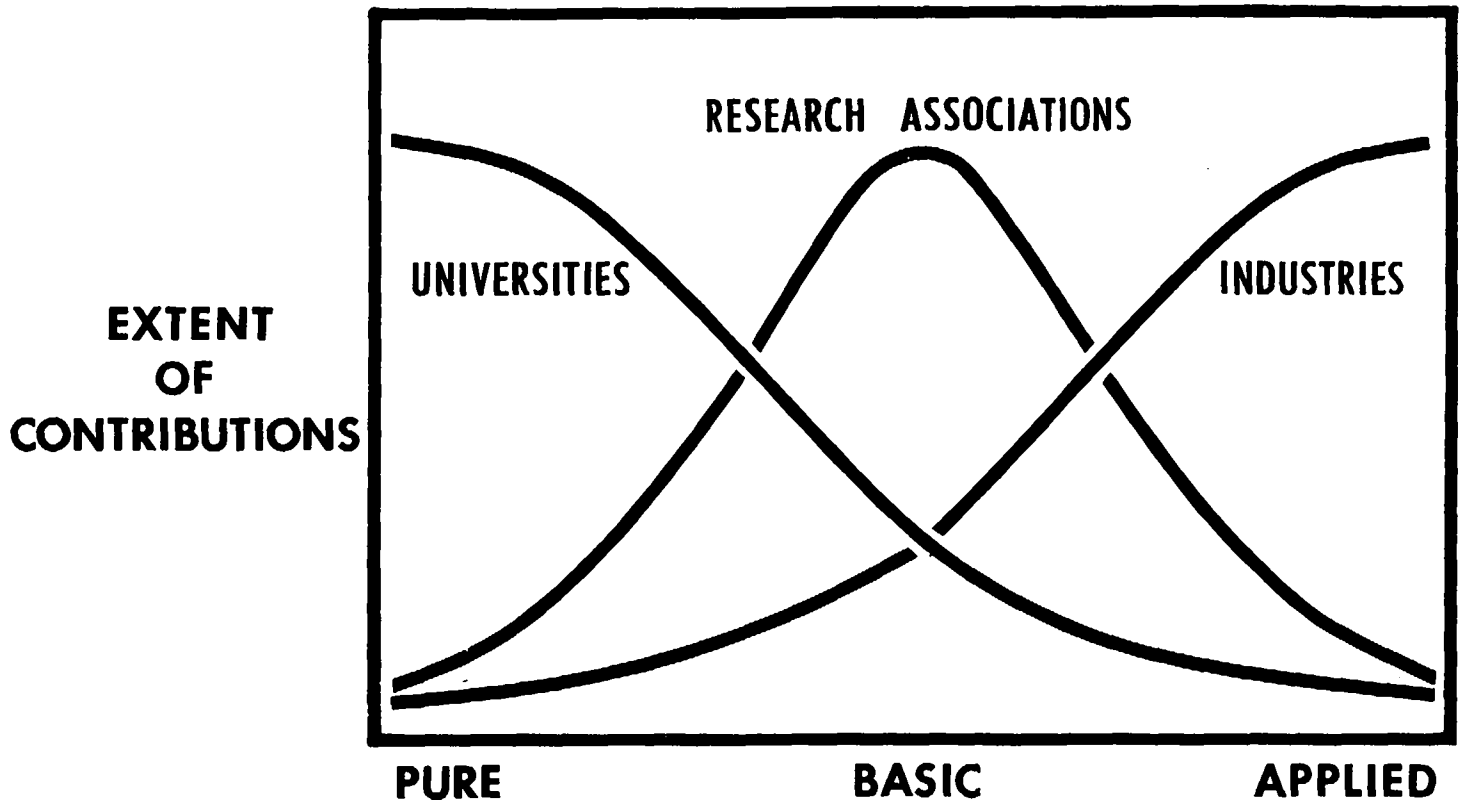


Chart 4, page 10.--Here is the way the research and development business looks to the bookkeeper, and usually to top management. You will note that the dollar spent during the research phase is pretty small. In an ordinary big operating business it is little more than a nuisance, and not too much attention is paid to it.

Then there is a development period, where the money becomes significant. As you go into production, you find that really large sums are involved in tooling, and so on. So that it is the production end of things that gets the attention.

This is not the way a research man looks at the problem at all, so I want to show you another chart which shows how a research man thinks his business ought to look.

Chart 5, page 11.--The research man is concerned with the percentage improvement in the product. When the production man talks about a small percent improvement in product or a small percent decrease in cost, he thinks he is doing something. The research man thinks in terms of factors. He wants a factor of 2 improvement, or a factor of 10 improvement, or something of this kind. So if you plot percent improvement due to your activity, this is the way the picture looks. And of course a picture of this kind would cause lifted eyebrows on the part of the financial people in any well organized industry.

Chart 6, page 12.--This chart, which plots knowledge on a vertical scale and time and engineering and progress on a horizontal scale, shows a typical pattern of development. As knowledge increases to some level--this is scientific knowledge and technology--it becomes possible to make some useful device. In this case we picked the piston engine.

A lot of people make a living out of this and continue working along this curve marked "piston" and making engineering improvements in this engine. But they become so dedicated to this design that they are not openminded, and in fact resent any developments which lead to other devices. And this is the reason, I maintain, that it rarely happens that a company which has become successful with one device is able to change its method of operation and develop a new device. The new devices have to come, usually, from outside influence and from new points of view being brought to bear on the problem.

Chart 4

DEVELOPMENT CONTRIBUTION

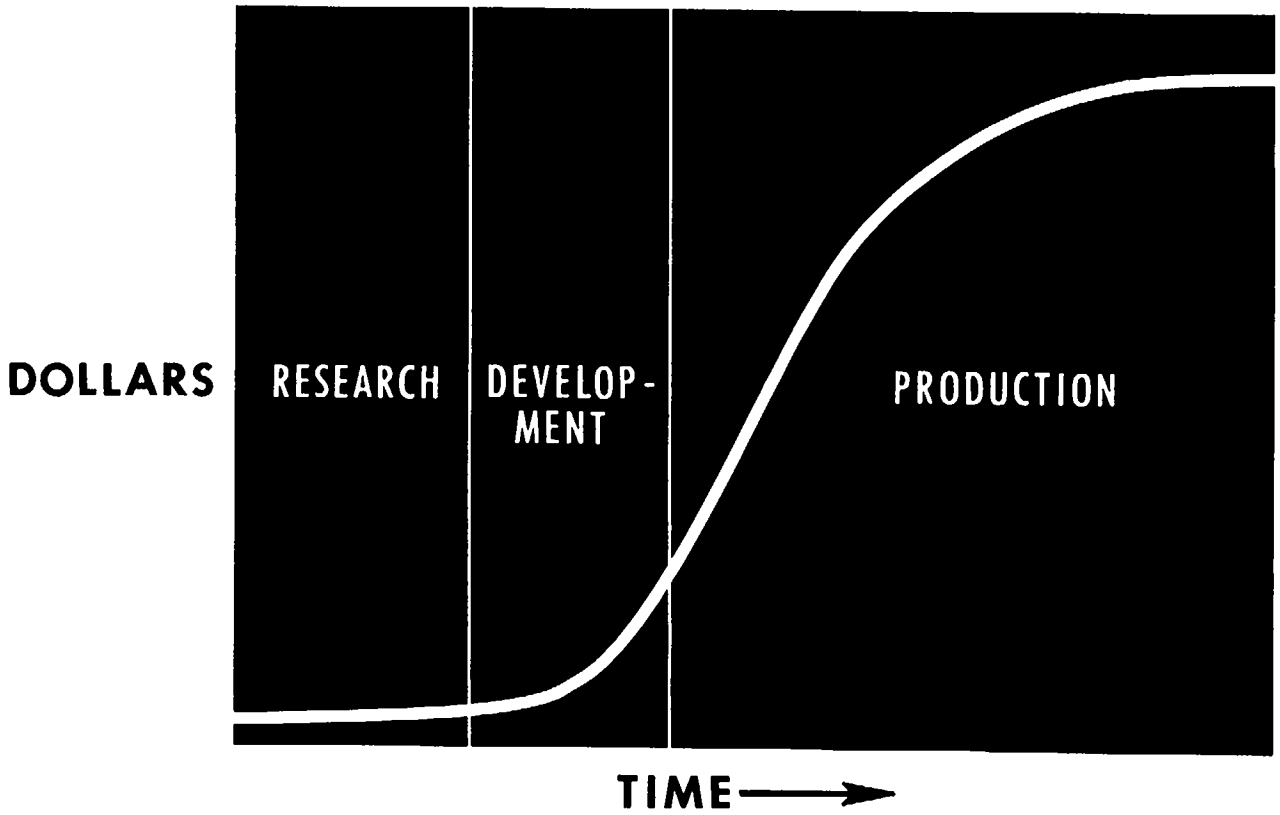


Chart 5

RESEARCH CONTRIBUTION

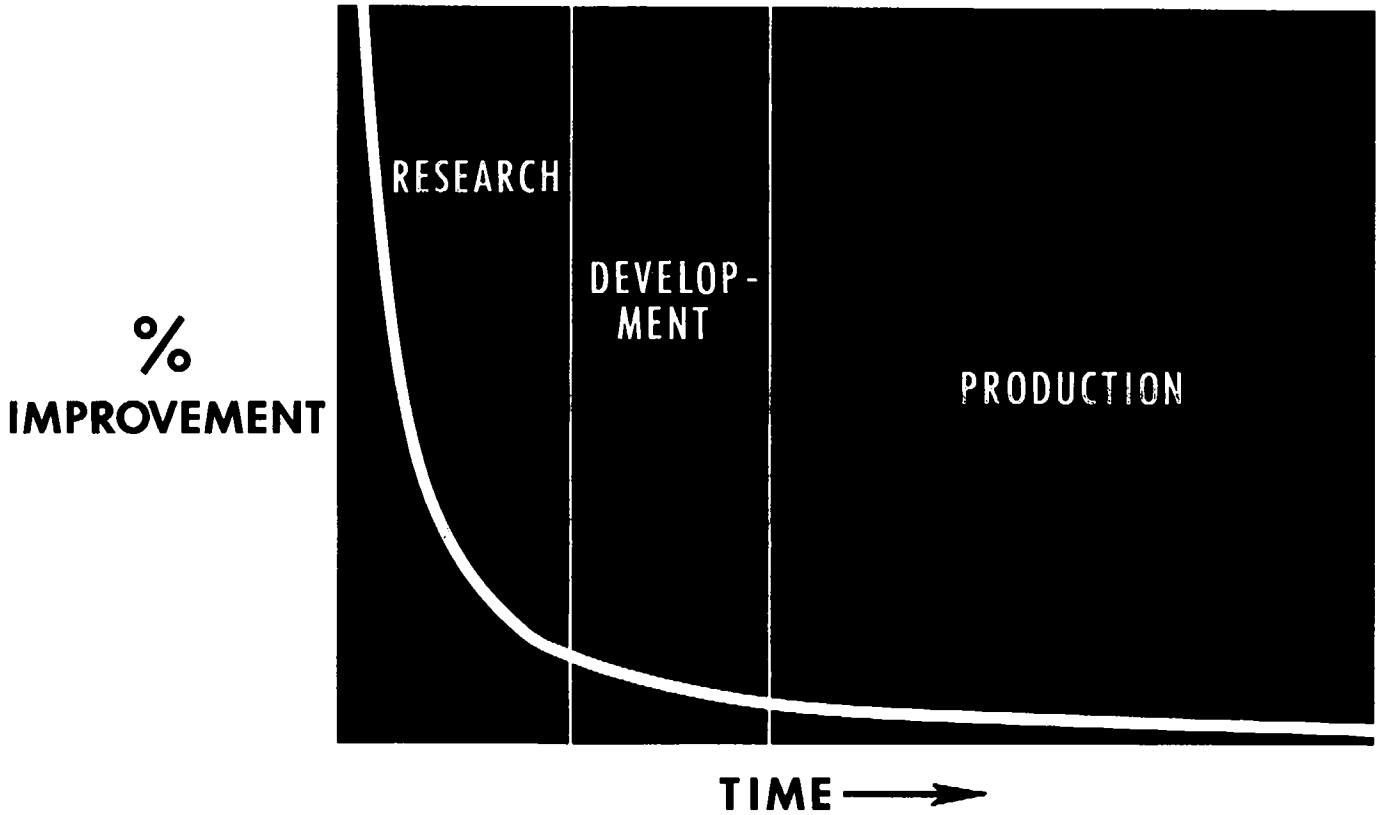


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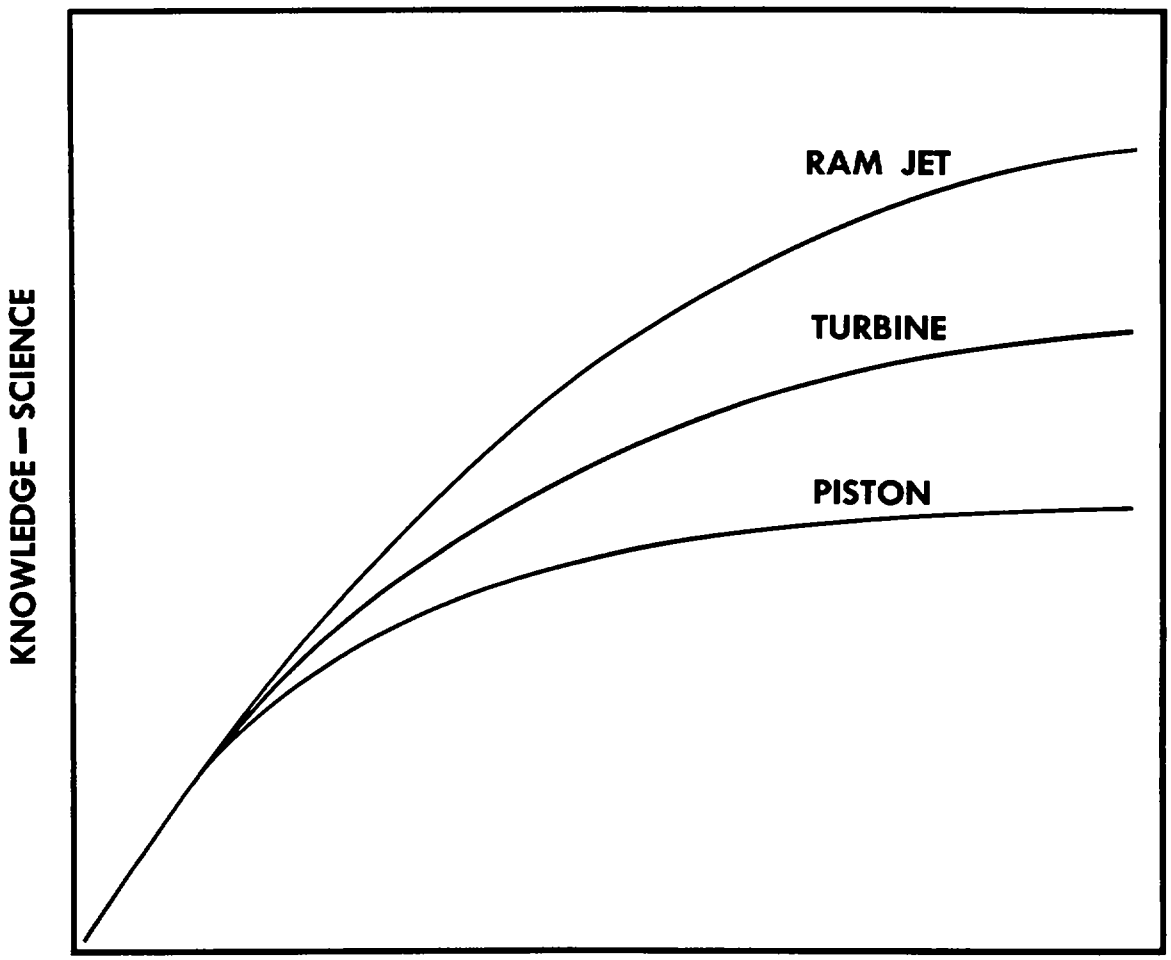
Chart 6

AIR BREATHING ENGINES



Similarly, the turbine people become involved in their day-to-day operations, and spend all of their time and energy and money making engineering improvements, and these are small-percent improvements, in the turbines. Somebody else has to come around to introduce really new things like ram jets or rockets, if we continue into other areas.

Chart 7, page 14.--One thing which has been changing over the last several decades is the time interval between the scientific discovery and the time of application of that discovery. I have tried to show this in this particular chart. You will note, taking the bottom, for instance, that from the time of the discovery of the chemical reactions by the scientists who were studying chemistry to the actual development of photography was nearly a century. Even when you come up to the telephone, as shown here, there was a long time between the scientific discoveries of electricity and magnetism and the application to the telephone. But, as you come up to this chart, you find that radio came through much faster, radar still faster, the A-bomb, as you all know, very, very rapidly. I show as the last example transistors, where the application started almost along with the discoveries in solid-state physics in the Bell Telephone Laboratory.

Chart 8, page 15.--Different companies and different industries have good reason to spend different amounts of money in R&D. It may be that the company management is only sleepy, but this does not necessarily follow, because the game is different as it is played in different industries. Here you will note you run from the aircraft industry, where there is about 9 percent of sales spent on R&D, down to the food business, where only about 0.2 percent is spent on R&D.

Chart 9, page 16.--This shows the distribution by company, and you will note that the leaders spend as much as 10 percent, 7 percent, and thereabouts on R&D, and one wonders why all companies don't spend about the same percent of sales. In fact, one of the suggestions is that any up-and-coming company ought to spend a given percent of sales on R&D. Some of my research-scientist friends are the most vociferous in arguing that this is the way it should be done.

I think there are several serious objections to that. One is that the business of research is of differnt importance in different activities. Another is that I feel that the percent of sales figure has a built-in phase error. The time to do R&D is before you have a drop in sales; not as, or after, you have a drop in sales. So this percentage approach to the problem guarantees that your R&D is always late. We have to do something better than that.

Chart 7

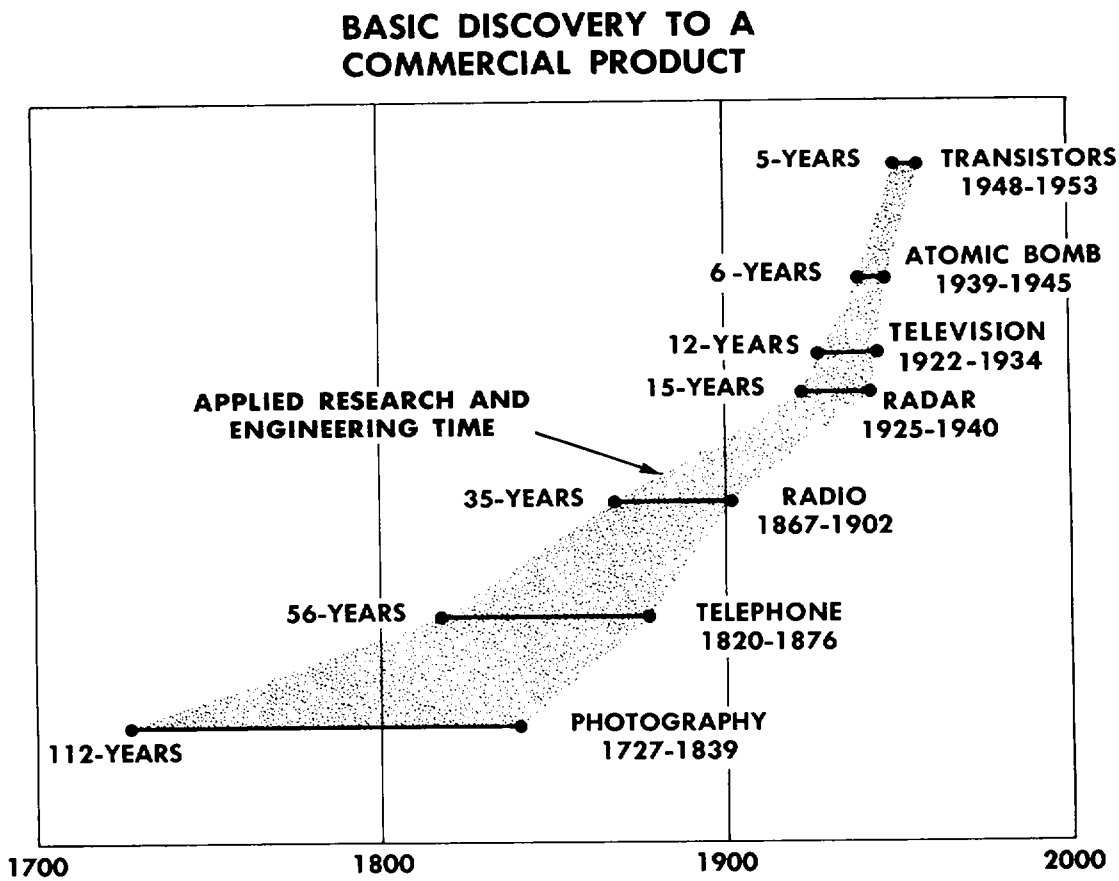

BASIC DISCOVERY TO A
COMMERCIAL PRODUCT
5-YEARS
TRANSISTORS
1948-1953
6 -YEARS
ATOMIC BOMB
1939-1945
12-YEARS
TELEVISION
1922-1934
15-YEARS
RADAR
1925-1940
APPLIED RESEARCH AND
ENGINEERING TIME
35-YEARS
RADIO
1867-1902
56-YEARS
TELEPHONE
1820-1876
112-YEARS
PHOTOGRAPHY
1727-1839
1700
1800
1900
2000

Chart 8

RESEARCH INVESTMENT AS PER CENT OF SALES

— By Industry —

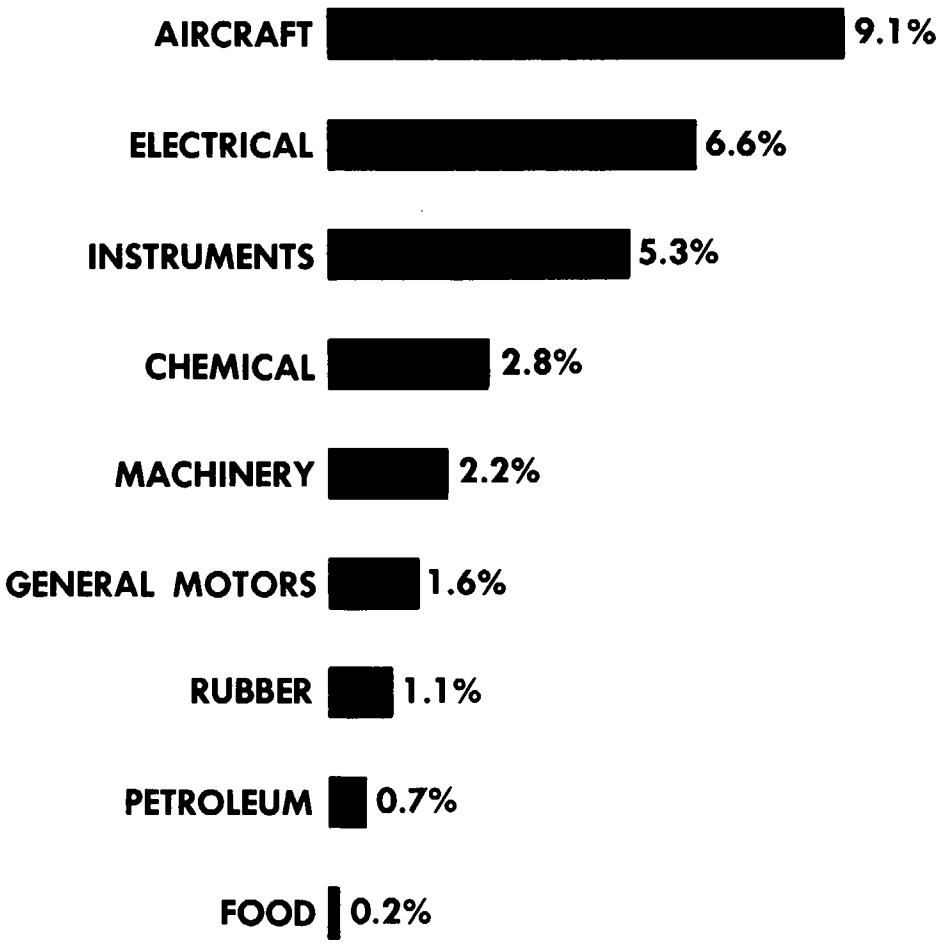


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Chart 9

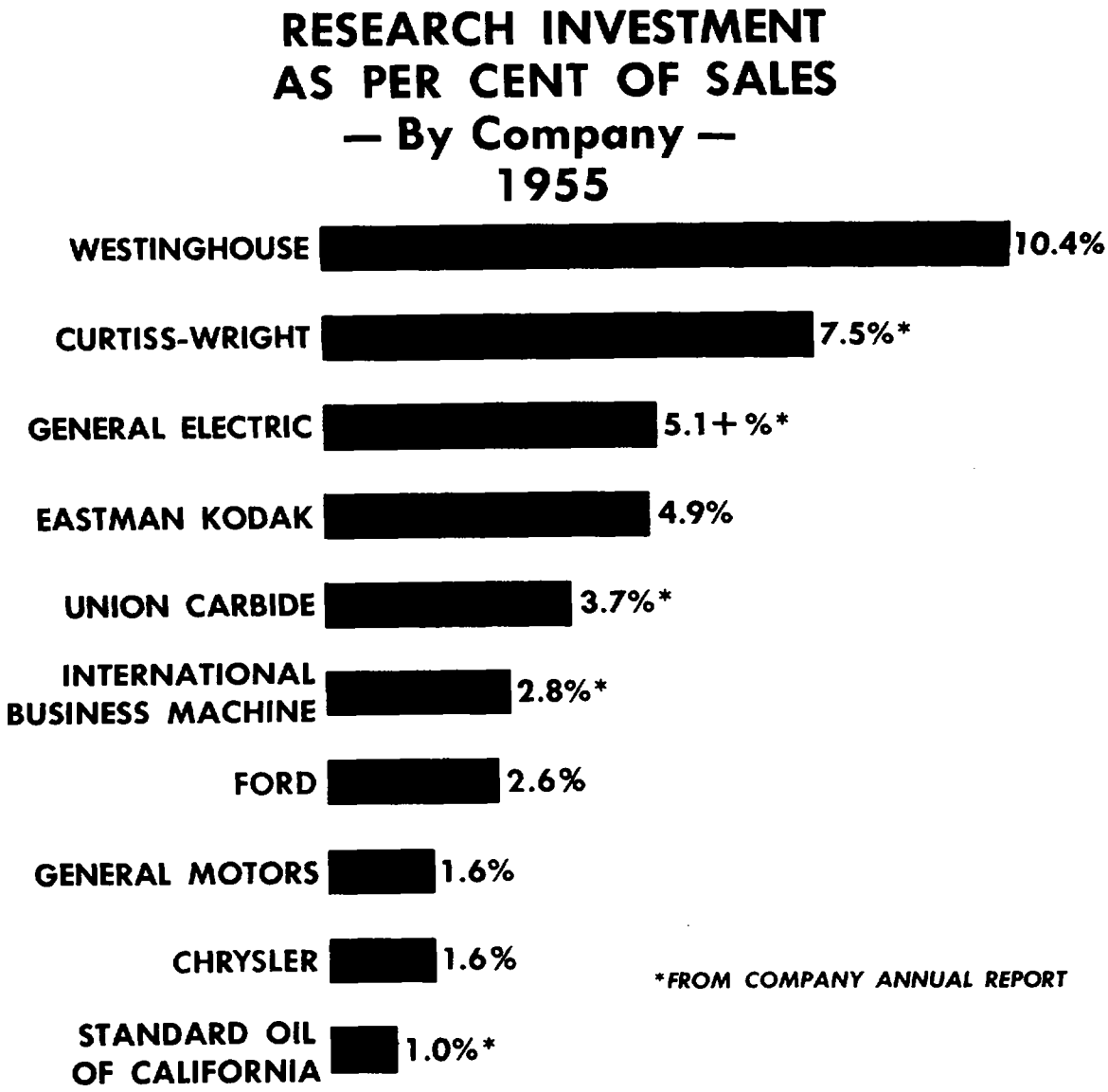

RESEARCH INVESTMENT
AS PER CENT OF SALES
— By Company —
1955
WESTINGHOUSE
10.4%
CURTISS-WRIGHT
7.5%*
GENERAL ELECTRIC
5.1+%*
EASTMAN KODAK
4.9%
UNION CARBIDE
3.7%*
INTERNATIONAL BUSINESS MACHINE
2.8%*
FORD
2.6%
GENERAL MOTORS
1.6%
CHRYSLER
1.6%
STANDARD OIL OF CALIFORNIA
1.0%*
*FROM COMPANY ANNUAL REPORT

Chart 10, page 18.--This emphasizes the same type of thing. You will note here the American Telephone and Telegraph Company is the leader with 476 physicists. I think if you will think over the nature of their business you will easily understand this, because their activities are those which can be helped by a group of what we have come to call "long-haired" scientists who help them with their problems.

By and large the automotive industry is low on this list, and, since I now happen to be in Detroit, I am going to try to give you some comments as to why this happens.

Chart 11, page 19.--Here is a little chart I made up to answer the criticisms of some of my scientific and engineering friends when they attack me about our modern cars. I think I have had more free advice from high-level scientists, Nobel-prize winners, and others than even General Motors could pay for if I paid by the hour for this advice.

This chart I dreamed over a lunch table. Here we show, plotted vertically, the cost; off to the left, the simplicity of the car; and to the right, the volume. As you all know, the cost of an item drops with the volume, so that you can run down this cost curve and come to the point marked "L," which represents the luxury model of my engineer friends want, because they say, "If you would only take this luxury car and remove a lot of the crud from it, we would have a very simple car and a very cheap car which would cost us only the small amount, 'E Prime,' on the chart."

Well, here I have to object and say that this sounds very logical, but what I call the transition from "L" to "E Prime" happens to be a forbidden transition. You just can't go along that line, for "E Prime" is the price you would pay per car if you were willing to place a single job lot order for, say, 2 million cars. You have to ask first: What would the volume of sales of this economy car, really be?

Thus you find that you have to move up to "E Double Prime" to establish the volume, and then you begin to simplify that car and you come down to, finally, "E" as being the position of the economy car on this three-dimensional surface. But now you may find that the economy car, "E," costs as much as or more than the luxury car.

This is the kind of problem you face once you agree, that "the customer is always right." And this is why I stressed that a few minutes ago.

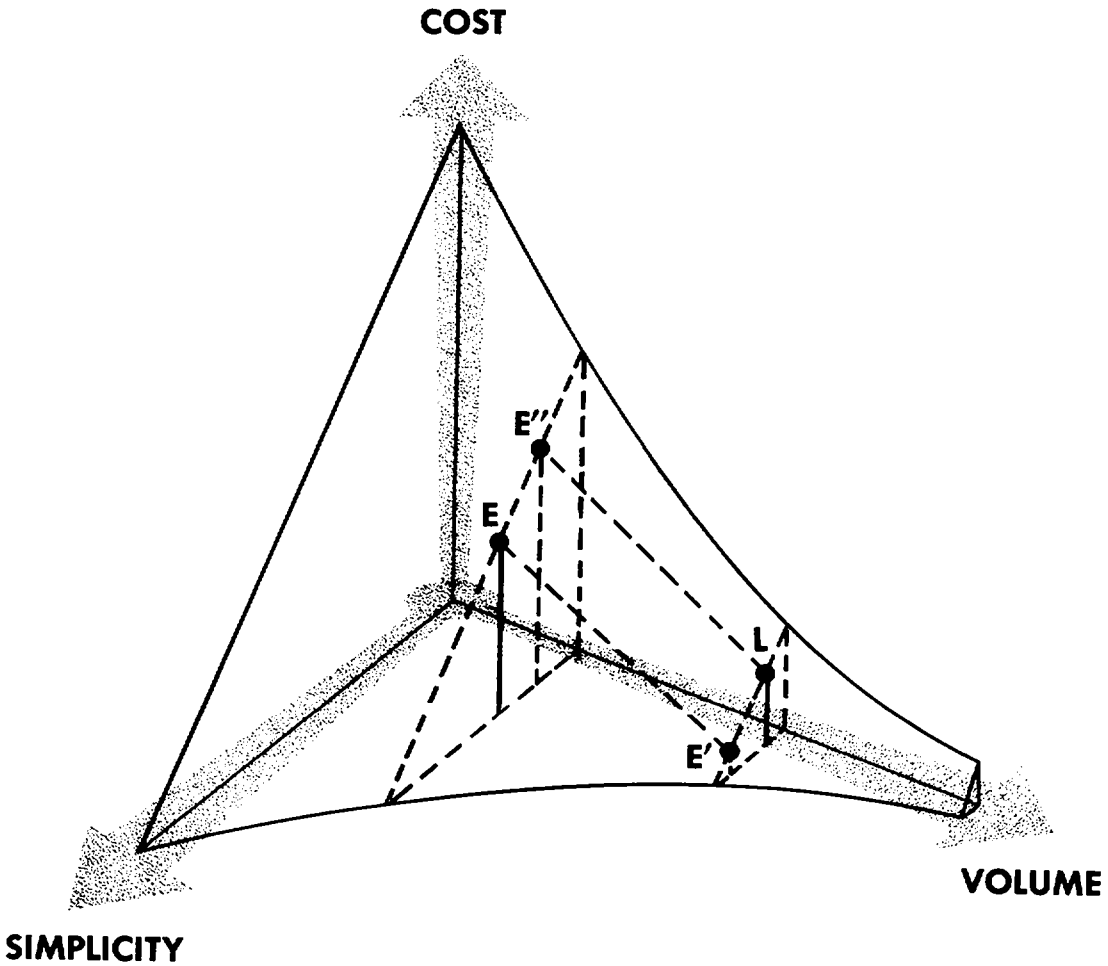
270

Chart 10

PHYSICISTS EMPLOYED BY VARIOUS CORPORATIONS

NAME	PHYSICISTS
American Telephone & Telegraph Co.	476
Westinghouse Electric Corporation	243
Hughes Aircraft Company	190
Sperry Corporation	180
Sylvania Electric ducts, Inc.	180
General Electric Company	160
Bendix Aviation Corporation	96
E. I. du Pont de Nemours & Company	91
International Business Machines	91
Eastman Kodak Company	78
Radio Corporation of America	77
Union Carbide & Carbon Corporation	68
General Motors Corporation	57
International Telephone & Telegraph Corp.	56
Goodrich, B. F. Company	52
Minneapolis-Honey ll Reg. Company	44
Corning Glass Works	40
American Cyanamid Company	22
United States Steel Corporation	21
United States Rubber Company	15
Chrysler Corporation	12

Chart 11



To further emphasize the kind of business you get into--and I have certainly had a liberal education in Detroit--I have naturally assumed as most of you do, and as most engineers do, that one could use a rational approach to the design of a car. But let me read what you are up against in trying to meet the desires and wishes of the customer. A 5-year study by an advertising agency resulted in these findings:

Four-fifths of all automobiles are bought by people who, at the beginning of the year, had no intention of buying a car or were uncertain about buying a car.

One-third of those who intended to buy a specific make, actually wound up buying a different make.

The survey showed that 77 percent of those questioned said that they did not intend to buy during the year. Eleven percent of these, however, changed their minds and did buy, and their purchases accounted for an amazing 48 percent of all automobile sales. Another 17 percent of the people queried were uncertain whether they would buy cars during the year; but 32 percent of them did buy; and they added up to 31 percent of the automobile sales.

I think these quotes and these figures begin to give you, as they did me, an understanding of why the automobile business is the way it is and why there is so much emphasis on chrome and tail fins. It is because they sell the cars! Those of us on the technical side are inclined to say the automobile business is about 50 percent engineering and 50 percent show business. People buy the cars on styling and then they complain about the cars based on the engineering.

This is all very unpleasant, as you can imagine, for engineers. We feel that there is something wrong about having so much emphasis on styling. Styling is really packaging. I have puzzled about this, too, and one has to learn to be philosophical about this. So I say this emphasis on packaging, however, is really not unnatural. After all, nature does a pretty good job of packaging when she produces a Marilyn Monroe!

This is a fascinating field for speculations, but I will quit these arguments and will turn to the question of how R&D is organized and managed. Let's see if I have some more charts on this.

Chart 12, page 22.--I think the Nelson paper that you were given to study gives an excellent compilation of the different techniques used by different people and different industries. It also nicely illustrates how different companies start out in the R&D business and, by and large, end up in exactly the same way.

I have just sketched here--and probably you can study this in more detail later--the way you go from basic research to applied research, to techniques development, which is important, and then move into the product--oriented areas.

I won't take the time to read this now. We'll move to the next chart.

Chart 13, page 23.--In general, any company that starts out with R&D ends up with some form or other of this thing which I call an idealized research and development laboratory. Management sits at the top, as usual, and away over at the right (on chart) we have a basic research activity. This is usually organized in line with academic tradition into chemistry, metallurgy, physics, electronics, and so on. This is natural, because the scholars like to have somebody to talk to and with this kind of an organization they can talk to each other. This is the way ideas get generated.

You start out this way, being as pure as you like in your research approach, but then you find that little warts start growing on this organization of yours. Take the chemistry department. In the talking that the chemists do, they come out with an idea which seems to have some commercial possibilities. Management then feeds in a little more money and a few more people and, out of the basic research activity, you begin to have a little applied research activity. Then this one starts growing and pretty soon it gets big enough so that you move it over to this next vertical column called applied research. You still have interaction between the applied research people and the basic research people, but the applied research activity makes more money, it is easier to sell to top management, and, as a result, it gets bigger. As it grows it overwhelms the basic research group, and pretty soon it begins to grow warts on it, too. And these are on a much larger scale. You get into major projects and in due course you lift these out and you put them over into what I call here Hardware Project No. 1 and then Hardware Project No. 2 and so on down the line.

Now, in this organization each of the hardware projects would have within the number of people working on it some of the same kind of people that you have over in basic research. You have chemists, metallurgists, physicists, electronics people, and so on.

Chart 12

ENGINEERING SPECTRUM

STATE OF THE ART

Basic Research	Primary interest to obtain new knowledge. Generally motivated by attempt to answer questions. Generally not motivated by any very specific product requirements.
Applied Research	Primary interest to apply new knowledge to specific product requirement. Generally motivated by a product deficiency or the desire to find new products.
Techniques Development	Primary interest to learn to use new knowledge in a practical, everyday manner. Generally motivated by a product deficiency or the desire to find new products.

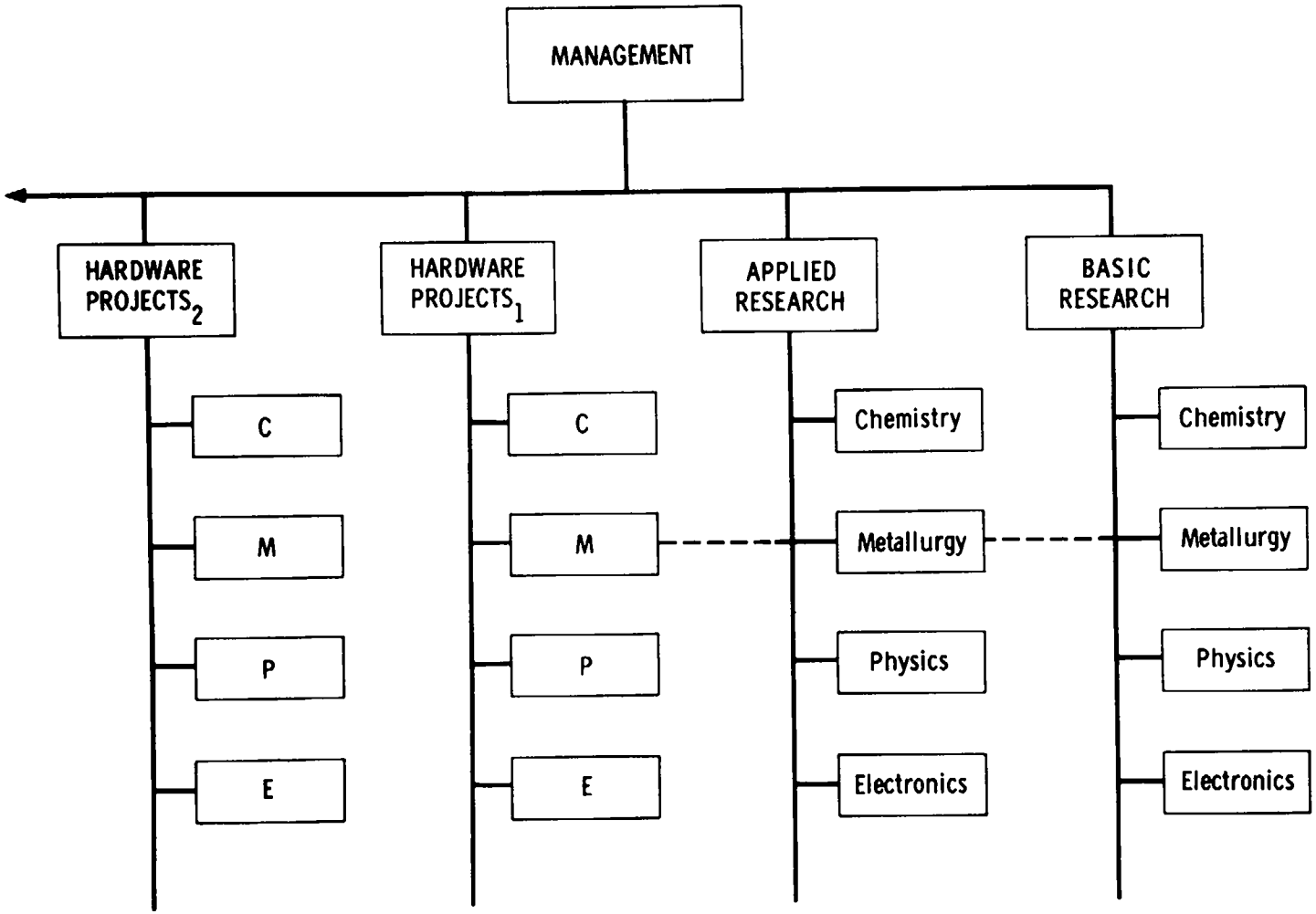
PRODUCT-ORIENTED

New-Product Development	Primary interest to design a new product on an established schedule at a specified cost and for a definite purpose.
Product Improvement	Primary interest to provide the customer or the factory with better or cheaper products.
Production Engineering	Primarily interested in methods rather than in the nature of the product.

SOURCE: The Management of Scientific Manpower, AMA

Chart 13

IDEALIZED RESEARCH & DEVELOPMENT LABORATORY



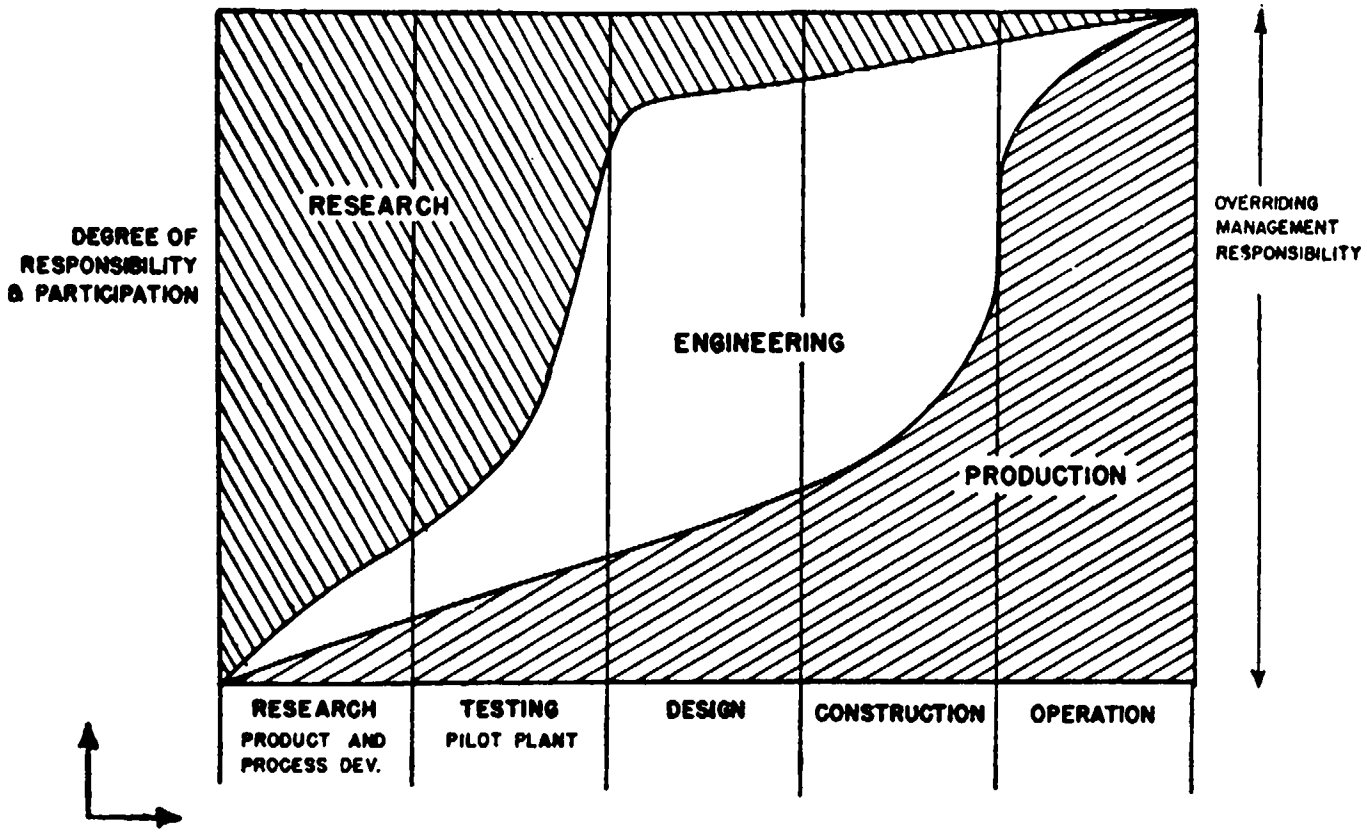
I think many companies have made what I consider an error in leaving all the working people over in the basic research or the applied research areas and then putting a project leader in charge of a hardware activity--Project No. 1, for example--but not giving him any people. So he is in charge of a project but his job is to "coordinate" activities in the working departments of mainly applied research and some basic research. This doesn't work worth a damn, as a matter of fact, because the people over in applied research are all busy with their own problems and have no intention of dropping what they are doing to work for somebody else. The only way to push through a project is to give the project leader a group of his own people, distributed as necessary through these different fields of technology but--this is very important--backed up with a lot of supporting people. Thus hardware projects would have a few scientists and highly skilled engineers and a lot of supporting people, whereas, by and large, applied research would have lots of highly skilled people and relatively few supporting people. As you go over to basic research, then you would have individual creativity, where you would have relatively more high-level scientists and creative engineers and less support in the line of additional low-level people.

There is only one rule that I know of to get hardware projects pushed through and that is put the project in charge of "a very good man with a pocket full of money." It's the only way you'll get the job done.

Chart 14, page 25.--Now, we get into what I call the transition problem. You move from research to engineering and to production. You start with an activity which was usually hatched in the research laboratory where a few people there got devoted to it and believed in it. One of the other stumbling blocks in industrial and military R&D is the business of taking a project which a certain group of research people believe in wholeheartedly and transferring it over to a production organization. You then run into what is classically known as the NIH problem, which means "Not invented here." If the people in the applied end of this--the engineering and production people--didn't get the idea themselves, obviously it can't be any good. For this reason it is almost impossible to transfer the research idea through engineering and finally into production.

Chart 14

Collaboration in Project Development



SOURCE: The Management of Scientific Manpower, AMA

I think the classic solution to this problem is to build up your research group, once you've got a small group there dedicated to the project, preferably adding people with engineering background and even from production, and feed these people in early, in order that you can begin to get their experience and their philosophy into the design of the gadget which the research people are making. Then, as the project approaches the hardware stage, I think the ideal solution is to split this new research group. Push the creative people back into research to dream up new ideas; then put a new man in charge of the remainder and move him over into the engineering activity. If he is the right kind of man, let him follow the development all the way through engineering and into production.

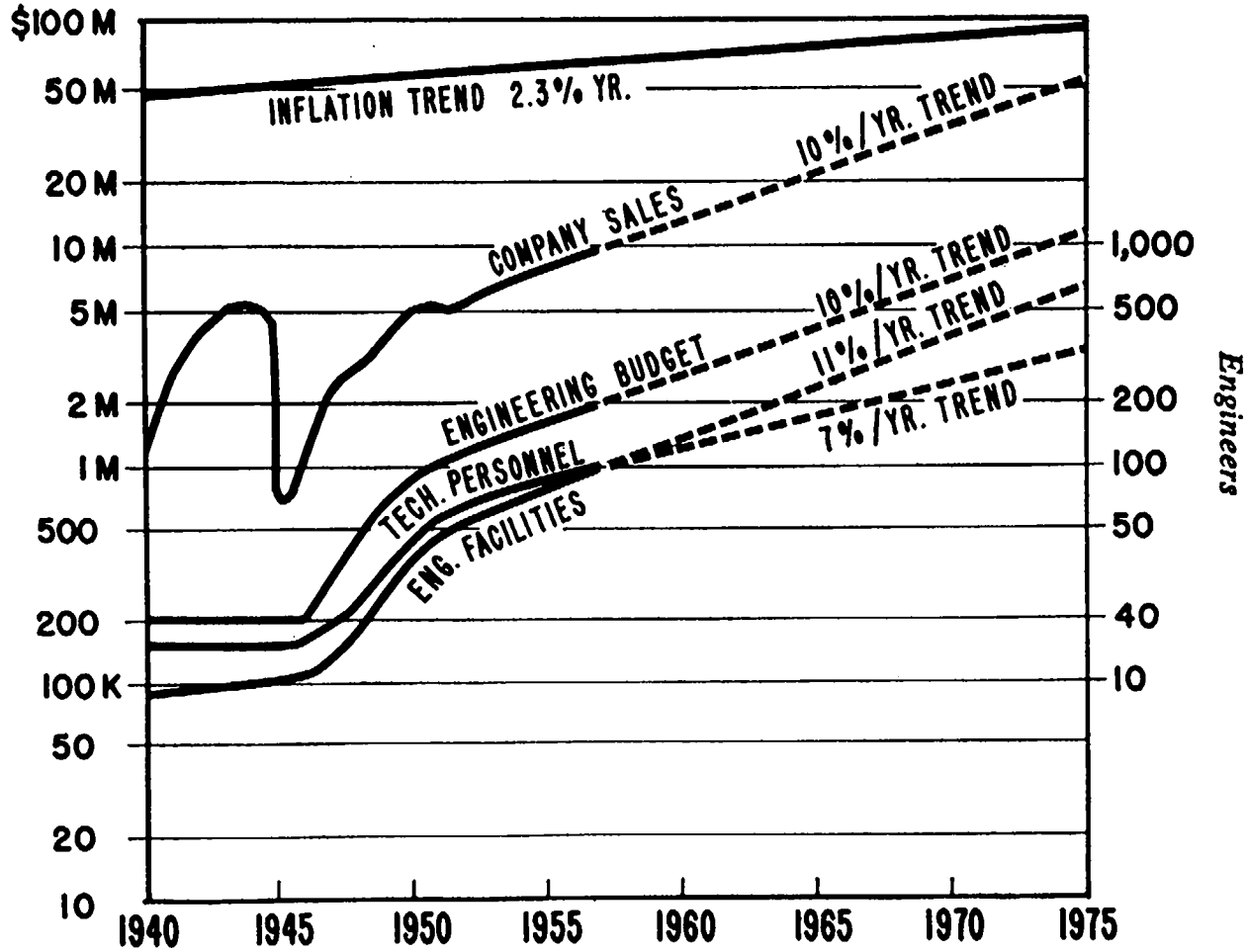
I call this the transition problem in R&D and it is a very difficult one, and one which has not yet been ideally solved, by any means.

Chart 15, page 27.--This shows how a company might be planning for growth. You will see that in such planning you have as a basis your company sales, usually a sales curve with violent fluctuations in it. One of the problems is to insulate your engineering and R&D effort from the fluctuations in the sales curve. The prediction for company sales increase in this chart is 10 percent per year, and your engineering budget and your engineering facilities, and so on, should presumably go up at this rate. But this rarely happens. The practical problem is to keep the money coming for engineering and R&D, and it has to be, usually, at a somewhat lower rate than the growth of the company. The money for R&D invariably lags, rather than leads, the sales activity.

Chart 16, page 28.--This shows, I think, why such a situation should exist. You will note here that this is for corporate business as a whole. The profits after taxes is the lower line, which is practically horizontal. Taxes rise slightly, but the compensation for employees rises very rapidly indeed. By and large, everybody who writes on this subject seems to be convinced that corporations ought to be spending more money for R&D. But remember, it comes out of the lower line, and this is one reason why it is so difficult for those of us in the R&D business, and those of us who believe in it and try to sell it, to try to squeeze out this money. In industry I have learned that you do work very definitely with hard money; not with the paper money that you work with on government contracts.

Chart 15

ENGINEERING FOR GROWTH



SOURCE: The Management of Scientific Manpower, AMA

Chart 16

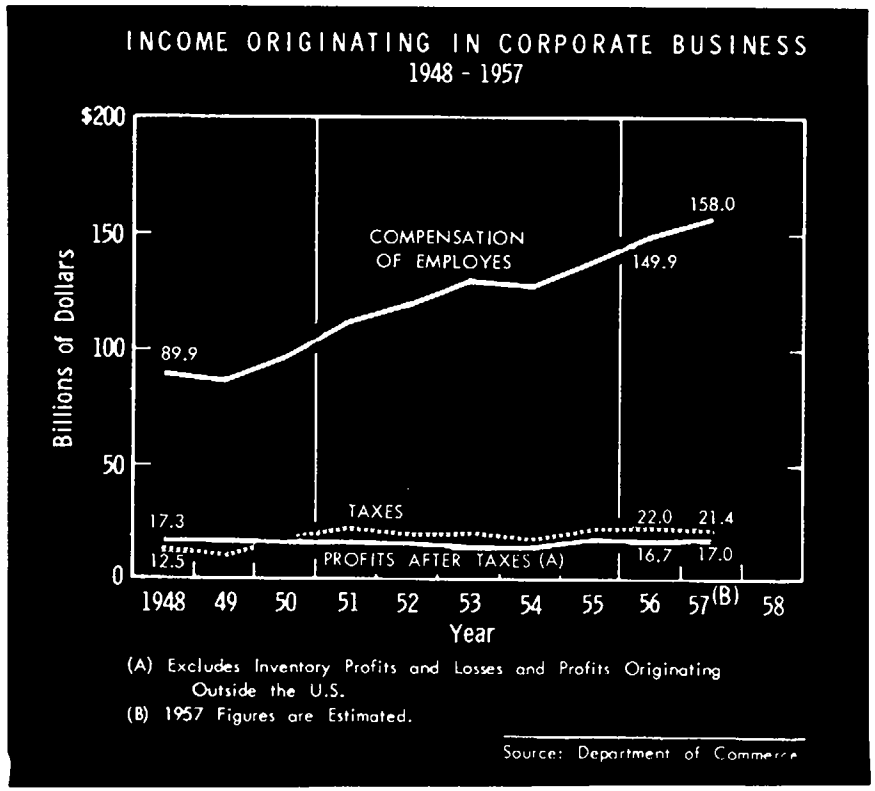

INCOME ORIGINATING IN CORPORATE BUSINESS
1948 - 1957
$200
150
100
50
0
Billions of Dollars
COMPENSATION OF EMPLOYES
89.9
158.0
149.9
TAXES
17.3
22.0
21.4
PROFITS AFTER TAXES (A)
12.5
16.7
17.0
1948
49
50
51
52
53
54
55
56
57(B)
58
Year
(A) Excludes Inventory Profits and Losses and Profits Originating Outside the U.S.
(B) 1957 Figures are Estimated.
Source: Department of Commerce

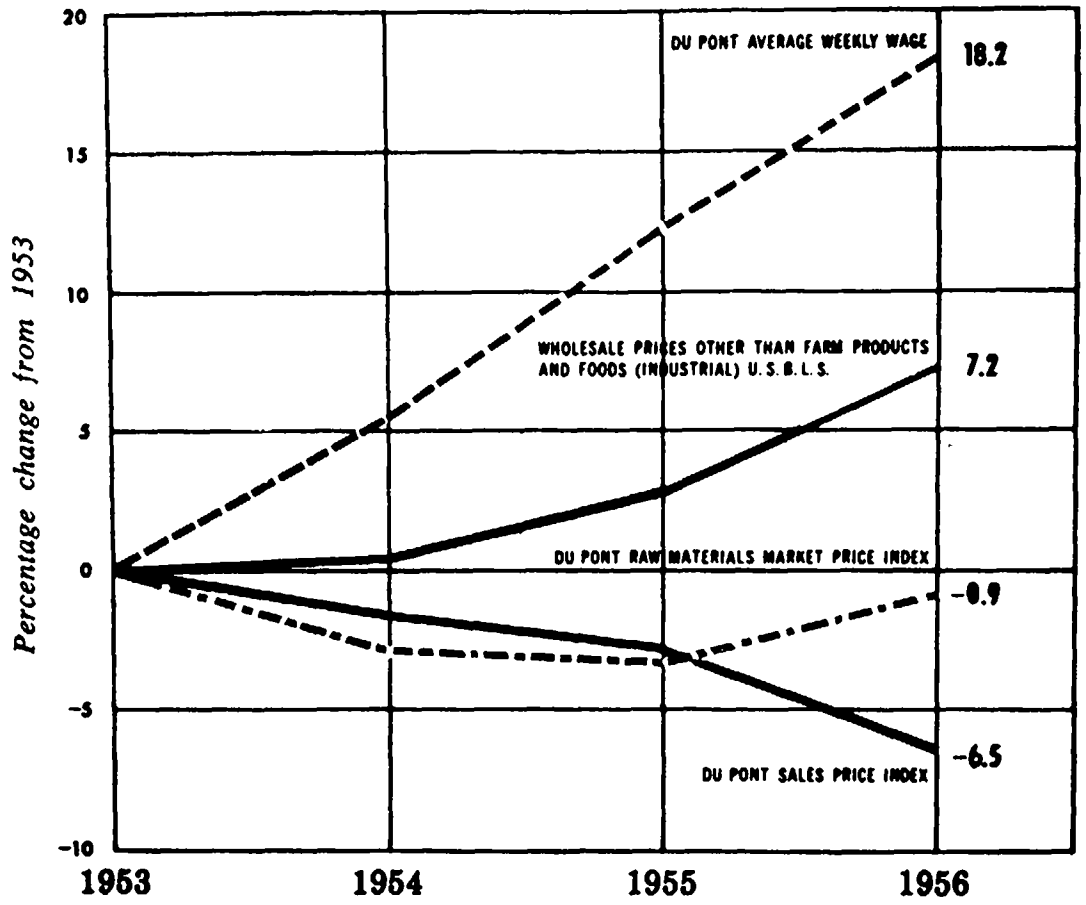
Chart 17, page 30. --This emphasizes the same thing still further. The upward curve shows the average weekly wage in the Dupont Company. The second curve shows wholesale prices other than farm products. The next one shows the materials cost that go into the product, and the lower solid line shows the sales price. So the problem for the research man in industry is not only to make a better product but to make a better product which can be sold in volume at a lower price. And this is a tough order indeed.

Returning now to my assigned outline, we have already talked about some of the problem areas in R&D. I think one mentioned here is cost, which I have discussed. The next important problem area is personnel. I could talk long on this subject, because the handling of personnel is a very controversial subject in R&D business. I think the reason for this is that for applied R&D you have to have an objective in mind. This applies to industrial or military R&D. And your people have to be dedicated to that objective. At the same time, as you all know from your general reading, the scientist insists on freedom to explore in any and all directions. This seems to be a very basic contradiction.

I think those of us who have been in the research-director business are not nearly so concerned about this as are the people who specialize in administration--say business administration students and writers. And I think there is a good reason for this. Those of us in the business recognize that we are, so to speak, at the same time the chairman of the department, as far as our basic science people are concerned, and the chief engineer, as far as the applied activities are concerned. Very often we have scientists working on engineering projects, and then they are damn well directed. On the other hand, we might have engineers who are off on an excursion, working in basic science, so to speak, and under those conditions they are not directed. Those of us in the business usually know which kind of project a man is working on, and it doesn't cause us, or him, any great concern as to whether he is or should be directed. The writers on business administration, however, are forever confused by this particular problem of how you manage to set an objective and yet give freedom to your people. Scientists, by and large, are individualists, particularly the creative ones, and these are the people we must work with.

Chart 17

Trends of Sales Prices, Major Costs, And Other Factors



SOURCE: The Management of Scientific Manpower, AMA

Let me just give you one more comment on costs. I think you will enjoy this. After all I have told you about costs and the difficulty of making up the budget and the evaluation, and so on, I thought you would enjoy hearing this conclusion from one of the fellows at G. E. I'll read you a little poem:

I multiply your projects by the words I can't pronounce,
And weigh your published papers to the nearest half-an-ounce;
I add a healthy bonus for research that's really pure
(And if it's also useful, your job will be secure.)
I integrate your patent rate upon a monthly basis
And I figure what your place in the race to conquer space is;
Your scientific stature I weigh upon some scales
Whose final calibration is the company's net-to-sales.
And so I create numbers where there were none before;
And thus have facts and figures and formulas galore--
And these volumes of statistics make the whole thing very clear:
Our research should cost exactly what we've budgeted this year.

Now I want to turn seriously to the question of the contribution of R&D to our national security. You have already read the article by Nelson. I would cite for you a couple more which I consider particularly important. One is by Charles Hitch, "Research and Development and Its Impact on the Economy," National Science Foundation Publication 58-36. It might be worth reading one of his statements which I think comes to the point of a very basic question.

"Judging from the press, there is general agreement that all is not well with military research and development. And again, judging from the press, there is rather surprising unanimity in diagnosing what is wrong. Apart from a small but distinguished group of dissenters, mainly from science and industry, practically everyone charges that military research and development is uncoordinated and inadequately planned and plagued by duplication, competition, secrecy, and waste. The remedies are alleged to be obvious. There must be strong central direction and coordination, more and better central planning, tough-minded decisions to eliminate duplication, suppression of interservice and other competition, probably some czars to knock heads together."

Now let's take a hard look at the character of research and development in the competitive economy. It is not coordinated, there is no central planning or direction, there are no czars, there is no weeding out of unpromising projects at any higher level than the individual competitive firm. There is intense competition, accompanied by secrecy and

poaching, an enormous amount of duplication and, from the vantage point of hindsight, much obvious apparent waste. In fact, in addition to the lack of coordination among firms, a good many companies noted for their achievements in R&D--for example, Bell Laboratories, G. E., Radio Corporation of America, and Dupont--deliberately decentralize control of research, each laboratory receiving a block budget within which it has complete freedom and responsibility.

I think this is worth pondering, because here we have all the criticism of the military R&D program because it is not centralized, yet we brag about (and I think, correctly) the achievements of private industry where we do not have centralized direction, and where we certainly have a lot of duplication and apparent waste. This can be understood only if we think hard about what the motivations are and what the controls are.

The great advantage that private industry has is always the balance sheet at the end of the year. In private industry you can do anything so long as you come out with a profit at the end of the year, and it shows up on the profit and loss statement.

In the military and the government business you don't have this, and I think this is the reason for all of the pressure for centralized authority and planning.

My own feeling is that there is room for improvement if we can somehow get the user into the act a little more effectively. I am thinking here of the military as the user. My worry is that the competition that exists is not competition in producing the best product or even in selling that best product to the final user, the military combat people. The competition, as things have worked out, is in selling the contract to the financial people, and this is an entirely different technique. It is troublesome because neither the industry, which is in the business, nor the user is happy with this deal. The number of actual useful combat devices that we have turned out in the last decade is really disappointing indeed, and very small compared with what was done during the war, for example, with much less money.

So my hope would be that somehow or other we could get the military back into the normal business of being combat people and choosing their own weapons. I think they have a right to pick their own weapons, and I think they ought to be very choosy about the weapons they get. They should not, however, be in the business of telling civilian groups how to make those weapons. If we could sort out these two functions I think it would be helpful.

I remember back during the war that we always used to have arguments with our military counterparts. We would say, " We need from the military a statement of their problems and their requirements and their needs, but they shouldn't tell us how to make the gadgets." I still think this is where one should draw the dividing line in the planning that is done.

We have talked quite a bit about lead time, and I would like to cite for you another article which I consider quite important in this area. It is a paper by Ellis Johnson, and it is in the Operations Research Magazine of January-February 1958. He analyses the reasons for the long lead time which we have begun to live with in our military developments. He stresses also the large number of technical choices which are now available to the people who have to make these decisions. The number of technical choices means that it is very hard for anyone except a professional in the business to really appreciate the pros and cons and relative weights to give to these technical factors that enter into the design. This is why I am inclined to agree with Ellis Johnson that we need more professionalism in this area. Johnson stresses too the question of incentives, and here is an area which I would like to urge the Industrial College to look at very seriously.

The incentive system, which I think served the United States so well from the time of the Robber Barons on to about 1930, is now gone. We have an entirely different governmental mechanism. And the thing that worries me in looking down into the future is not the conflict of Russia as a representative of Marxism and the United States as the exponent of capitalism. I think the problem is a very much more dangerous and a much more fundamental one. It is that the competition is now between the Russian incentive system and the American incentive system. We both use incentive systems. Their's is on the way up; our's is on the way down. As an engineer and a scientist, I think trends are ever so much more important than instantanteous values. This is the thing which I think the Industrial College group here ought to think very hard about.

Now, I have a few more charts that I would like to show to, I hope, emphasize this point a little bit further.

Chart 18, page 34.--This happens to be a population curve which many of you have seen. The population of the world from prehistoric times up to about 1700, or thereabouts, grew to about one-half billion people. From there on it has been growing rapidly indeed. It is called a population explosion. Now, I like to needle my sociologists and political-scientist friends by the next chart.

Chart 18

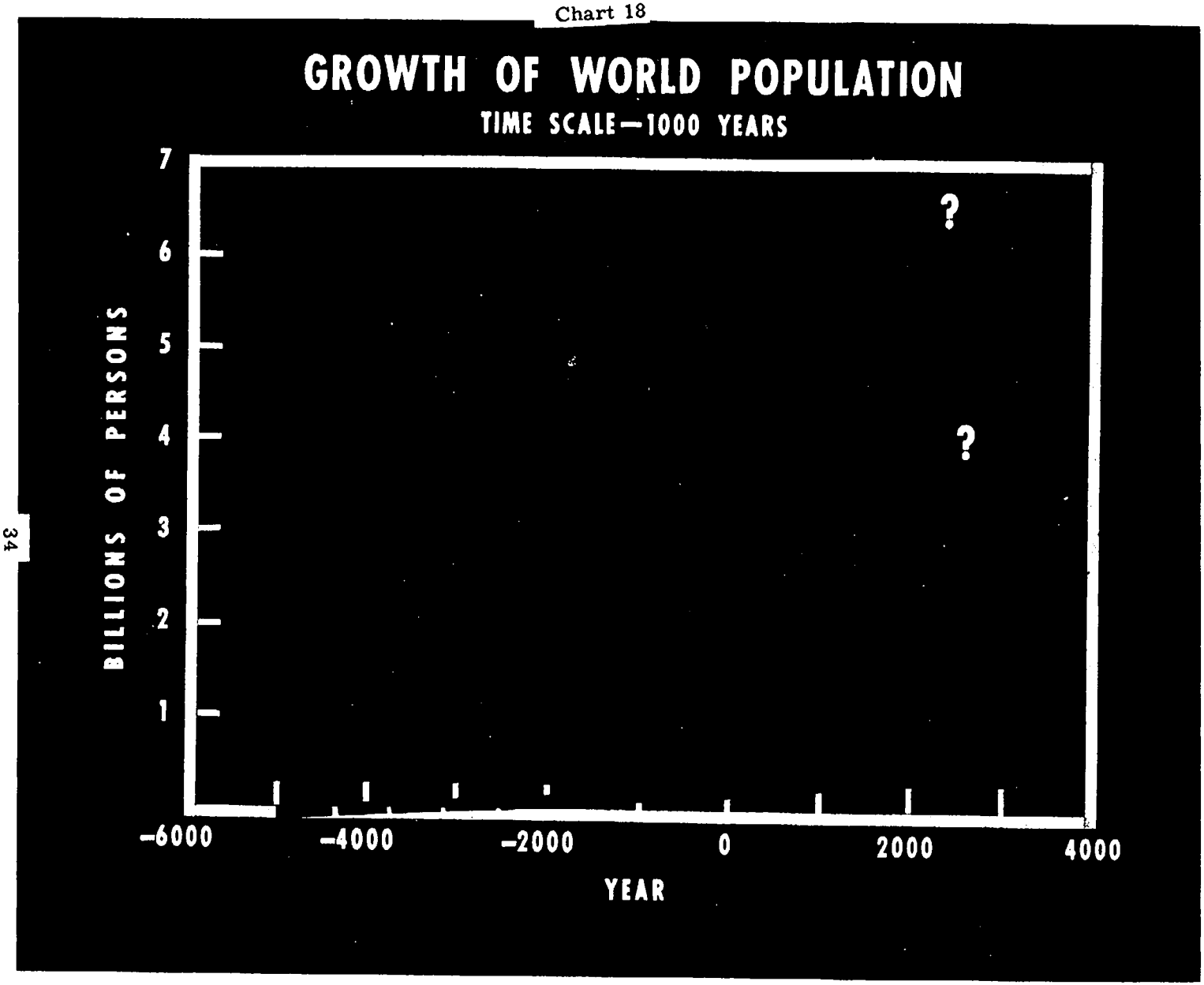

GROWTH OF WORLD POPULATION
TIME SCALE—1000 YEARS
BILLIONS OF PERSONS
7
6
5
4
3
2
1
?
?
-6000
-4000
-2000
0
2000
4000
YEAR

Chart 19, page 36.--Here at the bottom I show you the humanity contribution, because that hasn't changed very much since earliest history up to 1700; and then the technology contribution since about 1700 up to the present time. I think this is an appropriate presentation of the situation, because, by and large, the humanists, as I like to call them, and the educators, and so on, still can't be bothered about learning enough about science to control it and to guide its development. We are living in a technological society, but apparently nobody, except the engineers and scientists, are supposed to worry about this thing. And I think this is a fundamental weakness in our setup.

Chart 20, page 37.--This is the way I have tried to present what I see going on. Suppose you plot progress or increase in the standard of living in the upward direction, and plot time off to the right. By and large, scientists and engineers see the vertical steps, and the large amount of effort and energy that has to go into making this progress and making the improvements. The educators and the humanists, who can't be bothered with learning anything about science, look at it from the upper direction, and they see this progress merely as a series of tableaus. Each tableau--that's the stair step--shows a progressive improvement in the standard of living, and they seem to take it for granted that this will continue with time and extrapolate into the glorious future.

I remind you of some of those first charts that I showed, where R&D, if continued at the present rate, would absorb all of the working population of the United States for the electrical industry alone, if we are going to continue at the present rate.

These are the things which mean that this process must come to an end; but, frankly, I don't see any economists worrying about it more than saying that there is a 2.5 percent increase per year in labor productivity, that this has continued for the past 10 years, and that we assume it will continue in the future. By what right do the economists assume this will continue in the future? It has taken an enormous increase in R&D to maintain this rate. Furthermore, "labor productivity," as all of us know, is not an increase in the productivity of the laborer. Labor productivity is an increase in the tools which have been provided to the laborer. Labor productivity itself has been going down, what with coffee breaks and all of the other things which have gotten into the picture.

Chart 19

GROWTH OF WORLD POPULATION

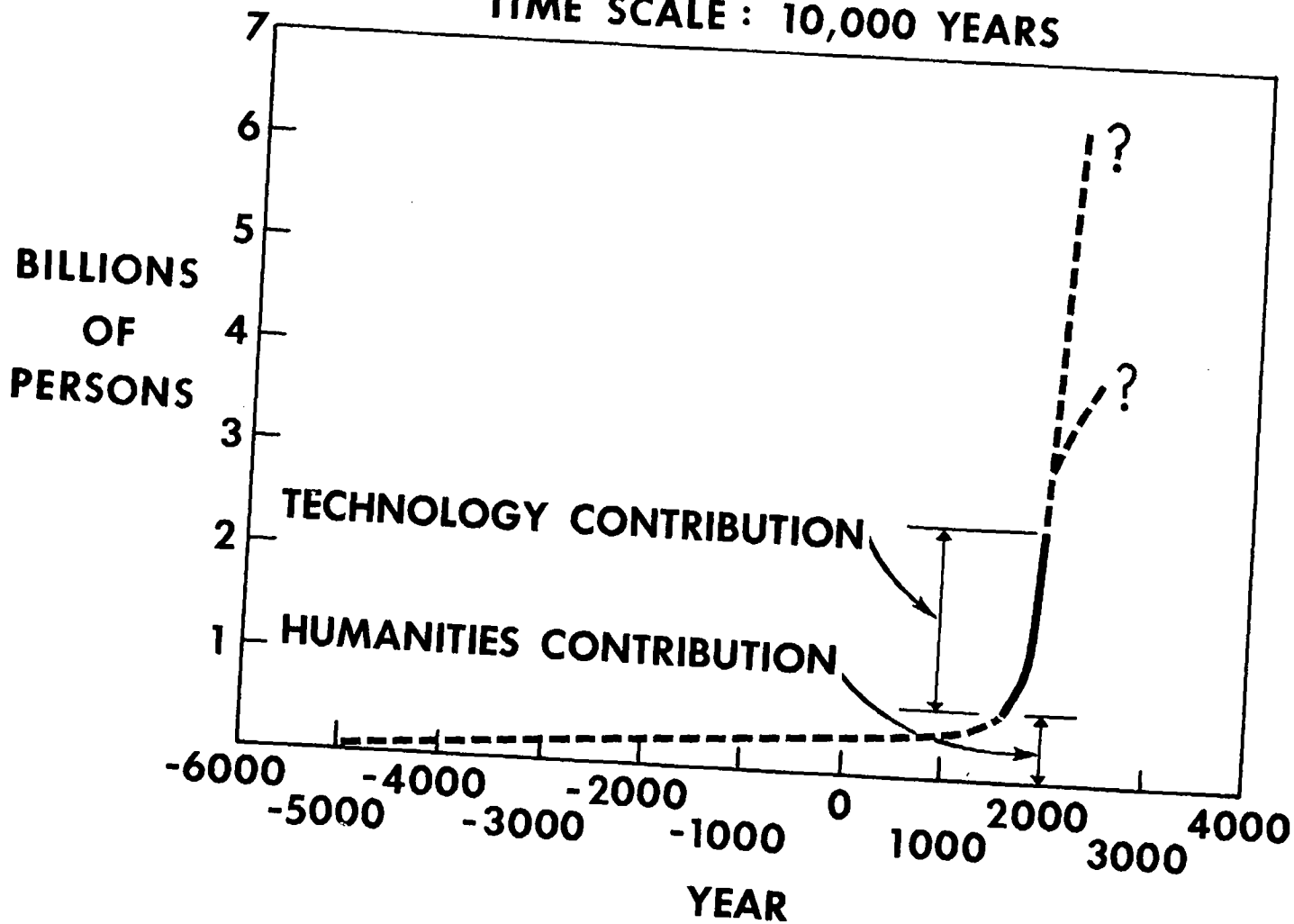


Chart 20

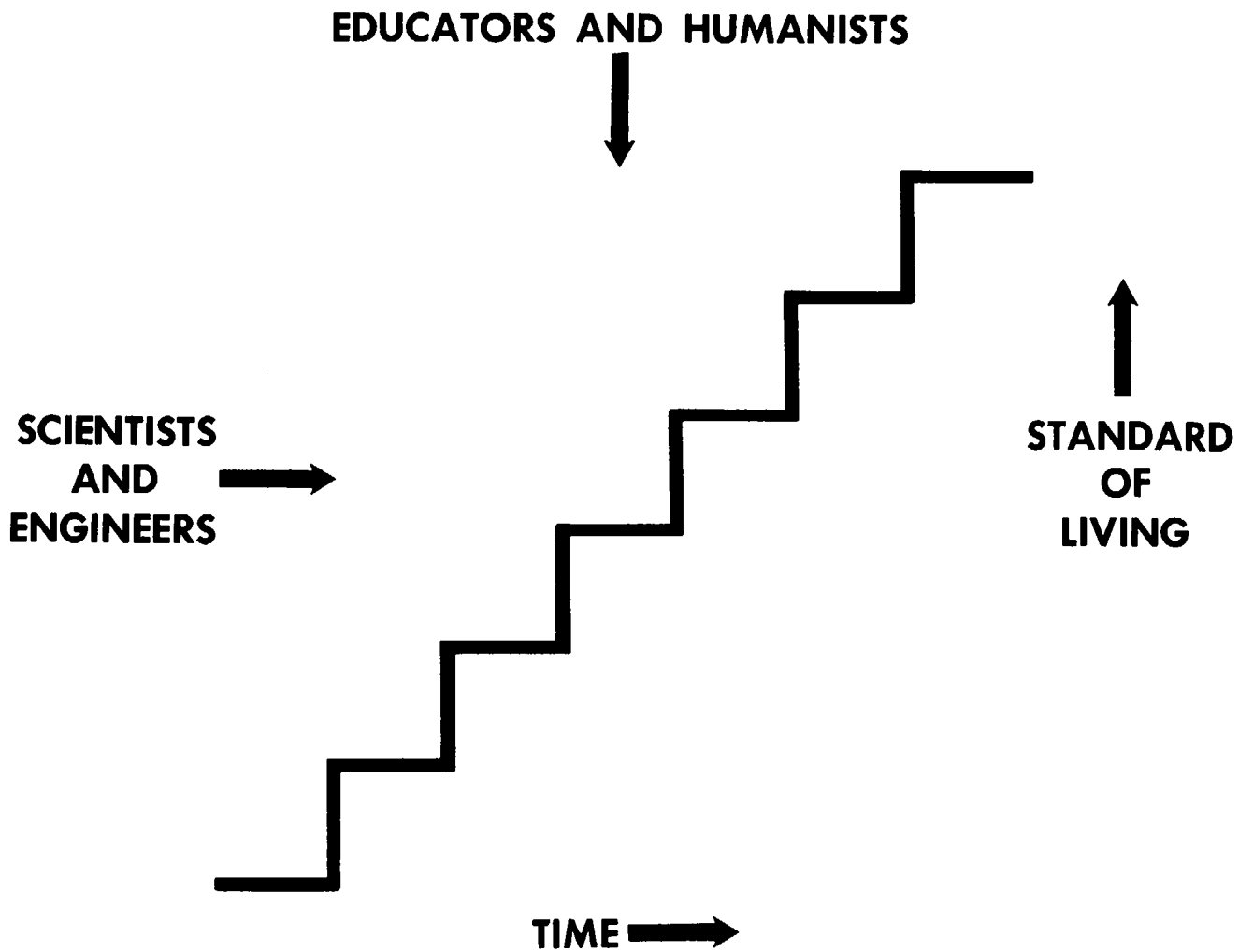


Figure 1

So my concern here is that the economists and the lawyers are very much alike, in that they have eyes only in the back of their heads. If there is anything that needs doing it is for a new group of people to start taking a look at our society and our economic system to see what it is going to be like if and as we extrapolate into the future.

I have one more thought I'd like to leave with you. Being an old professor, I like to leave my students with something to ponder about. It is this: Looking back in history, if you look over the societies that have grown and died and puzzle about them a little bit, I think you will find that we need in our assessment of these things something which I like to refer to as the lift-over-drag ratio. A society will make progress only if the lift is greater than the drag--not otherwise!

Thank you very much.

CAPTAIN FIKE: Dr. Hafstad is ready for your questions.

QUESTION: Dr. Hafstad, could we see that stair-step chart again?

DR. HAFSTAD: O.K. We'll see if we can raise it for you.

STUDENT: Assuming that politicians, State Department people, and other government employees are up at the top of that chart where they are looking down on the horizontal, and only the scientists and engineers are looking at the vertical, how can the scientists and engineers bring their logic, judgment, and scientific discipline to bear on those people up there so that we have better government?

DR. HAFSTAD: This is one I can certainly comment on. I have been feuding with these people for some time, particularly the progressive educators, and so on, and my contention is that what we ought to do from now on--we can't do anything about the past--is to make sure that all students get a reasonable education in science and technology. To me it is no more wrong to expect a lawyer to have passed a course in physics than it is for an engineer to take a course in English literature. And I think this would pay big dividends. Let me give you a personal example of this. One of my earliest experiences with government was when I was a student in college and my professor, who happened to be Professor Janski, was running to Washington, cancelling classes every so often, to talk to the Communications Commission, which was just being organized. Whenever he came back he told us about the struggles down here, and at that time the channels were just being allocated for various frequencies. His main trouble was with constitutional lawyers

who insisted that in this country every citizen has a right to a band of frequency in the spectrum.

This is what you have to contend with. It seems to me that even lawyers ought to know that natural law is slightly more fundamental than constitutional law.

QUESTION: In our reading we can all recall seeing that the automotive industry in this country has profited by adapting European invention, rather than by inventing things itself. Would you respond to this, giving us some examples of how you feel about it?

DR. HAFSTAD: Yes. I think this is quite clear, when you stop to think about it. By and large the innovations in the automobile business are not particularly difficult to make themselves. They can be made in a small machine shop, so to speak, and can be tried out on a relatively small-scale. And in Europe, with cheap labor and a lot of ingenious engineers, operating on a small-scale, with many, many different companies building a few cars, it is very easy for them to try out new and novel ideas. In this country we are already, so to speak, frozen in volume production, and it is just too dangerous, moneywise, to try out a lot of novel ideas on a very large-scale. The risk is too great. The tooling costs are too high. This tends to make our large industry conservative, compared to European small industry in this area, and naturally we watch and see what the customers like that is introduced in Europe, and then make an adaptation in this country.

Again you come back to these fundamentals: we are in business to make money; the customer is always right. We adjust to these two things and take advantage of what is done in Europe. There is no pride of authorship here at all.

QUESTION: Doctor, I noticed throughout your talk the words "technical progress," "technology," and "science" were almost used interchangeably in some places. What is your true definition of technology?

DR. HAFSTAD: I would say that the main separation to make in your mind is in science and engineering. To me science is the acquisition of knowledge, learning new things, understanding nature. That's where the scientist stops. It is up to the engineer to be an applied scientist--if you like--and he takes this knowledge and converts it into something useful for society, for the military, for whoever it is. The engineer works with technology. Once he has taken over, in my

definition and in my understanding, I would say that this is technology. As a society, we are interested in technology. I assume a society really doesn't enjoy or care for knowledge for its own sake. This is where I make the distinction. Knowledge for its own sake is the bailiwick of the "eggheads" and the scientists. Technology is the bailiwick of society as a whole.

QUESTION: I was interested in your comment on forecasting the future and your challenging the economists as to their right to forecast 3 percent a year for a time. If you don't use history projections, trends, and models, what method would you suggest that we use in handling this? I say this from the fact that I am now assuming it is true that the people who make these forecasts are also in the business of changing policies and legislation, and make the goals that are forecast realized.

DR. HAFSTAD: Unfortunately, I think you are right. But here I think I would urge that the forecasting be done in what I would call a more thorough way with more thorough studies. You can look at the gross-national-product curve--corrected for inflation, let's say-- and then say that, by and large, we are running 2.5 percent a year, or something of this kind. But underneath that 2.5 percent you have to satisfy yourself as to what it is that creates wealth, what it is that makes the society actually grow. What are the forces acting? Here I think you will find that in our present society, as the quotation from Schlicter indicates, the motivation force in this new technology which is coming is due to R&D. Then you ask yourself: What are now the forecasts for R&D? The game is getting tougher and tougher and tougher. All the easy things are done. I think it was Derek Price who pointed out that the results from research, if a thorough study is made, come out as the cube root of the money that is spent. He cited the volume of a pyramid as representing the amount of effort that goes in R&D, and the height of the pyramid as what comes out of it. So I would counter your suggestion by asking you the question: If you want 2.5 percent per year increase in our corrected gross national product, are you really prepared to pour in R&D money at an exponentially increasing rate, and for how long? This is the other half of the question.

STUDENT: Don't we do this now? Don't we pour in R&D money now? There is no assurance when you pour it in that you are going to get anything out of it. We have poured it in in the past. You are forecasting.

DR. HAFSTAD: Well, my whole point is that certainly you've got to put in more money. But there are other forces acting. The quality

of our R&D effort will degrade as the scale increases. I think most of you have seen evidence of this. Let me just take what I would call the inflation in the title of Ph.D. Before the war a Ph.D. was a man dedicated to research and to an understanding of nature. Now there is a cash value on the title of Ph.D. and a lot of people are going after the title; not after the knowledge that the title used to represent. There is a big difference in those two things. Those of you who are military people I would remind of the difference between a professional and a mercenary. If you read revolutionary history you know that the record of the mercenaries was not too good. I think the same thing tends to happen in the research and development business.

QUESTION: The trend in R&D in the Armed Forces seems to be going to the system type of thing, where the prime contractor does the R&D and also the production. In view of the seriousness of the problem that you point out in the transition, in your mind is this a good way of going, or do you really make the problem more difficult from one outfit to another?

DR. HAFSTAD: For any one project I think it is a very good way of doing it. If the thinking and analysis initially has been sufficiently good to insure that this project, if supported and carried out successfully, will end up in a weapon used by the military services, then I think it is excellent. The weakness and the trouble are that so many things started in this way are aborted, usually at about the 80-percent point, and the number of things that we have started in this country and almost finished is a little bit frightening. If all of the money had been poured into honest-to-God competition for end items to be selected by the military, I think we'd be better off. The weakness of this is that if we start a company, get it half-way through, or three-quarters of the way through, and then try to change our minds, we have to find something else for that company to do, for political reasons. Then we are committed with a large amount of our money going into things that have not been carefully thought out in advance. I don't know how to avoid this, but this is what happens as a result of this approach.

QUESTION: Dr. Hafstad, I believe you said that the incentive system which has served us so well from the time of the Robber Barons has gone. This was a most provocative statement, and I wish you would follow it up a little bit.

DR. HAFSTAD: I am a little puzzled as to what you want me to say on this. Don't you find from your general reading that this is confirmed

in all directions--not to mention your own experience? It seems to me that, if you just take a look at our society and see where the high incomes are, and ask yourself, as a sociologist or a political scientist: are we really rewarding the things that contribute the most to our society? You will find that there is a very real distortion in our incentive system. This is what I am referring to. I could just cite examples one after another of the incentives in industry. The return on Government contracts, the legitimate, allowed return, is so low that no reasonably successful commercial company can afford to drop its commercial business in order to take on the Government contracts. This has a consequence which worries me--that we tend to split our industrial society into two groups--a taxpaying activity and a tax-consuming activity. Surely this gives a peculiar base for an industrial society.

The incentive used to be profit; but now the profits are negotiated away. Even if you put on a fixed-price bid and the company sees a way of reducing costs and goes ahead and does this, there is a renegotiation procedure which comes into the picture and takes those profits away. So the trend in all of Government procurement is to eliminate the profits or reduce them to a minimum. This I maintain is contrary to the old-fashioned incentive system, which may or may not have been good but did work.

QUESTION: Sir, do you feel we are running out of basic research as the result of it all, and could we put a greater percentage of our effort into basic in order to meet longrun challenge?

DR. HAFSTAD: This is a problem that has been worked over pretty thoroughly. I was quite concerned about it up until the time we got the National Science Foundation rolling, and, by and large, I think this problem is now recognized--that we must have basic research supported with considerable latitude in order to have the raw material which our engineers and technologists can cash in on. I am sure the problem is not yet solved, but it is recognized and is getting the attention that I think it deserves.

QUESTION: Sir, to go back to the incentive question, I inferred some correlation between the trends and incentives that you spoke of vis-a-vis ourselves and the Russians and your comments on education. If my inference is correct, is there anything else we ought to do about reversing this trend?

DR. HAFSTAD: A lot needs to be done. How to do it is not my specialty. Let's take the questions which have been raised here on incentive. In your general reading you will find that the university teachers, research people, engineers, production managers and whatnot are the new elite in Russia. In this country, the way I like to express it is that our university people, by and large, are considered to be unsuccessful engineers or scientists. There is almost a stigma being attached to the university. I sometimes express it this way--that in Europe a scholar is recognized to be a success, even by his wife. That's more than you can say in this country.

CAPTAIN FIKE: On behalf of the Commandant and the students, I thank you for a most provocative and a very stimulating discussion here today.

DR. HAFSTAD: Thank you.

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