OVERSIGHT OF SCIENCE AND TECHNOLOGY POLICY

JOINT HEARING

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, TECHNOLOGY, AND SPACE

OF THE

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

AND THE

SUBCOMMITTEE ON
SCIENCE, RESEARCH, AND TECHNOLOGY

OF THE

HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY

ON

OVERSIGHT OF THE NATIONAL SCIENCE AND TECHNOLOGY POLICY, ORGANIZATION, AND PRIORITIES ACT OF 1976

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OVERSIGHT OF SCIENCE AND TECHNOLOGY POLICY

TUESDAY, FEBRUARY 14, 1978

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE; AND
HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY,
Washington, D.C.

The subcommittees met jointly at 9:40 a.m. in the Park Ballroom of the Sheraton Park Hotel; Hon. Adlai Stevenson presiding.

Senator STEVENSON. The meeting will come to order.

Mr. Daddario.

STATEMENT OF EMILIO Q. DADDARIO, PRESIDENT, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Mr. DADDARIO. Chairman Stevenson, Congressman Brown, as the president of the AAAS, I want to thank you for coming here to our annual meeting, to welcome you, and to tell you how pleased we are that you have been willing to take your ongoing meetings, and transfer them here for a little while so that we, the members of the AAAS, and the public present here, can participate in actual congressional hearings.

It is a unique opportunity, an opportunity for us to educate ourselves as to what is going on in Government and how it works, and the fact that you are willing to do this is just wonderful, from our point of view, and it adds in great measure to these meetings.

I would like to just express a couple of thoughts, if I might, before you proceed with your other witnesses.

As we have held these meetings over the course of time, it becomes increasingly important, I believe, that we pay additional attention to science education. Continuing support of science education is, in my opinion—and I think that is shared by a great majority of the people here—one of the most crucial areas of the whole science and technology establishment.

It is not just first-rate advanced education in the sciences which concern us, however, but the courses available at the undergraduate and secondary schools where most students decide if science is what they want.

We will not, most certainly, solve our serious social problems without adequately trained manpower. Therefore, our science training programs offered the students at their most impressionable ages should be of high quality within an attractive and adequate curriculum.

As of late, we are doing a lot of thinking, for example, about the transfer of technology from the developing countries. The United Nations meetings next year are probably highlighting that concern. Yet, we must carefully consider, together with that, perhaps even because of that, the importance of the distribution of the world's reserves of resources.

There is probably no single factor more important to the consumption of these reserves than the future application of technology. And yet, the combination of the scarcity of these resources and technological capabilities to apply them—and they are becoming more equally distributed throughout the world—raises all kinds of other issues which produce difficult tensions throughout the world.

Therefore, the training of scientific manpower in the use of them in the years ahead, when the scarcity of resources will put a premium on how those resources will be best used, will become a matter of increasing importance to all of us.

And just one further comment. Having worked for many years in the Congress to develop science policy matters, I was particularly pleased when science policy legislation was passed a couple of years ago, not only because of the importance of the contents of that legislation, but also because it forged a legislative-executive relationship which is of utmost importance.

The basic ideas in the legislation are sound. The fact that it gives an opportunity to increase the partnership of the legislative and executive branches in handling these complicated scientific and technical matters is also of importance, and I applauded the passage of the legislation at that time, and I do believe it is important that it be carried out so that those of you who have taken such an interest in these matters in the legislative branch can have available to you the kinds of information that that type of legislation makes available.

Again, I want to thank you and welcome you and wish you success in these hearings.

OPENING STATEMENT BY SENATOR STEVENSON

Senator STEVENSON. We thank you, President Daddario, for your warm welcome this morning, and all of the officers and the staff of the AAAS for their assistance in arranging this joint hearing of the Senate Subcommittee on Science, Technology, and Space, and the House Subcommittee on Science, Research, and Technology.

The House subcommittee is chaired by Congressman Ray Thornton of Arkansas, but this morning we are joined by Congressman George Brown of California, who will preside for the House.

This collaboration between the House and the Senate is unusual, and so is our procedure this morning. We have invited brief opening statements from our witnesses, to be followed by a discussion among the panelists. We will then open up the hearings to comments and questions from the audience.

This morning, the subject is the state of American technology and industrial innovation. I might mention a few familiar statistics which help form the background for this hearing.

Science Indicators, 1976, reports that since 1963 the United States has spent a steadily declining percentage of its GNP on research and development, down from nearly 3 percent to 2.2 percent. Japan, West Germany, and the Soviet Union recorded significant growth in the proportion of their GNP devoted to R. & D.

Foreign patents in the United States increased 91 percent between 1966 and 1976 to the point where patents of foreign origin represent 35 percent of all U.S. patents and are distributed across a wide range of subjects. The United States now has a negative patent balance with both Germany and Japan.

The United States' share of major technological innovations fell from 80 percent in the mid 1950's to 60 percent in the mid 1970's. In output per man-hour, the U.S. productivity gain between 1960 and 1976 was smaller than that of Japan, Germany, Canada, France, and Britain.

This morning we will examine the state of research and development in the United States, its effect on our economy, and what needs to be done about it.

Our witnesses are well qualified to help us in this endeavor, and we are fortunate to have them here with us.

Before turning to the witnesses, let me introduce and call on Congressman George Brown for any comments he might like to make.

OPENING STATEMENT BY REPRESENTATIVE GEORGE F. BROWN

Mr. BROWN. Thank you very much, Senator Stevenson.

I am very pleased to be here, and I have a brief statement which, in the usual congressional fashion, I will ask to be inserted in the record in full.

Senator STEVENSON. Without objection.

Mr. BROWN. And I just would like to make a few comments of appreciation. I'm very happy that the AAAS has provided this opportunity for a fairly unique collaboration between the House and Senate committees concerned with the health of science, and I'm looking forward to the benefits of this session.

I want to mention that Chairman Thornton of the subcommittee was extremely disappointed that he was not able to be here and asked me to substitute for him, which I will do to the best of my ability. But he has played a very leading role in science policy matters in the House and wanted to take part in this meeting.

There is an increasing feeling today that we have reached a watershed in the relationship between the Federal Government and the performers of the Nation's research and development in the universities where the bulk of the basic research is done.

We see substantial changes occurring, the outcome of which is far from clear. Enrollments are dropping. State support in the traditional form is no longer adequate. The leveling of Federal support has placed a hardship on the institutions as far as providing openings for young science Ph. D.'s. And, of course, we are faced with the prospect of an aging professor population.

Industry faces problems of a similar nature in terms of their ability to put funds into research and development. And, as Senator

Stevenson indicated, foreign competition seems to be getting ahead of us. In the House, we have been particularly concerned with this in connection with the steel industry, and this has led to the formation of a steel caucus, and since I have a steel plant in my district, I have joined.

We are concerned that basic industry is lagging behind in innovation and look forward to the contribution that our distinguished panel will make this morning.

I hope that today's work will give all of us a better understanding of the problems, and I'm looking forward to participating this morning.

[The statement follows:]

STATEMENT OF HON. GEORGE F. BROWN, U.S. REPRESENTATIVE FROM CALIFORNIA

Senator Stevenson, distinguished witnesses, ladies and gentlemen of the American Association for the Advancement of Science.

It is a great pleasure and a distinct honor for our House Subcommittee to join with the Senate Committee on Science, Technology and Space and its distinguished Chairman, Senator Stevenson in holding this public hearing on science policy matters. We are pleased at the invitation of the A.A.A.S. to hold our hearing in conjunction with the Association's annual meeting, and I personally look forward to benefitting not only from the statements and discussion with our witnesses, but also to hearing the views of our audience.

The session this morning will seek to explore a question which is increasingly of concern to the President and the Congress. This is the relationship between our national expenditures on research and development, innovation, and our national economy.

This question is significant because it affects a number of fundamental factors. It affects employment. It affects productivity. It affects health. It affects American agriculture. And it affects our competitive position on the world market.

The rationale for Federal support for research and development has been based on our experience in World War II and the immediate post-war years. During those years we found that the scientists who had descended from their ivory towers made a series of contributions to the winning of the war through such developments as radar, the proximity fuse, and, of course, the atomic bomb.

When the war ended the scientists turned their energies back to their laboratories on the campuses and in industry. But the Federal Government, having experienced the payoff in technology which the work of the scientists yielded, concluded that the continuing health of American science, was a Federal responsibility.

Since those years of Vannevar Bush our policy has been to continue that support, and since the years of Sputnik that support grew steadily each year, only to level off about six or seven years ago, partly due to the severe effects of inflation.

Today, there is increasingly a feeling that we have reached a watershed in the relationship between the Federal government's and the performers of the nation's research and development.

In the universities, where the bulk of basic research is done we see a set of substantial changes occurring, the outcome of which is far from clear. Enrollments are dropping and as a result state support in the traditional form is no longer adequate. The leveling off of Federal support has meant a leveling off of new openings for young science Ph.D's and the prospect for an aging of the professor population.

In industry we are told that the growth of regulatory requirements has tended to divert funds from research and that, as a result, innovation is less than it could be. Abroad, vigorous basic research efforts, and a growing diversity of government-industry collaborative efforts in such countries as Japan, Canada, and West Germany, are yielding a level of innovations which could place our own position at a disadvantage.

This hearing, Mr. Chairman, should permit us to understand better where these trends are leading us, and whether our own policies need change. I join you in welcoming our expert witnesses and look forward to their testimony.

Senator STEVENSON. Thank you, sir.

Our first witness is Jordan Baruch, Assistant Secretary of Commerce for Science and Technology. Mr. Baruch is an electrical engineer and computer specialist, with a doctor of science degree from MIT. He served in both industry and academe. Before joining the Commerce Department last year he was a professor of business administration and engineering at Dartmouth.

Dr. Baruch.

STATEMENT OF DR. JORDAN J. BARUCH, ASSISTANT SECRETARY OF COMMERCE FOR SCIENCE AND TECHNOLOGY

Dr. BARUCH. I want to thank you for inviting me to speak today, but before I go on the record, may I apologize for my unseemly entrance. Mr. Brown's comments about an aging professor population is true; I got halfway to the Hill before I remembered where I was testifying.

Again, thank you for inviting me to address the question of industrial innovation. It is a question that is of concern, not only to me, but to the administration in general, and to the rest of the country, of course.

Before I start, I would like to define what I mean by industrial innovation. Industrial innovation is the use of a new idea, concept, or technology by an industry to change the character of the goods or services it produces or the way in which it produces or distributes them.

Let me stress for a moment the word "use" in that definition. It is the use of a new idea. Invention is often the creation of a new technology, but until it is actually used, none of the potential benefits actually accrue to us or to society.

This definition is a little broader than the usual economist's definition. An old technology in one industry may become an innovation in another. For example, computer-aided design has been in use for years in the automotive industry, but were it to be adapted and applied to the manufacture of shoes, that would, indeed, represent an innovation.

The President and this committee have expressed a concern about the apparent decline of our innovation rate in the private sector. Mr. Hannay, I am sure, is going to address that.

We see some signs of our decline in that the average constant dollar investment in R. & D. by industry has increased by less than two-tenths of a percent per year from 1967 to 1977. There are studies in economic theory that indicate industry will tend to underinvest in innovation in terms of the ultimate benefits of innovation to society. In addition we all recognize that there is a declining competitiveness of some segments of U.S. industry in international markets.

The reasons associated with these shifts are very complex. Expenses associated with regulation, for example, divert some of the industries' discretionary funds. High interest rates, inflation, and uncertainties about future regulations increase the rate at which industrial decisionmakers have to discount future earnings on current investments. This biases their decision to shorter range activities rather than longer range activities. That is a rational bias.

The innovation process is complex, and it is also fragile. Innovation starts with an idea, generally in a confrontation of a problem, and it often encompasses a costly and time-consuming R. & D. phase. It includes a demonstration of a new technology and the assessment of its potential for commercial success, and, if successful, ends with the diffusion of that technology through industry or the market.

We can identify a string of factors in our society that encourage the process of innovation to proceed to a successful conclusion. The first and most critical is the existence of a market need, coupled with an ability to pay for the satisfaction of that need. You've got to have the want and the money. There have to be incentives for the assumption of risk by those with access to capital. There needs to be a corporate organizational and social infrastructure and attitude that are both supportive of change.

We need access to intellectual equipment and material resources. And lastly, we need the cross-fertilization of ideas resulting from the flows of information across disciplines and across industries.

Our Federal policies all have impacts on these five factors that I've just described; and while they are neither exhaustive nor exclusive, they are a critical list of factors.

For example, our fiscal policy can both affect market pull through depreciation allowances and tax credits. It can impact the level of risk assumption by the way it taxes both domestic and overseas R. & D. activities, and it can even influence the mobility of capital by the way it deals with distributed and undistributed income.

Our policies may both channel disposable income of the corporation into environment-enhancing activities, and increase the uncertainty about the future in such areas as regulations. We may thus increase the need for a business manager to have a high future payoff.

I ought to mention, however, that environmental and regulatory activities can often have a positive impact on innovation. Microprocessers, for example, got a big push through the automotive industry's need to meet Federal regulations on fuel economy.

That same pull of regulations, representing a market pull, is leading to a small revolution in computerized maintenance, and so forth.

Last but not least, the Federal procurement agencies not only aggregate the market for the manufacturer, but directly support research and development activities.

I ought to mention that the Department of Defense has had an historic impact upon the innovation process. We think of it in Defense, but it also took place in aerospace, and in fact was the greatest market pull for the development of the "tin can."

These are first-order impacts on the innovation process. Clearly, there are second-order ones: Federal support for basic research, Federal support for educational institutions and Federal activities relating to the rights of individuals to patent and to hold their inventions.

There is a wide range of places that the Federal Government impacts upon this process. What I think we would like to address is: What can we do to insure that those impacts, insofar as possible, are positive?

But, you know, every time we twist a knob to try to make something good, it always seems that something else happens. Every knob twist has a cost.

For example, how do we provide investment tax incentives to industry to improve innovation, and yet minimize the reduction in funds available for other national goals?

How do we strengthen the patent system to get good, strong patents, without, at the same time, strengthening monopolies?

Our basic question, it seems to me, that we face is: How do we manage an integrated Federal policy that reduces the existing inhibitions and provides effective incentives for industrial innovation, while minimizing the short- and long-range costs to society of any such policy?

That is a tough task, just from the examples I gave you. There are many Federal agencies involved; many different parts of the private sector. Big business and little business are going to be affected differently, and we need a detailed analysis of system performance before we start twisting knobs.

We, and the OSTP—Dr. Press' office—are planning to make a major effort during the next year to address the industrial innovation issue.

We hope that the process will eventuate in a set of options for the President to address, and an effort to select a "minimal energy solution" with the least number of modifications that we can introduce to get the desired effect.

I hope, gentlemen, that by next year at this time our offices will be able to pass on to you what we have learned.

Despite the fact that we will be involving many Federal agencies, the private sector, academe, and others knowledgeable in the field, we can already see one area in which we can have an impact, even now.

The Commerce Department is taking an approach that we call the "cooperative technology program." This approach focuses upon developing and institutionalizing a partnership among Government, industry, academe, research institutes, et cetera, to develop the fundamental technologies—what I have called before the "infratechnologies"—from which industry develops its goods and processes.

Now, many macroeconomists object to this approach of working with industries to help them. They observe that, historically, old industries fade away as new ones arise; labor shifts from one market to the other; and some communities wither while others prosper.

Unfortunately, some of them make the subtle shift from the descriptive to the normative statement that that is the way it "should" be; after all, that is the way it always has been.

This idea is really what game theorists call a zero-sum game. The net algebraic total of winnings and losings in the game have to come out to zero. It is my view—and it is critical to my discussion here today—that the role of technology in our future society is to convert the world from a zero-sum game to a non-zero-sum game.

Industries can prosper while the industries whose markets they have claimed can develop new products, new services, and also prosper.

Our proposed program to work with industry focuses on a set of disaggregated industries—that is, the collection of small firms with no clear industrial leader—whose productivity growth has been far below our national average. In the women's dress industry, for example, where they employ almost a quarter of a million people, they have had an annual productivity improvement of roughly two-hundredths of 1 percent. It's hard to believe: only two-hundredths of 1 percent per year.

There are many other disaggregated industries. We have identified several hundred of them, with the help of the Census Bureau. Compare that productivity growth of two-hundredths of 1 percent, or eight-tenths of 1 percent, with the ready-mixed concrete industry, with a national average of 4 percent.

And we can see that there are some industries which, while not critically ill, are sort of chronically malaised. Our hope is that we can work with these industries and, in each industry, that we can focus on the developments of those infratechnologies that will let them improve their products and processes.

Now there are industries with clear leaders, such as A.T. & T. in the communications industry, where a single firm can appropriate enough of the benefits from infratechnology development so that they can afford to tackle it.

In other industries—textiles, for example—the suppliers who are large characteristically provided that infratechnology.

In working with the really disaggregated industries, however, we find that the first requirement is a "need." The industries have to feel that they want help. There is an apocryphal comment going around that there are three main lies we hear circulating in our society.

In ascending order of their severity, the first is: "But, sir, the check is in the mail; you will get it in the morning." The second is: "Of course I will respect you in the morning." And the third, and most serious is: "I'm from the Government, and I want to help."

We don't want to come to an industry and say, "We are from the Government, and we want to help." We are going to work only with industries that express a need. Once they express that need to us, we expect to work with them to do a strategic analysis of that industry—an examination of their productive process, their microeconomics, and the structure of the industry.

Where can technology have an impact upon what they do? That kind of strategic analysis takes a lot of work, but we know how to do it.

After that, it is our expectation that the strategic analysis will lead to targets of opportunity in the area of technology development, and our hope is that we can develop those targets of opportunity and develop the technologies and use the other resources of the Federal Government—such as the EDA—to help the industry to get those technologies in place.

Now, we don't know whether this can be done. We have received permission to include in our budget proposal—and it has been passed on this year in the President's budget—a study to see whether we can see whether Government and industries can actually work in this mode. We will know the outcome of that, hopefully, sometime toward the end of 1979.

It seems clear, however, that there is a need. What is not at all clear is that a modality can be developed between Government and industry to meet that need.

Gentlemen, I could ramble on more, but I have given you a written statement which I hope you will permit to be inserted in the record, since it is more coherent than my verbal testimony.

I would like to end, however, by quoting something from the President's state of the Union address:

> I encourage a new surge of technological innovation by American industry. I am determined to maintain our Nation's leadership role in science and technology.

We share that determination. Thank you.

[The statement follows:]

STATEMENT OF DR. JORDAN J. BARUCH, ASSISTANT SECRETARY OF COMMERCE FOR SCIENCE AND TECHNOLOGY

Messrs. Chairman and Members of the Subcommittees:

Thank you very much for inviting me to appear before this joint hearing of the Senate Subcommittee on Science, Technology and Space; and the House Subcommittee on Science, Research and Technology. I am pleased to address what not only I, but what the Administration believes, to be a very profound and significant concern—a concern central to the economic viability of the Nation, to the economies and tax base of our cities and states and to the ability of the Nation to provide for the health, well-being, employment and financial security of our citizens. It is a concern for the status and vitality of the industrial innovation process, the process that is a major determinant of the competitive advantage of U.S. industry, that accounts for much of our productivity improvement and for our ability to procure a greater range of better quality products.

Let me define, at this point, what I mean by industrial innovation, particularly because I use the term in a manner different from that implied by the narrow definition given it by some economists. Industrial innovation is the use of a new idea, concept or technology by an industry to change the character of the goods or services it produces or the way in which it produces or distributes them. Let me stress the word "use" in that sentence. Invention may be the creation of a new technology, but until it is used it produces none of the social benefits of innovation. In my definition an old technology in one industry may become an innovation in another. Computer-aided design has been a fact of life for years in the automotive field; should it be adopted and used in the manufacture fo shoes, that would constitute innovation.

As President Carter said in his State of the Union Message of January 19, 1978:

"The health of American science and technology and the creation of new knowledge is important to our economic well-being, to our national security, to our ability to help solve pressing national problems in such areas as energy, environment, health, natural resources. I am recommending a program of real growth of scientific research and other steps that will strengthen the Nation's research centers and encourage a new surge of technological innovation by American industry . . . I am determined to maintain our Nation's leadership role in science and technology."

This firm commitment expressed by the President comes at a time when many factors suggest the need for a heightened Federal concern for the status of industrial innovation, several of which I am sure are familiar to all of you.

Investment in R&D to produce new technologies has been relatively stagnant. The average constant dollar investment in R&D by industry has increased by less that two tenths of a percent per year for the years from 1967 to 1977.

There are indications that industry underinvests in innovation in terms of the ultimate benefits of innovation to society.

There has been an increased private-sector R&D emphasis in recent years on low-risk, short-term projects directed at incremental product changes, and a decreased emphasis on the longer term research that could lead to radically improved products and processes.

There is a declining international competitiveness of some segments of U.S. industry as reflected in:

—a growth rate for productivity in manufacturing industries that is lagging behind that of some nations;

—the increasing penetration of domestic markets by foreign producers of intermediate technology and basic industrial goods; and,

—a level of production technology in certain important industries that lags behind that in other countries (for example, coal mining and steel production).

Small, high-technology firms encounter difficulties in obtaining venture capital.

There is a change in the direction of industrial innovation in recent years resulting from the mandated diversion of corporate effort from developing new products and processes to meeting other social goals such as environmental preservation.

The reasons for these shifts to a less innovative stance within much of industry are complex. Expenses associated with regulation divert some of industry's discretionary funds. High interest rates, inflation and uncertainty about future regulations have increased the rate at which industrial decision makers must discount future earnings. This increase causes a shift from longer-term to shorter-term projects, from research and advanced development to short-range incremental development. These and other current phenomena presage continuing difficulty for the technological innovation process on which we have come to depend for our position in world leadership.

Innovation, and the industrial vitalization that stems from it, is most complex. It is not only complex, it is fragile; inhibitory influences at any stage stunt the entire process. Innovation starts with an idea, or with the confrontation of a problem. It often encompasses a costly and time-consuming research and development phase. It includes a demonstration of a new technology, and the assessment of its potential for commercial success. It ends with the diffusion of the technology throughout an industry or a market.

The steps, of course, are not simply sequential. Market needs, technological advance and the very structure of the business to deliver that advance interact and change each other all along the way. Despite that complexity, we can identify a string of factors that encourage the process to proceed to a successful conclusion. Some of those factors are: the existence of a market need, coupled with an ability to pay for satisfaction of that need; incentives for the assumption of risk by those with access to capital, ofttimes with access to extremely large amounts of capital; the existence of corporate, organizational and social infrastructures supportive of change; access to intellectual, equipment and material resources; and the cross-fertilization of ideas resulting from flows of information and people across disciplines and across industries.

That short—and far from exhaustive—list of positive factors quickly leads us to appreciate the wide range of Federal actions that can and do influence our national propensity for technological innovation.

Federal fiscal policy impacts the market pull via depreciation rates and tax credits for new-equipment investment. It impacts the level of risk assumption via its tax treatment of domestic and overseas R&D expenses. It impacts the flow of capital to new ventures by the degree of distinction between capital gains and income and the mobility of capital by its relative treatment of undistributed and distributed profits.

U.S. foreign policy affects innovation as it affects our access to world markets on the demand side and our access to world resources on the supply side; as it governs international technology transfer; and as it influences export promotion and control.

Policies of Federal regulatory agencies influence both process and product development. They may channel corporate disposable income into health, safety and environmental areas. They are also often a major determinant of the time it takes for new technologies to be put into practice—an influence that reduces the discounted rate of return to the innovator. It is also important to note, however, that regulation may also act as a stimulant to productive innovation. For example, microprocessor technology received a major market pull from the automotive industry's need to meet Federal guidelines on fuel economy. That same pull is now leading to a small revolution in computerized maintenance and real-time control of engine performance.

Federal mission-oriented agencies provide financial support of goal-oriented R&D and hence reduce the private sector risk level—particularly in the early stages. Consequently, they have great influence on the magnitude and direction of innovation. For example, the laboratories of the Department of Agriculture perform R&D which would be difficult for the private sector to support given the disaggregated structure of farm production. HEW and NASA are other examples.

Federal procurement agencies, by aggregating an otherwise far-flung market, generate the market pull that often leads to innovation. Procurement agencies such as GSA have influenced the direction of innovation by the use of performance as opposed to functional specification. The Department of Defense representing both an aggregated market and a subsidizer of R&D has had an historic impact on the rate and direction of innovation in industries from aerospace to the early development of the "tin can."

In addition to these first order impacts, Federal policies and programs which affect our educational institutions, our labor pool, and the rights of individuals to ownership of intellectual property, also affect the long-term viability and productivity of the innovation process.

Clearly the Federal Government is a critical actor in the innovation process. There are a hugh number of "knobs" we can twist to influence the rate and direction of that process. Every facilitating twist of a knob, however, has a cost. How do we provide investment tax incentives to industry—and minimize the reduction in the funds available for social welfare projects? How do we strengthen the patent system—and minimize the risk of strengthening monopolies? How do we subsidize industrial research—and not simply displace corporate funds into profits? These questions can be subsumed by a single one: How do we manage an integrated Federal policy that reduces the existing inhibitions and provides effective incentives for industrial innovation while minimizing the short and long range social costs of that policy?

To formulate a policy meeting that desideratum is obviously not a simple task. While we and others believe a problem exists, while we can point to many aspects of the problem, prudence and complexity dictate that we proceed with caution. There is a need to base any change in current policy upon a better understanding of the causes of the problem, and upon a careful and detailed analysis of the impact of the many available Federal policies and programs upon the rate and direction of innovation. There is also a need to develop a *measured* Federal response—a minimal mix of programs and policies that will have the desired effect upon industrial innovation. There is a need *not* to overdo.

As pointed out by Dr. Press—the problem is serious but the opportunities for improvement are great. We are therefore planning to make a major effort in the next year to address the industrial innovation issue. This approach will be to propose to the President a domestic policy review of industrial innovation. We have been working closely with Dr. Press in outlining the scope of this study. One of the objectives of the study would be the development of Presidential level options that address ways that the Federal Government can assist industry in strengthening its rate of innovation. I hope that by this time next year Dr. Press will be able to report to you on what we have learned and on the progress we have made.

One of the options which Commerce is focusing on is the feasibility of a cooperative technology program. The approach focuses upon institutionalizing a partnership between government and industry in the development of the fundamental technologies within an industry on which that industry builds its goods and processes, technologies which we call "infratechnologies." It is an effort to which you have already been introduced through the President's 1979 budget request for the Department of Commerce.

Improvement in the innovation process can contribute to the public welfare in many classes of industries, in industries in difficulty, in industries whose output is particularly important in such areas as health, safety and the national security, and in industries where we may—as a matter of national policy—choose to take and hold a commanding lead.

Many macroeconomists object to this approach. They observe that, historically, industries fade away as new ones arise; labor shifts from one market to the other and communities wither as new ones with new advantages take their place. Some of these macroeconomists even make the subtle shift from the descriptive to the normative and say that that is as it *should* be. Few of those macroeconomists have ever lived in a shoe town or watched the human impact of a plant closing or seen the immobility of labor reflected in the agony of workers who stick to their homes at the price of a steady decline in their standard of living. Few of those macroeconomists have seen the owner of a small firm watch the enterprise built by a lifetime of effort shrivel under the impact of intense foreign competition backed by the resources of an entire nation.

Game theorists call the view that those macroeconomists have a "zero-sum game". That expression means that gains or winnings in one industry, one community, one nation are and must be accompanied by equivalent losses in another. We disagree. Indeed, we see the future role of technology as one of converting the world to a "non zero-sum game".

In deciding on a strategy to help break out of the "zero-sum game" model, we have found it useful to group troubled industries according to the cause of their difficulties:

1. Industries impacted by foreign trade such as shoes, apparel and steel.
2. Industries impacted by government regulation such as the textile industry by OSHA regulations or the jewelry industry by EPA regulations.
3. Industries impacted by marked and rapid changes in raw material or energy prices such as the plactics and petro-chemical industries.
4. Disaggregated industries—collections of small firms with no clear leader—whose productivity growth rate is significantly below the national average. The women's dress industry, for example, which employs over 200,000 people, from 1967 to 1972 averaged an employee-person-hour productivity increase of less than two-hundredths of one percent per year! Even the ready-mixed concrete business which employs 86,000 people, only averaged an eight-tenths of one percent annual improvement over the same period.

Our national average approximated 4% over those years.

While those categories are by no means exhaustive of the roots of industry's troubles—nor are they exclusive of each other—they have important policy implications. Help for group 1—the trade impacted industries—becomes an important part of our nation's pursuit of free-trade policy. Help for group 2—the regulation impacted industries—contains not only an element of equity but facilitates our pursuit of such social goals as environmental betterment and occupational health. Help for group 3 is complex because such changing factor prices produce opportunities in some industries such as coal and negative impacts on others such as plastics. It is also complex because other agencies such as DoE, in the area of energy, and Interior, in the area of mining, may have lead responsibility. Obviously in those cases careful collaboration will be called for. Help for group 4, the disaggregated industries are also represented throughout the first three classes but there are hundreds of industries such as machine shops, that are not.

Regardless of the class of industry, however, our approach to helping them is the same—although the resources to provide that help may come from different sources. In each industry we focus on the development of the infratechnologies that will allow those industries or their suppliers to develop the specific goods and processes that can contribute to emeliorating the industry's problems.

It is important to emphasize that the development of new infratechnology is only a precursor of further developments. Traditionally the creation of infratechnology has subsisted primarily on the accidental, reluctant, or bootlegged outputs of both research and development. We contend that creation of infratechnology is clearly too important at our present stage for us to leave it to chance, charity or chicanery. The Federal Government is concerned with a need to nurture that creation, to foster institution building and to provide the aggregating support that will lead our nation's creative minds—whatever their old labels—to build those new infratechnologies on which a country at our stage of development can build its future. For this reason, the government recognizes the need to cooperate with industry and academia in developing those new technologies. Cooperation with academia and other institutes is dictated by our policy goal of building institutions that can persist in symbiosis with industry on a long term basis. Such institutions can ensure the ongoing development of infratechnology and the gradual disappearance of government involvement with the process.

Cooperation with industry is dictated both by what we know of the innovation process and by our experience with past failures. It is industry that understands the contraints—financial, market, organizational, etc.—on its own operation. Furthermore it is industry that must take the results of infratechnology development and incorporate them in actual products and processes.

This need for collaboration and the goals of the proposed program lead naturally to a methodology.

Clearly the first thing that must be determined, for any industry, is whether, where and how technology can help. There *must* be a *need*. Too many failures have occurred through trying to impose a brilliant new idea on a market that didn't want it. To determine that need, in any but the most superficial manner, requires an initial strategic analysis. The task of strategic analysis is not a simple one; it requires expertise in many disciplines and functions (e.g., economics and industrial psychology; finance, marketing, and production). Strategic analysis must also be multidimensional. No one strategy will work for all firms and no one definition of an industry will be satisfactory. The industry manufacturing women's fashion dresses, for example, is very different from that making men's work clothes or even women's house dresses although all are apparel firms.

We have found there must be a strategic analysis of such industries. The task of such an analysis is to identify where technology can be of help, how it will impact and the broad functional description of the technology needed. It also serves to gear up the private sector participants to participate in the difficult phase of adaption or development. It will frequently be the case—in light of our concern for community decay—that the studies will indicate the potential for a profitable parallel effort by local government to incorporate the potential changes dictated by new technology in their local planning. Shared facilities serving several or many firms may be required; opportunities for new secondary businesses may be evident etc. Local government has a role to play in each such opportunity, and where such a role exists we will enlist their involvement.

We also need to learn from each cooperative technology project so that the next will be better. To that end, we look for a great deal of help from the current ETIP staff—a staff skilled in drawing the educational content from such field activities.

We have worked very closely with many agencies in formulating and initiating this program, the cooperative technology study, within the Department of Commerce, with OMB, from Dr. Press's office and with our many advisors in academia and industry. Within the Department, the Bureau of the Census, under the Chief Economist, has provided us with industrial and geographic data. The Industry and Trade Administration has helped us analyse the needs of specific industries. The Economic Development Administration has alerted us to industries in difficulty and, under its various authorities has provided funds for pursuing the program in several impacted industries. The Office of Minority Business Enterprise works with us to identify potential minority business opportunities and the Deputy Under Secretary for Regional Affairs has helped us identify communities where industry help can also help revitalize the community. With such cooperation, we have high hopes for the program's success.

Before I conclude my statement, please let me make one optimistic, indeed enthusiastic, observation. This entire administration effort, our cooperative technology efforts, the study we will share with Dr. Press, and our entire Department's continuing involvement, is a striking outgrowth of our times. The effort springs not only from negative forces, such as foreign trade and our urban problems, it springs from the positive drive provided by an administration commitment and by a sense of productive teamwork that are truly unique children of these times. I can think of no better way to end this statement than by repeating a part of the Presidential quotation that I started with:

"[I] encourage a new surge of technological innovation by American industry . . . I am determined to maintain our Nation's leadership role in science and technology."

We share that determination. Thank you!

Senator STEVENSON. Thank you, sir. Your statement along with the others, will be entered into the record. We will continue with the rest of the panel, and then come back to all of you with our questions and those from our audience.

Our next witness this morning is Dr. N. Bruce Hannay, vice president for research and patents of the Bell Telephone Laboratories.

Dr. Hannay is a Princeton Ph. D. chemist whose research is in solid-state chemistry, semiconductors, and superconductors. He is past president of the Industrial Research Institute and a member of an array of advisory committees, to NBS, OTA, DOD, and Brookhaven and Lawrence Livermore Laboratories.

He has served recently as study chairman of a National Academy of Engineering Panel on Technology and U.S. Trade.

Dr. Hannay?

STATEMENT OF DR. N. BRUCE HANNAY, VICE PRESIDENT FOR RESEARCH AND PATENTS, BELL TELEPHONE LABORATORIES, MURRAY HILL, N.J.

Dr. HANNAY. Mr. Chairman, I welcome this opportunity to speak to you about technological innovation. My full text is available to you, and I will therefore only cover the main points today.

Innovation in new products and services is central to the process by which an economy grows and renews itself. Also, technological innovation is an important element in international trade and the balance of payments.

Innovation and productivity are closely linked because cost reductions and efficiency gains arise mainly through innovations in methods for production and distribution.

Innovation is also required for progress with issues of great urgency for the United States—energy and materials resources, the environment, health and health care delivery, transportation, and many other things.

For these reasons, the national capability for innovation is a legitimate matter for public concern. In my view—and many share this—there has been a serious decline in our capacity for innovation.

There are increasing uncertainties in industrial research, and many companies feel that there are decreasing incentives for innovation. And I believe that it is a matter of national necessity to strengthen the U.S. innovative capacity.

I am pleased that national attention is being given to the problem, but unfortunately national actions and policies do remain a major part of the problem.

Now there are many signs of a decline in our innovative capacity. The growth rate of the GNP has been lower than that of other industrialized countries. The rate of increase in productivity is the lowest for any of the major industrialized countries. It is at its lowest level in 100 years. Business investments and trade figures also reflect the lower growth rate.

R. & D. is highly concentrated in a few industries. The balance of trade is favorable in industries that are R. & D.-intensive, and it is unfavorable—generally speaking—in industries that are not.

But I think the most important measure is the quality of innovation. Innovation is of several kinds: There is an incremental, or a "nuts and bolts" kind of innovation, and this can be very worthwhile even though it isn't terribly exciting. A substantial part of that currently is aimed at process improvements, and I would certainly agree that that is worth doing at the present time, in view of high costs. But a great deal of the product work is basically little more than product differentiation, and that is not going to move us forward to new levels of social well-being, nor will it add significantly to our economic strength.

More fundamental innovation results from major technological advances. The transistor, synthetic fibers, antibiotics, Xerography, the digital computer, the Polaroid process, and the laser are examples of this kind.

The major economic and social benefits flow from such innovation, and it is here that U.S. industrial research has accomplished so much, providing impetus for our industrial progress.

The central issue is the decline of the U.S. industrial research capacity for this sort of fundamental innovation. Important innovations for the civilian sector often come as the result of a commitment of R. & D. in which the reward comes in the long term. But only a few companies in a few industries are willing to take the long-term view. I am happy to say that my own company is probably the leading example of that today. But in much of the industry, the R. & D. is directed to short-term goals.

Thus, even though the figures show that industry funding of R. & D. is substantial and growing, the commitment to fundamental innovation is absent or has declined in broad segments of industry.

The innovation process is full of risks. It can be expensive. In the innovation of major new products, R. & D. may amount to less than 10 percent of the costs. With the costs and risks of the total innovation process so high, there has been significant decrease in the willingness of industry to undertake and support the kind of research that has the least certainty of success and the greatest potential payoff.

Not many of our industrial contemporaries are talking today about exciting, new, major discoveries that they think will change the world.

The outlook has become more focused on defensive activities. Admittedly there are strong forces working against innovation and the research that leads to it, but in my view industry should not succumb to these and the Government should give high priority to reducing these negative forces.

There are several reasons for this change in the character of industrial research.

First, and perhaps most important, are a number of related financial factors. Inflation and the cost of money have made it more expensive to undertake R. & D. and to launch new ventures. This has led companies to concentrate research efforts on cost-cutting activities.

The high cost of capital for investment in new plant equipment means that a very high rate of return is required for an innovation to pay for itself. A substantial part of the capital that is available for investment in new plant is being committed, in some industries, to pollution control, and there is no financial return from this.

Most important, however, is the financial uncertainty which stems from high and rapidly changing inflation and interest rates, changing tax policies, and concerns about other elements of costs and markets.

Unless the innovation is expected to be profitable, it won't happen. The safe course, many think, is to adopt a defensive position with risk as low as possible and seek to hold the market share while keeping costs to a minimum.

Many companies have moved in this direction, including some with impressive past performances in innovation. The industrial investment rate of the United States is now the lowest of any industrialized country, including Great Britain.

New venture companies are part of this. They are mostly, at least in a certain category, based upon an innovative technical idea. In 1972 there were over 100 such technical companies going into the market with new issue underwritings each year. By 1974 there were only 4, and in the first 6 months of 1975 there were none.

Now, there are some other aspects of Government policies and activities that relate to innovation. One, of course, is the support of research.

The Federal Government successfully funds basic research in the universities as well as applied science in support of its own missions. Recently, it has sought to affect civilian technologies directly through support of applied science. But this is a rather different matter.

The pluralistic nature of the Federal Government makes it more difficult to agree on priorities and common purposes, and lacking the close coupling to the consumer that is provided by the marketplace, the Government has no feedback mechanism to tell it what is succeeding and what is failing in choosing and managing R. & D. for commercial markets.

Another problem with Government R. & D. for commercial technologies is that there is some tendency for private industry to reduce its expenditures in those areas where Government funding is increasing, and Goverment R. & D. spending, obviously, should complement private spending, not replace it.

Regulation clearly has an effect on innovation, and the effect can be either positive or negative.

In many industrial R. & D. programs the portion of the budget allotted to meeting regulatory requirements is generally unproductive with respect to innovation.

We could cite a number of examples of negative impact on innovation, including some affecting my own company, but let me use the drug industry as an example, since it is the industry that leads all others in terms of research as a percent of sales. Yet the number of new drugs marketed each year in the United States has decreased by a factor of 4 in the last 20 years. In the same period the introduction of new drugs has not fallen off at all in Western Europe. There has been an enormous increase in this 20-year period in the effort required to meet FDA requirements. The time to get a drug to market has greatly lengthened; the cost has risen enormously.

Now, no one could argue against the need for drug safety and tight testing and reporting requirements, but consumers are also vitally interested in innovation of new drugs. The balance between the safety and the rate of innovation certainly needs reexamination.

It is not regulation, per se, that is the issue—we all agree that it is needed. Rather, it is the imperfections in the regulatory process, because sometimes regulations are promulgated when the scientific facts are still not clear, and when they do become clear, there is no way to turn back. Regulations often ignore economic logic when enormous additional costs are required for a minor additional benefit. Delays are injected into the innovation process. Industry generally puts regulation along with financial uncertainty as the principal factors inhibiting innovation.

Another area is antitrust. Antitrust threats inhibit certain activities that might promote innovation. For example, cooperative research between companies is effectively barred because few company lawyers would let their firms assume the risk. Antitrust relief could encourage firms too small to sustain separate fundamental research efforts to undertake a cooperative basic study, and it could foster cooperation between companies with complementary talents.

Also, we are now seeing an assault on some of the most innovative private firms with the goal of altering their essential structure, which, of course, has been central to their innovative success.

Patent policy is also central to innovation. In one important respect, it is counterproductive with respect to innovation. Federal contracts for R. & D. generally require that any patents that flow from the work be available to all. The idea, of course, is that since publicly funded R. & D. led to the patent, everybody should be able to use it. But the trouble is that what belongs to everybody is usually of interest to nobody in this connection, because the much larger investments necessary to manufacture and develop the market for a new product are unlikely to be rewarded by a satisfactory return on the investment in the absence of an exclusive license. The result is that Federal patents that might otherwise be commercially exploited are unused.

Tax policy is at present mostly neutral with respect to innovation, providing some encouragement as well as discouragement. Some of the relevant tax issues, of course, are the treatment of capital gains, investment credits, depreciation, and the tax treatment of R. & D. expenses in multinational corporations. It is of interest in this connection to note that our international competitors often use tax incentives as a stimulant for innovation.

Now let me say something about what might be done to remedy this situation.

There is, of course, a legitimate role for the Federal Government in stimulating innovation. The usual proposed cure for the inhibiting effects of government interventions in the market system is further intervention. The most useful thing the Federal Government could do is to stimulate the private sector to invest its own human and financial resources in innovation. While the risks, uncertainties, and costs have been increasing, there has not been any compensating increase in incentives for undertaking innovative activities.

One of the most important elements in the relationship of the Government and industry is uncertainty. Changing Government attitudes, policies and regulations create a climate of uncertainty, and the net effect is the shortening of the time scale in which a business will make its plans. But it has to have a longer range point of view in order to produce the kinds of fundamental innovations that we all seek. One of the most important things that the Government could do is to reduce this uncertainty.

The problems of capital formation and private investment in innovation are closely tied to such matters as tax policy, accounting rules, subsidies, and loans. These offer significant possibilities, I think, for the stimulation of private investment in technological innovations.

One mechanism that has been proposed but seldom exercised in the civilian sector is the use of Government procurement to stimulate private investment.

This is a potentially powerful lever. The Government is a very large consumer of civilian goods—health care, services and so on—and this suggests that procurement could be used to provide a market for innovative new products and reduce market entry risks for suppliers. Exploratory tests of this concept by the Bureau of Standards seem very promising.

Selective Federal support for R. & D. for civilian technologies can certainly be justified, and there are a number of criteria for selection. They might include such characteristics as a highly fragmented industry structure, the need for an R. & D. project on a scale too great for the capacity of any one company, the need for R. & D. to develop a technology with little commercial potential but large social importance, and a national urgency that cannot be met by privately funded R. & D.

There is a close link between innovation and productivity, and productivity gains are important to economic health. Any policy that discriminates against investment also discriminates against productivity gains. The advanced technology that increases productivity is concentrated in a few high-technology and/or capital-intensive industries and firms. Many smaller firms and a number of basic industries don't enjoy this position. We need to find mechanisms for extending to these industries the productivity gains that are clearly possible. It seems likely that specific direction of Federal programs could aid in this.

Let me conclude by reemphasizing several points.

First is the necessity for strengthening the U.S. innovative capacity in the civilian sector. The health of our economy and all of the attendant consequences of increased employment and improved standard of living and progress in social areas unquestionably depend upon this innovation. Innovation is not being given a high enough priority at the national level.

Second, innovation in the private sector will come only through greater effort on the part of both industry and Government. We cannot expect federally guided and funded research to provide the initiative because it lacks the focus and the connection to the ultimate user.

What can be done federally is to create a better climate for privately funded innovation.

At the same time, industry has to show greater faith in its own future. Any industry that believes it has a future should be willing to invest in it and in longer-term objectives.

And, finally, we must develop a much higher degree of cooperation and understanding between Government and industry. All too often this relationship has been marked by suspicion on both sides, in great contrast to the attitudes in many other countries. Government officials are frequently suspicious of the motives of large corporations and believe that industry is only interested in profits. Industry is concerned that Government officials sometimes don't understand the role of profits in supporting the economy, and sometimes seem to act irrationally in the administration of regulation, antitrust and other matters that affect industrial innovation. And it believes that Government policies create uncertainty, to an unnecessary degree.

Progress in these three respects is essential if we are going to realize our full potential for the application of science and technology for the common good.

Thank you.

[The statement follows:]

STATEMENT OF DR. N. BRUCE HANNAY, VICE PRESIDENT FOR RESEARCH AND PATENTS, BELL TELEPHONE LABORATORIES

TECHNOLOGICAL INNOVATION AND NATIONAL PRIORITIES

Innovation in new products and services is central to the process by which an economy grows and renews itself. Also, technological innovation is an important element in international trade and the balance of payments. Innovation and productivity are closely linked, as cost reductions and efficiency gains arise mainly through innovation in methods for production and distribution. Innovation is also required for progress with issues of great urgency for the United States—energy and materials resources, the environment, health and health care delivery, transportation, and many others. Opportunity for application of science and technology was never higher.

The national capability for innovation is a legitimate matter for public concern. The public is the ultimate beneficiary of technological innovation, and the public will be the loser if there is any decline in our capacity for innovation. Most of this innovation must come from industry.

The problem

The headline over an article [1] in *Business Week* read: "The Breakdown of U.S. Innovation." Another [2] called attention to "The Silent Crisis in R&D". In a report [3] to the U.S. Senate, Gilpin opened with the statement "Technological innovation in the civilian industrial sector of our economy is at a critical point." Jean Gimpel [4] states, "The collapse of U.S. innovation will bring down U.S. Society." These are ominous declarations.

Certainly, there are increasing uncertainties in industrial research. Many companies feel that there are decreasing incentives for innovation. The climate for innovation is less hospitable. This includes not only the economic climate, but also all the incentives and the barriers that are intentionally or unintentionally supplied by a range of government activities and interventions in the process of translating science into application. I believe that it is a matter of national necessity to strengthen the U.S. innovative capacity. Fortunately, national attention is finally being given to the problem.[5] Unfortunately, national actions and policies remain a major part of the problem.

What are the signs that indicate this decline in our innovative capacity? Some are to be found in the various measures of the U.S. economy, and the role technology is currently playing in supporting its growth.[6] The growth rate of the GNP has been lower than that of other industrialized countries. The rate of increase in productivity is the lowest for any of the major industrialized countries, and is at its lowest level in 100 years. Business investments and trade figures also reflect this lower growth rate.

U.S. total R&D (all funding sources) in current dollars totaled an impressive $41B in 1977, continuing its strong upward trend; this is more than double the 1965 figure. In constant dollars this represents little or no change over this period, however. As a percent of GNP, it shows a strong decline from its peak in 1964, and no longer leads other countries. Moreover, a substantial part of the U.S. R&D goes to defense and space, whereas relatively little does in such countries as Japan and West Germany.

In 1977, U.S. industry will have spent $17.5 billion of its own funds on research and development for commercial markets. However, in constant dollars there has been a small decline in the last few years.

This $17.5B is highly concentrated, with some 85% of the R&D expenditures in just six industries—electrical equipment and communications, chemicals and allied products (including pharmaceuticals), machinery (including computers), motor vehicles, aircraft and missiles, and instruments. Only 35 companies spent $100M or more on R&D in 1976. The top 50 companies in R&D expenditures accounted for over three-quarters of the industrial total, and the top four companies for nearly one-quarter of the total. Company-funded R&D, as a percent of sales, shows substantial variation. Some five industries, often called "high technology", are in the 3–4% range or higher (aircraft and missiles, electrical equipment and communications, instruments, chemicals and allied products, and machinery). At the other extreme are companies showing only a few tenths of a percent, or less.

Thus the gross totals for industrial R&D are mainly the result of a few industries and companies with substantial commitments to R&D, while large segments of industry contribute little.

Basic research is even more concentrated, with two-thirds of the 1974 expenditures in just two industries (chemicals and allied products, electrical equipment and communications). The total basic research funded by industry is around $600M, representing a 23% decline in real spending over the last twelve years. At the same time, national totals for basic research have held essentially constant, so our concern is directed to the industrial portion.

The U.S. balance of trade is favorable in industries that are R&D-intensive, and it is unfavorable in industries that are not. Products in the deficit area included motor vehicles, textiles and metals, among others. Computers, machinery, aircraft, chemicals and drugs, and electrical equipment contributed on the positive side.

Numbers don't tell the whole story. We must look also at the quality of industrial R&D. Innovation is of several kinds. There is incremental, or "nuts and bolts" innovation, and while this can be worthwhile, it isn't very exciting. A substantial part of this is aimed at process improvements, and this is useful and understandable in these days of high costs.

However, much of the product work is basically little more than product differentiation. Many companies do nothing more and not only survive, but flourish. But innovation at this level will hardly move us forward to new levels of social well-being, nor will it add significantly to our economic strength. Its main purpose is to achieve a favorable shift in market share, or to counter a similar move by a competitor.

More fundamental innovation results from major technological advances. The transistor, synthetic fibers, antibiotics, Xerography, the digital computer, the Polaroid process, and the laser, are examples. In such cases, there is a quantum jump to a new level of technological accomplishment, and major economic or social benefits flow from the innovation. It takes an inspired idea to start the process, and, usually, a great deal of sustained, dedicated, organized effort to turn the creative idea into a practical reality. This is where the rewards are greatest, for both society and the organization that makes the innovation. It is here that U.S. industrial research has accomplished so much, providing the impetus for our industrial progress.

The central issue is the decline of the U.S. industrial research capacity for this sort of fundamental innovation. Important innovations for the civilian sector often come as the result of a commitment to R&D in which the reward comes in the long-term. But, only a few companies in a few industries are willing to support basic research and take the long-term view that is needed for major new innovations. In much of industry the R&D is directed to short-term goals. Thus, even though industry funding of R&D is substantial and growing, the commitment to fundamental innovation is absent or has declined in broad segments of industry.

The innovation process is full of risks. It can be expensive. In the innovation of major new products, R&D may amount to less than 10% of the costs. The expensive part of the innovation process is not invention, but engineering, tooling and start-up for manufacture, and market development. Should one then conclude that R&D for this kind of innovation is not worthwhile? I would draw the quite different conclusion that research and exploratory development, which provide important options for innovation even though not all of them are carried through to completion, is a bargain. However, the payoff is most often in the long term.

Many companies find major innovations to be less attractive today than they once did. Despite the fact that the R&D is not a major part of the cost of such innovation, it still costs something. When management has decided that, for any reason, it is less interested in major innovations, then forward-looking, risk-taking, long-term R&D suffers. There has been a significant and alarming decrease in the willingness of industry to undertake and support the kind of research that has the least certainty of success but the greatest potential payoff. Not many of our industrial contemporaries are talking about exciting new major discoveries that they think will change the world. The outlook has become more focused on defensive activities. Admittedly, there are strong forces working against innovation and the research that leads to it. But, in my view, industry should not succumb to these, and the government should give high priority to reducing these negative forces.

The reasons

There are several reasons for this change in the character of industrial research. First, and most important, are a number of related financial factors. Inflation and the cost of money have made it much more expensive to undertake R&D and to launch new ventures. This has led companies to concentrate research efforts on cost-cutting activities—cheaper manufacturing processes, lower cost designs, labor-saving production methods, and so on. The high cost of capital for investment in new plant equipment means that a very high rate of return is required for an innovation to pay for itself. A substantial part of the capital that is available for investment in new plant is being committed to pollution control, and there is no financial return from this. Most important is financial uncertainty, stemming from high and rapidly changing inflation and interest rates, changing tax policies, and concerns about other elements of costs and markets.

Unless the innovation is expected to be profitable, it won't happen. A key characteristic of major innovations is uncertainty, both in the R&D stage and in creating a new market. If to these uncertainties is added an uncertain financial climate, the risk is correspondingly greater. The safe course, many think, is to adopt a defensive position, risk as little as possible, and seek to hold market share while keeping costs to a minimum. This leads to a strategy that concentrates on incremental innovations, where start-up costs are relatively minor. The financial advantage is much more certain, though smaller, and the return on investment comes sooner, though it is lower. Many companies have moved in this direction, including some with impressive past performance in innovation.

The unfavorable financial climate also discourages formation of new venture companies, most of which are based on an innovative idea. In 1972, there were over one hundred such technical companies going into the market with new issue underwritings each year. In 1974, there were just four, and in the first six months of 1975 there were none.

Uncertainty over possible changes in tax law plays a part, also. Some proposals being advanced would make investment in innovation even less popular. *The Economist* (of London) said,[7] "America is set for industrial senility unless its industrial investment rate goes up." That rate is now the lowest of any industrialized country, including Great Britain.

There are other government policies and activities relating to innovation. One is support of research. The Federal government has, since World War II, funded most of the basic research in the country, largely in universities. This Federal support has, of course, provided a firm foundation for all applied science programs, both Federal and industrial. Industry strongly supports Federal sponsorship of these programs.

The Federal government has also successfully sponsored applied science in support of its own missions, notably defense and space. More recently it has sought to affect civilian technologies directly, through support of applied science. But this is a different matter; here the government is less successful. The pluralistic nature of the Federal government makes it difficult to agree on priorities and common purposes. Lacking the close coupling to the consumer that is provided by the marketplace, the government has no feedback mechanism to tell it what is succeeding and what is failing, in choosing and managing R&D for commercial markets. A private enterprise has to be reasonably efficient at satisfying the market, or it soon goes out of business.

Another problem with government R&D for commercial technologies is that there is some tendency for private industry to reduce its expenditures in areas where government funding is increasing. To the extent that this occurs, it becomes merely the taxpayer paying for the R&D, instead of private industry. Government R&D spending obviously should complement private spending, not replace it.

Regulation clearly has an effect on innovation,[8] and the effect can be either positive or negative. An example of a positive effect on innovation is the new technology for pollution control that has resulted from environmental regulations. Regulation has a negative effect when it diverts R&D funds to work designed only to meet regulatory requirements and involving no significant new technology. In many industrial R&D programs, the portion of the budget allotted to meeting regulatory requirements is generally unproductive with respect to innovation.

The drug industry furnishes an example of regulatory impact. It is the industry which leads all others in terms of research as a percent of sales. Yet the number of new drugs marketed each year in the United States has decreased by a factor of four in the last twenty years. At the same time, there is no shortage of ideas for new pharmacologically active substances. The discovery of novel structure-activity relationships is no less frequent. The introduction of new drugs has not fallen off in Western Europe.

There has been an enormous increase in this twenty-year period in the effort to meet FDA requirements, which govern the methodologies for testing drug safety.[9] As an indication of the way these have changed, in 1938 an application for adrenaline in oil was presented in 27 pages. In 1948 an expectorant was described in 73 pages. In 1958, 439 pages, in two volumes, were required to describe a treatment for pinworms. In 1962 an oral contraceptive application ran to 12,370 pages, bound in 31 volumes. By 1972 a skeletal muscle relaxant involved 456 volumes, each 2″ thick—75 feet in total thickness and weighing one ton. The time to get a drug to market has greatly lengthened and the cost has risen dramatically.

No one would argue against the need for drug safety and tight testing and reporting requirements. However, consumers are also vitally interested in the innovation of new drugs. At the least, it is time to reexamine the balance between innovation rate and safety standards. As stated[10] in *Business Week*, "Regulation itself may become the nation's most serious health problem."

It is not regulation that is the issue. Rather, it is the imperfections of the regulatory process. Regulations are promulgated when the scientific facts are still unclear. When they do become clear, there is no way to turn back from an ill-advised regulatory action. Regulations ignore economic logic when enormous additional costs are required for a minor additional benefit. Delays are introduced into the innovation process. The impact on innovation is generally not considered in setting regulations.

Antitrust threats inhibit certain activities that might promote innovation. Cooperative research between companies is effectively barred, as few company lawyers would let their firms assume the risk. Antitrust relief could encourage firms too small to sustain separate fundamental research efforts to undertake cooperative basic studies, or it could foster cooperation between companies with complementary talents. Also, we are now witnessing an assault on some of the most innovative private firms, with the goal of altering their essential structure which, of course, has been central to their innovative success.

Patent policy is central to innovation. In one important respect, it is counterproductive with respect to innovation. Federal contracts for R&D generally require that any patents that flow from the work be available to all. The idea is that since publicly funded R&D led to the patent, everyone should be able to use it. The trouble is that what belongs to everybody is usually of interest to nobody, because the much larger investments necessary to manufacture and develop the market for a new product are unlikely to be rewarded by a satisfactory return on the investment, in the absence of an exclusive license. The result of patent clauses in Federal contracts for R&D is that many patents that might otherwise be commercially exploited are unused.

Tax policy at present is mostly neutral with respect to innovation, providing some encouragement as well as some discouragement, but there are pressures to make it more negative. Some of the relevant tax issues are the treatment of capital gains, investment credits, depreciation, and the tax treatment of R&D expenses in multi-national corporations. Our international competitors use tax incentives as a stimulant for innovation.

There are some other reasons for lack of faith on the part of industry in long-term research payoffs, unconnected to Federal actions and policies. One is doubt about the appropriability of the research. The firm paying for it sees the possibility that its competitors will be able to take advantage of the research almost as fully as the firm itself—without paying for it. But there is a strong counter-argument. Basic research supplies background knowledge in the fields of interest to the firm. If it is published in the scientific literature, it does become available to the firm's competitors; however, only the people who actually do such research can have a full and early appreciation of its implications and potential value. Also, they are better coupled to academic research and in the best position to take advantage of its findings. When the long-term research suggests invention, there is lead time for its exploitation. The patent system provides ownership of the intellectual property created in the invention itself.

Many studies[11] have attempted to correlate growth with R&D. What seems to be generally true is that those industries which are R&D-intensive are the ones with the most rapid growth. Rates of return on investment from specific product innovations are estimated to average between 10 and 50% per year, while returns on innovation leading to productivity growth are in the 30 to 50% per year range. This sounds ample, but with present money costs and inflation rates, it takes something like this to be attractive.

The remedies

There is a legitimate role for the Federal government in stimulating innovation, but it is not the one most frequently proposed in Washington. The usual proposed cure for the inhibiting effects of government interventions in the market system is further interventions. The most useful thing the Federal government could do is to stimulate the private sector to invest its own human and financial resources in innovation. While the risks, uncertainties and costs of innovation have been increasing, there has been no compensating increase in incentives for undertaking innovative activities. The major thrust of policy intended to stimulate innovation should be on the production and marketing stages, where most of the costs and risks fall.

One of the most important elements in the relationship of government and industry is uncertainty. Changing government attitudes, policies and regulations create a climate of uncertainty. The net effect is a shortening of the time scale on which a business will make its plans. But a long-term outlook is required for the process of transforming basic research and invention to a marketed product or service, and a heavy investment, both expense and capital, is involved before there is any return on the investment. If there is doubt as to whether Federal actions will change the environment substantially before the process is completed, the innovation is not likely to occur.

One of the most important ways the government could foster innovation is to reduce this uncertainty. Although economic instabilities are probably most important and need primary attention, the provision of a greater degree of stability and wisdom in regulation and antitrust is also urgently needed. It would be possible to reduce the inhibiting effect on innovation without loss of any essential benefits provided by regulatory and antitrust laws.

The problems of capital formation and private investment in innovation are closely tied to such matters as tax policy, accounting rules, subsidies and loans. This is a complex subject but offers significant possibilities for the stimulation of private investment in technological innovations.

A mechanism that has been proposed but seldom exercised is the use of government procurement to stimulate private investment. This is a potentially powerful lever, as the government is a very large buyer of consumer goods, health care, services, and so forth. This suggests that procurement could be used to provide a market for innovative products, by reducing market entry risks for suppliers. Exploratory tests of this concept look very promising.[12] The government gets new or improved products, which also become available to the public. There may be a substantial savings in cost to the consumer. And, the R&D is privately paid for, rather than by the taxpayer. Mechanisms like procurement are attractive because they focus on what the government can do with reasonable efficiency, that is, specify the result wanted. They do not depend upon what the government cannot do as well, which is to determine the method for getting the result.

Patents resulting from Federal R&D contracts could be a source of innovation, through provisions for exclusive licensing.

Selective Federal support for R&D for civilian technologies can be justified. Criteria for selection might include such characteristics as: a highly fragmented industry structure, the need for an R&D project on a scale beyond the capability of a single company, the need for R&D to develop a technology with little commercial potential but large social importance, and a national urgency that cannot be met by privately funded R&D.

There is a close link between innovation and productivity, and productivity gains are important to economic health. The U.S. has higher productivity than other countries, although the growth rate of its productivity is lower. Any policy that discriminates against investment also discriminates against productivity increases.

The advanced technology that increases productivity is concentrated in a few high-technology and/or capital-intensive industries and firms, and in agriculture. Many smaller firms, and a number of basic industries, don't enjoy this position. We need to find mechanisms for extending to these industries the productivity gains that are clearly possible. It seems likely that specific direction of Federal programs could aid in this. One way this might be done is through increased support of research and education in industrial engineering and manufacturing processes. A Federal program of information transfer to smaller companies would be useful; there is evidence that many of them do not know what is possible in manufacturing technology. Some of the most significant gains in productivity will undoubtedly arise from innovations in the application of computers to the management and control of manufacturing processes and industrial operations.

Conclusion

Several points deserve reemphasis. First is the necessity for strengthening the U.S. innovative capacity in the civilian sector. The health of our economy, with all the attendant consequences of increased employment, improved standard of living, and progress in social areas, unquestionably depends upon this innovation. Innovation is not being given a high enough priority at the national level.

Second, innovation in the private sector will come only if there is greater effort on the part of both industry and the government. We cannot expect Federally guided and funded research to provide the initiative—it lacks the focus and the connection to the ultimate user. What can be done Federally is to create a better climate for privately funded innovation. At the same time industry has to show faith in its own future. Any industry that believes it has a future should be willing to invest something in that future and in longer-term objectives. We must ensure that the technological achievements of industry in the future are a match for those of the past. And, we must see to it that government constraints do not limit the application of science for the public benefit.

Third, we must develop a much higher degree of cooperation and understanding between government and industry. All too often this relationship has been marked by suspicion or even hostility, on both sides. This is in stark contrast to the attitudes in almost all other countries. Government officials are frequently suspicious of the motives of large corporations, and believe that industry is only interested in profits. Industry is concerned that government officials do not understand the role of profits in supporting the economy, and sometimes seem to act irrationally in the administration of regulation, antitrust and other matters that affect industry. Industry believes that Federal actions create uncertainty, to an unnecessary degree, and uncertainties force business to shorten its time horizons and concentrate its R&D on cost reductions and short-term payoffs, rather than on major innovation.

Progress in these three respects is essential if we are to realize our full potential for the application of science and technology for the common good. We have the R&D resources for this, and the issue is: will we use them effectively?

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Senator STEVENSON. Thank you, Dr. Hannay, for an excellent statement.

Next we will hear from Stanley Ruttenberg, president of Ruttenberg, Friedman, Kilgallon, Gutchess & Associates, Inc., economic consultants in Washington.

Mr. Ruttenberg spent nearly 25 years in organized labor in the late 1950's and early 1960's as research director for the AFL-CIO. He joined the Labor Department in the Kennedy administration and served as Assistant Secretary of Labor for Manpower in the Johnson administration. Earlier he was a delegate to the International Labor Organization, and public adviser to the U.S. negotiators on GATT. He has written extensively on manpower issues and now serves, among other things, on the board of directors of Resources for the Future.

Mr. Ruttenberg?

STATEMENT OF STANLEY RUTTENBERG, RUTTENBERG, FRIEDMAN, KILGALLON, GUTCHESS & ASSOCIATES, INC., WASHINGTON, D.C.

Mr. Ruttenberg. Thank you very much, Senator Stevenson.

I think it is fair to say, from hearing what has been said already by the two previous witnesses, that the United States was the technological leader in the world. But it appears that that role is fading and may no longer be true. The fact that this hearing is taking place emphasizes the fact that there is a deterioration in the state of technology in the United States and that there is a loss of United States leadership. The United States as a leader in technology is certainly being threatened. And the seriousness and severity of the problem must be carefully looked at.

I was asked to discuss technological leadership in terms of, one, its impact on employment; two, its relationship to world trade; and three, its effect on the U.S. share of such trade.

No problem, in my judgment, poses a more serious issue to us than the diffusion of technology around the world and the resulting dissipation of U.S. technological leadership.

I would like to divide my discussion into four areas.

First, I would like to discuss what is happening in the development of U.S. technology.

Then I would like to look at why the U.S. technological advantage is deteriorating.

Third, I will consider the impact of current trends in technology, in technological development and transfer, on employment and jobs in the American economy.

And fourth, I will discuss what might be done about the problem—to correct the situation and to restore the ability of the United States to create enough good jobs for all its workers.

First, let me look at the problem of what is happening in technology.

I am obviously no expert on technology. Others are far better able to provide detailed information to you. However, there are some important developments that are public knowledge. Senator Stevenson has already emphasized some of the statistics, and at least one, if not both of our previous witnesses have.

There is a lag in American investment in research and development. The Data Resources, Inc., run by Otto Eckstein, a former member of the President's Council of Economic Advisers and a Harvard professor, did a study on the role of high-technology industries in economic growth. The conclusion: R. & D. is "suffering from malnutrition."

Senator Stevenson has already referred to the figures that the percent of GNP in research and development has declined over the past decade from 3 percent in the midsixties to about 2 percent last year—while West Germany and Japan have registered substantial gains in research and development expenditures.

Second, the U.S. lead in major technological innovations is declining, and again, since this has already been emphasized by Senator Stevenson I shall not go on to give you the facts or figures there.

Third, the pace of technological transfer out of the United States has accelerated, and this is a tremendously important problem to the issue we are discussing.

Coproduction arrangements being advanced by the U.S. Government, incentives for foreign investors, the whole concept of licensing and royalties, turnkey plants, multinational corporations, foreign government activities, joint ventures and the like all contribute to and encourage the flow of technology from the United States to other countries. The growing nature of the problem is borne out by two simple facts. The book value of U.S. direct investment since 1970 has advanced from $75 billion to over $137 billion in 1977. Licenses, fees, and royalties have increased from $1.6 billion to $3.8 billion in the 10-year period ending in 1976.

Our problem is that now transfers of technology even occur after research and development in the United States but before production ever takes place in the United States. I could cite many examples of products developed in this country that have never been produced in the United States for which we find production taking place elsewhere in the world.

It seems to me this should make the advocates of the general theory of comparative advantage and international specialization of production wonder what has happened to the theory. But those same people, mainly academicians, continue with their conventional wisdom, and that is what still prevails as we look at the problem of technological transfer.

Let's look at the second area. I want to talk about why the United States is losing its technological lead; what brings it about.

Well, I think, in the main there are two factors. There are many others, but two major ones I would like to refer to very briefly: first, the multinational corporation, and second, the lack of a consistent, current public policy by the U.S. Government to deal with the problem of technology development and technology transfers out of the United States.

Let's look at each of these, the multinational corporation and public policy.

The list of multinational corporations getting more than half of their total income from overseas operations, is growing, because, in the main, technology transfer is being assisted and given incentives. Incentives to develop technology and produce the product in the United States seem to be diminishing or are no longer there. In my view, it is the multinational corporation—with its talent for flexibility that international organization and operations provide—that is responsible for: one, accelerating the rate of technological transfer, two, the decline in U.S. R. & D., and three, the deterioration of the United States' technological lead.

No Government policy, it seems to me, exists to deal with this problem.

I want to relate in a moment when I conclude to the comments of President Carter in his budget and to one to which Mr. Baruch has already referred, but basically there is no Government policy to deal with this problem, and what Government policy there is encourages the transfer of technology.

Now, for the third area with which I want to deal: what is the impact of the loss of technological leadership?

There certainly is an impact on the ability of the United States to adjust to changing trade patterns.

Second, there is an impact upon the ability of the United States to shift to higher-technological industries.

Third, there is a basic attack upon the rate-of-productivity growth in the United States.

And fourth, technological transfer makes an impact on the rate of growth of the U.S. economy.

All of these four factors affect employment and jobs.

The theory that the United States need not worry about job displacements that occur because of import competition because we are a high-technology country is unfortunately no longer true.

What are the consequences—and I would like to develop that in more detail than it is developed in my paper—what are the consequences of this inability to shift to the use of high-technology in our industries? A loss of jobs, inability to provide employment?

The steel industry is the best example of that, and Congressman Brown in his earlier remarks referred to the steel company in his own district in California.

The question is, what will we export from the United States to pay for our oil, our raw materials, our foodstuffs, and other products which we need in the United States?

Technology? Well, we export technology, but that is a one-shot affair. Once the exporting of the technology is finished, its impact on the American economy is relatively nil.

I know that is a controversial statement, but I am prepared to argue it with those who want to argue.

What about royalties? Well, if we continue to license our technology and ship it overseas, the United States, yes, will get royalties and fees and income, but that means the United States must move to a coupon-clipping, service-oriented economy. The export of technology and the deterioration of the relative level of technology in use in the United States will reduce the rate of productivity growth.

Again, Data Resources, Inc., who I quoted earlier, indicate that high-technology industries have a much higher rate of productivity growth than low-technology industries, and there are some specific figures to bear that out.

The loss of technological leadership also leads to slower rates of economic growth and therefore lower rates of employment growth and higher unemployment.

The sequence of these steps bodes, in my judgment, only ill for the U.S. economy.

What needs to be done?

The United States can not afford to become a rentier economy, receiving rents from all of its exports of industry, exports of capital, and the exports of technology. All of this, these industries, capital and technology exports produce returns in the form of fees and royalties and interest on capital loans, but this will not permit the American economy to grow and produce jobs. This, it seems, is a foolhardy development, although not an easy one to deal with.

Look at the experience of the British economy. It experienced unrestrained export of technology and capital in the early years of the 20th century. It is a dangerous road for the United States to follow.

Nor can we become a polarized service-oriented economy in which industries such as wholesale and retail trade, banks or tourism provide low-skilled, low-paying jobs and where we might have computer-type industries with highly skilled technicians' jobs. That kind of a service-oriented economy provides no jobs for the masses of American workers, skilled and semiskilled, who are now working in American manufacturing industries.

That type of underutilization of our work force, with all of its economic implications, could be very serious. Therefore, we need to act now while there is still time to reverse the trend, a trend that if left unchecked, could spell disaster for the United States as it has for England. We must take steps to maintain economic growth and protect the U.S. economy from exploitation by the multinational corporations and encourage technological development with the full utilization of such technology by U.S. industries.

Several positive steps need to be taken. One, we must slow down the rate and pace of technological transfers by multinational corporations. We should require technological exporters to secure a license. Yes, I know Government involvement and Government regulations have already been referred to as a problem but that is a minor problem in relation to the issue.

We should require, as a corporation decides to export technology, such as—well, I won't mention—I have a lot of examples in my paper—but we should require those corporations to file an employment impact statement. They should be required to assess and consider and place in the public record the employment impact, positive and negative, from the export of the technology. This would permit, it seems to me, the objective consideration of technological exports, a consideration now not exercised.

But most of the developed countries of the world already are moving in this direction—Japan, Canada, Sweden, France, Australia.

Second of the steps that need to be taken, is the removal of the presently existing incentives for the export of technology. These incentives relate, of course, to the tax credits, the tax deferrals, the excess tax credits, the accounting rules and transfer pricing policies; all of these practices encourage overseas investment.

Third, there must be greater support for technological R. & D. in the United States. Tax incentives given to technological development or selective support of R. & D. would produce far more in the long run for the United States than any of the tax incentives for new equipment or new plant and equipment which is now part of our law.

Government support for basic and applied research efforts must be stepped up. The fiscal 1979 budget of President Carter proposes a slowing down of funding for civilian research and development.

Government, he says—and I quote President Carter's budget message—"wants to avoid overtaking activities that are more appropriately those of the private sector, such as the development and producing and marketing of new products and processes, as in the case of solar heat and air conditioning."

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And he goes on to say, "And it is the policy of the U.S. Government to avoid overinvesting in technologies that promise only marginal improvement, as in the case of coal gasification demonstration projects."

It seems to me this comment is in direct contrast—and needs to be looked at carefully—to the quote that Mr. Baruch took also from the same, I assume, budget message where the President says, "I encourage a new surge of technological innovation by American industry. I am determined," the President says, "to maintain our nation's leadership role in science and technology."

I think the two concepts contradict each other. There is the one which Mr. Baruch pointed out and I support strongly, but also the other factor, that if one looks at reality in terms of the budget, the situation is different.

Now, this position, it seems to me, is not only hard to understand, it is unwarranted and, in my judgment, unwise. We should be providing increasing support of R. & D., instead of withdrawing such support.

Thank you.

Senator STEVENSON. Well, that helps to get things stirred up. I have a feeling we will be back to you, Mr. Ruttenberg. Thank you.

Our final witness is Professor Bela Gold, professor of industrial economics at Case Western Reserve University.

Dr. Gold is a Columbia Ph. D. economist. He specializes in the economics of technological change and productivity. He has spent considerable time in Japan and Western Europe studying the state of their industrial technology and related government policies.

He has published frequently on technological innovation, especially in the steel industry, which I understand will be the focus of his testimony today. He is currently a member of the OTA Technology and World Trade Program panel on steel.

Professor Gold.

STATEMENT OF DR. BELA GOLD, PROFESSOR OF INDUSTRIAL ECONOMICS, CASE WESTERN RESERVE UNIVERSITY, CLEVELAND, OHIO

Dr. GOLD. Thank you very much, Senator Stevenson. I want to thank you and the two subcommittees for helping call public attention to a problem——

Senator STEVENSON. Professor Gold, would you speak directly into the microphone. Thank you.

Dr. GOLD. If you will permit me to repeat, I want to thank the committees for helping to call attention to a problem which I think is far more serious than many people realize and which, in my opinion, is generally not at all well understood in public discussion, because of the prevalence of vague generalizations about this technological lag, and of many misconceptions about what it consists of. These encourage some misdirection of proposed remedies.

With respect to the vague generalizations, I don't think you can talk about the state of American technology in general. It doesn't make any sense. We have industries which lead the world: computers, aircraft, a series of others. We have industries which are in a more vulnerable position: footwear, textiles, and a variety of others.

But the problem is well illustrated by the weird confusion in the public discussion about the technological capabilities of our steel industry. People keep referring to its terrible backwardness. It's true, we don't have the best steel industry technologically in the world, but we certainly have the second best. And that isn't the impression one gets from hearing the criticisms of, and the lamentations about, the industry efforts to deal with foreign competition.

What I would like to do is try to correct some of these impressions, and, in doing so, I would like to redress the over-emphasis on basic research and development alone. But you can multiply it 100 times and still not get the increase in the technological capabilities for our industries, which is really what we are concerned about in terms of their effects on employment, income, and the variety of problems having to do with the shortage of resources.

Basic research is only part of the needs. If you don't follow through with all of the intermediate steps which eventually bring it to commercial fruition, it alone is not enough, and pumping more and more into that end of the pipeline won't increase the output at the other end by more than a trickle.

Just to illustrate the importance of prevailing misconceptions: We were talking here about why people are concerned about technological lag. Most of the concern seems to have been generated by the tremendous increase in imports in manufactured goods.

But most people misunderstand the causes of that inflow. Most of the lower price import products coming into the United States are simply due to the differences in wage rates, not to inferior technology in the United States. A good part of them are due to government subsidies from abroad by governments which are determined to invade American markets at whatever cost.

If you tried to list those imported products which represent the result of superior production facilities abroad—and I will later talk about one—you will get a very short list. And if you then try to list the import products which reflect superior foreign technology resulting in greater efficiency and lower costs as the basis for the lower prices in American markets, you will wind up with a very tiny list, indeed.

That doesn't mean we don't have a real problem in terms of developing our technological capabilities. I think the real problem is to understand that it arises not from the limited pressures which we still feel from overseas. Rather, it arises from some of the very real needs we have in this country: to more effectively utilize resources that we are running short of; to keep raising standards of living; to reduce the threats to health and safety; and to improve our achievement of other major social goals.

We don't really need to worry about keeping ahead technologically of what's coming across the seas; we've got big problems right here. Advances in the technological capabilities of our industries represent probably the most powerful single means we have to promote the welfare of the United States. And that is the major reason why we ought to be really concerned about doing something in this area.

Now, I would like to shift from these general comments to take a concrete case. It is one of the most popular controversies now: what accounts for the differences in the technological development of the U.S. and the Japanese steel industries?

I have been over there a number of times, visited all of their major plants, and spent quite a bit of time studying this problem. I would like now to review with you some of my own personal judgments.

Until the late 1960's, the Japanese bought all of their technology in the steel industry. They started with practically nothing, and a large part of what they bought came from the United States, as Mr. Ruttenberg suggested. Since then, however, they have made major innovative contributions in every sector of the steel operations. Why were they able to do that more effectively than was done in the United States?

I shall concentrate on four major factors that were involved. The first is the strong unwavering support for major technological advances of the top managements of their steel companies.

This is based not only on normal entrepreneurial objectives, but also on two highly distinctive value commitments that the Japanese managers have. The first is a deep commitment to build the power and prestige of Japan, including entry into the forefront of industrial nations, and minimizing dependence on foreign technology. This nationalistic commitment is a critical one, and when there are instances in which company actions might yield profitability but might leave some stain on the image of Japan, the companies will not do it.

Second, Japanese managers have a tremendous commitment to long term criteria performance, not short term. They are always looking 5 years down the road. They don't care as much about current profitability, an attitude which unfortunately American industry cannot take.

I have been over there twice now during recession periods, and in each they were expanding capacity; they were operating at 70 percent of the capacity and yet they were building additional facilities.

They are looking down the road. They think the world will keep on growing. They think world steel demand will keep growing. And when it does grow, guess who's going to be there with the needed capacity? That long term perspective is the second distinctive managerial factor.

Now, how does this affect what they do? As one sugestion, it results in a much higher ratio of engineers than in the American steel industry. This reflects a continuous aggressive pressure for constant improvement in the technology.

Second, it results in R. & D. ratios to sales more than double those which are common in our country.

Third, the R. & D. programs have a major emphasis on significant advances in the basic processes, rather than on the modest improvements in products which tend to be dominant in the American industry for reasons which we will discuss.

To illustrate quickly the extent of the commitment to really developing major advances in technology, I will cite one instance. The Japanese, in the mid-1950's, picked up early research on plasticity theory that had been initiated in Germany and then dropped. They worked on it for over 10 years to develop the scientific foundations which were the springboard for their enormous advances in steel-rolling technology. And there is a widespread belief that you don't just figure out a currently cleverer way of doing something; you dig down into the fundamentals in order to generate the basis for a long step ahead of your competitor, rather than merely a momentary advantage.

After management's contributions, the second major source comes from the special commitments of the Japanese government. The Japanese government did not have all the resources in the world. They decided that they had to concentrate their efforts in a few key industries in order to develop the Japanese economy and their exports. So, steel was picked as one of the key industries.

Step two: They then helped to divert the limited capital resources of Japan into providing all of the funds needed to build giant new steel mills. Such mills required investments of billions in plant after plant after plant. And the Japanese industry did not get such funds by demonstrating higher profit prospects in the private capital markets than was expected in the U.S. industry. It was through Government help that funds were allocated to them.

Third, the Government then was pressing to achieve a place in the forefront of the world's steel industry. And, consequently, there was tremendous pressure for effecting major technological changes, in order to be sure that the second generation of plants built would be superior to the first generation, and maintain a lead over the rest of the world—again reflecting long-term perspectives.

In addition, the Japanese Government, by selecting this as an elite industry, by insuring its major expansion, and by committing itself to major technological progress, made it possible for the steel industry to cream off the best technological graduates in universities all over the country.

This represents one of the most immense contributions to maintaining the technological momentum of an industry that is imaginable. You get the best brains, and they are going to be with you for a long time, and that is a major resource.

In addition to managerial and governmental contributions to advancing technological capabilities in steel, the peculiar organizational relationships in large Japanese companies represented a third source of contributions. Just two illustrations that I want to refer to hurriedly—the first has to do with relationships within management. Of course, all management and technical people have lifetime employment security. But, also important, these people are moved around from department to department, from plant to plant, and function to function—instead of the tendency in the United States and Western Europe to have a dominantly narrow vertical line of career development.

The result, then, is that people in management maintain a strong loyalty to the company, not to a particular plant or a particular unit or particular operations. The basic commitment is to the company.

Also, there is sufficient managerial and technical turnover in each of the operating units to prevent the dominance of people with strong commitments to the way things were done in the past. New people are coming in, and they are receptive to suggestions for changing past practices.

Turning to the wage earners, they also have lifetime employment security in addition to gaining wage rate increases on the basis of years of service rather than skill levels. Consequently employees are quite receptive to technological innovations because they do not threaten their jobs nor their wage levels. Thus there is no reason for the resistance which is quite rational in countries where innovations are regarded as threats to the wage earner.

The fourth factor contributing to advancing technological capabilities of the Japanese steel industry was its rapidly expanding output. This in itself furthered the momentum of technological progress because of the unending opportunities to apply resulting advances—technological progress, unlike the United States, which I've studied extensively. There, almost every company has a shelf full of technological advances which aren't being implemented because they are not building the new facilities which could most effectively utilize such advances. After a while the motivational air leaks out of the innovation-producing tires and managers wonder, "How much more can you keep on investing in developing basic technologies without being in a position to apply them?"

In Japan, however, output was expanding. New plants were being built. There was high utilization of the existing capacity. Therefore, there was a good reason to keep trying to increase it, to keep trying to improve the way in which it functions, and, to bear in mind that not long from now we will have built another plant which will incorporate all of the advances made since the last one was completed.

Finally, it has also helped the Japanese to utilize increases in labor productivity without violating lifetime employment guarantees. If the market expands enough, all of the people released from previous tasks through technological advances can be used to produce the additional output demanded.

Now, quickly, how do the factors responsible for the accelerated technological development of the Japanese steel industry compare with the situation in the United States? Well, not only did the American steel industry not receive positive contributions from these four sources but each actually exerted negative pressures.

In the first place, industrial management in this country faces a powerful emphasis on short-term performance. This derives from the pressures of our sophisticated capital markets which shift investments around quite rapidly, not only on the basis of long-term changes in the prospects of a company, but also on the basis of quarterly financial statements.

If a firm comes up with four or five successive quarterly financial statements which are unfavorable, investment funds begin to flow away—or even on the basis of daily stock market quotations—to the increasing discomfort of directors and management.

One cannot run large, capital-intensive industries effectively on the basis of responding to such short-term urgent pressures. That is a difficult problem for managers. As a result, the managers of American steel companies are understandably reluctant to make long-term commitments to risky kinds of undertakings, because of the unfavorable impact on their profitability until the benefits eventually emerge, with resulting reflections on their managerial performance and rewards. Such considerations tend to inhibit investments in longer term basic research, as well as the construction of large new steel mills.

Do you know how long it takes to build one? It takes 6 to 8 years. And it takes 8 to 10 years to build a powerplant. If you make that investment, you face the certainty of no returns for a long time. This insures a decrease in the ratio of profit to investment because the investment is increasing while the profit is not. For managers being evaluated by short-term changes in this ratio, the case for making such long-term commitments is often likely to be considered unpersuasive.

Second, turning to the role of government, the Japanese and the Western European governments all helped their steel industries to modernize and expand. They helped to make funds available and provided various forms of subsidies and other kinds of help to enable them to expand. In this country, Government pressures tended to be in the reverse direction. Repeatedly, when efforts were made to raise steel prices, the Government objected, without ever proving that increased prices were not justified by demand and cost pressures. Its position was simply that raising steel prices was bad for the economy.

OK. We can understand that motivation. But the fact is that if the steel industry does not raise prices when market conditions are favorable, and if it cannot avoid losing money during the recessions, one cannot be surprised to learn that its average rate of profitability has been only one-half to two-thirds of the average for manufacturing as a whole.

An industry like that finds it difficult to raise even the $4 billion necessary to build a mill which is half the size of a modern Japanese mill—for example, the proposed new U.S. Steel mill.

Also, while the European and Japanese governments were actively consolidating their steel industries into fewer firms and larger plants, in order to get the economies of scale and attendant competitive advantages, our Government's pressure has been exactly the opposite, namely, a very strong hostility to allowing any increase in concentration in any of our industries. Greater concentration has been assumed to guarantee a decline in competition, without bothering to prove it.

As a result, the Japanese have steel mills that run 8—12—16 million tons, while the last steel mill built in the United States—at Burns Harbor—is still running between 4 and 5 million tons capacity and the proposed new U.S. Steel plant is also targeted for a 4-million ton capacity. Thus, the Japanese have developed technologies attuned to a much larger scale of operation because it has certain, very real benefits for them, but such technologies have not been found applicable in the United States so far.

American managements have not even been able to propose sufficient capacity expansions to supply rising steel consumption in our own markets. People don't seem to understand that the rate of increase in the consumption of U.S. steel has indeed continued at a steady rate since about 1905. But during the last 10 years all of the increase has been creamed off by imports. Yet the U.S. Government did not even make serious efforts to determine whether some of these imports were based on uneconomic pricing as a deliberate tactic for invading the American market.

Having reviewed the unavailability to the U.S. steel industry of some of the factors encouraging increases in the technological capabilities of the Japanese steel industry, I would now like to discuss five active deterrents to advancing technological capabilities which are applicable to a wider area of American industry.

Listing such deterrents then poses the question for the Government: What should we do to reduce or minimize these deterrents, or to help offset them with some sort of incentives?

The first deterrent is the strong emphasis on short-term profitability. This leads companies to favor a marketing innovation, or some kind of financial operation rather than investing in major technological development because they are considered to represent less risky, shorter term and more quickly rewarding expedients.

Short-term profitability objectives also encourage the concentration of research on short-term projects, dominated by essentially minor product improvements and the curtailment of projects seeking advances in technology. And it also discourages the building of expensive, big, new plants. Instead, more modest gains in efficiency and capacity are sought by "rounding out" existing plants and by trying to retrofit some new technologies—such as computerization—into plants that weren't really built for them. In short, this involves limiting improvement and expansion efforts largely to what can be squeezed into, or out of, building new plants.

Now, what could Government do to reduce these costs and risks, which are perceived as deterrents within the current framework of emphasizing short-term profitability? There are a variety of possibilities to be considered. First, would be the possibility of more favorable tax treatment of capital gains and of long-delayed profits from the long-term technological improvement projects that are to be encouraged.

Second, it may be necessary to consider special allowances for losses on such projects. One must remember that a large proportion of efforts to develop major technological advances either fail to work, or don't really yield rewarding returns. I'm aware of a number of major technological innovations during the past 20 years that were not profitable even after 5 or 6 years of use. So you're asking people to undertake very big risks. You cannot evaluate costly industrial research projects simply on the basis of whether it produces a published paper or a patent. The more relevant criterion is whether after 5 or 10 years it repays all of the investment plus a reasonable rate of profits.

Third, there is the possibility of cost-sharing grants between the Government and industry with respect to the support of more risky projects. Let me give you just two examples. One, such developments would involve using nuclear powerplants to help meet the tremendous energy requirements of the steel industry.

For example, there have been explorations of the use of the output of high-temperature gas reactors to fuel the direct reduction of iron ore.

As a second example, industry has invested substantial sums in trying to develop ways of using nonmetalurgical coals to meet steel industry requirements, thereby easing pollution problems and also increasing the supply of coal needed for making steel. Private investments in both of these efforts have not been terminated.

But there is a national stake in solving some of these energy, pollution and resource supply problems. Hence, my point about possible "cost sharing."

Or, fourth, there might be a need for accelerated depreciation in order to deal with the major new plant projects which would take a long period of time to build.

Some way must be found to reduce the average amount of investment tied up for such a long period of time without returns.

And just one other possibility that I would like to mention: There was a period when I was in the Agriculture Department, and I was very much impressed by the tremendous contributions made to American agriculture by the research centers that the Government set up all over the country.

Maybe the time has come, as Mr. Baruch has said, to set up some basic research centers to develop the technological infrastructures of major industries. This is the most risky part, and the part most difficult to justify in terms of corporate investments. And yet the results of such relatively basic research could then be fed into industries where companies achieving further advances would have proprietary rights to benefit from them—thus dealing with the question that Mr. Hannay raised.

Turning now to the second widespread deterrent—the decreasing benefits of major resource saving innovations—one must recognize that such savings have been major stimuli to technological advances in the past in most industries, especially in the case of prospective labor-saving. But the actual benefits of labor-saving innovations are falling far short of technical expectations in the United States for two reasons.

First, because of widespread unemployment, our trade unions are becoming more resistant to permitting reduced employment levels in order to utilize new technologies. I have traced a whole series of these in industry. Union says that, officially, they have no objection to such innovations. But I have been in plants where management is prevented from utilizing the innovation effectively, thereby curtailing and even eliminating the benefits expected.

And second, even when some reduction in the employment level is achieved, the union demands offsetting increases in the wage rate.

So, the increase in wages per man-hour offsets the benefits of reduced man-hours per unit of output to result in unchanged wage costs per unit of output.

Many people don't realize this, but the facts demonstrate that this has been the case for decades in the steel industry in the United States. More managers are accordingly beginning to say:

> Look, this is a silly game. The engineers show us how much we can save on manpower, but in fact we don't get the cost-saving benefits; why do it?

What can the Government do about it? Well, we have a program now which is designed to ease the hardships caused by imports: plants impacted by imports get funds which helps support the displaced wage earners during a hardship period, and also finances retraining.

Why do we do that only if foreigners have caused the hardships of displacements? Why not do it to ease hardships generated by our own technological advances? This seems to me a quite misguided limitation.

Another possible change in Government policy may be necessary to encourage one of the major sources of advances in the technological competitiveness in many industries: what we call increases in the "scale." This has been influential in cement mills, powerplants, petroleum refineries, ships, steel mills—a whole series of operations in which significant economies are achieved through using the very large-sized facilities needed to more effectively utilize the available technology.

But in most cases, building facilities of this scale and using them effectively tends to encourage expansion in the size of the firms involved, and the result is a tendency towards what we call "concentration."

Of course, we have an official policy which is opposed to any limitations on competition—quite understandably. But I can't help questioning whether it is correct to assume that, if you have further concentration in an industry, competition is always reduced or eliminated. Instead of assuming this to be true in all cases, it should be tested and proved in each case where the claim is made. In my view, we must learn how to take advantage of the economies of increasing scale technologies, and yet prevent any resulting collusion to reduce competition, instead of continuing to assume that one is impossible without the other.

One last point has to do with the problem of imports. It is a much more serious threat than people realize because, in addition to the jobs we are losing now, it involves two other aspects of technological capabilities.

First, a number of industries are curtailing technological advancement efforts because of a belief that any resulting achievements leading to reduced costs and prices, will be matched by reductions in import prices, not because of simultaneous technological advances, but because of additional aids from their governments in order to maintain employment, to prevent increased political opposition, and to continue earning needed foreign exchange. Hence, they find it difficult to justify investments in long term and risky technological efforts in view of the unlikelihood of gaining reasonable benefits.

Second, what happens if they don't push for continuing technological progress? Bit by bit, such industries undergo a gradual regression in the state of their technological capabilities. Reliance in progressively older plants and older technologies insures that at some point the foreign technology will in fact be better.

Thank you, very much.

[The statement follows:]

Statement of Dr. Bela Gold, Professor of Industrial Economics, Case Western Reserve University

ADVANCING THE TECHNOLOGICAL CAPABILITIES OF U.S. INDUSTRIES: NEEDS AND SUGGESTED POLICIES

Thank you for inviting me to participate in today's Hearing. My name is Bela Gold and I am the William E. Umstattd Professor of Industrial Economics as well as Director of the Research Program in Industrial Economics at Case

Western Reserve University. I have been trained as an engineer and as an economist and have been doing research on the factors affecting industrial technology and on the economic effects of resulting innovations for more than 25 years, mostly in the United States, of course, but also in Western Europe and in Japan.

I am certain that many others join me in expressing appreciation to the members of these Sub-committees and their staffs for calling greater attention to the critical national issues to be discussed in these Hearings.

My remarks are divided into three sections: the first tries to clarify the bases for evaluating technological capabilities in reasonably practical terms; the second offers a concrete example of the issues to be faced in developing appropriate national policies by concentrating on one of the most popular controversies in this area—the factors responsible for differences in the technological capabilities of the U.S. and Japanese steel industries; and the last reviews some of the resulting targets for policy development.

I. CLARIFYING THE BASES FOR EVALUATING TECHNOLOGICAL CAPABILITIES

There are very good reasons to be concerned about certain aspects of technological capabilities in the United States. But these are not widely understood as yet because much of the public discussion has centered around vague generalizations and mistaken conceptions of the actual problems to be dealt with.

A. On the General Level of U.S. Technological Capabilities

It is true, of course, that the United States does not dominate all fields of technological progress. But we never did. And so one can always cite some sector in which others have gained the leadership without thereby demonstrating any pervasive weakness in our achievements. It is also probably true that the United States is accounting for a decreasing proportion of total scientific and technological progress in the world. But to expect anything else seems naive in view of the increasing industrialization and rising education levels of many countries. On the other hand, some might derive comfort from the absence of persuasive evidence that U.S. technological capabilities as a whole have been surpassed, or even closely approached, by any other nation.

But such generalities are meaningless. There is no effective measure of "overall" technological capabilities which can be used either to compare different countries, or to evaluate changes over time within one country. Rather, it is necessary to recognize that technological capabilities tend to be highly specific. Thus, our aircraft and computer industries lead the world; our footwear and textile industries seem to be in a much more vulnerable position; and recent ostensibly knowledgeable discussions about our steel industry reveal the most astonishing confusion about the international ranking of its technological capabilities. Accordingly, meaningful evaluations must be made on an industry by industry basis.

B. On the Elements of Technological Capabilities

Similarly, there is no single or direct measure of technological capability. At the very least, it would seem to cover the maximum level of output capability, the quality and mix of products involved, the so-called "efficiency" of production and perhaps even resulting cost levels. But the superiority or inferiority of technological capabilities in any industrial sector might also be appraised by evaluating such of its basic determinants as: the level of advancement of its basic and applied technical knowledge; the size and quality of its technical manpower; the modernity of its production facilities; the skills and productivity of its labor; the supply and quality of its raw materials and fuels; the usefulness and attractiveness of its product designs; and the attractiveness of its market prospects.

One cannot, of course, weight such elements to arrive at an over-all measure even of relative technological capability. Advantages in some can obviously offset disadvantages in others. And improvements in any element may well tend to improve the whole, though not in any measurable way.

Then how are such evaluations to be made for practical purposes? The most common expedient is to derive a judgment from an examination of such aspects of economic performance as prices, production costs and even profitability, as well as growth in output. It is obvious, however, that such deductions may be highly erroneous because these aspects of economic performance are heavily responsive to a wide array of factors not necessarily associated with the level of technological progress. Hence, effective evaluations of technological capabilities require analyzing both the technological and the economic aspects of performance and then tracing their interactions. Only then can we assess the prospective economic benefits of alternative improvements in any of the technological determinants of performance; and also uncover any non-technological sources of observed changes in economic performance.

Finally, in order to develop useful bases for designing policies to improve technological capabilities in any industrial sectors, it is necessary to explore the factors which have influenced past changes and which may encourage or deter current efforts to achieve further advances. In this connection, particular attention might well be given to any sources of encouragement or deterrence which affect a variety of industries instead of being relevant only to individual cases.

C. The Import Test Versus More Basic Tests of the Adequacy of Technological Capabilities

In view of such formidable difficulties in the way of making valid judgments about relative technological capabilities, it is useful to ask what has caused the upsurge of public concern in recent years about the adequacy of U.S. technological capabilities. More than anything else, it seems to have been triggered and intensified by the increasing flow of imports of manufactured goods into our markets, with attendant threats to domestic firms and employment levels. But the largely erroneous implications drawn from this development illustrate the problems of correctly interpreting changes in aspects of economic performance which were noted above.

It is understandable that many observers, lacking specific knowledge about the particular industries and circumstances involved, have assumed that increases in imports must be attributable to their lower prices, that these result from greater efficiency, which derives, in turn, from superior technology. Even among the imports that are priced below domestic products, however, most gain their advantage from lower wage rates; and others are traceable to special cost-reducing subsidies or aids from their governments, designed to increase employment or to earn needed foreign exchange. Cases in which lower import prices reflect lower production costs attributable to more efficient production facilities are relatively few. And product imports which have gained increasing sales in the U.S. because of lower costs clearly attributable to superior technologies are quite rare, except for some highly specialized machines and instruments serving limited markets.

Despite such largely erroneous interpretations of their causes, concern about increasing imports has helped to attract needed attention to the adequacy of recent advances in the technological capabilities of some major industries. But even more widespread and insistent public interest would be developed if there were a fuller realization of the enormous contributions which could be made to the nation's economic and social welfare by more intensive efforts to develop greater technological capabilities in many industries. The national objective in this area should reach beyond the limited goal of regaining technological superiority in the relatively few industries in which foreigners have caught up with, or even surpassed, domestic producers. Instead of merely responding to such foreign achievements, all domestic industries should be responding to the national need to overcome shortages of natural resources, to keep raising standards of living, to continue reducing threats to health, safety and national security, and to promote other important social goals.

The preceding discussion suggests two complementary approaches to sharpening our understanding of needs and potential corrective measures in this area:

a. Analyzing individual industries to probe for the most influential sources of *differences* in the rates of advancing technological capabilities over time or as among countries; and

b. Exploring an array of domestic industries to determine whether there seem to be any *common* deterrents to the more intensive development of their technological capabilities.

The first approach will now be illustrated by summarizing the major factors which seem to account for the more rapid development in recent years of the technological capabilities of the Japanese than the American steel industry. The second approach will be dealt with briefly in the following section.

II. FACTORS AFFECTING TECHNOLOGICAL CAPABILITIES IN THE U.S. AND JAPANESE STEEL INDUSTRIES: AN ILLUSTRATIVE CASE [1]

Until the late 1960's, the Japanese steel industry was dominated by technologies licensed from foreign producers, especially American. Since then, they have made significant innovative contributions in virtually every sector of the industry. As a result, it is my opinion that the technological capabilities of the U.S. industry have been surpassed by the Japanese, though by no other.[2] The following discussion will be limited to the four factors which seem to have been most influential in accounting for this Japanese achievement.

A. The Role of Top Management

Perhaps the single most important contribution to the rapid technological development of the Japanese steel industry was the strong and unwavering impetus to such efforts generated by the top managements of leading companies. That support was rooted not only in common entrepreneurial motivations, but also in deep commitments to such distinctive objectives as: building the power and prestige of Japan by entering into the forefront of industrial nations and terminating dependence on foreign technology; and emphasizing long term over short run performance targets. Such objectives were implemented in several ways. They employed a much higher ratio of engineers to wage earners than in the U.S. so as to support more aggressive pressure for continuous technological improvement. Research and development allocations approximated 2–4 times the average ratios to sales revenue in the U.S. steel industry. Such programs also placed greater emphasis on major process improvements, in contrast to the prevailing stress on product improvements in the U.S. In addition, Japanese management apparently provided fuller support to developing the scientific foundations of key production processes—for example, spending more than 10 years to extend the early German research on plasticity theory as the springboard for their eventual advances in steel rolling technology.

B. The Role of Government

A second major source of contributions to the rapid technological development of the Japanese steel industry was its designation as one of the key industries in the government's program for economic development and export expansion. This resulted in the government's ensuring the availability of the enormous investments required for the industry's unprecedented construction of new facilities, without having to compete for funds solely on the basis of profit prospects. In turn, the construction of giant new plants permitted utilization of the latest technological advances and the fullest exploitation of scale economies, in addition to encouraging further developments along these lines for application in the planned next generation of new plants. Its government-awarded elite status combined with the steel industry's intensive technological advancement efforts and its expanding promotional opportunities also enabled it to attract the best technical graduates from the leading universities—an invaluable further contribution to continuing advances.

C. The Role of Organizational Relationships

A third source of significant contributions to rapid technological progress in the Japanese steel industry was the unusual character of organizational relationships within large firms. The common practices of lifetime employment and of shifting university graduates among departments and among plants as well as between line and staff—instead of the more common emphasis in the U.S. on relatively narrow vertical career lines—tends to facilitate receptivity to innovations by stressing loyalty to the company rather than to smaller organizational units and by providing for turnover in the managerial and technical staffs of such units. Moreover, lifetime commitments to wage earners, and the basing of earnings increments on years of service rather than skill levels, tend

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[1] Based on my recently completed paper, "Factors Stimulating Computerization Advances in the Japanese Steel Industry" (Research Program in Industrialized Economics Working Paper 83, Case Western Reserve University, February 1978). It is one of the reports resulting from extensive field studies of the Japanese steel, automobile and electronics industries in 1972 and in 1977, financed respectively by the Ford Foundation and by the Joint Committee on Japanese Studies of the American Council of Learned Societies and the Social Science Research Council.

[2] See my "Steel Technologies and Costs in the United States and Japan", *Iron and Steel Engineer*, March or April 1978.

to minimize possible labor resistance to technological innovations as constituting threats to employment or to skill benefits.

D. The Role of Expanding Output

A fourth major source of contributions to the rapid technological progress of the Japanese steel industry was the sharp increase in its output. This encouraged continued development and application of technological advances yielding scale economies and increases in capacity without comparable increases in investment—in addition to those reducing waste and improving product quality. Expanding output also facilitated the full exploitation of manpower-saving innovations despite lifetime employment guaranties.

As is apparent even from the preceding brief summary, the rapid technological progress of the Japanese steel industry was attributable to a variety of factors whose interactions intensified their combined effects. For example, annual output per wage earner in the best Japanese steel mills was more than double the U.S. average because of more advanced processes, larger scale equipment and fuller computerization as well as strongly committed labor efforts.[3] The U.S. steel industry, on the other hand, was not only bereft of positive contributions from each of the major sources enhancing Japanese technological capabilities but faced deterrent pressures from them.

E. Contrasting Pressures in the U.S. Steel Industry

As in all major industrial firms in the United States, steel company managements are under increasing pressure to maximize short term rather than long term performance. Our highly developed capital markets facilitate the rapid reallocation of investments from one company to another on the basis of the changing information provided by quarterly financial statements and even daily stock market quotations. Hence, many industrial executives have been understandably reluctant to undertake research programs or construction projects requiring long term investments before eventual returns begin to flow, lest the negative impact on profitability during the intervening period reflect unfavorably on their performance as managers. Moreover, such general attitudinal pressures have been reinforced by the use of capital budgeting techniques whose substantial discounting of future returns tends to favor short term investments.[4]

Also, while the Japanese and Western European governments were actively helping the expansion and modernization of their steel industries, the U.S. government repeatedly exerted pressure against steel price increases, regardless of demand or cost justification. This helped to hold the average level of profitability to only ½ to ⅔ of the average for all manufacturing industries, thus curtailing the possibilities of obtaining the enormous investments required to build large new steel mills either from the companies own limited cash flow or from capital markets facing more profitable opportunities. Then, too, the governments of Japan and of other steel exporting countries actively encouraged and even forced the consolidation of their industries into fewer firms and larger plants as a means of maximizing scale economies and related competitive advantages. But large U.S. steel companies have had to worry about competing aggressively enough to drive out smaller, less efficient firms, lest resulting increases in concentration induce more government intervention or even penalties. Nor could steel company managements in the United States justify favorable estimates of the benefits of building large new plants because of the continuing expansion of domestic demand for steel, in view of the apparent acquiescence of the government for years in having all of these gains absorbed by imports (without even undertaking serious analyses of whether they involved uneconomic pricing supported by foreign governments).

A number of other factors also tended to inhibit intensive efforts to effect major technological advances in the U.S. steel industry. Increasing concern about unemployment in recent years has undermined the past ready acceptance of labor-saving innovations by trade unions. And even those which are accepted tend to yield limited reductions in unit wage costs because of union demands for increasing wage rates in proportion to increases in output per man-hour.[5]

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[3] See B. Gold, "Steel Technologies and Costs in the U.S. and Japan," *Iron and Steel Engineer*, March or April 1978.

[4] For further discussion, see B. Gold and M. G. Boylan, "Capital Budgeting, Industrial Capacity and Imports," *Quarterly Review of Economics and Business*, Fall 1975.

[5] For some relevant empirical findings, see B. Gold, "Tracing Gaps Between Expectations and Results of Technological Innovations: The Case of Iron and Steel," *Journal of Industrial Economics*, September 1976, pp. 15–17.

Increasing technological specialization has also tended to engender resistance by technical and managerial personnel to innovations involving unfamiliar technologies, as illustrated by experience with computerization. And the prevailing under-utilization of capacity has minimized interest in technological advances which offer scale economies that can be realized only at high utilization levels, as well as in advances which offer increases in capacity without substantial increases in investment, but whose benefits cannot be realized when even existing capacity is under-utilized.

Two conclusions would seem to follow from the preceding comparison. First, even Japanese interest in continued intensive development of the technological capabilities of the steel industry would tend to be undermined if the array of benefits of primary concern to their managements were to be curtailed by new government restrictions, by increasing trade union pressures, or by changes in input availabilities or market opportunities. Second, motivating U.S. steel companies to intensify efforts to further their technological capabilities would clearly require substantial improvements in their currently perceived financial benefits of doing so.

III. APPROACHES TO DEVELOPING CONSTRUCTIVE NATIONAL POLICIES

In order to design national policies to further development of the technological capabilities of industry, it may be useful to begin by clarifying the basic needs to be considered and the locus of primary responsibility for dealing with each. Attention may then be turned to the specific problems and deterrents to be confronted in seeking to meet recognized needs as the basis for considering policies which might help in dealing with them.

A. Basic Needs and Primary Responsibilities

As was mentioned earlier, an assessment of the technological capabilities of industry must cover eight components. In respect to the first two—the level of advancement of general scientific knowledge and the adequacy of effectively educated technical manpower—the U.S. obvious enjoys world leadership. In view of increasing progress abroad, maintenance of these advantages probably requires further increases in support of basic scientific research. Our large existing educational establishment, however, suggests that further advances in this sector may depend more on raising performance standards than on adding facilities. Responsibility for leadership in these areas must, of course, remain with the government, supported by philanthropic agencies and academic specialists.

On the other hand, further development of the technical knowledge directly applicable to particular industries, and of their production facilities, obviously remain the primary responsibility of the firms comprising them. Even those which are world leaders may have to increase outlays for these purposes in the face of intensifying efforts overseas—as well as to augment their past contributions to the U.S. economy. And such needs will be all the greater for the other industries whose efforts to survive and prosper are already facing stronger challenges from abroad. Although they obviously vary widely among industries, the most common needs in these two areas seem to center around: (a) expanding allocations for longer term research seeking substantial rather than essentially minor improvements in processes and products; and (b) increasing investment in new facilities which make fuller use of recent technological advances and are better adapted to changes in product demand and locational advantages. Of course, individual firms must also remain solely responsible for improvements in product design, a fifth element of technological capabilities.

Labor productivity is obviously one of the most important elements of technological capabilities and it may well be the one in which past U.S. advantages over foreign competitors have been declining most rapidly. Many factors are obviously involved in determining man-hour requirements per unit of output, including the modernity and scale of production facilities, which have already been mentioned as managerial responsibilities. But the magnitude and effectiveness of labor contributions to output also involve dimensions—including the continuity and extent of effort, the steadiness of conformance to prescribed work methods and quality standards, and the receptivity to improvements in operations—which are determined by trade union policies and wage earner attitudes as well as by the quality of supervision and working conditions and by compensation arrangements.

Two elements of technological capability remain: the availability on reasonable terms of adequate supplies of needed materials and energy; and the maintenance of encouraging market prospects. Individual firms plainly have no choice but to seek to find and use cheaper or better input materials and to minimize avoidable energy consumption. But their technological capabilities can also be affected substantially by governmental efforts to increase supplies of such needed inputs, to develop effective substitutes, to encourage conservation and to help prevent, or to minimize the effects of, artificial price and supply controls by foreign producers. Similarly, although individual firms must take primary responsibility for expanding their markets through product improvements, attractive pricing and energetic sales efforts, they must rely on government to promote the growth and stability of the domestic economy, to restrict unfair competition from imports and to secure entry into foreign markets for our exports on comparable terms.

B. Some Widespread Deterrents to Increasing the Technological Capabilities of Industries

The extent of efforts to develop the technological capabilities of private firms depends, of course, on decisions by their managements. And such decisions are determined by estimates of the relative profitability of alternative development rates, after allowance for the investments, risks and delays that would be involved. Such estimates necessarily include a variety of components which are, or can be, affected by governmental measures. Hence, if the government considers it in the national interest to induce greater efforts to increase technological capabilities in given sectors of private industry, it needs to devise policies designed to ease or eliminate existing deterrents, and perhaps add some incentives as well, in order to make the prospective benefits of undertaking the desired developmental efforts attractive to the managements involved.

A number of the deterrents identified earlier as discouraging faster development of the technological capabilities of the U.S. steel industry seem to be applicable to many industries. The most important of these partially overlapping deterrents seem to be:

1. The emphasis on maintaining favorable profitability in the short run, with the threat of substantial penalties to management of unfavorable profitability even for periods as short as two years.

2. The high costs and substantial risks involved both in undertaking long term research programs seeking major technological advances in processes or products and also in building large new facilities embodying innovative technologies and designed to supply newly developed products.

3. The diminishing prospective benefits of technological advances in production processes and facilities due to: (a) widespread trade union pressures to minimize resulting reductions in unit wage costs; (b) frequently associated higher capital charges because of attendant investment increases relative to capacity; (c) the substantial costs of capacity under-utilization in capital-intensive industries subject to output fluctuations; and (d) the government's heavy participation in profits when innovations are successful, combined with its withdrawal from sharing the losses likely to result from many (and perhaps most) efforts to advance industrial technologies significantly.

4. The threatening prospect faced by large companies—frequently those with the largest personnel and financial resources for undertaking major technological development efforts—that successful outcomes might induce governmental intervention or penalties if their application would increase the firm's market share or increase concentration by driving out some competitors.

5. The belief in the increasing array of domestic industries faced by rising imports that help from their governments will enable foreign producers to reduce prices sufficiently to offset whatever cost-savings might be achieved through expensive and risky domestic technological development efforts.

Additional deterrents of particular significance in selected industries are likely to be uncovered by more detailed studies. These include possible changes in environmental pollution standards, potential threats to employee health, and indeterminate product liability risks—all constituting uncertainties threatening further burdens.

C. Some Potential Directions of Policy Development

The most important and the most widespread of the above deterrents is the emphasis on maximizing short term performance. It tends to favor marketing, financial and other relatively low cost and quickly effected innovations over technological development projects. In respect to research undertakings, it tends to favor immediately applicable over more basic objectives, concentrating efforts on modest product improvements over basic advances in key processes and especially on catch up with threatening achievements by others. In respect to the adoption of innovations developed by others, it tends to favor waiting until technological and marketing risks seem to have been substantially reduced.[6] As for building now capacity, such pressures make it more difficult to obtain funds for projects unlikely to produce revenue for four years or more, especially in industries subject to substantial fluctuations in capacity utilization rates.[7]

To help redress this imbalance in the interests of encouraging increased development of technological capabilities, the government might consider policy adjustments and innovations which would increase the rewards realized from long delayed benefits and decrease the costs and risks of such undertakings. Among the specific approaches which could promote such ends, one might include: substantially more favorable tax treatment of the capital gains or delayed profits derived from desired long term projects; special allowances for losses attributable to such efforts; cost-sharing grants for especially urgent or risky projects—either to individual firms or to joint projects of several companies; accelerated depreciation for capital projects providing needed modern additions to capacity but involving long construction periods; and the establishment of an array of major government-financed research centers to conduct basic research on the scientific foundations of various industries, akin to the enormous past contributions of the government to strengthening the scientific foundations of our agriculture through the establishment of research centers.

Such measures may seem unduly far-reaching, of course. But it is worth considering whether, in the absence of such measures, the government itself tends to reinforce the very pressures for maximizing short term performance which are inhibiting the desired further development of the technological capabilities of industry.

Because differences in unit wage costs have been a source of significant competitive advantages and disadvantages in many industries, efforts to gain such advantages have been one of the primary stimuli to technological development projects in the past. Such undertakings are being discouraged, however, by the tendency of labor-saving innovations to yield smaller and shorter-lived benefits than are anticipated on the basis of technical considerations. This has resulted in some cases because unions have resisted reductions in employment and, in many other cases, because they have demanded increases in wage rates in proportion to the decrease in unit labor requirements. Such shrinkages of expected benefits are especially serious whom labor requirements are reduced through the substitution of capital for labor, in the form of new processes, or larger scale facilities, or increased automation. Such innovations actually reduce labor effort and skill while increasing capital investment. But most engender union demands for higher wage rates nonetheless, thereby discouraging an important sector of prospective advances in technological capabilities.[8]

One component of this problem might be eased by extending to cases of technological advances the current policy of easing the employment impact of imports through providing those losing their jobs with hardship payments and training opportunities to facilitate transfer and re-employment. Government aid of this sort might help to encourage the development and utilization of domestic technological advances—without waiting for foreign pressure—by reducing labor's resistance to such innovations and also decreasing attendant costs to the company of gaining needed acquiescence from affected employees.

One of the important sources of improved technological capabilities in recent years has been increasing the scale of operating units whether ships, or power plants, or cement mills, or petroleum refineries, or pulp plants, or steel mills. Effective development and utilization of such facilities, however, have tended to encourage increases in the size of the firms operating such units and, hence,

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[6] For an extended discussion, "The Decision Making Framework for Major Technological Innovations" in B. Gold, *Explorations in Managerial Economics: Productivity, Costs, Technology and Growth* (New York: Basic Books, 1971).

[7] B. Gold and M. G. Boylan, "Capital Budgeting, Industrial Capacity and Imports," *Quarterly Review of Economics and Business*, Fall 1975.

[8] B. Gold, "Tracing Gaps Between Expectations and Results of Technological Innovations. The Case of Iron and Steel," *Journal of Industrial Economics*, September 1976.

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to increasing dominance of many industries by a relatively small number of firms. In other countries, the harnessing of these potential increases in efficiency and competitive advantages have been actively supported by their governments. In the United States, however, the interpretation of our official commitment to maintaining effective competition within all industries (except public utilities) as requiring resistance to whatever may be considered "excessive" concentration at different periods by different officials has tended to discourage efforts to realize the full potentials of scale increases. And it has also tended to discourage the development and full exploitation of major technological advances that might significantly increase concentration and thus invite government threats or even penalties.

However, it might be worth exploring the possibilities of supporting further increases in scale and advances in technology which lead to greater concentration, where these can be shown to yield significant increments in productive efficiency as a result of recent or prospective technological advances. This need not ease governmental demands for the maintenance of effective competition. But it would, of course, undermine efforts to claim that increases in concentration necessarily involve reductions in competition, even if persuasive evidence to support such contentions cannot be adduced.

Finally, it is important to consider possible measures for reducing the deterrence to technological development efforts in the increasing array of industries facing the prospect of losing market share to imports. As the largest and most affluent market in the world, the United States is the natural target of export drives from the developing countries as well as from Western Europe and Japan. Many of these governments regard the expansion of such exports as less burdensome—even if based on subsidies and pricing below cost—than increases in unemployment payments and accompanying increases in political apposition. Moreover, not many of our industries could survive determined government-supported invasions of our markets. Hence, the deterrent effect on domestic producers of the likelihood that any cost reductions which might be obtained through technological development programs would be offset by import price adjustments supported by foreign governments committed to expanding their exports. But such deterrence also tends to ensure progressive deterioration of the competitive position of domestic producers relying on progressively aging facilities and technology.[9]

In this connection, the conclusion seems inescapable that the undermining of a considerable array of private industries in this country by uneconomically-priced or otherwise government-supported imports can be prevented only if the U.S. government makes a determined effort to restore fair competition in our markets and access for our exports to foreign markets on fully comparable terms.[10] This would require not only immediate measures to gradually curtail uneconomically-priced imports, but increasingly tough long run restrictions to assure American producers against a resurgence of such practices whenever overseas economic pressures are intensified.

IV. CONCLUDING REMARKS

In short, this statement is based on the judgments that: 1. major advances in the technological capabilities of industry are essential to promoting the national welfare; 2. achieving such major advances will depend very heavily on increasing commitments by industrial firms to costly, risky and long run technological development programs; and 3. a wide array of current government policies must be revised if industrial firms are to be fully justified in undertaking the substantial programs that seem necessary.

Senator STEVENSON. Thank you, very much, and thanks to all of our witnesses.

You all agree on one thing: Whatever is wrong, it is the fault of Government. Except, of course, for our Government's representative,

[9] B. Gold and M. G. Boylan, "Capital Budgeting, Industrial Capacity and Imports," *Quarterly Review of Economics and Business*, Fall 1975.

[10] For a fuller discussion of policy needs, see B. Gold, "The Challenge to National Policy of Increasing Steel and Other Industrial Imports," Statement to the U.S. House Ways and Means Subcommittee on Trade, *Hearing on World Steel Trade: Current Trends and Structural Problems, September 20, 1977—Serial 95–37* (U.S. Government Printing Office, 1977, pp. 164–168.

which suggests that there is very little agreement among our witnesses this morning.

They have given us a lot to chew on, and I dare say, some subject for comments as well as questions, and we invite yours.

Now we are going to have to establish a procedure because this is a hearing of the Congress, and we must keep an accurate transcript.

So I will ask those of you who do have questions or comments to fill out the slips which the red-coated ushers will have, giving your name and address. They will bring up the slips and I will recognize you from them. As I do so, you will have to go to one of the microphones to make your comment or ask your question.

Let me make a couple of observations which will lead up to a question for our panelists.

Professor Gold, it is my understanding that the Japanese tax profits, including capital gains, at higher rates than we do in the United States. Though comparisons are difficult to make, they do, as you have indicated, find other means of supporting certain industries and the development of certain technologies.

My information is also that they perceive the reduction of labor costs by high technology in steel and the creation of new capacity throughout the world, much of it in the developing countries such as Brazil. Consequently, they see their own industry as meeting only domestic requirements in the future.

Already they have been undercut by the EEC countries. They see more cutthroat competition down the road. Consequently, they are no longer building up capacity and, in fact, are beginning to direct some of their steel capacity into the production of other commodities for which there will be a market in the world, whereas this country may and certainly has attempted to increase the capacity for the production of commodities for which there is no longer any market.

Now Dr. Baruch suggested that we ought to identify industries that need assistance. He mentioned foreign competition as one of the factors that makes an industry deserving of special assistance.

You cited the shoe industry, I think. If you didn't, you might well have, because it has been singled out by the Commerce Department for special attention notwithstanding information, particularly from the GAO, that indicates that this industry may not be suffering seriously from foreign competition.

What I am wondering is whether we should undertake to identify industries in need or instead put aside the adversarial relationship of government and industry, as our principal competitors seem to do, and identify future markets for which technologies and commodities need to be developed.

The relationship in the past has been spasmodic. It has been clearly defined in the case of the NASA-oriented industries. The spinoffs from Government-supported research for defense and space frequently find their way into commerce and have substantial economic value to industry; but that is largely coincidental.

Personally, I can't accept everything that Stanley Ruttenberg suggested. I say this with some experience in another subcommittee, of the Senate Banking Committee, that has the jurisdiction over export controls. It is not entirely possible to control exports of technology even if it were desirable to do so; and I question that it is desirable. In fact, I have strong reservations about protecting domestic industries as opposed to enabling American industries to compete in local markets.

Why, as some of you have suggested, do we single out industries? Perhaps they are dying industries. Why don't we pool our resources, as I think the Japanese and the West Germans do, to give ourselves a better vision of the future? The oil industry and government together could not even perceive, let alone act upon, an obvious emerging energy crisis.

Perhaps with different institutional arrangements that provide greater economic incentives, and with Government cooperation in these incentives, we could perceive the commodities and technologies for which there will be a need in the future. We could then dedicate the necessary resources, including Government resources beyond support of research to develop appropriate industries.

Rather than more steel capacity, this might mean a steel industry producing composites. The problem is not just competition from low cost, high technology producers; it is also continuing competition from other materials. Perhaps, we ought to be looking into production of those materials by the steel industry.

This is a series of observations, and I don't know how one pieces them together.

But the suggestion is, why not learn from our economic adversaries instead of complain about them? If I am right about some of those lessons we should put aside the adversarial relationship and develop new means of cooperation between government and industry, not to support dying industries but to redirect industry toward the future.

I invite everyone to respond.

Dr. Gold. May I comment on the first of your notions about Japan?

I first went to Japan in the recession period of 1972. In Tokyo, they told all visitors, including me, that they were going to slow down the development of the Japanese steel industry because export markets had already peaked.

And yet, every plant I visited during the next 10 weeks was expanding capacity. I saw the holes in the ground; I saw the foundations being laid; I talked to the engineers about their plans.

When I visited there this summer, I was told again: "Well, of course, our export growth is over; we've got to slow down further development." Once again, however, every plant I visited was expanding. I predict that there will be 35 million tons of new steel capacity in Japan by 1983.

Why? Because world steel demand is going to keep expanding; because every other country in the world has cut back the building of new steel mills; and because the Japanese have these modern, huge plants, built before the big inflation. It is easy to guess, therefore, who's going to have the big advantage in these markets over the next 5 years.

As for giving up on seemingly dying industries, I would merely like to mention that I have done a study of long-term trends in American industries over the past 100 years. It is hard to find any which disappeared quite as fast as the contemporary opinion expected.

The coal industry reached a peak in 1920, and everybody wrote it off, not imagining its future enormous potentials. A whole series of industries have similarly reached peaks in past periods, followed by extended declines only to revive again 10 or 15 years later because of new technological or market developments.

As for composite materials, I agree that they offer important opportunities, but I don't think the demand for steel is going to decline for the next 50 years.

Senator STEVENSON. Any further comments?

Dr. HANNAY. I would like to offer support for the idea that you just expressed, Senator Stevenson, because I think that in fact it is quite unrealistic to believe that every American industry is going to survive and be healthy for all time and lead the world. We just simply can't achieve that. I think industry changes are a much more dynamic process.

In fact, some of the most competitive industries that we now have did not even exist a short time ago—such as the computer industry. We must encourage the formation of competitive new industries, not just simply seek to preserve what existed before. I am not ready to say that steel is going to disappear, but I believe your general thesis is a much broader one than just simply focused on a single industry.

I agree with you, further, that the proposition that we can build a wall around ourselves and isolate ourselves in order to preserve our technology is unrealistic. That disappeared from the realm of possibility a long time ago. And in fact, some of the technology that we see that is new is not being generated in the United States; it is originating elsewhere. Technology transfer works both ways. We should be prepared to receive technology from abroad that can help us.

The only thing that can really maintain our strength is a vital, innovative, economy. If we have that, the rest of these questions will be taken care of.

Mr. RUTTENBERG. May I, Senator Stevenson, comment?

By suggesting the idea of some form of export control on the shifting of technologies, I don't mean at all, in the slightest case, to suggest "building a wall around the United States."

Obviously, there are and have been many technologies invented elsewhere in the world from which the United States has, itself, benefited. But I think that now we have the kind of a problem which needs to be faced.

Because, when one sees specific kinds of technologies being developed in the United States, and then through coproduction arrangements and joint ventures that technology is transferred overseas and produced overseas, one then has to ask themselves the question of what that means for us. In terms of building—the issue which you raised, Senator Stevenson—in terms of building a closer working relationship between Government and industry, we have to try to reverse the trends that are occurring.

Maybe we should think in terms of kinds of incentives that are specifically geared to the technology, and the use of technology, that we are talking about.

For example, I am disturbed by the generalizations, even in Dr. Gold's presentation, suggesting that we ought to have changes in our capital gains tax laws; or that we ought to have accelerated depreciation; or that we ought to do other things, tax-wise.

I am not averse to using tax incentives to encourage something, but I think they need to be pinpointed. It is not enough to talk generally about "reducing the capital gains tax," or to talk generally about "accelerated depreciation," one has to relate it specifically to the kinds of things that one wants to accomplish—such as innovative research kinds of programs.

And, maybe it is tax incentives, and maybe it is direct grants, but at least instead of shooting a big shotgun shell out and trying to catch things by overall reductions in corporate rates or overall increases in tax incentives for plant and equipment, we ought to be pinpointing the rifleshot directly into the kinds of activities we ought to engage in.

Senator STEVENSON. Dr. Baruch, is such a cooperative notion acceptable to OMB and compatible with zero-base budgeting?

Dr. BARUCH. Well, I think what OMB has done is said: Go study the process and see whether it is going to be effective.

The only way I can answer questions about it, is based on the assumption that it proves sufficiently effective so that the President will want to establish an ongoing program in this area. If it is not effective, then we have no problem. We'll just fold our tents and quietly go away.

I would like to correct a misapprehension that I hear in this discussion going on.

People have talked about helping "dying industries." And one of the ones they point a finger at is the shoe industry. I am not so sure the shoe industry is dying. I am not so sure that we don't have significant economic opportunities in that area and the possibility of bulding a comparative advantage for the U.S. shoe industry.

We talk about our "leaders" in industry. In the communications field and the computer field, everybody feels there is a difference in kind in comparison with the shoe industry.

It may not be a difference in kind. It may merely be a difference in "time." The Japanese government, and the Japanese banking community, have combined to invest $40 million in fiber optics research; $100 million in flat-screen television research; and $300 million in research on very large-scale integrated circuits.

They don't want to sell fibers, and they don't want to sell flat screens, and they don't want to sell integrated circuits. But, if those investments in infratechnology pay off they will support the Japanese clock industry, their radio industry, their television industry, their computer industry, and their communications industry.

We may well meet here again, at some unspecified future time, and be talking about whether we should really be making an effort to save the "dying" U.S. computer industry.

I don't think we can make those distinctions any more. Industry has changed. Industrial degredation produces severe local dislocations. When you close a blast furnace in South Chicago, the people around it are not interested in migrating some place else and becoming computer workers. They are interested in doing something they know how to do, where they know how to do it, where they live.

It is my feeling that we can no longer effectively distinguish between high-technology industries and low-technology industries; between the elite industries and the industries that currently have trouble.

We have to recognize that we are engaged in an evolutionary process; that technological lead is eroded by time; and that we have to keep feeding it in order that that erosion is exceeded by the amount by which we build it.

Otherwise, we are going to be in a meeting like this in 1983 at the then meeting of the AAAS, and talking about a lot of industries that seem favorable right now.

Senator STEVENSON. Thank you.

We will now turn to the audience, and I will call on these individuals in the order in which I received their names. The first is Dr. Ronald Cape, president of Cetus Corp. in Berkeley.

I think I see a recombinant DNA coming.

Dr. CAPE. Mr. Chairman, I am president of a small, new company, in a highly innovative field—molecular biology—exemplified, as you said, most recently by recombinant DNA activity which has received so much publicity recently.

I would offer two observations:

First: as Dr. Hannay pointed out, there is substantial hesitation on the part of U.S. industry to become involved in innovative fields; and, it is true in recombinant DNA as well. I speak from 7 years of experience in trying to sell it.

By and large, the response has been: If the activity won't pay back the investment in 2 or 3 years, sorry, we're not interested.

Mr. Chairman, whatever the complex causes, this attitude is a substantial departure from the imagination and guts that built this country.

Second: Many of us have participated in the public debates regarding regulation of recombinant DNA activity, including valuable hearings held by the two subcommittees who are with us here today.

Before going further, I want to say that my company very much wants to see Federal regulation of all work in the field, including, of course, work in industry.

But the point I want to make here this morning is, that almost without exception, those people who have been most vocal in opposing recombinant DNA work, or who want it severely restricted—these people are almost unanimously and outspokenly hostile to the private sector, hostile to and suspicious of the industry.

Some go far as to suggest that the best way to develop this technology is to keep it out of the hands of industry. This is especially ironic because, as I have just said, very little of this activity is taking place in the private sector right now.

At the same time, the extensive public discussion of the pros and cons of this issue in our open society eclipses, by a long shot, any discussion—public or otherwise—outside the United States. Outside the United States it is mostly "otherwise." It is mostly private; it is mostly elitist; it is mostly discussion behind closed doors.

And I am sure that none of us here want to trade this public-discussion mode with anyone else's way of doing business.

But what of the future? Clearly, this new innovative technology, if it is going to be harnessed, to be applied practically for benefit to the American public, it should be developed by U.S. industry.

This fantastic technology was invented in this country, and we would like to see it brought to fruition in this country.

I want to be sure that everyone here knows that the specifics in the governmental regulations, existing and proposed, governing recombinant DNA research, are more stringent in the United States than anywhere else in the world.

I think this should concern us. This isn't building a wall around ourselves. I suggest we should keep in mind that, tying ourselves into knots, let's be sure that we are safe and prudent, but let's not back ourselves into a corner while the rest of the world takes the ball away from us and runs with it.

Thank you.

Senator STEVENSON. Any response from the panel, or comments?

Dr. BARUCH. I would like to make one comment, to add to the plea on recombinant DNA. I would like to point out that, when we do propose regulations for recombinant DNA research in industry, one of the problems we face is removing the ability of private industry to secure the benefits from what it develops, by making all their information publicly available.

Any regulatory scheme that we develop in this country that focuses on a regulatory process, that makes the activities, the protocols, the research designs, of private industry public will perhaps improve our safety, but it will also markedly increase the real estate values in the Bahamas and Bermuda, where people will flee to open new laboratories not so controlled.

I think we have to make very deliberate assessments of the effects that we produce when we "twist knobs." That doesn't mean to say that we can't regulate and insure the safety of the activities of private industry. It is just that we must do it with full knowledge of the impact of what we do on the innovation process itself.

Senator STEVENSON. Next we will call on Prof. R. Roy of Pennsylvania State University.

Mr. ROY. Mr. Chairman, to address a huge problem, you wonder if you can make any contribution at all. And so I'm suggesting that if this one has any specific merit, it is the zero-based budgeting. And since next year you have agreed graciously to speak to the AAAS on the theory of zero-based budgeting, maybe this year we can touch a smaller section of that.

But this suggestion stems from my interest in the interaction not of government and industry which many people are hinting at, but the academic sector of our economy and industry. For years we have studied the ways in which industry and academia can interact in the innovation process. I suggest that the Congress has taken no steps to encourage that, and the Federal Government has usually paid lip service to it but has put no money into it. Now I'm suggesting, not that they put new money into it but that they redirect some of the present money which goes to basic research budgets of the universities toward coupled activities.

I also suggest a major gain would not be discrimination per se, but it would be a change in the attitudes of academia to make their products more relevant, more interesting in the innovation process. And I think that is probably a bigger gain than all of the research benefits which we get.

So I believe that with a relatively small mandating of the DOD and NSF budgets to do coupled research, that it will be possible to make one contribution toward U.S. innovation.

Thank you.

Senator STEVENSON. I understand that NSF is proposing to support joint industry-university research ventures and that the budget that has recently been received by the Congress from the Carter administration proposes an 11 percent increase in funds for basic research.

The administration is attempting to reverse the previous decline in support, though at the expense of many large development projects.

I have also noticed that the largest increase in basic research is for the Department of Defense.

Mr. ROY. I suggest that unless you mandate a certain percentage of the NSF budget as a line item, it will probably end up as window dressing. In most cases we find that the Defense Department—precisely the kind of thing I'm alluding to—is doing this year, just what I'm talking about. The Defense Department takes the lead; it sets the models. I suggest that if the Congress is serious, then they are really mandating and requiring line items, with the budget items, showing that this will be for coupled research.

Senator STEVENSON. Thank you.

I certainly think we need to pay close attention to the plight of research in the universities.

Is there a comment or response from the panel to the professor's suggestion?

[No response.]

Senator STEVENSON. The problem is well recognized.

Next, Mr. Sidney Roth of Washington, D.C.

Mr. ROTH. Over many years I have attended many sessions on R. & D. matters and one of the recent major complaints that I have participated in and witnessed has been something that has only been alluded to here, rather than detailed. This is that most industrial executives, research administrators, mention as a strong disincentive for large-scale investment and innovation in this country, the excessive regulatory process or set of processes imposed by the Federal Government.

From a longstanding academic commitment of my own of many years at New York University and now with the Department of Energy, I will suggest that this complaint is echoed by leading academic scientists in other disciplines as well.

Many believe that these regulatory processes have driven technological R. & D. out of the country and this has been suggested by, I think, Dr. Gold and some of the other panel members.

And then we have the output.

I would like to ask Dr. Gold and the panel in general how Japan acts in this area—to what extent are they regulating or overregulating R. & D. and technological innovation to the threshold of disincentive?

Dr. GOLD. I can't answer that in any kind of detail, but the point you raised bears on what Senator Stevenson said earlier about the Japanese exporting some of their technology.

They do this in a very carefully thought-out way. The Japanese have not been building giant new steel mills just anywhere. They have built smaller plants in various countries around the world. They were going to participate in building a large plant in Brazil, but they backed out of it.

Now, second, one of the reasons they build processing facilities abroad is because they are forced to do it in some countries which have the raw materials that the Japanese need. That is why Brazil can say, in return for taking large amounts of iron ore you've got to build some facilities here.

But the Japanese are not simply running around and offering all of their technology to anybody who's willing to buy it. Bits and pieces, yes. They have made advances in pollution control which are being bought by rival steel companies in other countries. British Steel, for example, and United States Steel are buying Japanese technology with respect to pollution. Most of their exports of steel technology have involved particular processes or facilities, rather than entire plants of modern scale, except in Western Europe where they feel that Japanese exports of steel products face barriers to further growth.

Finally, I would just like to add my deep concern about continual references to steel as an "old industry," implying that it faces progressive obsolescence and extinction. I want to join Secretary Baruch in warning that we don't know what an old industry is. There has been tremendous innovation in the textile machinery industry in the past 15 years. And I would not like to bet on being able to guess in which industry the big innovations are going to emerge over the next 15 years.

So I would not like, as it were, to give up the bird in hand in order to run after the birds in the bush. They might not be there, or we might not be able to catch them.

Dr. HANNAY. To return to the specific question that was asked, the Japanese and Germans and others do have a number of specific ways to encourage the application of R. & D.—for example, tax write-offs of R. & D. equipment and the tax treatment of R. & D. itself. Another is a cost-sharing arrangement in certain selected industries. For example, the thing that Dr. Baruch referred to, the development of very large scale integrated circuits is being handled on a cost-sharing basis between the Japanese Government and industry. That is a large factor in the specific encouragement of innovation in Japan.

However, I would point out, as I did in my remarks, that R. & D., per se, is not the bottleneck; it is what happens after that. It is the development of markets, of manufacturing technology and so forth that are the real keys to an innovative economy.

Senator STEVENSON. Dr. Baruch?

Dr. BARUCH. Yes. The question was asked about regulation and its inhibition on R. & D. I'm sure you recognize that the Carter administration has made a commitment to work on the problems of regulatory rationality. I mentioned the study that Dr. Press's office and mine would be doing on the innovation process. One of the areas we will be specifically addressing is the factual determination of how regulation in areas ranging from the Federal Communications Commission to the EPA do impact upon innovation. I think we need to know those facts so that we can understand how either a specific regulation can be modified, how the regulatory process can be modified, or if those social needs are important, how we can compensate for the impact of those regulations.

But that is a very important part of the Government's present action in the whole area of innovation, and I hope that our work will have an important influence later on.

Senator STEVENSON. Well, we're going to need to get much more specific about the effects of regulation. If it were not for technological innovation, we would not have most of the regulations. Regulation is a response to toxic substances, industrial pollution, and workplace hazards that have resulted from technological innovation. Sometimes it has become excessive.

Now we will hear from Jacob Rabinow of the National Bureau of Standards.

Mr. RABINOW. Mr. Chairman, I've been an engineer for some 25 years, and I've been studying this problem for a long time as executive director of the National Inventors Council, which was disbanded just before Mr. Baruch came aboard.

It is a fact that the great innovations of our day, and starting back in the year 1, were done by outside laboratories, with all due respect to Bell Labs. As a matter of fact, computers were born in atomic energy. Lasers were done at the university. Microwaves, radar, xerography, color photography, you name it, and outside of the transistor, which is no small matter, and outside of television, it was always done in small companies. As a matter of fact, most of the large corporations of America no longer have technological innovations.

And I would like to ask Dr. Gold whether this is true, that the management of Japanese companies is more patriotic than the management of our companies. They don't seem to need the same incentives to take a look 20 years down the line that our people do.

I would like to say that something should be done about the antitrust department of our Department of Justice. They seem to hate patents. And I have had personal run-ins with them, where they would like to think patents smell like monopolies even though they are not. But I don't know what can be done about this, because any law that is passed in Congress that has anything to do with innovation automatically has to go through the Department of Justice and through the antitrust division.

And I would like to ask Dr. Baruch to speak about this.

I'm not sure that you can because you would have a fight with them, I suppose. But I hope you would speak about this.

And, finally, I would like to say this. I quite agree, since I started two small companies, that getting money for small companies is very, very difficult now, and the general solution of R. & D. that Wall Street has experienced, and I think Government has to provide risk capital to small companies as is done in Denmark, in Sweden, England, Canada, in many other countries, and indirectly in Japan.

And I would like to ask the whole panel, should the Government provide risk capital?

Senator STEVENSON. Dr. Baruch, would you like to go first?

Dr. BARUCH. I won't address the question about the Government providing risk capital. That is a little out of my bailiwick. But I will address the comments made about the Department of Justice.

Patents are a monopoly. They are, however, a limited monopoly. They are a monopoly for a period of time, and they are a monopoly that is awarded as a reward from the Government to the inventor for advancing the creative arts and industry.

However, I think it is a mistake to think of the Justice Department as any longer having a knee-jerk reaction to patents.

We had in the Government Patent Policy Committee recently a spirited but productive discussion of the procompetitive aspects of patents. John Shenenfield was there from Justice and I think there is a growing understanding in all parts of the Government of the role that patents play in the innovative process and the limitations on them as monopolies.

So I would not give up hope yet, Jack.

Dr. HANNAY. As a comment in passing, the first digital computer was built in New Jersey.

But let me address the last point you made, Senator Stevenson—should the Government be the source of the risk capital?

It strikes right at the heart of what we're talking about here. We have a system in which the risk capital should be available, and it should come from the private sector. It has become unattractive for that to happen. Now, we should examine the question of what we could do to make investment attractive once again, by removing some of the disincentives, rather than by proposing that government action be taken to supplant the private sector and itself provide the capital.

We need to examine disincentives and remove as many as possible, in order to restore once again the interest of the private sector in providing capital as it has done in the past.

Mr. RUTTENBERG. I would like to comment on that if I might because I think the issue of underwriting capital for innovative research is at the heart, as has been said, of the problem we're discussing, but I think to go the route—and I said this earlier in my remarks—I think to go the route of hoping to get innovative research as well as carry the R. & D. into the actual production and operating stages, one cannot rely upon a shotgun approach of removing the disincentives.

I think again—and I repeat—the Government has to pinpoint its actions in the field of underwriting capital, risk capital, in the field of providing the right kind of tax incentives, and in the specific area of avoiding this generalized approach to trying to get the solution to the problem.

Now, it has been suggested by a comment from the floor—and by Dr. Gold on my left here—that there are some kinds of Government actions involved in technologies in terms of export actions—again, while one might not like the idea of controls on exports of technology, one has to examine what it is that other countries in the world are really doing, the developed countries of the world are really doing in terms of their own technology which they as a government participate with private industry in developing.

And therefore it just is not sufficient to dismiss the notion of some form of looking at the export of technology by saying that we really don't want to build a wall around ourselves. Let's look and see what some of the other industrialized countries are doing, and maybe we can learn a lesson or two that might be helpful to the United States.

Senator STEVENSON. I would like to follow up with Mr. Rabinow on that subject.

Capital is available, though interest rates may be higher than they have been in the past. There is a cliche that the world is changing more rapidly than ever before, and the need for technological innovation and the opportunity for profit, should be greater now than ever before in the past. Our economic competitors are proving that.

What has happened?

Are you suggesting that the character of corporate managers has changed? Are we all middle-aged now?

Mr. RABINOW. Yes, sir, I'm suggesting exactly this. The type of manager that was presented by Mr. Sarnoff of RCA who took 20 years to develop television no longer exists in RCA. Zenith was run by Mr. McDonald who happened to like radio. And I happened to talk to a man there and asked him what they were going to do, and he said they were going to have to import engineers from Taiwan.

We have only one large company now run by a man who loves technology, and that's Mr. Land of Polaroid. Most companies are run by business school graduates who should be assistants, not managers, of large technical companies. We have conglomerates with companies like Beatrice Foods, who runs 400 companies. They run a company that has a license to build one of my phonographs. I don't know how you visit 400 companies in 1 year.

This is a very serious problem. I work as a consultant for some of the largest corporations in America, and I can assure you that when the management builds the transistors and doesn't know what it is building, the company goes bankrupt. I work for other companies that are profitable, and this is going to happen much more often than otherwise. I notice that the president of Sony is an engineer who was just inducted into the National Academy of American Engineers. So, apparently, the president of Sony doesn't know what his TV sets look like and why they work.

Senator STEVENSON. I would point out, in response to what you said and also to some of Mr. Ruttenberg's comments, that the capital flows have shifted. It is flowing in now. Foreign entrepreneurs and companies are now building their Volkswagen plants in the United States and producing automobiles in the United States that will compete very effectively with ours, as they have abroad. And I have seen this happening in my own State. Japanese managers can run Motorola's television division, Quasar, which failed under American management.

I think Sony manufactures or assembles in the United States. Zenith is closing down.

Mr. RABINOW. But that has nothing to say about the management and the engineering. The engineering of Japan in high-fidelity equipment is much ahead of ours.

What happens is, the stuff is being designed abroad. I think the reason they are setting up factories here is, they are afraid of our protectionist side; they are afraid, if they don't, we will start putting walls around the country in self-defense. So they are beginning to assemble here.

I don't like to see the American people becoming a country where they can get cheap labor where the design is done abroad. But I think this is going to happen. Certainly, they are being assembled here out of Japanese parts and Japanese design.

This is my concern. Where is the thinking being done?

Senator STEVENSON. Is that because of the character of the individuals, or is it because of the structure of the industries?

Mr. RABINOW. I think Dr. Gold could probably answer that better.

I think it is both. I think there is a climate of reservation in the country.

For example, there are fewer patents being issued to independent inventors, even though independent inventors did most of the engineering. The electronic computer was done at Pennsylvania University, and it was built—the first Univac was bought by Census and the Bureau of Standards. And I was involved in that purchase. And it was done by university students.

So the large industry makes all of the big money, which they should, but the innovation always comes from the middle class. But the highly technically trained people like the MIT's, like the Bureau of Standards, like the universities, like Chicago and so on—and I think that the large industries should get the credit for producing it.

If you want new technologies, you've got to support small businesses.

I think to say that, as Dr. Hannay said, that you should remove the disincentives to investment, I would like to know how you are going to reduce the interest on tax-free bonds from 4 to 9 percent, which I can get now and do, to 3 percent. That was a fact when I wanted investment in 1956. Wall Street gave me all the money I wanted. And I went back in 1968 for another investment, and they said high technology is no longer sellable on Wall Street. The 9-percent, tax-free bonds even with a risk like New York is still a lot of money tax free, and I think the Federal Government sees to this.

But the fact is, money is very, very expensive. There's a general solution with R. & D., and today Wall Street will simply not be investing in small companies. The figures were cited earlier about how many new companies were founded.

Senator STEVENSON. I visited a laboratory at one of the largest corn and soybean processing plants in the world in my home State just a few weeks ago, and at the laboratory the scientists began to talk excitedly about the high-fructose sweeteners which have an enormously large market for corn products.

I asked the scientists, "Did you develop this miraculous sweetener, this food for all of our Illinois farmers?" An embarrassed silence followed.

And I said, "Well, who did?"

By then I knew what was coming. The Japanese. They had licensed the technology to produce the high fructose.

Gentlemen, do you have comments?

Dr. GOLD. I would like to add something to what was said.

Why is the capital coming to the United States? There are two completely different sets of reasons when we talk about Western Europe as compared to Japan.

Capital is coming from Western Europe primarily because of the fears of people who own large amounts of capital about political trends in their countries. Second, they are worried about the increasing strength of the trade union movement, which is politicalized in Western Europe and which they feel also represents a threat to increasing productivity gains and holding down wage costs in the future.

I might add, by the way, that I had a professor from the University of Paris talk to one of my classes about why the French were investing heavily in the United States, and it was like kicking the class in the belly when he said, "Why they come over here for the lower wage rates."

The Japanese, on the other hand, are coming to the United States because they are worried about being excluded, both from here and from Western Europe by some kind of import controls. To avoid such possible barriers they feel it necessary to build some plants inside our boundaries. In addition, it is important to recognize that the Japanese are really quite confident, and they have a lot of evidence to back them up, that they have a style of management which will work in the United States as well as, or better than, traditional American management. And wherever they have built plants in this country, it turns out that they have indeed developed very good relationships with their workers.

And the same thing has happened in England. English workers, who apparently cause difficulties for their own managements, seem to work effectively and happily for the zipper company, the television company and others that have Japanese managers.

One of the reasons for such acceptance, let me add, is that the Japanese interpose no status barrier between their engineers and managers and the workers.

Oddly enough, it is in our democratic country where you find engineers and managers tending to distinguish themselves from workers in what they wear, in the way they speak, and in their behavior as they go through plants. This difference represents to me a fascinating cultural contrast.

Senator STEVENSON. Next, M. L. Thomas, of the Oak Ridge National Laboratory.

Mr. THOMAS. You were speaking about infratechnologies and cooperation between government and industry. Are you familiar with the National Fertilizer Center in Mussel Shoals and what it has done for the fertilizer industry? Currently, at the laboratory, we are cooperating with the fertilizer center and the fertilizer industry on a related topic, that is, uranium extraction from the phosphoric acid. But I believe the TVA has had a long history of providing the research for the fertilizer industry.

Dr. BARUCH. I'm not familiar with the program at Mussel Shoals, although I know the institution. There are many good industrial laboratories set up on a separate basis that serve an entire industry and develop infratechnologies very well.

My hope would be that any program that the Government develops would support the activities in those areas and try to assist them, rather than try to supplant them.

Mr. THOMAS. This is a particular case where industry—at least, I have been told—does not have resources to do their own research, and the Government was able to provide the research in a very effective way.

Dr. BARUCH. We have some other examples of that, as well, and we see it as a very exciting area, to get industries built up to where they can be effective.

I am glad to hear about the Mussel Shoals program, and we will look into it.

Mr. THOMAS. By all means.

Senator STEVENSON. Thank you.

Next, David T. Goldman, of Potomac, Md.

Mr. GOLDMAN. Mr. Chairman, I believe that one thing that ran through each of the speakers' comments this morning was the need for good, long-range planning. We heard the difficulty of implementing this in the private sector, with its need for short-term profits.

I would like to raise the question of whether the short-term budget cycle of the Federal Government—that is, between 1 and 3 years, at most—doesn't also mitigate against the establishment of viable, responsive long-range planning? If so, would not commitments for long-range reliable funding for other policy considerations by the Government have to be made that are not radically revised without very careful consideration?

Senator STEVENSON. I hope you will accept the modification of that question to include the effect not only of the cycle but also of that of zero-base budgeting. And before we get too far on it, I will remind you all that we will be getting into this subject this afternoon.

Dr. Baruch?

Somebody?

Dr. BARUCH. I pass.

Mr. RUTTENBERG. Certainly, the concept of having budget appropriations and available funds committed over a long period of time is essential. And I think, if one looks at zero-base budgeting, if it is going to be done on a year-by-year basis, one might very well find, if carried to its logical conclusion, that something started one year may not be supported the next year. And I think that has to be looked at very carefully.

I think that we need to commit ourselves to much longer term funds available for specific kinds of projects in the research and development field, and we had better be careful that zero-base budgeting, as good as it is, might not destroy that. Zero-base budgeting might be looking at a new project every 5 or 10 years, yes. But if zero-base budgeting, as far as research and development is concerned, is looking at each year, it may destroy the whole principle.

Senator STEVENSON. As you probably know, the Congress wrote the requirement into the Science and Technology Policy Act for 5-year projections by OSTP. The reorganization has shifted that responsibility to NSF.

Margaret E. Smith, of Minneapolis, Minn.

Ms. SMITH. Mr. Chairman, I am not accustomed to speaking in public, at public affairs, and I'm here on vacation. I've worked for Metronic Laboratory for 10 years as a laboratory administrator, doing research for heart pacer maintenance, and I would like to make three short observations.

One, our company and the industry in which I am employed has been classified as a high-technology industry and is moving very rapidly to innovations with different colors of pacemakers instead of really different innovations, and the major reason, they suggest, is the regulatory costs.

It is my suggestion that we look at support of a verification of regulatory costs at a certain level when the description of the innovation has reached some level. Then, you have your patent control—you have your patent person still controlling his own patent, but the Government might be able to underwrite part of the regulatory verification costs.

The second thing is that, throughout the testimony here, I think you are seeing a concern about wages for people. People themselves have been greatly concerned about losing their jobs, and I think the GI's right after the war received a great deal of educational support. I think the adult wage structure should be looked at in some way. I think that it would help us with people who have to change industries, even possible relocation costs, both for the industry and the person.

The third thing that I wanted to talk about was the reason why our capital seems to be inflowing into this country. They specify low wage rates, political instability, and exclusion. I think we should look at that as a mirror to see whether we are doing the right thing here in order to support that support. Political instability comes from when people are very frightened, as they are in Western Europe, and I think we should be sure that our wages and our employment keep at a high level in order to avoid that political instability ourselves.

Thank you.

Senator STEVENSON. Thank you. Those are good comments.

Any response from the panel?

[No response.]

Senator STEVENSON. Next, Norman Bredesen, of the National Center for Health Services Research.

Is he still here?

[No response.]

Senator STEVENSON. I have a comment from him on this card:

> There seems to be a tremendous amount of duplicative research within Government departments, and certainly HEW. Why aren't all research proposals broken down into essential components and then computer-screened?

I encountered a doctor and prominent researcher over the weekend who made a similar suggestion and indicated that computer retrieval services that simply popped out information as they do now were being underutilized, and it might be possible to program ongoing research to keep abreast of it, instead of the products of completed research.

Being neither a scientist nor a researcher, I don't understand this, but I gather to the questioner and to him, it was a very important matter, and in Government, I think, at least we might hope that it could be done, and it might eliminate some overlapping of research.

Is that something we should be heeding also, that suggestion? Any thoughts?

Mr. RUTTENBERG. But doesn't that, Senator, then raise the issue of the private enterprise system and the whole profitability of investments? The question is whether or not individual companies engaged in research, whether under Government contract or not, want to share it publicly for fear that they might lose the long-run benefit of it. Isn't that a fundamental issue involved in the question?

Senator STEVENSON. I suppose that is one issue. Much information is published. We find, as you have indicated, it is picked up and turned into products in foreign countries before we do, and libraries are frequented by officials from embassies as well as foreign industries.

I should think that the better information management on a global as well as national basis might not pick up all of the proprietary information that is available but might pick up and disseminate a great deal of the public information and enable it to be utilized for the benefit of humanity as well as industry.

But that is a layman speaking, again.

Dr. BARUCH. I would just like to voice a caution about one offsetting cost of having that kind of a system. There are benefits that accrue out of pluralistic approaches to similar research. In history there have been a great many times when authoritative figures controlled some research field, to its detriment.

I'm not sure that redundancy in research is any worse than it is in human communication. I think it may be necessary for that kind of progress we want.

Senator STEVENSON. An information system, even if it did not eliminate redundancy, might improve redundancy by making similar research known to the researchers and laboratories.

Dr. BARUCH. The Smithsonian Institution, as I'm sure you are aware, has a retrieval system which describes Government research in progress; whereas, the NTIS currently does it only after the research work has been completed.

We've been examining the possibility of combining those two systems, so that researchers could effectively secure information not only about completed research but research underway and develop some knowledge about the others involved in such research. We would hope to get synergy from their combined approaches.

Senator STEVENSON. Our final question for the morning session is from S. J. Hotch, of Whelan, Mass.

Mr. HOTCH. I am an engineer, an electrical engineer, employed by Mitre Corp. of Bedford, Mass. I direct a group in communication theory.

In listening to the discussions today, one thing seemed to stand out. It seems that traditionally in the United States the major impetus, our major force toward technological development has come from one or more goal-oriented, large goal-oriented programs: For example, the space effort, a major directed program with a specific goal in sight. It seems to me that in recent years such programs have been missing. The Government, indeed, has turned its efforts more toward the nitty-gritty. I have heard about programs, about suggestions, and I've heard suggestions made about how we should support individual effort in a very specific manner, either by tax advantage or by outright grants, direct support to education.

However, this is not traditionally the way we in the United States have functioned nor the way we in the United States have moved.

We talked about the computer. It came out of NASA, as far as the application of the microcomputer. We talk about LSI. Where did the impetus come from? Where did the money come from? It came from the space program. It came from these needs, general needs. We said, "We need the technology," and the technology was forthcoming, and we made the money available for the technology as it became necessary.

This is what seems, to me, to be absent at the present time, and we are not dealing with this situation. Actually, moving in the opposite direction, trying to handle, as I said before, the nitty-gritty.

I don't believe that government, particularly a government the size of the United States, with the number of people that we are involved with, is in any way capable of dealing with microcosmic problems, as it were.

I think that we are trying to buy the serendipity that we should be getting from a major national commitment.

Senator STEVENSON. The Senate subcommittee has a responsibility for NASA. One of our long-term interests in space applications is the development of a global information system.

But what you say is obvious. The suggestion that I've heard this morning is that, just as space exploration was a national objective, perhaps now it should be industrial innovation.

Mr. HOTCH. Perhaps I generated some confusion. The thing that is absent from a program like this is a clearly defined goal. The thing that is present in a program such as the NASA program was placing a man on the Moon in a given period of time. In the case of a war, the object is winning a war.

These other programs, such as a national commitment to the advancement of technology, this is an amorphous goal. This is not something specific. This is not something in which the scientific community or with which a national community can identify specifically. This is sort of like motherhood: Everybody is in favor of it. We all know that. We are all in favor of getting out of the energy crunch. But a specific goal for the development, for example—and I have no ax to grind—but a specific goal for the operation of a 10-megawatt fusion plant by 1985, for example, has never been made.

I don't know whether this is possible. However, what is missing is a specific goal that one can address so that the technology can be developed to meet that particular goal.

I think perhaps Dr. Gold, in his observations on Japan, which, to my knowledge of Japan—it's very much more limited than Dr. Gold's—but it seems to me that the Japanese are specifically goal-oriented people and have a goal-oriented technology which has been very productive for them and has been productive for us in the past.

I think our problem is the amorphism which has been developed. I was wondering if Dr. Gold could comment.

Dr. GOLD. They have had a very commonly used term in Japan when they initiate a major new program. It is called "standing on the foreigners' shoulders." After selecting a new target, they buy the best available technologies all over the world.

For example, when they went into continuous casters in the steel industry, they bought the Russian model, as well as Swiss and German models. After installation, each was submerged by many engineers seeking to develop some kind of commercially applicable improvements which could then be sold.

Mr. Ruttenberg. Isn't it also important to emphasize, Dr. Gold, that it was the joint cooperation and coordination between the Government and the industry that does this?

Private industry itself innovating, in Japan, does not occur. It's all in connection with the Government; isn't that true?

Dr. Gold. Only in some industries. That isn't the reason why the photographic equipment industry has reached such a first-class industry, nor has it been true of a number of others. But it has been the case in steel. It is the case in computers and electronics and a number of other areas. Always, the Japanese pick a few selected targets on which they can push real hard.

Senator Stevenson. The Japanese have a goal and, in a sense, it is about as amorphous as winning. It includes identifying market technological and related research opportunities. It marshals a great deal of will, imagination, vitality and drive as well as resources. And it does not include a space program. It includes something, I think, for the welfare of every individual in that system.

We do have specific goals, but with regard to space we are in a transitional period. The new administration is assessing its goals for space; and there are many options, including the global information system that I mentioned a moment ago, that are receiving serious consideration, not only in the administration but also in Congress.

I don't know if you are all familiar with what I mean by a global information system. It is far more than just communications. It means sensing resources, energy and mineral resources. It means monitoring weather, including ocean surface temperatures and crop production capacity. It is a real possibility and a very exciting one that such a system may materialize in the near future.

I remind you that we are about to enter the Shuttle era. What will emerge from the use of the Shuttle no one knows; but there are bound to be many applications not foreseen at the moment.

Unless there are any further questions or comments, we will adjourn now until our next session, beginning at 2 this afternoon in this room.

Congressman Brown will preside this afternoon.

The witnesses are Lewis Branscomb, vice president and chief scientist of IBM; Hazel Henderson, codirector of the Center for Alternative Futures; Derek de Solla Price, professor of the history of science at Yale; and Steven Weinberg, of the department of physics at Harvard.

It has been a lively and productive session. I am grateful to all of our panelists, our audience, and, again, to Mr. Daddario and the AAAS officers and staff.

We are adjourned until 2.

[Whereupon, at 12:30 p.m., the hearing was recessed, to reconvene at 2 p.m., this same day.]

AFTERNOON SESSION

OPENING STATEMENT BY REPRESENTATIVE GEORGE E. BROWN

Mr. Brown [presiding]. Our afternoon session will come to order.

I am Congressman George Brown, substituting for the chairman of our Science, Research, and Technology Subcommittee of the House, Congressman Ray Thornton, who wanted very much to be here but was unable to do so.

Senator Stevenson, also, is expected shortly, but we will proceed without him and demonstrate our autonomy and flexibility in doing that.

I have a brief statement which I will read, and if I don't care to read it all, why, it will all be in the record, if nobody objects, and nobody here will object, I'm sure.

As was the case this morning, our hearing is being held jointly by the Subcommittee on Science, Technology, and Space of the Senate, and the House Subcommittee on Science, Research, and Technology.

It is a pleasure for me to join again with Senator Stevenson in these important hearings.

The topic before us this afternoon is the science and technology policy agenda for 1983 and beyond. Our hope in this session is that we will be able to shed some light on the longer term trends in American science policy.

This is important for a number of reasons. One rather modest reason is that the Congress, several years ago, by law, directed the executive branch of the Government, more specifically, the newly established Office of Science and Technology Policy, now headed by Dr. Frank Press, to prepare annually a 5-year outlook.

This outlook is to cover future developments in science and technology which are likely to be of national significance. We want to be in the best possible position to evaluate that report when it reaches us, and we hope to benefit from our session here this afternoon in that regard.

Much more important, in my opinion, is the urgent need for the Congress to be more aware of and more sensitive to the longer term forces which are bound to influence and shape our science policy. I am thinking here of both developments within science itself and of developments in the world at large.

Let me suggest only one example of this, the example of agriculture and agricultural research.

In testimony before the committees of the Congress over the last several years, scientists have reported that important new breakthroughs in the basic biological sciences are likely to produce new varieties and whole new crops that will substantially affect not only agriculture but our society as a whole.

At the same time, the specter of a world food shortage is on the horizon and is already evident in many parts of the less-developed world. Demands for increased productivity and for crops that can grow in areas of the world, such as the tropics and the arid zones, where new land is available to be placed in productive use, are already exerting pressures on researchers for new advances.

Overlying these developments is the vastly increased use of chemicals in agriculture for many different purposes and their far-reaching impact on the environment.

We need to do a better job of recognizing these forces in the field of biological research and agriculture, and the comparable forces in the many other areas of science and of human endeavor where this interaction takes place.

I think we all recognize that such forecasting is not going to be easy. In the Congress, we established some years ago the Office of

Technology Assessment, which has as one of its important functions the forecasting of new scientific and technological developments and their primary and secondary effects.

The OTA has begun to do this kind of work, but I think we have all recognized the difficulties involved and need to break new ground in order to achieve success.

We welcome the four distinguished witnesses who have agreed to give our committees the benefit of their wisdom and insight, and I am particularly pleased to note that among them are two physical scientists, a social scientist, and a historian of science. I think that may well represent just about the right mixture of what, on a larger scale, we will need to help us peer into the future.

Our first witness will be Dr. Lewis M. Branscomb, well known to the Congress. He is vice president and chief scientist at the IBM Corporation in New York, and we are very pleased to have him lead off this afternoon.

Dr. Branscomb.

STATEMENT OF DR. LEWIS M. BRANSCOMB, CHIEF SCIENTIST AND VICE PRESIDENT, IBM CORP., ARMONK, N.Y.

Dr. Branscomb. Thank you very much, Mr. Brown.

I am pleased to have been invited to express my views as an individual scientist on the future of science policy agenda that is so important to our Nation.

I will abbreviate the remarks that I have prepared, in order to leave more time for our discussion, and therefore I will fall very short of giving you a comprehensive dissertation on that subject.

Mr. Brown. The full text of your remarks will be made a part of the record, Dr. Branscomb.

Dr. Branscomb. Thank you, sir.

Science policy in the 1980's must, like other areas of public policy, equip the Nation to deal with the changing world of opportunity, challenge, and uncertainty. Americans are already aware of the agenda of issues, finding alternatives for scarce resources, allaying the threat of the arms race, providing equitable access to participation in and the fruits of our economic life, fulfilling the public's expectations for improved quality of life, and political and economic accommodation with other nations.

In the middle 1980's, we can predict with confidence that these issues will still be with us. But certain trends will become more visible to the public and more a focus of national concern. These include the following:

First, the growing importance of the international dimension of our economic life;

Second, the necessity of a high innovation rate and the scientific research to support it, in order to restructure our technology to fit resource constraints and productivity requirements;

Third, a long period of zero or at least slow growth in our universities will unhappily challenge their ability to serve as the driving force for new knowledge and new ideas;

Fourth, the continued fragmentation of global political structures will be accompanied by increasing dominance of north/south tensions as our foreign policy concern, and that will be accompanied by demands for expanded technological cooperation as the price for resource supply stability;

Fifth, information technologies will be central to a growing number of national opportunities and issues;

And sixth, the continued accumulation of complex technical public policy issues about environment and health and safety will stress the consensus machinery of our democracy because they require controversial public decisions in the near term, despite substantial scientific uncertainty about future consequences.

Now, this list could certainly be extended, but it should be sufficient to demonstrate that, as circumstances change, the institutions and traditions for public decisionmaking will have to change, too.

We Americans must find a way to bring to public policy formulation the traditional pragmatic and objective attitude that we have prided ourselves on in the past. The historical American technology advantage has come from a flexible, pragmatic attitude and a willingness to accept facts for what they are.

Any advantage we have in education, talent, or management skill follows from this pragmatic egalitarianism, which emphasizes open ended opportunity for the individual. Yet, today, each faction in the public debates about technology accuses the other of relying on fear, emotion, and ideology, instead of fact, analysis, and experimentation. Many people want to act on "technology assessments" before the technology has even been reduced to practice. The Congress is repeatedly asked to choose among technologies that should be suppressed or to select technologies that should be required. The role of chief engineer to the American economy ill suits the greatest deliberative body on Earth. Nevertheless, political conflicts derived from fears of new technologies must be resolved, and the Congress does the best it can.

Political conflict could be reduced if early entry into the market of innovations were encouraged, together with provision for measuring their environmental and social costs and benefits from actual experience. Many oppose this approach and, indeed, argued against the limited operation of SST, for example, on the grounds that once innovations are introduced, those associated with their further development would make it politically impossible to act upon the facts that might emerge from technical studies.

This is surely a counsel of despair for our democracy, for it denies us the opportunity, perhaps even the possibility, of resolving issues about future harms on the basis of present facts.

Thus, a high-priority challenge for science policy in the 1980's will be to reduce the rigidity and unpredictability of government regulation that increasingly throws the burden of technology management on the Congress and, when it cannot resolve the issues, on the courts.

Each time the Congress and the executive are unable to achieve a public consensus on a technologically complex issue and the dispute reverts to the courts, we witness another failure in the consensus process of our democracy. If this continues to happen with increasing frequency, the pressures to alter the political foundation of our society inevitably grow. A new process is needed that balances the risks associated with today's level of activity in technology against the benefits to be gained from quantifying the knowledge of future consequences and benefits.

To build that knowledge, we will need new problem-oriented institutions for both scientific and policy research, experienced and credible enough to deal with problems that are fraught with complexity and uncertainty. Few such institutions exist today, and the principal reason is the lack of continuing financial support for work in an institutional environment reasonably free of pressures of short-term political and economic interest. Such institutions could serve as a common ground for objective evaluation of the facts and elucidation of the research agenda for the future.

Another topic of equal importance, which I will skip over because I believe it has already had a lot of attention today, is the imperative of the public understanding the issues well enough that they will permit the leadership to take decisions for the public that involve risks.

I have dwelt on the character of governmental intervention into the technology generation and delivery system and the decision structure that brings science to bear on public choices because I believe the way the Government manages its regulatory and legal process for guiding technology choice determines, in the large measure, the Nation's opportunity to use technology to solve problems.

Government exercises stewardship over most of the Nation's scientific and educational resources, and the Government's regulatory and economic policy heavily influence private investments in research. But this stewardship is exercise with little explicit attention being given to the impact on innovation. In the executive branch, economic policy seems to be made in every agency; technology policy is made in virtually none. The intersection between economic and technology policy is thus very superficially addressed. Several abortive efforts to focus on this point in the past have failed to achieve decisive results, but I understand that discussions are now underway in OSTP to initiate another such effort on a governmentwide basis. A Presidential review memorandom on innovation that leads to new policy and appropriate agency restructuring could be one of the most important achievements of this Government.

Among the issues that will need to be faced are three:

First, an economic strategy that takes account of the strengths and weaknesses of American industry and the technology on which it rests, sector by sector.

Second, Government must support most of the basic scientific research upon which that innovative capacity rests, and this will have to be done in such a way that the magnitude of the research effort is not constrained to the level that is appropriate to be associated with graduate education. That doesn't mean it should not be done in universities.

Third, the principal source of applied research and exploration of advanced technologies is in private industry, and it surely will be in the early 1980's. Larger companies also perform a significant amount of long-range scientific research. Government subsidy is not required for such commercially motivated industrial research, but adequate profitability and the environment for an optimistic attitude toward future economic opportunities are required. Technological protectionism does not help in the industries where our technology lags, and it hurts in the industries where we lead by denying opportunity to exploit our advantage.

Finally, the Nation must come to grips with many issues that can be grouped under the rubric "information policy." Most of the traditional leaders of the scientific and engineering community are uncomfortable with this area of science and technology policy, and, indeed, the locus of the study of the subject in the executive branch has been kicked around from pillar to post for the last 10 years. It is, nevertheless, an area of growing importance and is recognized as such by a great many members of the Congress and the public. There are many facets to this issue, and I shall not have time to explore them. Let me only note that knowledge and the ability to use it are our Nation's greatest assets. The majority of our work force is engaged in information generation, distribution, or exploitation. We lead the world technically in the industries most deeply involved: computers, communications, publishing, and office systems. Yet, America faces government-supported competition abroad in all these areas. Countries like Japan seek to build their economic expansion and their internal development on their information industries, because they consume little energy and materials are generally nonpolluting and take advantage of a well-educated work force. Vigorous competition will continue to drive U.S. technology leadership. But competition and regulation make poor companions, and many issues are unresolved concerning the limits to communications regulation. Also, those industries such as education and health that are vehicles for bringing the benefits of information technologies to the public tend to be sectors heavily dependent on government financing, operations, or regulation.

Thus, Government shapes the evolution of our information technologies and the services they permit, to a degree not encountered in less technically vigorous sectors. And it does so with increasingly inadequate institutional capability.

But there is an even deeper reason to focus on information policy as a challenge for the 1980's. Our political values are deeply rooted in constitutional principles that protect freedom of expression and personal rights. The concept of privacy is evolving and strengthening in response to social change that accompanies the new information technology. Clearly, the government must be the mechanism for establishing consensus on these new concepts and principles. But how is the balance to be struck between freedom of expression, thought, and information-gathering, and restraint on abuses of privacy, denigration of minorities, and affront to public morals? These problems are complex enough, but the personal rights issues and the economic issues are deeply intertwined, and, indeed, that is true on a national as well as international level, as illustrated by the growing debate in Europe and in the OECD on transnational data flow. Today, we have no official U.S. policy, and we have weak mechanisms for formulating one at this time.

Now, this abbreviated discussion of policy issues concerning the information sector of our economy illustrates a dominant question for science and technology policy in the 1980's: Can Government improve the objectivity of its interventions in technology generation and introduction, fostering research and innovation to maximize long term opportunities, while at the same time evolving a national—indeed, international—consensus on the values that motivate those interventions?

Thank you.

[The statement follows:]

STATEMENT OF DR. LEWIS M. BRANSCOMB, CHIEF SCIENTIST AND VICE PRESIDENT, IBM CORP.

My name is Lewis M. Branscomb, chief scientist and vice president, IBM Corporation, Armonk, New York. I am pleased to have been invited to express my views as an individual scientist on the issues important to the future of this nation.

The Committee is to be commended for arranging these hearings on science policy issues of the future in this innovative manner, providing maximum access to both scientist and citizen in this country. The American Association for the Advancement of Science, which I am proud to have served as director, has enjoyed not only good working relationships with the Congress and its staffs but the active participation of both congressional members and staff in its work. These hearings will, I hope, serve well the purposes of the Congress, which has demonstrated its concern for the development of science and technology policy through legislation which not only established the Office of Science and Technology Policy and the position of Science Advisor to the President, but established in the first article of that statute the policy framework that guides the nation.

Since the Executive Branch has not yet implemented those features of the Act designed to make explicit the long range science policy of the Administration, it is appropriate indeed that the Congress should stimulate public discussion of these issues in order to lay the basis for the consensus on which positive action must rest. Thus these hearings may serve as much to stimulate the thinking of the scientific community and the general public as to assist the Congress with sorting out the issues it must face in the coming years. It is a great privilege for me to participate in this historic process.

Science policy in the 1980's must, like other areas of public policy, equip the nation to deal with a changing world of opportunity, challenge and uncertainty. Americans are already well aware of the agenda of issues—finding alternatives for scarce resources, allaying the threat of the arms race, providing equitable access to participation in and the fruits of our economic life, fulfilling the public's expectations for improved quality of life and political and economic accommodation with other nations.

In the middle 1980's we can predict with confidence that these issues will still be with us, but certain trends will become much more visible to the public and more a focus of national concern. These include:

(1) The growing importance of the international dimension of our economic life.

(2) The necessity of a high innovation rate and the scientific research to support it, in order to restructure the technology to fit resource constraints and productivity requirements,

(3) A long period of zero growth in our universities will challenge their ability to serve as the driving force for new knowledge and new ideas,

(4) The continued fragmentation of global political structures with the increasing dominance of north/south tensions and demands for expanded technological cooperation as the price for resource supply stability,

(5) Information technologies will be central to a growing number of national opportunities and issues, and

(6) The continued accumulation of complex technical public policy issues—about environment, health and safety—will stress the consensus machinery of our democracy because they require controversial public decisions in the near term, despite substantial scientific uncertainty about future consequences.

This list could certainly be extended, but it should be sufficient to demonstrate that as circumstances change the institutions and traditions for public decision-making will have to change too.

We Americans must find a way to bring to public policy formulation the traditional pragmatic and objective attitude that we have prided ourselves on in the past. The historical American technology advantage has come from a flexible, pragmatic attitude, and a willingness to accept facts for what they are. Any advantage we have in education, talent or management skill follows from this pragmatic egalitarianism, which emphasizes open-ended opportunity for the individual. Yet today each faction in the public debates obout technology accuses the other of relying upon fear, emotion and ideology instead of fact, analysis and experimentation. Many people want to act on technology assessments before the technology has even been reduced to practice. The Congress is repeatedly asked to choose among technologies that should be suppressed or to select technologies that should be required. The role of chief engineer to the American economy ill suits the greatest deliberative body on earth. Nevertheless, political conflicts derived from fears of new technologies must be resolved, and the Congress does the best it can.

Political conflict could be reduced if early entry into the market of innovations was encouraged, together with provision for measuring their environmental and social costs and benefits from actual experience. But many oppose this approach on grounds that once innovations are introduced, those associated with their further development would make it politically impossible to act upon the facts that might emerge from technical studies.

This is surely a counsel of despair for our democracy, for it denies us the opportunity, perhaps even the possibility, of resolving issues about future harms on the basis of present facts. But innovations derive from the public's need for energy, transportation, food, medicine and the like. The need for them will not go away. The development of more rational decision processes related to public strategies for generating, introducing and managing technology are vital to the survival of democracy itself.

Thus a high priority challenge for science policy in the 80's will be to loosen the rigidity and unpredictability of government regulation that increasingly throws the burden of technology management on the Congress, and when it cannot resolve the issue, on the courts. Each time the Congress and the executive are unable to achieve a public consensus on a technologically complex issue, and the dispute reverts to the courts, we witness another failure in the consensus process of our democracy. If this continues to happen with increasing frequency, the pressures to alter the political foundation of our society inevitably grow. A new process is needed that balances the risks associated with today's level of activity against the benefits to be gained from quantifying the knowledge of future consequences and benefits.

To build that knowledge, we will need new problem-oriented institutions for both scientific and policy research, experienced and credible enough to deal with problems that are fraught with complexity and uncertainty. Few such institutions exist today, and the principal reason is the lack of continuing financial support for work in an institutional environment reasonably free of the pressures of short term political and economic interest. Such institutions could serve as a common ground for objective evaluation of the facts and elucidation of the research agenda for the future.

In the next decade not only the expert's but the public's understanding of technical matters must improve. Unless the public understands the opportunities and the risks associated with new technology, it may be politically impossible to achieve the consensus necessary for taking prudent risks. Most scientists do not communicate effectively outside the group of experts in their field. Political leaders have a substantially better ability to understand the experts than they are usually given credit for. Their shortcoming is time, patience and the public support for taking the long-range point of view. To take a topical example, I would suggest that the DNA controversy, which was initiated by scientists responding to a sense of obligation to inform the public, leaves few scientists and few political leaders feeling good about the ability of either community to deal with such issues satisfactorily. But such issues cannot be avoided or covered up; scientists and public bodies must gain experience and confidence in each other, and both communities must invest in the public's ability to understand and make correct decisions in its own long term interest.

I have dwelt heavily on the character of governmental intervention into the technology generation and delivery system, and the decision structure that brings science to bear on public choices, for I believe the way the government manages its regulatory and legal process for guiding technology choice determines the nation's opportunity to use technology to solve problems. The wellsprings of scientific curiosity, the inventive genius and of entrepreneurial dreams and ambitions are still deep in this country. Indeed, these strengths constitute the greatest economic comparative advantage we enjoy over foreign competitors. They constitute the basis for the level of well-being our citizens can enjoy in the future.

Government exercises stewardship over most of the nation's scientific and educational resources and government's regulatory and economic policy heavily influence private investments in research. But this stewardship is exercised with little explicit attention being given to the impact on innovation. In the Executive

Branch, economic policy seems to be made in every agency; technology policy is made in virtually none. The intersection between economic and technology policy is thus very superficially addressed. Several abortive efforts to focus on this point have failed to achieve decisive results. The last major effort of this kind was undertaken by the President's Science Advisory Committee under the leadership of Dr. E. E. David, then Science Advisor to President Nixon. I understand that discussions are under way in the Office of Science and Technology Policy to initiate another such effort on a government-wide basis. A presidential review memorandum on innovation that leads to new policy and appropriate agency restructuring could be one of the most important achievements of this Administration. Among the issues that will need to be faced are the following:

(1) An economic strategy that takes into account the strengths and weaknesses of American industry and the technology on which it rests, sector by sector. Our policy for dealing with economic well-being must build on the sectors of national strength to enhance employment opportunities and to ensure that continued international competitiveness rests on a solid foundation of advanced technology. It must also promote the basic skills, retraining opportunities and adaptability of the U.S. labor force and compensate appropriately for the dislocations that sometimes accompany technological change.

(2) Government must support most of the basic scientific research upon which the innovative capacity rests. Such research has been generated primarily in universities. They will face in the 80's rising costs and falling enrollments. They need institutional as well as project support for research, at a level adequate to meet the nation's public policy and technological requirements. We must not restrict the level of research effort to that necessary to sustain the level of graduate instruction.

(3) The principal source of applied research and exploration of advanced technologies is in private industry. Larger companies also perform a significant amount of long range scientific research. Government subsidy is not required for such commercially-motivated industrial research, but for such profitability and the environment for an optimistic attitude toward future economic opportunities are required. Technological protectionism does not help in the industries where our technology lags, and it hurts in the industries where we lead by denying opportunity to exploit our advantage.

Finally, the nation must come to grips with many issues that can be grouped under the rubric "information policy." Most of the traditional leaders of the scientific and engineering community are uncomfortable with this area of science and technology policy. It is, nevertheless, an area of growing importance and is recognized as such by a great many members of the Congress and the public. There are many facets to this issue that I shall not have time to explore. Let me only note that knowledge and the ability to use it are our nation's greatest assets. The majority of our work force is engaged in information generation, distribution, or exploitation. We lead the world technically in the industries most deeply involved—computers, communications, publishing and office systems. Yet, America faces government supported competition abroad in all these areas. Countries like Japan seek economic expansion of their information industries, which consume little energy and materials, are generally non-polluting and take advantage of a well-educated work force. Vigorous competition will continue to drive U.S. technology leadership. But competition and regulation make poor companions, and many issues are unresolved concerning the limits to communications regulation. Also, those industries, such as education and health, that are vehicles for bringing the benefits of information technologies to the public, tend to be sectors heavily dependent on government financing, operations or regulation.

Thus, government shapes the evolution of our information technologies and the services they permit, to a degree not encountered in less technically vigorous sectors. And it does so with increasingly inadequate institutional capability.

But there is an even deeper reason to focus on information policy as a challenge for the 80's. Our political values are deeply rooted in institutional principles that protect freedom of expression and personal rights. The concept of privacy is evolving and strengthening in response to social change that accompanies the new information technology. Clearly the government must be the mechanism for establishing consensus on these new concepts and principles.

But, how is the balance to be struck between freedom of expression, thought and information gathering and restraint on abuses of privacy, denigration of minorities and affront to public morals? These problems are complex enough, but the personal rights issues and the economic issues are deeply international, as illustrated by the growing debate in Europe and in OECD on transnational data flow. Today, we have no official U.S. policy and have weak mechanisms for formulating one.

This abbreviated discussion of policy issues concerning the information sector of our economy illustrates a dominant question for science and technology policy in the 1980's. Can government improve the objectivity of its interventions in technology generation and introduction, fostering research and innovation to maximize long term opportunities, while at the same time evolving a national—indeed, international—consensus on the values that motivate those interventions?

Thank you.

Mr. BROWN. Thank you, Dr. Branscomb, for a very provocative statement.

We will continue with the next witness, who will be Dr. Price. He is professor of history of science at Yale University, and we are very pleased to have Dr. Price here with us this afternoon.

STATEMENT OF DR. DEREK DE SOLLA PRICE, AVALON PROFESSOR OF HISTORY OF SCIENCE, YALE UNIVERSITY, NEW HAVEN, CONN.

Dr. PRICE. Thank you, Mr. Chairman.

It is my belief that in 1967 the United States underwent a far-reaching and permanent, but of course, nonviolent revolution. It was a strangely silent revolution for, although the transformation was quite sudden and rapid, it passed virtually unnoticed and unrecognized. Only now, a dozen years later, can we begin to see the outlines of the quite new state of society into which we have emerged.

What happened was that at least three long-term progressions of our society came simultaneously to a screaming halt when the brakes were slammed on at a blank wall of total impossibility of further growth and change.

The first saturation was that of the historic transformation of the labor force of the Nation from predominantly agricultural work in the 18th century, to equal parts of industrial production and service industry today.

For 200 years this transformation proceeded at one-half percent of the labor force every year, and by 1967 agriculture had been reduced to a virtual minimum of a tiny fraction of the population. Since that date, the only change possible has been a slow transformation from industrial production to service industry.

We have passed the point where those engaged in producing goods have become a minority and will eventually be a small minority of the labor force. The wealth of the United States depends decreasingly on the basic production of food and manufactures, and increasingly on a heavy investment in brainpower that increases the value of high technology production in international trade, and gives us a quality of life superior to most nations.

It is, however, no longer possible as of 1967 to pursue the traditional transformation from agrarian to urban occupations, and instead we have huge difficulties in shifting the base of our labor force from production to service, as well as a huge increase in labor resources arising from the womens movement.

Essentially, money is a surrogate for production and there are difficulties in managing a predominantly service economy by the minority occupation of production of goods. New policies must increasingly be person oriented rather than money based.

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Second, around 1967 the universities and colleges which had been growing for more than a century from elitist education to a democratized university system came to the stage where half of each age cohort entered college.

The intensity of higher education had doubled every 15 or so years, and obviously could never double again. The situation was masked by the Vietnam War crisis in the colleges, but the change was sudden.

Universities could never expand again and the need for teachers declined sharply, from 7–8 percent per annum, to a replacement rate of about 2 percent per annum.

Since college teaching is the major locus of basic scholarship in the Nation, this activity suffered a potential slash by a factor of 3 to 4, about half of which has already emerged from the academic pipeline.

Third, at the same date, and working on the same population, an inevitable decision had to be made to hold the national R. & D. expenditure to a ceiling. This expenditure had reached, by that time, a magic number of about 2½ percent of the GNP.

This proportion had been steadily doubling every 15 years; it had been only about 1 percent of the GNP in 1953, and a tiny fraction of a percent before World War II.

I shall now try to show that this peaking out of our national funding in R. & D., coupled with the problems of a service economy and a saturated university system, have the gravest consequences and are probably responsible for a declining economy and increasing unemployment.

The national expenditure on R. & D. is about half the money that industry spends on its own development projects. The other half is the federally funded R. & D., which now amounts to about $28 billion, or 1.4 percent of the GNP.

That might seem little, but since the Government can collect only about one-fifth of the GNP—we eat and spend the rest—but it represents 7 percent of the Federal outlay. Then again, since half the Federal outlay consists of interest, Social Security, pensions, and other payments over which we have little discretion, federally funded R. & D. represents 14 percent of the controllable budget.

This is a high proportion: about one-seventh of the total expenditure. Essentially, the brakes had to be put on at some point near this, for at the long-term conventional growth rate the entire allocable budget would have been eaten up before the year 2000, with nothing left over for other governmental activities. The Mansfield amendment in 1967 caused the cutoff to be very abrupt, but it would inevitably have happened anyhow.

Of the federally funded R. & D., half is spent by the Government on industrial development. We have, therefore, a total of three-fourths of the Nation's R. & D. budget spent in industry in a way that makes it essentially an overhead on the Nation's purchase of innovative technology.

It comes to about $40 billion a year spent in this way on specific technical purchases—the great bulk of them being in aerospace, electrical, and communication items of defense materiel.

It must be pointed out that the bulk of this money goes to people who work lathes and drill presses, rather than to any scientific or technological research community. Of the other half of the Federal budget, some two-thirds, amounting to $9.3 billion, goes to inhouse research and development and useful services performed by the Nation by its civil servants.

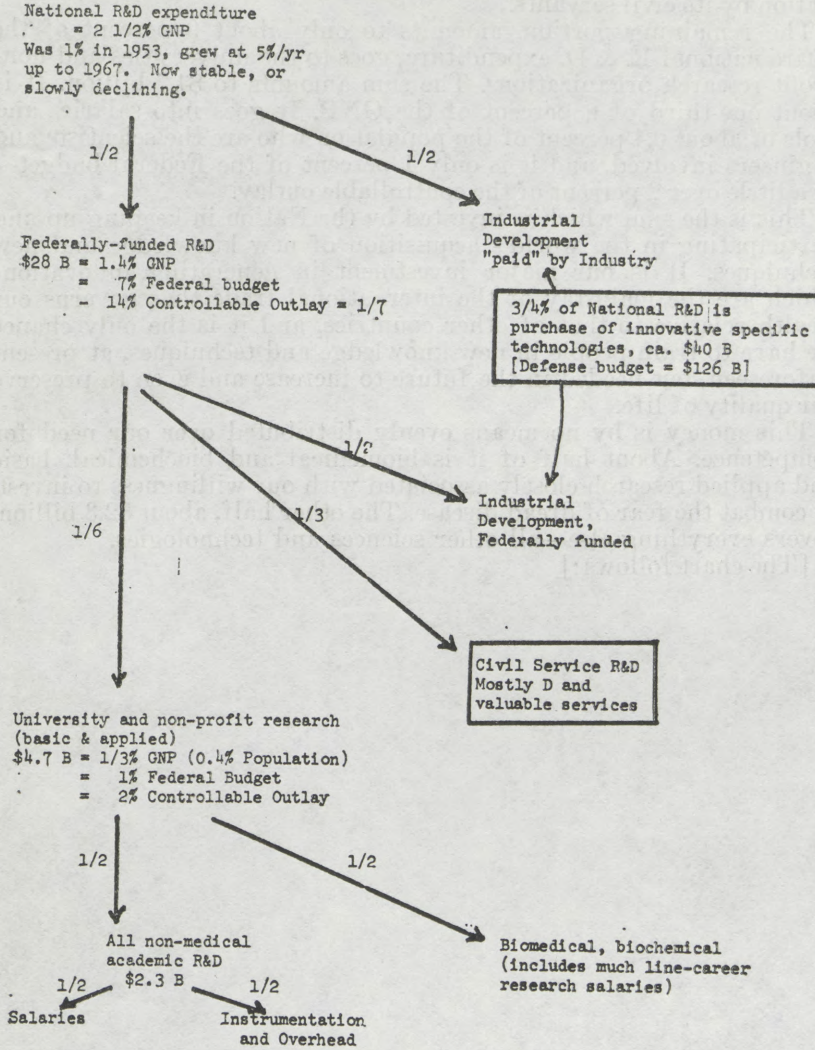
The remaining portion, amounts to only about 9 percent of the entire national R. & D. expenditure, goes to the universities and nonprofit research organizations. The sum amounts to $4.7 billion. It is about one-third of a percent of the GNP. It goes into salaries and tools of about 0.4 percent of the population who are the scientists and engineers involved, and it is only 1 percent of the Federal budget—or a little over 2 percent of the controllable outlay.

This is the sum which is invested by the Nation in keeping up and participating in the world's acquisition of new knowledge and new techniques. It is our major investment in generating innovations which are the mainstay of the international trade that governs our wealth relative to that of other countries, and it is the only chance we have to train people in new knowledge and techniques, at present unforeseen, but needed in the future to increase and even to preserve our quality of life.

This money is by no means evenly distributed over our need for competence. About half of it is biomedical and biochemical, basic and applied research closely associated with our willingness to invest, to combat the fear of dread disease. The other half, about $2.3 billion, covers everything else—all other sciences and technologies.

[The chart follows:]

Overview of United States R&D, 1978



It is easy to show that the peaking out of this particular part of the funding 12 years ago has, by now, resulted in an underinvestment by something like a factor of 2. The present expenditure amounts to about 23 percent surcharge on the total salary of all the academics involved in research. But of that money, only a half goes in support of people—the other half being instrumentation and overhead expenses.

Each of these is being shortchanged by the factor of 2 that would have been produced by growth at the previous traditional 7 percent rate in the dozen years that have elapsed since 1967.

It is relatively easy to show that the current figure is only about half that which is demanded from theory. Looking at it one way, the purpose of academic research is to give participatory access to all of modern knowledge to those so engaged.

It prevents their 4 years of graduate school training from obsolescing away at 6 percent per annum as the world's scientific knowledge grows around them.

Six percent of 4 years' training is 24 percent of the research person's working time and salary. Looking at it another way, one gets, quite simply, the same result by considering the summer salary convention whereby many academics can add summer stipend of two-ninths (22 percent) of their annual salary during that period.

For more than a decade, academic research in science and technology has been running effectively at half speed compared with the world growth rate of a 6 percent per annum increase in scientific and technological activity.

Many of the other most developed nations of the world have followed our lead a few years later, but still—relative to the rest of the world—the United States is falling back at about 3 percent per annum.

It is this loss in our "scientific and technical empire." I make an analogy with the loss of British empire which I experienced in my youth—which makes itself felt in the adverse balance of our dominant high technology international trade, and thereby devalues the dollar in the world exchanges.

This 3 percent inflation must be added to the internal inflation at 7 percent per annum produced by the inability of our economic system to handle service industry economy and it gives a total inflationary rate of 10 percent per annum.

In 1967, at peak, the United States was about 33 percent of all world science and technology, across the board. The decline due to saturation at the previously mentioned 3 percent per annum has been producing a 1 percent fall in our share of the world's science and technology every year and we are now, so far as I can make a guesstimate, only about 25 percent world science.

Since the United States has only about 7 percent of the world population, one can express these figures by saying that, at peak in 1967, we had about 5 times the average share of world affluence or per-capita GNP.

It is now, in 1978, about 3½ times the average; and unless heroic measures are taken, we will have been reduced to only about double the world average before the year 2000 AD.

It is clear that heroic measures of some sort should be taken to remove this particular limitation on our investment in the future—

which has been produced, in my opinion, by a dangerously misleading aggregation of technology purchase and civil service with academic research, by combining them into an overall R. & D. budget.

By limiting the whole, we have cut down academic research in science and technology so that it is now half the size it would have been if the long tradition of pre-1967 growth had continued.

It is also recruiting new people at an almost minimal rate so that the slow and steady decline in the posture of the United States in science and technology research will imply a much more rapid erosion of potential for the researchers of the next generation.

It seems to me inevitable that something more must be done than a return of the basic science budget to moderate increase instead of decline. This year's planned budget increase of about 11 percent—minus inflation—for basic research is, of course, welcome; but it is not nearly enough to restore the damage caused by a decade of vigorous pruning by attrition and inflation.

This view, I hasten to add, is not the usual special pleading by an interest group for a larger share of the action. It proceeds from a very general analysis of our best science indicators.

One solution, of course—but I think an unlikely one—would be to double at least the nonmedical portion of science and technology academic research by injecting about $2.3 billion a year into that part of the budget.

This could be balanced by a relatively small loss in cutting that part which now purchases specific technology. If this were done, something like half the money would go to support of people, particularly into investment of young scientists and engineers, preventing us from the present loss of more than half of each year's vintage of rare talent.

The other half of the injected money would go partly into instrumentation, which not only gives research its tools but also purchases the most fertile area where the craft of experimental science is the growing tip of radical innovations, which are often later turned into valuable high technology.

The situation is complicated because the saturation of the universities makes it difficult for them to hire new young people without a much-increased subsidy.

Furthermore, the revolutionary change in our service industry economy implies that the civil service must also be saturated, and other service industry posts in the private sector become increasingly difficult to fund—however much they are needed for quality of life.

It is difficult to see what can be done in these circumstances to prevent resources of talent from being lost. The most conservative policy, I feel, would be to gradually restore the cut, over something like the same 10-year period it has taken for the decline.

To do this, one would need a general increase in the academic basic and applied research budgets by about 16 percent per annum, over and above any inflationary trends. That is to say, we need an increase of 10 percent above the normal worldwide 6 percent general increase in opportunity offered by the world body of knowledge.

Thus, if one estimated only a 6 percent inflation in current dollars, the increase of academic science budget would need to be set at 22 percent per annum, or about twice the rate that has been set this year.

Shortly after the cuts of 1967, I had the privilege of analyzing this very situation for the President's Science Advisory Committee, and showed them that—even assuming that we were planning for a saturated economy for academic science—it would be prudent to increase their budget linearly at 6 percent per annum over and above inflation, presumably by shifting support from the D to the R.

Looking back, I think I was right, and I am sorry that the corrective measure in being a few years late requires almost three times the former change in deployment of funding.

The revolution of 1967 changed the ball game of research and development, just as we had learned to play the old way. Those who think we are living in a state of some cyclical depression are wrong. The old world can never be put back.

The United States has had the privilege, as the world's most developed country, of being the first nation to evolve from adolescent growth into a new scientific and technical maturity in a service economy we do not yet fully understand.

I feel that, unless we take an heroic measure to put back our traditional investment in creative know-how, we risk a rapid decline in our capacity to remain a land of self-determination and power over our environment.

Thank you.

Mr. Brown. Thank you very much Dr. Price. That is a real challenge to the President's budget this year.

Our next speaker will be Ms. Hazel Henderson who is co-director of the Center for Alternative Futures in Princeton and whom I have gotten acquainted with as a member of the Technology Advisory Council to the Office of Technology Assessment.

We are happy to have you here, Ms. Henderson, and you may proceed.

STATEMENT OF HAZEL ANDERSON, CO-DIRECTOR, PRINCETON CENTER FOR ALTERNATIVE FUTURES, PRINCETON, N.J.

Ms. Henderson. Thank you, Congressman Brown.

I want to talk about a revolution, too, but I want to talk about the revolution from hardware to software, and I will explain as I go along.

I think today our society and all mature industrial societies have already reached what I call their conceptual limits to growth long before the actual exhaustion of their physical resources, and I believe that what we face today is really a metaphysical impasse, and that this is impeding our efforts to create alternative technological futures rather than to continue in a straight line from our old technologies.

And I have noticed, as many of you may have, that when societies or individuals face rapidly changing conditions, the two most likely responses are either, we rigidify and redouble our efforts or we begin to reconceptualize our situation. And today, I believe, the task for our R. & D. agenda is to reconceptualize our situation. This, in turn would require a very broad definition of technology: human knowledge applied to human problem-solving, and that involves both hardware and software.

The science and technology policy agenda for the next 5 years and beyond, I believe, has to be seen in a profoundly changed context.

The emerging agenda in this and all other mature industrial societies must now take into account the new paradoxes that they are now encountering in the trajectory of the industrial innovation process itself, as it reaches the limits of its own particular logic.

This 200-year process of technological innovation with which we are most familiar, and we also know as the industrial revolution, has been based on premises and logic that are now becoming exhausted: The maximization of material production measured by narrow criteria of "efficiency" which has allowed us to sub-optimize social and ecological efficiency; the focus on increasing labor productivity, which is now at the expense of energy productivity and capital productivity; and all of this measured by per capita averaged, undifferentiated growth of the gross national product (GNP).

And so we overlooked the looming crises in distribution of the fruits of productivity, as well as the increasing strain on our natural resources, so that today we see in most of the industrial societies the structural unemployment and inflation, this new stagflation which is afflicting them all.

Mature industrial countries are now facing an inevitable transition from maximizing of production, consumption, and waste based on nonrenewable resources to the capitalization of newly designed production systems based on renewable resources and managed for sustained-yield productivity over the long term. Farmers understand sustained-yield management and now we're going to have to teach it to economists.

So the entire industrial innovation process and the current statistical apparatus used to measure its progress are going to have to undergo redesign before a corrected course for technological innovation can be pursued.

Our current stage of technological plateau in the evolution of industrialism is what I have termed "The Entropy State" in an article I wrote in 1974, and what I'm talking about is the saturation of their particular growth curve rather than the more extrapolative view of a post-industrial state that we have heard from Dr. Price and we also hear from Dr. Daniel Bell or the euphoric "hyper-industrial state" as seen by Herman Kahn. And I define "The Entropy State" as a society where the technology innovation process has generated such scale and complexity and interlinkage that it has become unmodelable and therefore unmanageable.

The soaring, unanticipated social impacts and costs, which, illogically, we add to the GNP as if they were real production, begin to exceed the real productivity of our economy. In fact, I speculated that the only fraction of our GNP that is growing is probably the social-cost fraction.

And I think that one of the most persuasive pieces of evidence, from my view, of this entropy state is cited in the monthly survey of the Morgan Guaranty Bank in New York which wrote in their January newsletter:

> On January 27th the U.S. economy will pass the $2 trillion GNP mark. Although reaching the first trillion required over 200 years, the second trillion was added in a little over seven years.

And,

> Of the second trillion, nearly two-thirds was inflation.

Clearly, a reconceptualization of the underlying premises of the industrialization process as viewed in economic theory is one of the most urgent items on our national research agenda. Chairman Richard Bolling of the Joint Economic Committee in releasing their latest study on "U.S. Long-Term Economic Growth Prospects: Entering a New Era" stated that the lower growth scenarios it portrayed "would challenge economic policy as never before."

The essence of the issue is that while we are all familiar with the typical S-curves associated with diminishing returns and the plateau stage of many specific technologies—for example, the progression from radio and the vacuum tube to the transistor, to integrated circuits and microprocessers—we are less familiar with the idea of the scenario of diminishing returns and the plateauing of an entire constellation of technologies underpinning an entire type of society: industrialism itself.

We must now examine industrialism as a particular type of society with its own world view, its own set of beliefs as to the nature of reality, with its own self-referential logic, paradigms, values, and goals, and buttressed with it's own intellectual paraphernalia, science, and validations system. It is now necessary, as Thomas Kuhn termed it in "The Structure of Scientific Revolutions," (1962) to restructure the belief-system within which knowledge acquisition takes place.

The major belief-systems of industrialism—continual economic expansion, technological determinism, and the linear logic of left-brain-hemisphere dominance, of narrow Cartesian reductionism—must now give way to more balanced, transdisciplinary, holistic world views. Today this tunnel vision has also led to the now familiar explosion of negative feedback from the global ecological system—climatic variability, increasing desertification, worldwide air and marine pollution, as well as diminishing availability of resources, notably petroleum. For these and other reasons, global interdependence is now a fact of life.

Therefore, the future context for our science and technology agenda must also be planetary. We have created with our globe-girdling technologies of communications, transportation, military and space, the hardware of global interdependence. The greatest task before us now is to write the new programs of software needed to manage this global system: the monetary agreements, the conflict-resolution and peace-keeping mechanisms, the systems of law to manage our common property resources—its air and oceans—and to create maps of various cultures' value systems and where they converge. The Club of Rome has been doing some very interesting work in this area, for example "Goals for Mankind" (1976).

It is encouraging to see already some of the shifts in our paradigms from former reliance on hardware and the technological fix and the supply-side approaches to our problems toward the software approach where we are beginning to look at ourselves and our social and institutional frameworks as the targets of modification. Nowhere is the shift more visible than in energy systems where the limitations of hardware, technical fixes, and the supply strategies have become painfully obvious, from those involving the dismal laws of thermodynamics and the trade-offs in speed of exploitation versus efficiency, to other limiting factors such as capital availability, process water and other inputs.

Our energy policy has been forced into addressing the software aspects of the problem: The demand side, the institutional design, the behavior, attitudinal, sociological, and political questions. An invisible hand can no longer be relied upon. In fact, the short-term adjustments of the no-longer free market price system are now actually preventing us from dealing with the long-term structural adjustments. For example, the temporary oil glut due to recessions in industrial countries is fostering a back-to-normalcy complaisance.

This shift to the software focus implies that we reexamine the composition of all of our scientific boards and advisory committees, to correct for the current overrepresentation of hardware-oriented, hard sciences, engineering personnel, and to add more social and behavioral scientists.

The shift to software is also an inevitable aspect of the broader paradigm shift now under way from material-based, empirical, objective and instrumental rationality to more subjective, value-oriented cultures, such, for example, as Ronald Inglehart's research in "The Silent Revolution" (1977) has shown, is going on in all industrial countries. The entire emphasis on hard sciences and reductionist research will yield to the much more difficult transdisciplinary research using models that capture dynamic, qualitative change processes rather than simpler Newtonian mechanistic models.

Before our society can reengage its gears, major goals and values need to be clarified and reformulated, and new contexts mapped, a process already under way in our political system—for example, the current debate over the bankrupt logic of our medical system costing 8.5 percent of GNP, and predicated on ever more technological research to "cure" disease, rather than a preventive, health-maintenance approach to reducing stress and hazards of industrial culture that lead to disease.

Similarly, before our science and technology enterprise can embark on a new and more fruitful course, it must address a similar task of metaphysical reconstruction.

So our first agenda item must be research in epistemology. We simply cannot proceed without designing more explanatory models of where we are, of causation, of the way nonlinear systems interact with the deeper structures and variables of our socio-technical systems as well as ourselves. All of our more inclusive new research methods: technology assessment, general systems research, environmental impact statements and future studies—all present our decisionmakers with ever greater uncertainties. Symptomatically, our decisionmakers become more uncertain and, if they are honest, will admit that they do not know what to do and cannot master the avalanche of data in thousands of unrelated studies of interacting issues. Political issues are fought with intellectual mercenaries, marshalled into producing ever more prestigious reports buttressing opposing positions and interset groups. The political arena has become an information war fought with data and symbols and often decided by the computer firepower and research footsoldiers that each group can afford to mobilize.

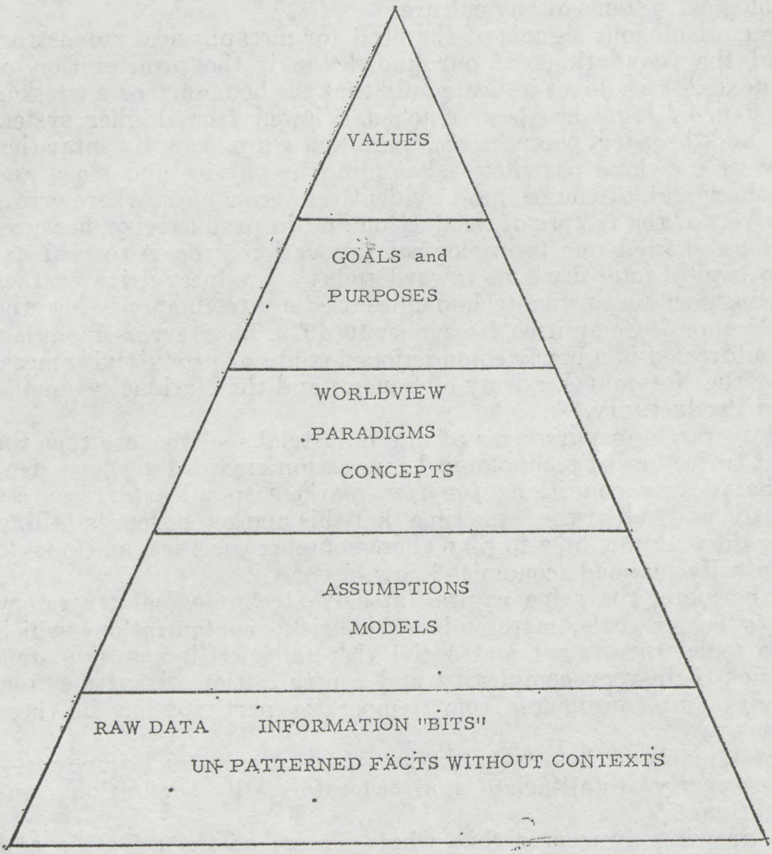
But today much of the data we are drowning in is poor data, inappropriately collected, based on the obsolete paradigms of the past. There is a hierarchy of information quality, which I have expressed as a diagram.

[The diagram follows:]

FIGURE 1.

INFORMATION QUALITY SCALE

(i.e. meaning of information as relevant to human purposes)



The raw, unpatterned data in which we are all drowning is meaningfully patterned by the use of models; the models are driven by assumptions and concepts and a worldview which in turn are controlled by goals and purposes, all of which are driven by values within the systems. And it is in this way that values drive our entire information systems, knowledge constructs, and the economic and technological systems of any culture.

The most obvious signals of the need for metaphysical reconstruction of the foundations of our knowledge is the proliferation of "paradoxes." Paradoxes indicate only that the boundary of a particular system of logic has been reached. Viewed from higher system levels and broader perspectives, paradoxes are complimentarities. Today we see these paradoxes abounding in physics and math and psychology and, of course, most evidently in economics, where errors in analysis of the factors of production and in productivity measures have long skewed our technological innovation process toward excessive capital-intensity and toward today's producer-driver rather than consumer-responsive technologies. See my testimony before the Joint Economic Committee, November 16, 1976. These errors are at last being addressed in a newly commissioned study of productivity measures by the National Academy of Science and the National Commission on Productivity.

The overarching paradoxes of our industrial societies are that the current trajectory of technological innovation creates interdependencies that desroy conditions for free markets to allocate resources efficiently, and yet, at the same time that this market system is failing neither do we know how to plan these complex societies, and nor do the centrally planned economies know either.

Furthermore, the same capital-intensive technological trajectory leads to larger scale, more vulnerable, risky configurations which require social investment and social risk-underwriting at the same time that their very complexity and centralization disenfranchises taxpayers and consumers from democratic participation in these decisions.

Indeed, many of these technologies—for example, nuclear power—are inherently totalitarian and therefore, by definition, unconstitutional.

The growing awareness that whole classes of the scientific and technological enterprise may simply be incompatible with democratic forms of Government is seen in the rising public opposition to nuclear power—our first socialist technology—genetic manipulation via recombinant DNA research, and in the pervasive, creeping "bigbrotherism" of electronic data-processing and funds-transfer systems.

The public's healthy reactions to such technologies, justified on unscientific sloganeering about their supposed productivity and greater efficiency, is skeptical. People say, "Efficient for whom: The consumer or the producer, the corporation or the society?"

These technological issues are so pervasive, and their impacts so widespread, that they have become, per se, value issues and pose not only political questions but epistemological questions which can only be dealt with by reformulating our research agenda and rethinking our current technological commitments.

What is required of our scientific and technological enterprise is not so much micro-rigor and more data collection and more unrelated facts, but pardigmatic rigor, where we unravel the models and examine their deeply embedded asumptions. This also requires that we expose intellectual as well as financial investments, and full public disclosure of both is essential.

One of the key areas of software innovation will continue to be that of shifting our conceptual basis from that of traditional equilibrium systems, such as those underlying economics, to portraying dynamic disequilibrium systems undergoing irreversible qualitative change and structural transformations—that is, morphogenetic systems. Exciting work on capturing the dynamics of these deviation-amplifying, mutual causal processes is now under way, from the qualitative mathematics of Rene Thom's catastrophe theory to Ilya Prigogine's theories of order maintained through fluctuation. This seemingly abstract field of morphogenetic modeling is, however, immediately relevant to pragmatic issues involving whole sectors of our existing economy. For example, the quiet crisis in our insurance industry involves the paradox of literally incalculable risks in our unstable socio-technical systems in constant disequilibrium, while the basic models for calculating probabilities are still largely predicated upon equilibrium assumptions, and what Maruyama describes as the probabilistic unidirectional causal paradigm.

For example, conventional probability calculations are based on the notion that the greater the disaster, the less likely its occurrence—for example, in nuclear accident probability calculations. Yet under disequilibrium conditions and deviation-amplifying processes, it is just as likely that the greater the accident, the greater its probability of occurrence. The point is, we do not really know, and we need to investigate the behavior of such systems to find out. Under such a drastic shift of conditions to greater uncertainty, private enterprise-based insurance becomes indistinguishable from gambling. Demands are now appearing on all sides to socialize such risks at local and state levels, such as auto insurance pooling and, at the Federal level, for medical malpractice, pensions, et cetera, or in the socializing of nuclear energy risks in the Price Anderson Act. Pushing such uninsurable risks up to higher levels of society merely buys some time, but at the expense of greater systemic vulnerability and cascading breakdowns.

Another key area of needed software research is in global modeling, in order to better grasp the global interactions that human activities have set in motion that are now modifying our planetary habitat. The international journal, "Technological Forecasting and Social Change" on whose editorial board I serve monitors much of this work, for anyone who's interested.

As I have tried to point out for the past 10 years—see my collected writings, "Creating Alternative Futures," 1978—the most fruitful models and analogies for portraying the extraordinary complex socio-technical systems we have created will be those based on biological and organic models rather than Newtonian, mechanistic processes. Such processes cannot be captured using reversible arithmetic models of locomotion. Economics is not a science but a value-based set of assumptions too often paraded as science. Indeed, the Nobel Prize Committee may be relieved of unnecessary embarrassment in the clarification that the prize that they sponsor in economics is not a

Nobel Prize at all, but was set up by the Central Bank of Sweden in 1968 as a separate category, and is actually the Nobel Memorial Prize.

I have drawn attention to this long agenda of needed software innovation because I fear that in our objectified hardware-oriented world it will be the aspect most likely to be overlooked. Rethinking our situation rather than committing our resources to hasty and potentially irreversible or disastrous investments along the old capital-intensive, technological path is the wisest course. We are faced with the oldest riddle of evolution: Nothing fails like success. Growth requires structure, and structure gradually chokes growth. New trajectories for technological innovation have not yet been charted, but we know some of the parameters of the emerging regenerative resource-based economies within which our technological innovations, both hardware and software, will unfold: greater global equity in access to resources, within ecological tolerances, within the range of human psychological and social adaptability.

For specific technologies we might ask the following list of questions: Is it labor-intensive rather than capital- and energy-intensive, and how much capital is required to create each work place?

Does it dislocate settled communities and cultural patterns, and if so, at what social cost?

Is it based on renewable or exhaustable resource utilization?

Does it increase or decrease societal flexibility?

Is it centralizing or decentralizing?

Does it increase human liberty and widen the distribution of power and knowledge and wealth in societies, or does it concentrate them?

Does it embody multi-disciplinary thinking and global interactions, or is it parochial and one-dimensional?

Does it favor self-reliance or create further dependency on large institutions?

Does it make maximum use of existing infrastructure, or will it entail costly or duplicative infrastructure?

Are its cost, benefits, and risks equally borne by all groups in society; and if not, then who will be the winners and who the losers?

What risks does it impose on workers, consumers, society at large or future generations, and can they be assessed by current probability calculations? If it is irreversible and poses massive intergenerational transfers of risk—for example, the breeder reactor technology—then it should be assumed socially unacceptable until proven otherwise.

Thank you.

Mr. BROWN. Thank you very much, Ms. Henderson.

Our last speaker this afternoon will be Professor Steven Weinberg, Higgins professor of physics at Harvard University.

Dr. Weinberg?

STATEMENT OF DR. STEVEN WEINBERG, PROFESSOR OF PHYSICS, HARVARD UNIVERSITY, CAMBRIDGE, MASS.

Dr. WEINBERG. Thank you, Congressman Brown.

I gather that my role here was to represent the basic sciences, and to provide somewhat of an overview of exciting problems and developments that will be likely to occur in the basic sciences in the 5 to 10 years.

As you know, we are terribly specialized; and I don't think there is any working scientist who could give you a valid overview, as a whole, of the sciences. Perhaps Isaac Asimov could do it, but I can't.

I certainly would not dare to enter into the biological and medical sciences. I will have nothing to say about them. It simply reflects my own ignorance. Even for the physical sciences—which is my field—I would not try to give you a comprehensive overview.

Instead, I have just decided to choose three problems which interest me, and where I think it is not unreasonable to expect "exciting developments in the next decade or so." The three, I repeat, are representative, rather than comprehensive, and are only meant to stand for the whole.

They are: The problem of the origin of galaxies; the problem of the nature of physical force; and the problem of turbulence.

We know a great deal about galaxies. We know that the stars are not flung out at random around the sky, but instead are clustered into great islands of stars. We know the sizes of these islands. They run, typically for large galaxies, on the order of 100 billion stars—perhaps going up to a trillion stars; getting down to smaller galaxies, perhaps as few as a million stars.

They rotate with rotational speeds of a few hundred kilometers a second. They also move with relative speeds of a few hundred kilometers a second.

We know something about their composition. They are mostly hydrogen and helium, but the relative amounts vary somewhat from galaxy to galaxy.

And finally, the galaxies themselves are not flung out at random around the sky, but form clusters themselves—from small groups to great clusters, such as the one in the constellation Virgo, which contains upwards of 2000 galaxies.

What we don't know about these galaxies is how they were formed. We don't have a convincing picture of the origin of the galaxies. And that means, then, that we don't have any understanding of why the galaxies have the properties that I've just mentioned.

We have, however, a fairly good idea of when the formation of galaxies began. It began when the universe was about 700,000 years old. For the first 700,000 years or so in the universe's history, the universe was very hot, very dense, and filled with radiation. So much so, in fact, that any clump of matter that began to collapse in on itself under the influence of its own gravitation was immediately blasted apart by the intense radiation that filled the universe.

When the universe was about 700,000 years old, it more or less suddenly became transparent to radiation. To be technical, it is because suddenly the electrons and the protons, which had up to then been moving freely, combined to form neutral atoms of hydrogen. And so, from then on, the matter was free to coalesce under the influence of its gravitation and form more and more pronounced islands of matter out of the background of the cosmic soup.

We don't really know how that happened. We don't have a reliable theory for how the galaxies formed. However, there is a very exciting prospect that, in the next decade or so, we are going to be able to get evidence that will tell us, in vivid detail, something about the origin and early history of the galaxies.

I said that when the universe was 700,000 years old, it suddenly became transparent to radiation, and that is why the galaxies began to coalesce at that point. Well, that radiation that filled the universe at that point is still all around us. And in fact it is detected by Earth's radio astronomers. This is the radiation that was discovered in 1965 at the Bell Telephone Laboratories, and that is sometimes called the "cosmic black body background" or "microwave radiation background." It is a very faint, diffuse microwave static that apparently fills the universe—the same in all directions, corresponding to a temperature of the whole universe of about 3 degrees above absolute 0.

This radiation, as I say, was emitted at a time when the galaxies were just beginning to form. So, if we study this radiation, if we observe it very carefully, its dependence on direction, look for lumpiness, look for hot spots, look for cold spots, we may be able to see not the galaxies themselves but the seeds, the initial fluctuations out of which the galaxies formed.

This is a task, I think, for ground-based infrared astronomy. The ground-based infrared astronomers, if they can find a suitable wavelength to work at, may be able to see, at some time in the 1980's, the very beginning of the galaxies that we now see spread across the sky.

Another possibility is that we will see galaxies not at the very beginning of their growth, but in their vigorous youth. We can look out, now, with optical telescopes, to a distance of about 10 billion light years. That means that the light we are seeing has been traveling for 10 billion years.

So, the things that we are looking at, we are seeing as they were 10 billion years ago. These objects, then, represent galaxies in their youth, and we can try to see if there is anything peculiar about them.

In fact, we see a lot of objects in the sky that look very peculiar indeed. We see quasi-stellar objects whose size is not more than a light year or so—less than the distance between us and the nearest star—and which emit about as much radiation as a whole galaxy.

Many people believe that these represent an early stage in the evolution of galaxies, and it will be very exciting to find out. This may be a task for satellite-based instruments, like the space telescope which will be going into orbit in a few years.

As a wonderful byproduct of this, if we can learn something about the history and the physics of galaxies, we may be able to turn that into learning something about the history of the universe as a whole. Because if we understand galaxies better, we may be able to use them as what are called "standard candles." In other words, if we understand them, we will know how bright they really are. Looking at how bright they appear to be, we will know how far away they are. Comparing how far away they are with how fast they are moving, we will know something about the curvature of the universe as a whole, and about whether the universe is open or closed; and whether the universe is eternal or will come to an end when it all collapses back again—certainly not uninteresting questions.

Well, I will turn away now from the problem of the origin of galaxies to another problem which is even more fundamental. That is, the problem of: What are the forces of nature? That is: What are the laws which govern the behavior of matter and energy throughout the universe and throughout the history of the universe?

There is now a widely accepted theoretical framework in which the laws of nature, on the deepest level that we now understand them, are expressed. This framework is known as "quantum field theory."

In one sentence, the key idea of quantum field theory is that the inhabitants of our universe fundamentally are fields. There is the gravitational field; there is an electromagnetic field; there are less familiar fields; there is an electron field; a neutrino field; and what have you.

Further, material particles, in quantum field theory, are seen as simply bundles of the energy and momentum of these fields. That is, they are "quanta" of these fields in the same way that light, which is a wave in the electromagnetic field, can be understood in terms of bundles of energy called "photons," which behave just like particles. In the same way, there are bundles of the energy of the electron field which we recognize as material particles, electrons. And likewise for every other kind of particle that exists.

A consequence of this point of view is that the distinction between the forces of nature and the particles upon which they act is washed away. For example, the electric and magnetic forces between two electrons are seen to be just due to the exchange of another kind of particle, the photon; and the electromagnetic force between a photon and electron is due to the exchange of electrons. The nuclear force between two protons in an atomic nucleus is due to the exchange of another kind of particle, the meson, and so on.

But quantum field theory, although by now pretty nearly universally accepted as the language in which we are going to have to address the problem of the laws of nature, only provides us with an empty stage. We have to know what the actors are. We have to know what the different kinds of fields are and how they interact.

The one interaction that we really understand well is the electromagnetic interaction—that which is responsible for throwing photons back and forth between electrons. This is the basic interaction which holds matter together, which holds the electrons inside the atom. Almost all the properties of the objects on this table, for instance, and the speakers at this table, are due to the electromagnetic forces that act between the electrons and the nuclei of the atoms of which they are composed.

One of the triumphs of the quantum field theory was the understanding of electromagnetism in the late 1940's by a young generation of theoretical physicists in the United States and Japan. In the last decade we have come to understand that electromagnetism is itself just one aspect of the more unified and larger picture of a unified quantum field theory, which also accounts for another of the grand classes of the forces of nature—the weak interactions. The weak interactions, among other things, are responsible for the first step in the chain of nuclear reactions which heat the stars.

It turns out that the photon—which, remember, is the quantum of electromagnetic radiation—is just one of a family of particles. It has siblings, and its siblings include a very heavily charged particle called the "W particle," with a mass about 75 times that of a hydrogen atom, and an even heavier neutral particle called the "Z particle."

The evidence for these particles is quite compelling, but so far it is entirely indirect. No accelerator in the world today is capable of producing these particles.

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I think that the experimental discovery, and then the study of these heavy photons—these particles which play for the weak force, the same sort of role that the photon does for the electromagnetic force—is surely going to be one of the most exciting items of scientific progress in the next 5 to 10 years.

Unfortunately, this is very likely going to occur in Europe. Because, given the present state of funding for elementary particle research in the United States, I think more and more of the most exciting experimental developments are going to come out of Hamburg and Geneva, rather than out of Stanford or Batavia or Brookhaven. It's unfortunate, but I think true.

Lastly, I turn from the origin of the universe and the forces of nature, to a really hard problem: The problem of turbulence.

Everyone knows what "turbulence" is. It is a common fact of experience that, if you take a fluid, like a glass of water, and stir it slowly, the flow will be smooth; the fluid will move in regular, smooth sheets across itself. And one knows very well how to calculate the properties of such smooth fluid flows.

However, it is also a matter of common experience that if you stir the water more vigorously, the smooth flow will be broken up. Suddenly you will find that eddies form. And, as you stir more and more vigorously, the eddies will become more and more complex. There will be big eddies carrying little eddies on them, and so on.

It has been a major problem which has been studied now since the end of the 19th century, whether there are any features of universality in this kind of turbulent flow. At first sight, it doesn't seem like a very promising arena for a physical scientist to work on. It is just a matter of understanding fluid flows when they are messy.

But in fact, many hydrodynamicists think that properties of turbulent flow, when studied on a sufficiently large scale, are universal. That is, that there are things you can say—statistical things you can say—about turbulent flows which will be true for all turbulent flows no matter how you do the stirring, wherever it occurs, whatever the fluid is, everywhere in the universe.

This is a great question which has not yet absolutely been settled experimentally, although the experimental indications are that there is a kind of universality. It is a question of great importance technologically, unlike the other questions I have discussed, because turbulence rules our weather, it rules the way airplanes fly, it rules the way submarines move in the ocean. We live in a turbulent world.

It is a major problem for theoretical physics, to come to grips with the problem of predicting the universal properties of turbulent flow—and this is a problem that, as I said, has been around for the whole of the 20th century, and on which very little progress has been made.

It is a problem, interestingly enough, for which—quite unlike the other two problems I have discussed here—we understand the fundamental laws. We know all there is to know, as far as it is relevant to this problem, about the basic laws of hydrodynamics. In fact, the basic laws of hydrodynamics is called the Navier-Stokes equation. Mr. Navier wrote it down in 1822, and Mr. Stokes wrote it down in 1845. So, we've known these laws for a long time, and it is not a problem of fundamental physics in the sense of the other two, but it is an attempt to understand, by mathematical means, the kind of universality that exists in nature. Many of us hope that some mathematical methods which have been developed originally in elementary particle physics, and which go under the name of the "renormalization group"—which I would not dream of trying to explain—and which, have had a very profound impact on the theory of critical phenomena—boiling, for instance—will prove to be very valuable in understanding turbulence.

If that is so, it will be a wonderful example of the unity of science. And if we do understand turbulence, the next problem then I think will be to understand the turbulence of a fluid which feels the effect of its own gravitational field. And that will take us back to the problem with which I started: The problem of the origin of galaxies.

Thank you.

Mr. Brown. Thank you very much, Dr. Weinberg.

I think you have given us an interesting counterpoint to the earlier testimony—assuming that we can reverse the deterioration of basic science, we may solve those questions.

We are going to ask for questions from the audience, at this point, and we will follow the same procedures as we did this morning. Namely, asking you to put the questions in writing, and identify yourself, so that the questions may be made a part of the record.

And, while you are doing that, I am going to do two other things. I am first going to ask Senator Stevenson for any comments that he may have on the presentation we have heard. And following that, I am going to ask the panelists themselves as to whether or not they would care to identify any commonalities or differences which they perceive in the statements that have been made.

Senator Stevenson?

Senator Stevenson. Thank you, Representative Brown. I apologize for not getting here sooner.

I am not in a very good position to comment, at this point, not having heard all of the presentations. Let me just say that, following the morning procedure, I don't think we need the question in writing. If we could have just the name and address, and if the individual will go to the microphone, that might be good enough.

I will, while we are getting questions, I will venture one observation—and it is not a very hopeful one, but Hazel Henderson had some rather critical comments about the functioning of the marketplace.

And I think, in varying degrees, we all have to agree that the marketplace is not, by any means, a perfect means of determining economic or technological priorities, or allocating resources sensibly.

Our history—recent history—has proved that its shorter provision increasingly tends to be more powerful—not necessarily the most efficient, or the most visionary.

Contrary to what she said, it seems to me that it is consumer oriented in response to public wants, or expressed needs. It is certainly the economists' and their cycles in government attempt to control economic conditions, not so much by the manipulation of the control of supplies, as you were suggesting, as they do by controlling the aggregates of demand influencing consumer choices.

Now the point I wanted to suggest is that government is already interfering in a large way, particularly through conventional economic policy—whether it is monetary or fiscal—and with macroeconomics, the demand-management policies.

It is also interfering, to some extent, on the supply side—to decrease the supply of food in the world, to increase the supply of energy in the world. And, being retrospective about it, with results that cannot at this point inspire any more confidence in its ability to manage than in the ability of the marketplace and those who act within the marketplace and industry.

She talked about software to manage hardware technology. That raises a case in point that is of great concern to those of us who have followed it.

I refer now to space. The potentials for human betterment in space are, I think, very substantial. We discussed this morning, very briefly, the global communications system as one example. The benefits from human activity into space are all clouded now by the very real possibility, if not probability, that the strategic arms race will enter, or already has, a new environment.

Nations are developing at least one, and I fear two, means with which to destroy satellites. And, as long as those means exist or are threatened, every possibility for human betterment through activities in space is going to be clouded.

And the decisions to embark upon them will require an acceptance of risk, soon including the risk of destruction, and investments that are going to run into the tens upon tens of millions of dollars—and, to say the very least, raise the very large possibility of simply arresting the most hopeful activities in space while those that are the most destructive continue.

It may already be too late to stop, or prevent, the strategic arms race from entering space—although I hope not, and it is certainly not too late to make an effort to negotiate an immediate moratorium on testing and deployment of such weapons.

And hopefully, through the SALT negotiations, we will agree to control that. But, having said all of that, I am not quite sure where I come out. But having emphasized the software in the institutions which manage hardware—or at least the need to manage hardware—how do we do it, if on the basis of experience we cannot trust the marketplace, and as I am suggesting, cannot trust the Government, either?

Ms. Henderson. I think you're putting your finger on exactly this basic dilemma that we have to face up to, that markets do not work well, nor do we know how to plan.

Now, a lot of people say, "If we can't trust marketplaces to work because of these tremendous interlinkages and we don't know how to plan, where does that leave us?" But I believe that the first step—is to face this particular dilemma.

Now, this leads me in the following direction. First of all, the marketplace, as Adam Smith originally described the conditions under which it functions, that is where buyers and sellers meet each other in the marketplace with equal power and equal information and there are no significant effects visited upon innocent bystanders, in any situation where those Adam Smith conditions are still met, then markets are the best possible way of allocating resources.

The whole problem is that the scope and the interlinkage of our capital-intensive type of centralizing technologies simply prevents the market from functioning.

Now, we could then say, as I do, that in that case we ought to look and see how much we can decentralize them and how much we can not only think of decentralizing, possibly our populations which are so large and crowded into cities, but let's also look at areas where our technologies are unnecessarily centralized.

And, of course, the perfect examples are the nuclear powerplant versus solar energy. And I am an unabashed supporter of solar energy development, not just flatplate solar collectors on people's houses and apartment buildings. But what I'm talking about is: As the petroleum age declines, we see the dawning of the solar age, and that is not just solar energy technologies directly, but it is also windpower, geothermal, and fuel from biomass and waste conversion. For example, the article by E. Lipinsky in Science [Feb. 10, 1978] for anyone who's interested in seeing what has been done with integrating food, fuel, and material biomasses systems.

Basically it is necessary for us to look at our technologies and see where they have become unnecessarily centralized and where we can bring them back to the level of smaller businesses, and less of this excessive interlinkage, which we now see as new vulnerabilities, and all kinds of cascading breakdowns where you have a blackout all over the northeast. We need smaller scale technology that is much more resilient and that could be owned by lots of small businesspeople. And so that is certainly the most appropriate direction, I think, for us to try and approach this conundrum.

The other thing that I think we have to remember with traditional economics, is that economics is perfectly fine if it is used as bookkeeping to keep the accounts between firms and individuals. Micro economics is just fine. But the trouble is that the economists blew up their methodology in 3D and cinemascope and tried to map the whole macroeconomic system with these very narrow conceptual tools which just aren't up to the job. And so, what we have is they are off by many orders of magnitude. They see our economy as if it were a bathtub, and they think that you can manage it like a system of aggregate demand, and this is where economics itself has become part of the problem. And it is this area of theory that is most crucial for managing the kind of tremendously complex, centralized societies that we have with their centralized technologies.

So to turn to your second area of concern, which I share very deeply—that is, the global system and how and if we can develop in time to save the human species, the software of peacekeeping and conflict resolution in the world, to slow the arms race and begin to think of ways which we could use our wealth in all of these countries to meet basic human needs.

And I would agree very much with Mr. Howard Kurtz, who is sitting here in the first row, and has been telling us all about the ways we can utilize satellites for communications and all kinds of useful purposes. I can see the danger now that NASA is getting more and more linked with the Department of Defense, and this is a very, very dangerous drift, I think.

Mr. Brown. I'm going to ask Dr. Branscomb if he would care to comment. I think I saw him squirming a couple of times over there. And if anybody can solve the management of complex global systems, it should be IBM.

Dr. BRANSCOMB. Thank you, Mr. Brown.

I heard Professor Price and Hazel Henderson and myself all in substantial agreement on one point, and that point is that we are engaged in a transition to a knowledge-intensive society in which material goods and manufacturers are becoming relatively less important, just as activity in agriculture has become a smaller fraction of our national activity than in the past.

And I heard Hazel and myself agree that increasingly technical strategies and values are intermixed, and, for that reason, one of the difficulties in getting agreement on technology strategies and on goals is because we are in the process of changing our values and trying to get consensus.

And, indeed, those technological capabilities are stimulating the changes in values, or at least permitting them. And so there is an interaction between the evolving values and the evolving technologies. In a democracy where consensus is hard to achieve, this may cause a problem.

Hazel says the markets don't work if we don't know how to plan, and yet it is the market system that produced that knowledge-intensive society that we're talking about. It was not planned. It was the result of innovation, ingenuity, and imagination on the part of a lot of people.

I agree with the Senator when he suggests that, despite all of the shortcomings of the market system, it is the best economic system for satisfying the public's desires. I believe it was Maurice Chevalier who said when somebody asked him how it feels to be 80, that it feels great compared to the alternatives. And I think that is probably a good characterization about the market system. Ms. Henderson does not have confidence in it and believes that we don't know how to plan. But she then wants to plan and, in particular, she wants to choose the technologies that have the values embedded in them that she likes and to suppress the technologies that she does not like. Some of my friends struggle with the problem of choosing "appropriate" technologies. I have trouble predicting which technologies they like and don't like, because it turns out they don't like big, expensive, things like nuclear powerplants and large computers. On the other hand, they seem to like satellites and very large solar electric power arrays very much, both of which are also capital intensive.

So, I have a little trouble anticipating their preferences. I think we should struggle very hard not to attribute values to technologies but instead to struggle with the fact that we must set those values as human beings through a consensus. And if we want to understand what the technologies do by way of impacting values—and they do—then we need to get pragmatic, practical experience with the technologies and measure them and characterize them.

My final comment is that I certainly agree with her that the march of knowledge-oriented technologies does increase interdependence and interlinkages at a very great rate. And there is concern about the resiliency problem that relates to that. Interdependence has its price. On balance—and if you look at that debate in the OECD and the European Community and the Parliament of Europe last week on transnational data flows, you will find the principal issue is the concern about harmonizing national regulations on privacy, a very important objective.

But the second agenda is a concern about what is being called "information sovereignty," nations who are concerned that their concept of controlling their national destiny is internally threatened by interdependence. And I think there is some real truth to that, which proves that, as each nation becomes more dependent on its communications traffic with others, with knowledge and other resources in other countries, they become less than masters of their fate. I suspect it also makes the world a more stable place in which to live, with respect, at least, to social instabilities. We do have to worry about the technological instabilities.

It is amusing that the debate often focuses on trivial examples whereas there are important ones to look at. The classic trivial example is that there is a fire department in Malmo, Sweden, which every time there is a fire, notes the location and cause of the fire and puts that in a data base which is located in Cleveland, Ohio, where the computer happens to be. When they lay out their strategies for responding to fire alarms, they use the data in the data base in Cleveland, Ohio, in order to map that strategy. The Swedes, we are told, worry about whether the fire service in Malmo has somehow become dependent upon some computer in the United States.

Of course, they are very much more interdependent with other nations through their monetary system, through the transportation system, most particularly the airlines, which have to be network-connected to other airports and other airlines through computer communications and the like.

So, interdependency is a two-way street. But I think fundamentally it is the sounder direction for the world to go in than is a retreat to nationalism or a retreat to rural societies everywhere. I think we must, as a pragmatic matter, face up to the aggregation of risk issues, which is real, and make provision for those systems to be fail-safe systems and to provide enough decentralization in their architecture so that, in fact, they don't have the vulnerability that they might otherwise have.

Mr. Brown. I know Hazel wants to respond, but I think I will defer that for a little while and see if we can get some audience participation here.

Our first questioner is going to be Howard Kurtz, whose name has been mentioned.

Howard, would you like to go ahead?

Mr. Kurtz. This is directed toward Senator Stevenson's deep and appropriate concern for the age of hopelessness which will open up if a race begins for space war. Scientists and engineers were helpless to release the power of the atom until after President Roosevelt and Congress established a bold, concrete national goal and commitment.

Scientists, engineers, and specialists of a thousand professions were helpless to make the Moon safe for human visits until after President Kennedy and Congress released the creativity and power of America with a concrete national goal and commitment to get men to the Moon and back safely within a decade.

I suggest that not only the American people but the people of the whole world are waiting for the President of the United States and Congress to establish a transcendent new concrete goal and national commitment for the next generation, which is the purpose of these hearings, to open a pro-and-con and create a public and professional discussion.

I have one suggestion. There are about 150 sovereign nations on the planet. The nation which by its inspiration and leadership to the people of all these nations will not be the nation continually winning the race to produce the power to obliterate and annihilate the world's civilization. It will be the nation whose leadership has the vision and courage to provide world leadership for the next 20 years, pioneering the unprecedented world-sized systems and new institutions capable of guarding the national security, independence, and development of all 150 sovereign nations, as air traffic control guards the safety and the progress of all airplanes in a cloud.

Today, and for a very few years, the United States has a dominant world lead in the global systems technologies and management skills to meet all requirements for our own defense and, in addition, to lead the world in the pioneering development of civilized world systems of the future.

Would the members of the panel and the two congressional committees here widen a discussion of a greater new American purpose such as this?

Senator STEVENSON. To my own way of thinking, whether the objective is achieved by private industry or by the Government is of secondary importance. What is important is, as you have suggested, to identify our objectives and our purposes and to get the job done. And I suspect that, in most instances, getting it done will require the cooperation of both Government and industry and may very well require new forms of cooperation.

It seems to me that there is more agreement than might meet the eye between Dr. Branscomb and Hazel Henderson. I don't think Hazel Henderson is suggesting that the marketplace can make no wise decisions, or that Dr. Branscomb is suggesting that it can make all of them.

There is a place for both government and for a marketplace to which decisions are made by the individuals and by industry. But what we need now, as you suggest, is something to do, and then we will determine how to do it.

Now, it seems to me that one of the reasons we haven't settled on what to do is because we have first to settle on how to do it.

It has been said frequently of this administration that it has overburdened the Congress, but what has it overburdened the Congress with? One, milk-toast energy program; two, Panama Treaties; recently, a welfare plan; and a reorganization plan. That is the agenda.

Our preoccupation has been with the means, and not with the ends. I don't say that as critically as it may sound. This administration has been in power for about one year, and it may still spell out an agenda, and the choices it made recognize and identify certain objectives. I think the energy crisis has to be of overriding importance.

So, I have to agree with you again, Dr. Kurtz, and go one step further to suggest that our failure to identify objectives in this most interdependent world is because of our preoccupation with methods. And perhaps what we should do is, as you suggest, to try, though it is not possible to do it in the United States without the President, to try and hopefully with the leadership of the only person who can even communicate with the public, which must be involved (the President), to identify what it is we want to do, and then figure out how to do it. And by developing not only the institutions for cooperation between the private and the public sectors in the United States, but also between the countries of the world, which—well, all of them have to be involved in such large objectives as the one I mentioned, now for the third time, the global communications system, that I can definitely perceive involving and benefiting all of mankind under the leadership of one country that can give the world that leadership.

I'm sure we could all come up with many other possibilities, but—and in fact we have already commissioned some studies, but I don't think it is for me to get into all of the possible objectives.

Mr. Brown. We have another question from the audience. Mr. Sam Raff.

Mr. Raff?

Mr. Raff. First of all, it seems to me that in order to be worthy of addressing the problem it must be to some extent, an important issue. It must also be in some sense a problem that shows some promise of solution, just like politics is the art of the possible, to which the Senator was referring a while ago when he talked about what can be done.

The problems which science attacks must be problems that have some possibility of solving. There must also be some kind of a track record in that area. In the field of physics, there is at least a track record.

When we talk about the gathering of galaxies, there are approaches that are there that maybe we don't all understand. I'm not in that field, but we have some basis for having faith because these approaches and these techniques have solved other problems which seemed quite difficult.

The problems which Ms. Henderson wants to address are certainly worthy problems. They are certainly important problems. You want to solve the world's emotional problems and teach the world to sing in perfect harmony, but the track record in the social sciences is really not very good. I mean, you can look at the rehabilitation of criminals, the Head Start program—there's an awful lot of argument about whether that really did anything or didn't, the whole poverty issue which is still very much up in the air.

One has the feeling that maybe we don't know how to attack these problems. There are things we don't know, and certainly if we're going to spend an awful lot of money on this, I would feel uneasy.

Let me address for a moment the markets question. I recall, if some of you are old enough to remember with me, that shortly after World War II Chrysler Motors made a survey of the market for new automobiles, they were going to make a big hit, and they decided they would give the customer what he wanted. So, they sent out a questionnaire and found out that what the customer wanted was a car with lots of head room, not too flashy, not too much chrome, good maintenance, easy to get at.

And they started to build that car, and they built it for two or three years before they discovered that when the same guy who answered the survey got in the showroom, that wasn't what he bought.

Now, you really could not blame that on the automobile companies. It is some peculiarity of people, which, again, is something we don't understand.

Now, what disturbs me most about the discussion here is the sort of antitechnology bias and the desire to go backward. At least, I conceive it as such. What happened to the good old days of Kennedy, when we were going to go forward? We admit that we have some problems with fuel and oil. I was reading in the latest issue of Science Magazine that there are 900 billion barrels of oil in the Canadian field. Now, this is enough to last the United States, at the present rate of oil consumption, for about 400 years. That is now being mined. There is a company making money on that at about $11.50 or $12 a barrel.

Now, it seems to me to indicate some cause for not just throwing up your hands about the energy problem. There are things that can be done, and in the line of things that can be done, I would like to urge us to do something.

What really disturbs me about the antitechnology program is the throwing up of the hands and the sort of giving up and going back to doing things in a small way with a small farm and all of those things which have a certain nostalgic value but don't really survive in the marketplace.

I think we are facing some very specific problems in this country. There is ample evidence that they are getting worse. These jobs have to do with the balance of payments and high technology, the fact that other countries are overtaking us in the high-technology areas. And this has a tremendous impact ultimately on U.S. leadership, on jobs, and on a lot of things that are really very important to us. They are not epistemological issues. They are real important things that are going to come around and bite us. So, I'm sort of hoping that maybe Dr. Branscomb has some approach to this problem that has some real significance in terms of these problems which are very real and pressing and getting worse.

Dr. Branscomb. I think it would be fairer to let Hazel respond to this, because I responded before.

Ms. Henderson. I would just like to take a minute or two.

First of all, regarding your automobile story. I thought the punchline was going to be Volkswagen. Because we have to remember, you know, that Detroit was not producing that kind of automobile that Americans wanted. So people did buy Volkswagens, didn't they, and they are still buying them.

At last, I think Detroit has finally caught up with that whole situation.

I think we can at this point all agree that about that whole business of "free markets," I think we all need to be very careful about where the free market lies, that what is necessary is for us to clarify in which instances we ourselves are the invisible hand. And we do a lot of legislating markets and creating micromarkets of one kind or another, and we then forget that it was not God that did it, it was us.

And so, as long as we clarify that we shouldn't create markets by legislation and then pretend that God did it, that is the clarification that I was trying to make. As regards the antitechnology charge—I just have to point out that the kind of technologies that we are going to have to develop for the renewable-resource economies of the future are far more sophisticated and far more subtle than than the kind of meat-ax technologies that grew out of our great abundance of resources. And the new technologies based on more careful use of resources, deeper understanding of natural systems, are going to be far more sophisticated than anything we've seen to date.

Also there is a whole movement in the population, and the census data in this country is beginning to show, that people are choosing freely to drop out of the urban rat races and the larger corporations and the huge mindless bureaucracies that they work in, and they are going back and they are starting general stores in small towns, in Maine, and things like that.

So, we would hope, at least, that you'd allow those people who are moving in that direction or what the Stanford Research Institute calls "voluntary simplicity," where they forego the cash rewards of our kind of system for more psychic riches, that they would be allowed to have a free choice in the system. And I think that is really a large part of what the "small is beautiful movement" is saying: Don't eliminate all of our choices; don't continue down the "Big Brother" road to 1984 until all of us have to fit into your little boxes in the enormous institutions and technological configurations preferred by some of us.

And we have to remember, too, that in a society like ours, all people are not able to assert their values, because the ability to assert values in the political system and make your value choices stick depends upon your power and wealth. And the only institutions in this society that are regularly permitted to play about with people's values are, of course, major corporations, who spend almost $40 billion a year messing around with our values through advertising, and I'm sure, therefore, that I might also be entitled to express my value preferences. When I articulate the kind of values I am articulating I agree with Mr. Branscomb entirely, that there should be a consensus, and I think we are, in this society, coming to a new consensus of the values that are going to lead us into our third century. They are going to be different, and I am merely exercising my right to put them into a public discussion arena.

I am glad, incidentally, that IBM has gotten past the stage that they were in about a decade ago, of telling us the computer was just a tool, like a hammer, that did not really change any social configurations. I know this is true, because my husband worked for IBM 10 years ago, and that was company policy then, that "the computer is a tool no different than a hammer; don't get into the whole business about it changing social configurations." So they gave $5 million to Harvard and said, "You can study that problem."

Mr. Brown. Do you have a brief comment, Dr. Branscomb?

Dr. Branscomb. Yes. I would like to just endorse what Mr. Raff said, in the following sense:

Two years ago I had the privilege of leading a discussion for the National Academy of Sciences called the Ballagio Conference. That discussion involved a group of about 18 scientists and engineers from around the world, including some social scientists. We discussed the question of science and technology and the prospects for mankind.

We tried to address, as best we could, the question of whether the problems facing mankind have reasonably tractable solutions, from a scientific and technical point of view. We concluded, I guess without much surprise, that we felt that in large measure they do, although with some substantial risks involved.

Then we addressed ourselves to what it would take to permit the science and technology capabilities we have to do the job. The conclusion that we came to was that a great deal of restructuring of the basic technology that industrialized societies depend on today will be necessary, much as Hazel has suggested.

But our concern really was two things which she referred to. One had to do with the process of making decisions, where it is appropriate for government to make decisions, that set the environment within which that competitive market system operates efficiently to produce the right broad directions for the society.

That process is one which has got to become more objective, more pragmatic, and more rational than it is today. I am referring to the whole panoply of ways of dealing with environmental impact of technology assessment, with regulatory environment, and the like.

The second conclusion that we came to was: The public must be deeply involved in its understanding of these issues, because it is the public that has to permit the political leadership to catalyze the consensus of that public.

Unless there is reasonable public agreement on the issue of both the significance of technologies and the character of the benefits and risks that may lie out in the future of their exploitation, then even the most visionary President, or Senator, or Congressman, will be restricted by lack of public support in his or her ability to exercise leadership.

Mr. Brown. I want to recognize one more member of the audience for a question or a comment—Dr. Homer J. Hall—and that will be the last one for this afternoon.

Dr. Hall?

Dr. Hall. We have had considerable discussion of values here this afternoon. And the question of values gets very rapidly into a question of dimensions.

We will argue about whether a thing is black or white. I say it is black, you say it isn't black. But you're thinking about whether it is red or green. It is very easy to fall into a two-dimensional fallacy where one says: If we disagree, and I am right, you have to be wrong.

The real world is multidimensional, and we have had a couple of examples of that this afternoon, and I would like to have you discuss them, briefly.

The information system we have allows divergence. We have information systems which are proprietary. We have information systems which are concerned with basic knowledge. We have information systems of government which are concerned with the general interest, versus the proprietary interest.

Now my question is: Doesn't our information system have to allow contradictions—to have incompatible elements? Aren't we inherently killing ourselves, if we say that any one system can be right, no matter what it is?

The second question is: Doesn't the same thing apply to global communications? If any global system is going to work, doesn't it have to be open to people who not only don't agree but don't have to agree to get into the system?

Dr. Branscomb. I think tolerance and diversity is a fundamental requirement, both for technological and for social arrangements.

Ms. HENDERSON. Yes, I would absolutely agree. The diversity and redundancy are important. I think the access to the system, I think the model, for me, of developing uses of information technology, is really the system where almost everybody can get into the system. I think that would be a useful design principle to bear in mind. Also, I think contradictions are like paradoxes. Paradoxes are really complementaries from another viewpoint.

Mr. BROWN. OK. I want to personally express my thanks and I'm sure, that of Senator Stevenson, to the panel members for their very valuable contributions, and also to the audience. I think you all recognize that you have been sort of participating in a demonstration of how policy attempts to get formed in complex areas.

I can assure you all that this has been a valuable contribution to the review by the Congress, of a number of science policy issues which are currently before us, and I hope that we produce results that are as successful as this meeting.

Thank you all for participating this afternoon.

The meeting will be adjourned.

[Whereupon, at 4:20 p.m., the hearing was adjourned, subject to the call of the Chair.]

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