United States Department of Commerce
Technology Administration
National Institute of Standards and Technology

NIST Special Publication 825

NBS/NIST
A Historical Perspective

A Symposium in Celebration of NIST's Ninetieth Anniversary
March 4, 1991

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Co-sponsored by the Standards Alumni Association
and the National Institute of Standards and Technology

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Office of Information Services
National Institute of Standards and Technology
Gaithersburg, MD 20899

Issued April 1992

U.S. Department of Commerce
Barbara Hackman Franklin, Secretary

Technology Administration
Robert M. White, Under Secretary for Technology

National Institute of Standards and Technology
John W. Lyons, Director

The paper used in this publication meets the minimum requirements of American National Standard for Information Sciences—Permanence of Paper for Printed Library Materials, ANSI Z39.48-1984.

National Institute of Standards and Technology
Special Publication 825
Natl. Inst. Stand. Technol.
Spec. Publ. 825
78 pages (Apr. 1992)
CODEN: NSPUE2

U.S. Government Printing Office
Washington: 1992

For sale by the Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402

FOREWORD

This *Symposium on a Historical Perspective of NBS/NIST* commemorates ninety years of outstanding and dedicated service by the National Institute of Standards and Technology (formerly the National Bureau of Standards) to the people of the United States, other government agencies, industry, academia, professional societies, trade associations, standardization bodies, and the international scientific and engineering community. The speakers, all former or current staff members, have provided a series of historical snapshots in the form of factual and nostalgic descriptions which capture the spirit and creative atmosphere of this unique laboratory. They tell a story which all Americans, particularly the younger generation, should read, of dedicated public service to the nation, intellectual integrity, honesty, fairness, and superb craftsmanship in the difficult field of precise and exacting measurements which form the basis of modern science and technology.

The Symposium was planned and organized by the Standards Alumni Association with indispensable help from the NIST staff. The Association is comprised of more than 400 retirees and former employees with average Federal service of about 30 years. This adds up to a formidable number of years. In a manner of speaking, participation in the Symposium was our way of saying "Thank you" to NBS/NIST for creating a work environment which made it possible to render a public service while fulfilling a rewarding and interesting career in government. We are confident that this laboratory will continue in its tradition of excellence and will make further significant contributions to the well-being of the nation.

Emanuel Horowitz
Symposium Chairman and
President, Standards Alumni Association

PREFACE

During 1991 we at NIST celebrated the completion of nine decades of service to the Nation. A number of events were scheduled including a very exciting open house for school children in September and a symposium on science, technology, and competitiveness in November. The "NBS 90 NIST" program co-sponsored by the Standards Alumni Association and NIST was the first commemorative event and took place on the actual date of the anniversary of the signing of the first legislation setting up the National Bureau of Standards. This symposium was, except for my own remarks, a retrospective. Attended by many NBS old-timers, the meeting covered history that for many represented personal experience. Dr. Passaglia, author of a brilliant tract on the AD-X2 episode, related episode after episode from our history, taking his audience on a whirlwind tour of the century. (We look forward to Elio's forthcoming history of NBS from World War II to 1988.) Former Directors Branscomb and Ambler offered both recent history and observations on its meaning as we enter our last decade of the century. Then we had a series of talks on building new sites at Gaithersburg and Boulder and the rise and fall of several interesting program elements. It was a most enjoyable day for all present and launched our year-long celebration in fine style.

John W. Lyons
Director

CONTENTS

Emanuel Horowitz

Opening Remarks

Good morning, ladies and gentlemen. My name is Manny Horowitz. I worked in this laboratory for about 30 years and retired in 1980. It is my pleasure to welcome you to this symposium "A Historical Perspective of NBS." This year we are celebrating the ninetieth anniversary of the National Bureau of Standards, now known as the National Institute of Standards and Technology. Incidentally, it is also the twenty-fifth anniversary of the move of NBS from Van Ness Street and Connecticut Avenue in Washington, D.C., to the Gaithersburg site. As former NBS employees, current staff members, and Americans, we are all proud of the many accomplishments and contributions of this laboratory to the nation over the past 90 years.

Speaking of 90 years, on this occasion we received a letter from Frederick J. Schlink, who at 99 is, we believe, the oldest living alumnus of NBS. If there is someone in the audience who can beat that, please stand up.

I should mention that today's program has been arranged by the NBS/NIST Standards Alumni Association, with the magnificent help of Sara Torrence, Paula Killen-Fry, and the NIST supporting staff. My thanks to all those behind the scenes who made this important day possible. It is also my special privilege to introduce the principle speakers on today's program, including our NIST Director, John Lyons, and former NBS Directors, Lewis Branscomb and Ernest Ambler.

John W. Lyons

Introduction by Emanuel Horowitz

I want to introduce our first speaker, Dr. John Lyons, who is the Director of the National Institute of Standards and Technology. John, I remember our first meeting when you first came to NBS. You might recall it, too. You told me about your plans as you headed up the Fire Research Center and some of your aspirations. I remember that meeting very well. You later went on and served as Director of the National Engineering Laboratory. John was appointed by President Bush as the ninth Director of the National Institute of Standards and Technology in 1989 and took office on February 9, 1990.

Dr. Lyons will lead this laboratory into the next century, as foreboding as that may seem. He will also add to the historical perspective, which we will be reporting on the one hundredth anniversary of this laboratory in the year 2001.

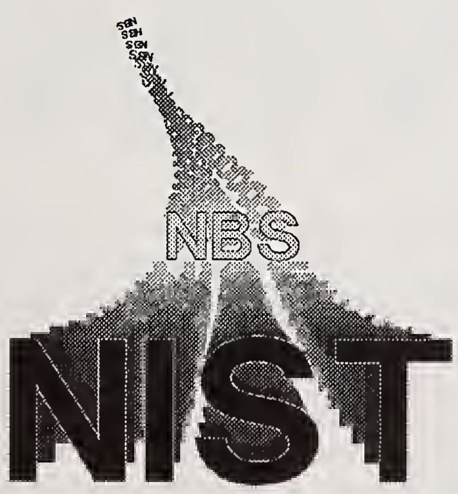
It is my pleasure to introduce John Lyons.

WELCOME AND CURRENT VIEW

John W. Lyons

Thank you, Manny. Good morning, everyone. Welcome. Manny mentioned some of the key historical events. I remember when Sara Torrence first came to me to talk about the anniversary celebrations. One of my reactions was, "Let's not overdo it, because in ten short years we want to have a real blow-out." Actually, we're having a pretty good celebration as it is. I doubt that I'll be here for the turn of the century, but the longevity of NBS Directors is well known. It's a well-known fact that there are twice as many former living presidents of the United States as there are living former Directors of this great institution. I'm only the ninth in 90 years, and I haven't served very long, so the average tenure is quite considerable.

We're very conscious of history here. Many of you will know that Elio Passaglia is writing a second volume of the history of this institution. He has a committee of kibitzers and helpers, including former Director Ambler and many others. Periodically, he issues a pile of paper that I try to read. It's very interesting. Elio and I recently had a conversation about the problems of a historian. I sought his advice on how to sort our files, because my staff are always saying, "Can't we throw this out? Can't we throw that out?" I've listened to the stories Elio tells about trying to track things down through boxes that only have dates on the front and are not indexed, and have decided to try to do something about that. We're going to get some help from professional archivists, so that in another 30 or 40 years, when we try to do volume three, we'll be a little better organized.



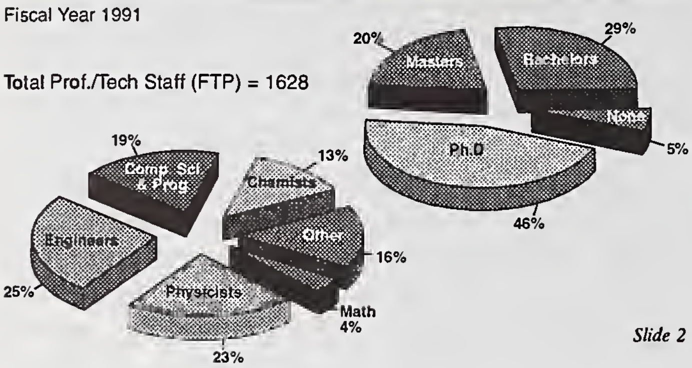
Slide 1

There are some changes at NIST. The most obvious change is the name. The second most obvious change, if you are here at night, or if you go down highway I-270 after dark, is the fact that the flag is now flying 24 hours a day and we've arranged spotlights to illuminate it. I must say, it's quite an inspiring sight, especially in the last 5 weeks, to go up or down that highway at night and see Old Glory waving in the spotlights. There's a story that goes with it that's not quite as inspiring. Having been overseas to some of our embassies, in particular the one in Bejing where my daughter served, I noticed that the flag ceremonies are treated with considerable respect. When the flag is raised or lowered in an embassy compound, everyone is expected to come to a halt, no matter where you are in the compound. Not salute exactly, but stand in respect while the flag is raised or lowered, which is reminiscent of military reservations, where, in fact, you're supposed to salute. I thought that as the flag comes down here at 5:00 or 5:30 and people in their cars are zipping around the area of the flag pole, it would be nice if people stopped out of respect. So I asked Guy Chamberlain what he could do about that. He came back after a while and said, "John, it's going to cost us additional staff on the guard force to stop the traffic." The usual budget stuff. We thought about it some more and not too much later Guy came back and said, "I have a better idea. Why don't we just leave it up?" As you know, you can't leave the flag up unless it's illuminated, so that's exactly what we did. Now, in the recent Gulf War, a lot of people decided to illuminate flags and leave them up, but we were ahead of them by some several months. Anyway, that's a second change.

The third change is that when you came in here you had to get cleared through the gate. That's a very unfortunate development that I hope will not last. When the hostilities began in the Gulf, we decided there was just too much at stake on this campus and too high a chance of terrorism to allow business as usual and let just anybody come and go. Certainly, we have very expensive equipment here, including the reactor and other items, so we reluctantly closed the site and required that staff wear these badges. I think we'll evaluate the situation over the next month or a little more, and as soon as possible we'll revert to the old open form.

My assignment is to tell you where we are now and to take a quick look into the future in order to set the stage for the historical discussion, which should, if we all do our part, build to a logical tie to what we're doing today. Let me begin with some status slides.

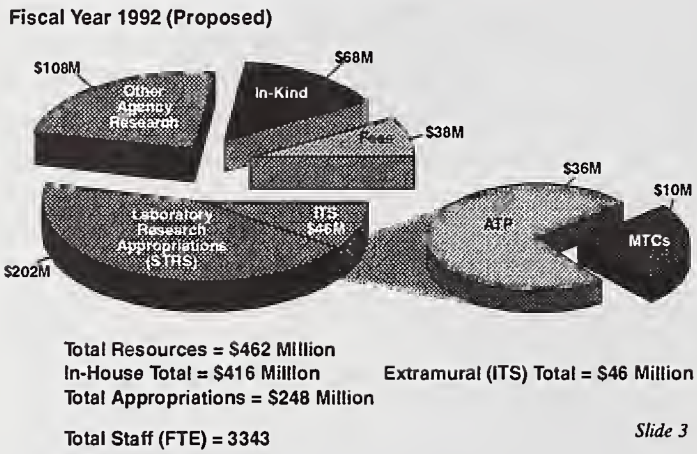
NIST PROFESSIONAL STAFF



Slide 2

This is the professional staff. Those of you who have been away for a while will notice the increase in computer-trained people. It's still not very high. If this were Bell Labs, that number would probably be 40 percent or more of the staff, but for us it's an increase over what it used to be. Otherwise, not very different. I guess the physicists have shrunk some, and the Ph.D. level is about as it has been as long as I can remember—approximately half of the staff.

NIST RESOURCES



Slide 3

This one will probably amaze some of you that have been away perhaps only a short time. It now costs about $400 million to run this institution each year. If you add the In-Kind, that is the donations and loans of staff and equipment and so forth, it's better than $450 million to run the operation. The staff has risen from a low of 2,700 or 2,800 back up to over 3,300. Actually, this is the proposed budget for 1992. It's a bit less than that, but still over 3,000 staff today. Another thing that's new about this slide is that we now run some programs outside the laboratory—extramural programs. I'll have more to say about three of them later. You see they've gotten to the point of being about 10 percent of the total. We're now a combination laboratory and program manager.

The direct appropriations are a bit over half of the total. If you look at the In-Kind as well, then other agency funding is less than the number you're used to. We've talked about 40 percent other agency, but if you add the In-Kind that number is down to about 25 percent. This depends upon how you do the numbers.

NIST BUDGET SUMMARY ($M)

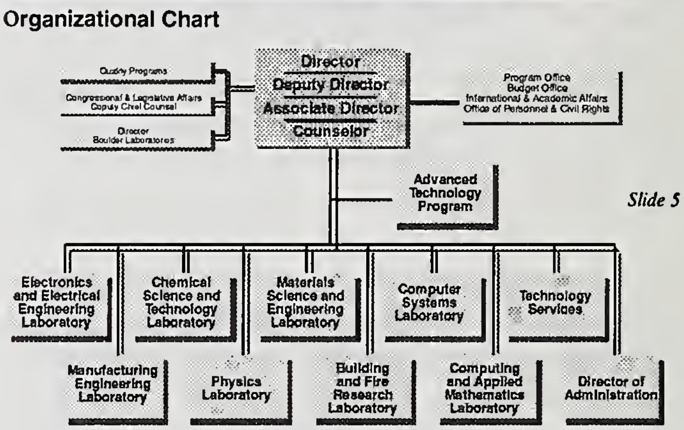
	FY 1991	FY 1992
In-House	$370	$416
Extramural	$ 49	$ 46
Total	$419	$462

Slide 4

Another way to look at it is just the inside-outside breakout. For this year, the year we're actually operating in today, the extramural is a bit larger than the 1992 proposal, but that has to do with carry-over and other budget details. The number is, in fact, constant. You see that the in-house work has gotten a very nice increase. That's all in the appropriated accounts. I'll come back and talk about that in a few minutes.

National Institute of Standards and Technology

Organizational Chart



Slide 5

Another thing that's new is the organizational structure. I spent half of my career in industry. Some of you did, as well. In industry, we used to reorganize every month or so, not all of the company, but parts of it. The organizational changes tracked the market. A changing market meant changing structure. In fact, you had to watch the bulletin board to know who was on first and who was on second. This institution is a little different. Elio says that the 1964 Astin reorganization, which created the Institutes, was in fact the first major reorganization of NBS since the beginning. (By which, I take it he means that all other changes have been evolutionary or one-at-a-time shifts in Divisions and so on.)

When Ernie Ambler reorganized in 1978, it was actually only the second general reorganization, 14 years later. I have decided on and have just completed this reorganization in 1991, or 13 years after the last one. You will see that we have eight technical laboratories. In addition to those eight, we also have Technology Services and Administration as equivalent elements. We call all of these operating units. Then we have the Advanced Technology Program, set apart. I'll explain the reason for that in a few moments. And then there are various staff functions.

The idea behind this reorganization was first of all to eliminate the old former institute and laboratory level, The National Engineering Laboratory, The National Measurement Laboratory, and so on. It turned out in all of the upheavals of the last couple of years, the managers in NEL and NML had all gone somewhere else, so it wasn't very hard to reorganize them out of existence—merely a paper *coup de gras*. We wanted to set the units up so that they were large enough to have a fairly firm and independent base. Each of these units is of the order of 250 to 300 staff and $30 to $40 million. Therefore, in theory at least, they have a great deal of flexibility. Each of these units should be able to set up its own financial reserves and begin new work with the mere notification of the Director, rather than coming in every time they need $10,000.

TECHNOLOGY COMPETITIVENESS ACT

"TO MODERNIZE AND RESTRUCTURE [NIST] TO AUGMENT ITS UNIQUE ABILITY <u>TO ENHANCE THE COMPETITIVENESS OF AMERICAN INDUSTRY WHILE MAINTAINING ITS TRADITIONAL FUNCTION</u> AS LEAD NATIONAL LABORATORY FOR PROVIDING THE MEASUREMENTS, CALIBRATIONS, AND QUALITY ASSURANCE TECHNIQUES WHICH UNDERPIN UNITED STATES COMMERCE, TECHNOLOGICAL PROGRESS, IMPROVED PRODUCT RELIABILITY AND MANUFACTURING PROCESSES, AND PUBLIC SAFETY"

August 23, 1988

Slide 6

Now let me go back and trace some of the rationale for how we got here. As you know, in 1988 the Technology Competitiveness Act was passed as part of the omnibus trade legislation of that year. The statement of purpose of that Act is shown here. The underlined part is what is new. In effect, it tells us to take more seriously and raise in priority the assignment to work with industry. To help industry improve its competitive posture in global markets. Market places are now global rather than national, and our industry is struggling to keep up with some of our off-shore trading partners. That's the statement of purpose.

NIST FUNCTIONS

- Assist industry in the development of technology and procedures needed to
  - improve quality,
  - modernize manufacturing processes,
  - ensure product reliability, manufacturability, functionality, and cost-effectiveness, and
  - facilitate the more rapid commercialization ... of products based on new scientific discoveries.
- Develop, maintain national standards of measurement.
- Assure international compatibility of national measurement standards.
- Advise industry and government on scientific and technical problems.
- ...

Slide 7

The NIST mission is enunciated in terms of new and traditional functions, all of this being by way of a large amendment to the enabling legislation of 1901. Here you see that the first function is to assist industry in a number of specified ways with a focus on quality and improving the way industry does business. Cost and quality, really. And secondly, a major focus on manufacturing or processing. We, in the past, have focused more on products and product-related measurements, not so much on processes. In this law we're told very pointedly to pay more attention to process technology. Number two on the list of functions is the traditional measurement assignment, a national system of measurements, and number three, international standards, and so on.

I should say before I talk about the goals that the change in mission is not an abrupt change, it's a matter of emphasis. This laboratory has always worked in support of industry. In fact, carved in stone in the lobby is a statement by the Committee in the year 1900 saying that they could think of nothing better to do for manufacturers than to establish the National Bureau of Standards. Thus it is not a new idea. What is new is the emphasis and underscoring of the importance of worrying about industry. As you know, we are the only Federal laboratory with broad programs that is assigned that as a major function: that of helping industry.

NIST GOALS

- Support industry
- Conduct selected programs in health, safety, and the environment
- Support scientific and engineering community through fundamental studies

Slide 8

Given this background, I have enunciated three goals for the laboratory. I did this as part of my confirmation process. The first one is to support industry. The second one is special because Washington tends to be a digital town. Either we're all onto something or we're all off it. In the background are other assignments to NIST, not the least of which are some in health and safety (and I should include the environment in that list) where we play a key role in establishing the facts through better measurement. In the case of building and fire research, you know that we have a very old and traditional role. More recently, we've worked very hard in things like clinical standards in support of the health industry. I regard these as very important assignments, and it's very easy for them to get lost. Alternatively, it's very hard to get folks in the Administration who are worrying about trade and industry to think with you constructively about health and safety. We in management are responsible for keeping these areas in focus as well.

Third, and very important, is the fundamental base of the laboratory. We do fundamental scientific work, and fundamental engineering studies, really for two purposes. One is to be a good citizen in the scientific community where we are expected to do certain kinds of tasks as part of our role in our technical society. Secondly, to keep up the quality of the rest of the work. I assert that one can't do good applied work without doing good basic work. The quality of this place rests squarely on the foundation of long-term, fundamental work.

NEW MECHANISMS

- Advanced Technology Program
- Manufacturing Technology Centers
- State Technology Extension Program

Slide 9

I'm not going to talk about the laboratory programs, but I am going to talk just briefly about the new mechanisms that have been established.

STATE TECHNOLOGY EXTENSION PROGRAM

- To help states get started
- Nine planning grants awarded in 1990

Arkansas	Minnesota
Georgia	New York
Maryland	Pennsylvania
Massachusetts	Tennessee
Michigan	

Slide 10

There are three in the law. I'm going to talk about them in inverse order. The first program, called the State Technology Extension Program, is Congress' instruction to us to help the states establish analogs of the Agricultural Extension Service, an enormously successful joint effort among Federal, State, and county governments, and the backbone of the technical side of American agriculture. States are trying to emulate this in the industrial area. They're struggling and Congress thought we could help them, and gave us a little money and an assignment to attempt to coordinate the state efforts. Last summer we awarded small grants to nine states. Some of these grants actually tied the state efforts back to the second program, the manufacturing and technology sentence.

MANUFACTURING TECHNOLOGY CENTERS

- To translate, harden, and transfer technology to industry
- Regional
- Three set up in 1989
  - Great Lakes Center in Cleveland, Ohio
  - Northeast Center in Troy, New York
  - Southeast Center in Columbia, South Carolina
- Two more set up in 1991
  - Industrial Technology Institute, Ann Arbor, Michigan
  - Kansas Technology Enterprise Corp., Topeka, Kansas

Slide 11

The second program, somewhat larger, is a series of entities to help small business connect with NIST and other technology sources in manufacturing technology. These new entities do not do R&D. They're strictly chartered to move and to diffuse technology. They're called by some "Holling Centers" after the senator whose idea this was and who promoted the legislation. They're intended to be regional, to reach eventually most of the industrial parts of the United States. We started with three in 1989; one in Ohio, one in New York, and one in South Carolina. We're going to announce within about 2 weeks two more centers [in Michigan and Kansas]. The budget calls for additional ones next year. The original thinking was there would be a dozen of these. There is a sunset provision, so that the Federal money will be withdrawn after 6 years, and the discussion now is what to do with that money once withdrawn. Should we use it to start more centers? Or should we terminate the Federal effort and let these centers go about their business?

ADVANCED TECHNOLOGY PROGRAM

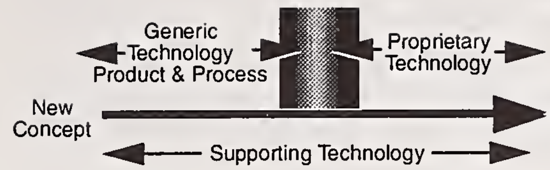
Goal

Assist U.S. business to carryout R&D on PRE-COMPETITIVE GENERIC technologies, which are

- ENABLING – offer wide breadth of potential application and form an important technical basis for future product-specific applications; and
- HIGH-VALUE – when applied they offer significant benefits to the economy by enhancing economic growth and raising productivity.

Slide 12

The third program, far and away the one with the largest potential impact on this institution, is the Advanced Technology Program (ATP). The point of the ATP is to help business commercialize exciting new technologies – not to generate technology, but to help commercialize it. This is done through giving money to companies – something new. It's relatively new anywhere in the government, and it's certainly new here, for appropriated funds to be passed to industry for civilian technology. The funds can go either to single companies or to consortia of firms, with an emphasis on consortia. The idea is to help go to market, not in niche technologies, but in technologies with the potential to have a major influence on the economy. The judgement as to whether or not a technology is ready for this kind of investment and whether it has the potential for large leverage on the economy, whether there are technical barriers, whether the companies are qualified to do the work, and so on, is part of the competitive procurement evaluation. All of the decisions are made here with assists from people from industry and other federal agencies. Ray Kammer has spent a lot of his time overseeing this activity. I'm pleased to say that we're just completing round one, and tomorrow morning at Commerce we'll be announcing the first awards under this program.



Slide 13

It's important to note the generic and precompetitive criterion, and here's a slide that explains in oversimplified fashion what we mean by that. You may have noticed that the phrase "generic and precompetitive" has appeared in the speeches and testimony of the President's Science Advisor. It has, in fact, appeared in a speech the President himself gave and is bandied about considerably in Washington these days as the answer to the criticism that programs like this smack of industrial policy or the selection of winners and losers. The way around that was devised by people here and downtown who were writing the first rule for the ATP, and it was hammered out with the aid of OMB. The idea is that if you're going to market with something new already in hand, and you're trying to get to routine production and sales, you go through a two-part process. The early part is where the risk is high and the technical barriers are openly discussed. For example, I cite the high-temperature superconductors, where the problems are sufficiently difficult that firms engaged in such R&D have been sharing widely what they've learned. At some point as time goes by, people begin to see some answers and then they stop talking and the information becomes proprietary. In fact, a better word would be preproprietary rather than precompetitive, because obviously it's all competitive. Anyway, we coined this phrase, generic and precompetitive, and it's now part of the Washington lexicon. We shall invest via ATP in the generic and precompetitive (preproprietary) part of the development time line.

NIST STATUS

- ~1000 guest scientists
- 103 Co-op R&D agreements (CRDA's)
  – 30 more in progress
- 5 Manufacturing Technology Centers (MTC's)
- 11 Grants awarded under the Advanced Technology Program

Slide 14

We now have about 1,000 guest scientists per year here. They average about half a year per guest, so that we get about 500 staff-years from that group. Two hundred of these are Industrial Research Associates, up by a factor of about two from 10 years ago. We've executed under authorities legislated during the 1980s, almost 90 cooperative R&D agreements. This is known as CRDA. We have another almost three dozen such agreements in the pipeline. That makes us either number two or number three in the Federal race, NIH being in the lead position and, of course, they're four or five times bigger than we are. We're doing very well in executing agreements with industry. We have three of the manufacturing technology centers; soon we'll have six. And we have just gone through our first experimental year on the ATP.

PRESIDENT'S 1992 BUDGET

"... A 15% increase to ... $248 million for NIST. The ... projection will result in a budget that is approximately doubled by 1996."

Slide 15

In the President's 1992 budget it first says that there's a 15 percent increase approved for NIST, and that's for the laboratory, not for the extramural programs. The appropriated funding will rise to almost $250 million. Then the budget goes on to say that the budget projection will result in a budget for NIST that is approximately doubled by 1996. That's an extraordinary statement for this institution. We now have OMB saying that NIST should be treated the way they wanted NSF to be treated, doubled in 5 years. What can we do with that?

It turns out if you talk to the folks over at NSF, despite their disappointment that they haven't gotten the doubling so far, that having projections that are on the rise makes an enormous difference in how you can think and talk and write about the institution. It is now, for example, okay to write expansionist plans, because the projections are for a very substantial increase. So we can publish, for the first time, a strategic outlook or a long-range plan that talks about new programs built on top of existing programs. That gives us flexibility that we haven't enjoyed in the past. In fact, we've written precious few long-range plans here in the last 20 years because of the difficulty in publishing anything significant, given the set of zeros in the OMB marks for out-year increases. This is a very significant achievement for us and we're very pleased by it. It puts us in the spotlight, and in fact, we have been in the spotlight since the 1988 legislation.

STRATEGY/OUTLOOK

1. External work will grow fast
2. Technology development – fast
3. Supporting technology – slower
4. Fundamental research – priority
5. OA work – proportional

Slide 16

I want to spend just a few minutes talking about a strategic outlook document that we just released to the senior management here for their use in writing their own plans for the 1990s. This is just a summary. There are 10 bullets in our strategic outlook, designed to suggest to people where we think we're going. The first one is that the new external work will grow rapidly. Congress is talking about $100 million for ATP in the third year. We got $10 million the first year, and $36 million the second year. There has been talk in Congress of numbers as high as $250 million. I didn't say so, but the ATP money has to be matched dollar-for-dollar, so we're talking about very substantial influence.

Secondly, I think our work that is aimed at technology development, generic and preproprietary, will increase relatively rapidly. It will go up in lockstep with the outside funding.

Third, the supporting technology—things like reference data, reference materials, some of the measurement work (not all, because a lot of the measurement work is part of technology development) will grow more slowly, but I think it will grow. Everything here will grow some. We'll keep fundamental research as a priority; it's up to us to maintain a proper percentage of that. Nobody knows what the right level of fundamental work should be, but it's somewhere around 15 percent. The other agency work, I think, will not grow proportionately, but will grow somewhat slower so that the number will come down several points over the next five years, and perhaps more than that over the next ten.

STRATEGY/OUTLOOK (Cont'd)

6. Collaborations – increase
7. National facilities – more
8. Technology transfer – more, new ways
9. Staff – better, more sophisticated
10. Facilities – major improvement

Slide 17

More and more collaborations. The example of the Cooperative R&D Agreements, I think, points that up. It will become a way of life here to do things in partnership, not only in planning as we always have in workshops, but actually in the doing. Our success with the Cold Neutron Research Facility encourages us to be on the lookout for more national user facilities like that one. We'll be opportunistic about that. We'll find new ways to do technology transfer. In fact, Don Johnson has a group thinking hard about new institutional ways to work with the private sector. The staff will become ever stronger, more sophisticated. Because of a personnel demonstration project that we have here, our staff, I think, is stronger than ever and the chances of keeping it strong are greater than ever. Furthermore, there was a pay adjustment, finally, this last fall for our senior managers, so that I think we'll do better retaining and employing senior staff.

Finally, we need to do something about the facilities. The facilities look great; I don't want to slam them, but they're getting tired. We now have an architectural/engineering firm looking very carefully at what it will take to get us into the next century. Of course, if we're going to double the laboratory staff in five years, that's going to put a severe strain on the capacity of our facilities. We have gotten in the 1992 budget several million dollars for the first wave of improvements. I think that we're looking at something on the order of a magnitude greater than that when we really get into this.

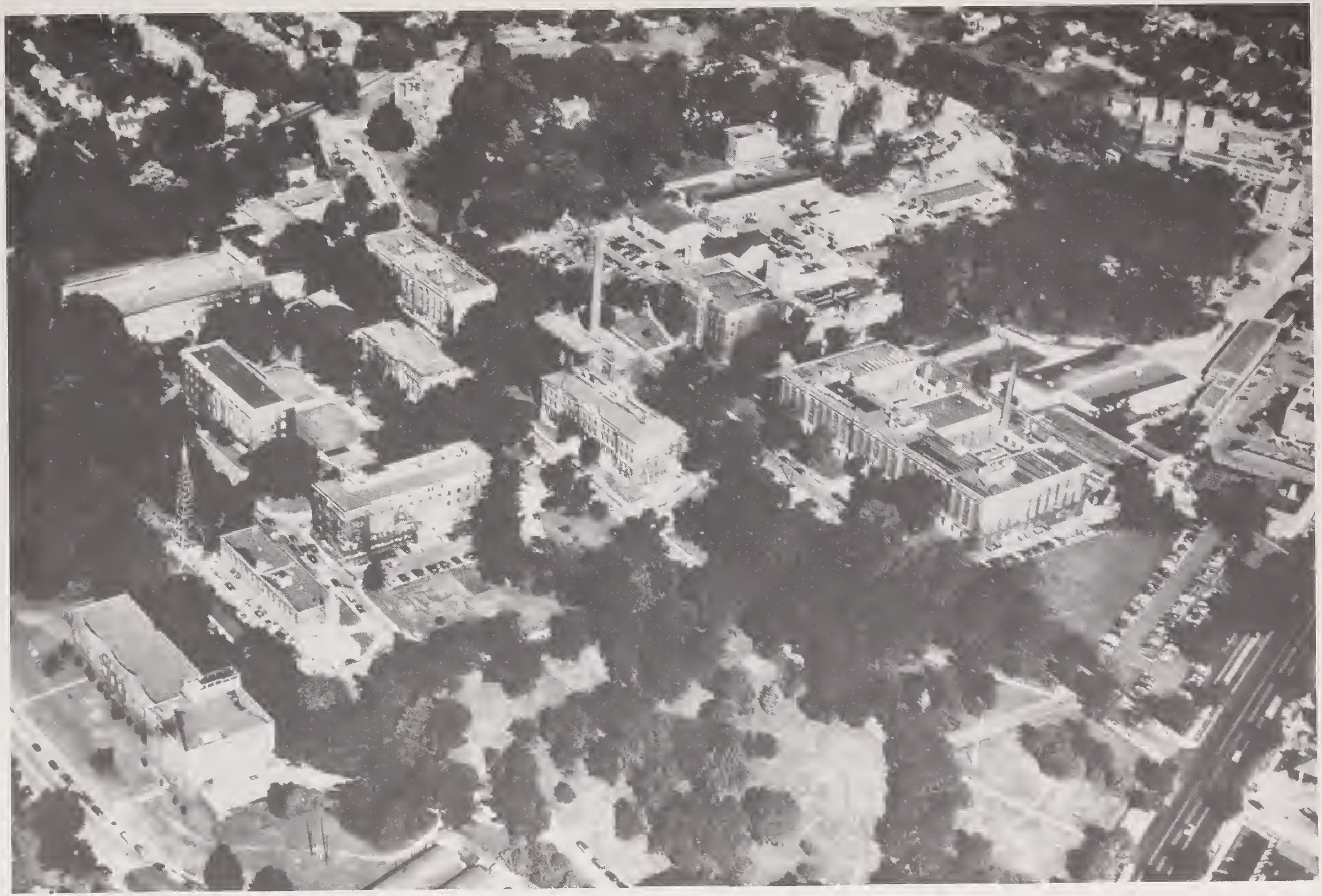
POSSIBLE MODELS

- NSF
- DARPA
- NIH

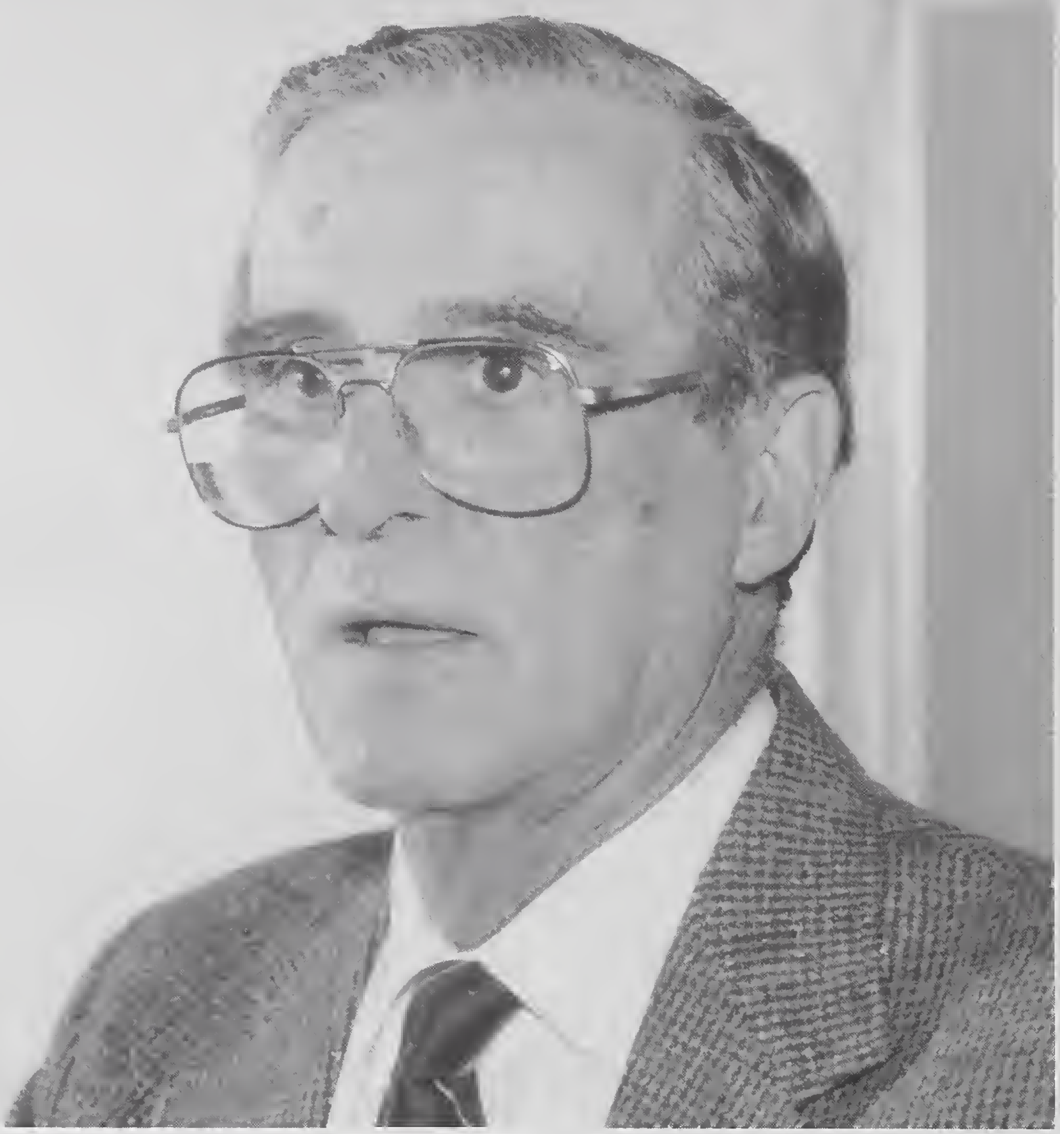
Slide 18

Lastly, the question is, What should be a model for NIST as we go into the future? There are those who say that you can't run a program management function at a laboratory. A lot of people in Washington think that if you're going to set up something along the lines of NSF or DARPA, that you can only do so by damaging the laboratory. Therefore, they would like to see the ATP Program moved out of this laboratory. Well, it's assigned to us, and so very pragmatically, it's our job to figure out how to make it work. So we cast about for models where doomsday doesn't have to be the answer. It's right under our noses. Down the street at NIH is a highly successful laboratory, budgeted at about $2 billion, running a grants program of about $7.5 billion. I submit that both the NIH laboratory and their grants program are world-class and run the medical research in a very successful way for the entire world. So our model is NIH, and, although we'll never see that kind of money—I'm sure we won't ask for it—it is instructive in how to run a laboratory and a grants program together.

That's where we are and that's where we're going. I hope that sets the stage for the next speakers, Manny. Thank you.



National Bureau of Standards—Washington, D.C.



Elio Passaglia

Introduction by Emanuel Horowitz

Our next speaker is Dr. Elio Passaglia. Elio joined the National Bureau of Standards in 1961 as a physicist in the Textile Section. He is a former Deputy Director of the NBS Center for Materials Science and he is currently a professor part-time at Johns Hopkins University. It seems that old NBS employees somehow find their way to Baltimore. As John Lyons has mentioned, Elio is writing a history of NBS from the 1950s, roughly where the previous history ended, until it became NIST in 1988. Directors of this laboratory have, for a long time, turned to Dr. Passaglia when there was an especially difficult task needing scholarly thought, as for example, the Flammable Fabrics Program. There are many, many others that I could mention. Elio retired from NBS in 1987.

It is a pleasure for me to introduce a personal friend and great colleague, and an important person of this laboratory, Dr. Elio Passaglia.

HISTORICAL PERSPECTIVE: 1901–1970

Elio Passaglia and Karma Beal

As many of you know, Karma Beal and I are working on a history of the Bureau starting approximately in 1950 where Rexmond Cochrane's fine book *Measures for Progress* ends, bringing the history up to the formation of NIST. We are now working on Chapter IV, which covers the period 1957 to 1964.

In preparing for our account, we reviewed much of the Bureau's history, and in the process formed some ideas of important events that either shaped the nature and character of the Bureau or were of particular significance in its history. We find, however, that the process of writing is also one of continued study, and our perception of events in the Bureau's history continually changes. Nevertheless, I am going to share with you our present perception of those events. Our ideas may change with further research and study, but while our present perception may prove shallow, we do not believe it will be proved wrong. The period I will cover is from 1901, when the Bureau was formed, to 1970, where other speakers will take over. This is a very long period indeed, so our account will of necessity be broad-brush. It will be neither an eagle's-eye view, for I am not knowledgeable enough, nor a worm's-eye view, for I don't know enough detail. You can think of it as an eagle's view through the eyes of a worm.

What I am going to do is give you a series of dates and explain to you why I believe they were important in the Bureau's history. Some of them will be new and strange to you, but after I finish I hope you will agree that they were important ones. Obviously I will have to leave out a great deal. Karma and I have had to be selective, but we hope not misleading. And you may find some of the dates provocative.

The first date is 1900, one year before the establishment of the Bureau, and the event is the establishment of the General Electric Research Laboratory. This will seem like a strange date to pick, but I want to make two points. The first is that the growth of the electrical industry at the turn of the century was the catalyst that forced the formation of the Bureau. Indeed, one year before the Bureau's formation, the electrical industry was well enough established that it resulted in the first central industrial research laboratory.

Now, I cannot enter into the Alice-in-Wonderland history of nineteenth-century measurement standards in the United States, but I will mention one date. In 1893 at the Columbian Exposition in Chicago, an international meeting agreed on definitions of all the electrical units, and Congress a year later legalized those units. But the United States had no standards for them, whereupon Congress asked the National Academy of Sciences to prescribe and publish specifications "necessary for the application of the ampere and the volt." A year later the Office of Weights and Measures began the study of the Academy specifications, but the work of that office had little standing and less legal status. The Nation had reached an impasse on electrical standards. Something had to be done.

The other reason for bringing up the GE Research Laboratory is not very obvious, but very important. At the turn of the century there were not many research laboratories around, and Table 1 shows the dates of formation of a few of them.

Table 1. Establishment Dates of Research Laboratories

1900	General Electric
1903	DuPont
1904	Westinghouse
1908	Corning Glass
1912	Eastman Kodak
1925	Bell Telephone
1928	U.S. Steel
1901	National Bureau of Standards
1912	Bureau of Mines
1923	Naval Research Laboratory
1886	A. D. Little
1925	Battelle

Notice that the Bureau, formed in 1901, predates all of them except GE. The table is a little misleading in that most of these organizations previously had some kind of engineering or scientific work going on, particularly Bell Labs, which was preceded by Western Electric engineering and scientific laboratories in 1907 and 1911, but it was not until the dates shown that research had become a centralized activity.

In the Federal Government there was also research, notably in the Department of Agriculture and the Geological survey, but there was nothing that could be called a physical science laboratory until 1901 when the Bureau was established. Indeed, the laboratory that many of us feel is most similar to the Bureau in scope of activity—the Naval Research Laboratory—was not formed until 1923. Oddly enough, the first contract research laboratory, A.D. Little, dates from 1886, but Battelle was not formed until 1925.

The point of all this is that for a large part of its history the Bureau was the only physical science laboratory in the Federal Government, and one of the few in the Nation. As a result it was called upon to do things simply because there was no one else. There are numerous examples of this, and we will mention two important ones later.

Proceeding now on our historical trek, we come to what is perhaps the most important event in shaping the character and nature of the Bureau. In 1899, then Treasury Secretary Lyman Gage, in whose Department the Office of Weights and Measures resided, took the bull by the horns and responded to the clamor to do something about national standards. Now serendipity took over. He asked his Assistant Secretary, Frank A. Vanderlip, to suggest someone to prepare a report proposing legislation for a national standards laboratory. While a student at the University of Illinois, Vanderlip had a friend who was now a professor of physics at the University of Chicago. The friend's name was Samuel Wesley Stratton, and Vanderlip wrote to him. Stratton accepted the task, came to Washington, and, with the title of Inspector of Standards, began work on the legislation. By early 1900 he finished the draft of a bill for what he called a "National Standardizing Bureau," marshalled arguments to be used at the hearings, and obtained an overwhelming number of endorsements.

As we all know, on March 3, 1901, Stratton's proposed legislation was passed into law with a single—but felicitous—change. National Standardizing Bureau became National Bureau of Standards, but otherwise Stratton's text was untouched. It was a short law, requiring but two pages, but in it were buried the seeds of the Bureau's future nature. We all know what was in that law, but let me refresh your memory and then point out two characteristics that were crucial in determining the nature of the Bureau, aside from the appointment of Stratton himself as the Bureau's first director. In the law the Bureau was given these functions:

(1) the custody of the national standards;
(2) the comparison of the standards used in science, engineering, manufacturing, and commerce with the national standards;
(3) the construction of standards when necessary;
(4) the testing and calibration of standards measuring apparatus;
(5) the determination of physical constants and the properties of materials when such data are of great importance to science and manufacturing ...and are not available in sufficient accuracy elsewhere.

All except the last are what might be considered obvious functions for a standards laboratory. The last one gives the Bureau considerable freedom to engage in scientific research, but there is one final function that best captures the spirit of the law. One of the functions given to the Bureau was "the solution of problems which arise in connection with standards." Now, since in a technological society it is difficult to conceive of an area that does not involve standards in one form or another, the law in effect authorized the Bureau to engage in any aspect of science and technology, provided only that it show involvement with some standards problem—which inevitably means with measurement technology—a not too difficult task. Many years ago, in a goose blind on the Maryland Eastern Shore, that irrepressible gad-fly of the Bureau Irl Schoonover, in discussing this clause in the law said, "Elio, it's better than a license to steal." What Schoony meant was that the Organic Act gave the Bureau authority to do almost anything it wanted to do, if it were somehow connected with standards and hence measurement capability. Robert Huntoon, that eminent scholar of the Bureau's role, coined the word "permissive" for the law, and the freedom it gave the Bureau is one of the most important factors that shaped its character.

The other factor that shaped the Bureau's character is something the law does *not* say. Nowhere does the law give the Bureau any regulatory function. It was given no policing authority; this is left to the states and other agencies of the Federal Government. In effect, the Bureau was shielded from the political arena. In cases of dispute, its sole function was to discover scientific truth. Truly, in its shaping of a scientific institution, and in its simple wisdom, it would be difficult to devise a better document than Stratton's two-page law. That is why I feel that Stratton's hiring is the most important event in the Bureau's history.

The next date that was important in determining the nature of the Bureau was 1904, just three years after the Bureau's establishment. In that year the Bureau—the only physical science laboratory in the Government—was approached by another agency on the prosaic question of light bulbs. These seemed to be burning out with unexpected rapidity. Could the Bureau do something about it? The Bureau tested a batch of light bulbs and found that not only did they not conform to the minimal Government specifications, they did not even conform to the manufacturer's own requirements. Agencies quickly learned that they could save a lot of money by having the Bureau test their purchases for conformance with specifications, and despite the fact that the Organic Act says nothing about the Bureau testing Government purchases, it got into testing—and the development of specifications—in a big way. This led to a great deal of routine testing at the Bureau, which was partly the genesis of the three materials divisions. But perhaps more important, this work was extended to testing for regulatory agencies like the Federal Trade Commission and the Post Office Department, which were concerned with truth in advertising and mail fraud. The Bureau published letter circulars, circulars, handbooks and whatnot for the consumer on such topics as antifreeze, washing and polishing materials, sun lamps, health lamps, mercury arc lamps, and battery additives—almost a Consumers Union that did not name names. It was a great service for the Government and the general public, but would eventually lead the Bureau into serious trouble.

Thus, before the First World War, the Bureau was busy establishing its full line of standards in weights and measures, temperature and heat, electricity, X-rays and radioactivity, and chemistry, and doing a large amount of acceptance testing. It was also involved in what might be called national problems such as underground corrosion, railroad failures, and fire prevention, as well as standards and research for new technologies like radio and aircraft.

But the next really important event in determining the nature and character of the Bureau did not come until May 20, 1920. In my view, this was second in importance only to Stratton's hiring, and to understand its significance we have to discuss the Bureau's activities in the First World War. In Cochrane's words,

> . . . there was scarcely an investigation of the National Research Council or the War Industries Board, or a problem of the military services in which the Bureau was not concerned in one way or another. From aircraft construction to camouflage, from coke-oven investigations to concrete ships, from precision gages to illuminating shells, from optical glass to rubber, from submarine detection to X-rays and radium research, the Bureau participated in almost the whole range of America's wartime effort.

The best-known of these efforts was the glass plant which produced (not merely studied, but produced) optical glass for the whole war effort, and was still producing optical glass during the Korean War. Similar comments could be made in spades about the Bureau's activities during the Second World War and the Korean War, where the best-known outputs were the proximity fuze, guided missiles, and electronic computers.

Now, it is important to note that these activities had little to do with the fact that the Bureau was the Nation's central measurements and standards laboratory. Rather, it had more to do with the fact that the Bureau was peopled with capable scientists whose talents could be turned to the solution of problems brought about by the war effort. It was technology development, but not technology development limited to measurement technology; it included a much broader range of activities—the development of products. The effort in the First World War extended the Bureau's horizons beyond measurements, standards and data.

But our concern right now is how all of this activity was financed. Largely, all this work was for mission agencies—primarily the military—who had the responsibility for pursuing the war. Now, the Bureau had done work for other agencies before the war, but in doing so, no funds were transferred from the other agencies to the Bureau. Rather, the Bureau used its own funds or requested special appropriations from Congress for the work. Agencies simply did not have the authority to transfer funds among themselves, although it was occasionally done. However, to improve efficiency, during the war the Congress passed the Overman Act, which permitted the transfer of funds from one agency to another to carry out work the transferring agency needed to be done. With the end of the war, the Overman Act expired, but the military still had a lot of work it wanted the Bureau to carry out, and Stratton, who was against the idea of transferred funds, was induced to ask Congress for authority to receive funds from other agencies. Thus it came about that the appropriation act for FY 1921 contained a codicil that permitted the Bureau to receive funds from other agencies. The Bureau was the only agency that had this privilege until 1932 when the Economy Act permitted such transfer among all agencies.

The appropriation act of 1920 permitted the camel of other agency money to stick its head into the tent, never to be removed and changing forever the lives of Bureau middle management. In later years, a new requirement for financial entrepreneurship was added to their functions, along with new bosses in the form of clients. Many are the division and section chiefs who, when faced with a sudden loss of a hundred thousand dollar contract, wished the camel had never been allowed near the tent.

But it seems to me that this authority to accept other agency money had an even more profound effect on the Bureau. During the war years the Bureau had shown that it could engage in unfettered technology development, and could do it very well indeed. Now, absent some Bureau policy to the contrary, it had a mechanism by which it could continue this type of work—at least for specific clients. A whole new horizon had manifested itself. As we shall see, in the aftermath of World War II the march toward this horizon would become so great that the Bureau's principal horizon of providing new and needed measurements and standards for emerging technologies would be obscured.

The Bureau after World War I, imbued with confidence after its performance during the war; believing that the military work it had done had industrial value; and having formed a new, trusting relation with industry; undertook, in Stratton's words, "to carry out the applied research for industry that industry could not do for itself." It declared itself "fundamentally concerned either directly or indirectly with the improvement of the methods of production or the quality of the output" of industry. It wanted to occupy "somewhat the same position with respect to the manufacturing interests in this country that the Bureaus of the Department of Agriculture do to the agricultural interests." Thus, in 1920, with special appropriations from Congress, new programs in metallurgical research, high temperatures, industrial research, sound, industrial safety, automotive engines, and standardization of equipment were begun. One of the first results of this new policy was the installation of the industrial research associate program, and by 1923, 21 associates representing 18 industries were at the Bureau.

Then, in 1921 Herbert Hoover became Secretary of Commerce and reinforced and took over these industrial aims of the Bureau. Reacting to the short but intensive recession of 1920 and 1921, his prescription for the recovery of industry was through "the elimination of waste and increasing the efficiency of the commercial and industrial systems ..." His prime candidate for spurring the economy was home construction, for it promised the quickest means of stimulating other industries and providing work for unemployed. He thus formed a Division of Building and Housing *in his own office*, with a program at the Bureau to provide scientific, technical, and economic research; simplification and standardization of building materials; and revision of municipal and state building codes. Also established at the Bureau were divisions of simplified practice and trade standards, again with counterparts in his own office. In modern parlance, they were activities programmanaged from downtown. Hoover's program included direct assistance to both new and established industries, with specific help for the new aviation and radio industries. And spurred by Hoover's campaign against waste in industry, the Bureau began investigations on the utilization of raw materials, the quality of manufactured articles, and on new uses for industrial by-products.

Now, Karma and I have not done the research this period merits, but when I look at the results of all these activities, I come to some tentative conclusions. When the Bureau provided support services in its traditional outputs of measurement methods, standards, and data, the programs were quite successful, as for example in properties and dimensions of building materials, and in automobiles where the Bureau developed the octane rating for gasolines. When it came to providing new technologies, as in the production of chemicals from sugar wastes, the record of success is not great, nor is it in the production of sugars. For example, capitalizing on its knowledge of sugar chemistry arising from the assay of sugar for customs purposes, and on its wartime success in developing an industrial process for the production of dextrose, the Bureau had great technical success in developing manufacturing methods for levulose and xylose, but failure economically because the price was far too high and the market far too small. But, when the market or the client were well established as in the development of aircraft equipment, success was high. What I deduce from this period of the twenties is that despite its technical capabilities, the Bureau was not an industrial research laboratory, for it lacked the supporting structure provided by marketing and manufacturing divisions that those laboratories need. But it is fair to say that in this period, the Bureau and industry came to know one another better—not always a frictionless process.

I want now to jump to a date of immense historical interest to the Bureau and in fact the world. This date will prompt me to make some remarks about what happened to the Bureau during the great depression of the thirties.

On October 11, 1939, Alexander Sachs delivered to President Roosevelt the fateful letter from Albert Einstein and a covering memorandum from Leo Szilard alerting the President to the discovery of nuclear fission and hence to the possibility of a new and immense source of energy, and possibly even an atomic bomb. Who was the President to turn to for advice? It was a matter that had to be kept in the official family and not complicated by military prejudices, so he called on Lyman J. Briggs, Director of the Bureau, the only non-military laboratory around. The story from then on is well known: how the President appointed an Advisory

Committee on Uranium with Briggs as its chairman; how some seven months later, still under Briggs, this became the S-1 Section of the National Defense Research Council; how in 1941 this was transferred to the Office of Scientific Research and Development; and finally, how the final stages of research and development of the atomic bomb were taken over in 1942 by the Army Corps of Engineers as the Manhattan District.

Dr. Briggs' operation of the Advisory Committee on Uranium and its successor S-1 Committee has received some criticism. Cochrane writes,

> It was an awesome responsibility that had been thrust upon Dr. Briggs. In his 66th year . . . he had witnessed a serious reduction in Bureau funds and staff . . . . A younger man might have seized on the adventure into the unknown promised by nuclear fission, but Dr. Briggs had learned to be cautious. Nor was he at all certain that this was the kind of research, or direction of research, in which the Bureau ought to become involved. He and his committee hesitated.

I. I. Rabi, quoted by John Newhouse in his book *War and Peace in the Nuclear Age*, is more direct. "[He] was out of his depth," Rabi is quoted as saying, "and that held things up for a year."

Strong words, and they merit attention, so let me now enter into some speculation, and before I begin, let me assure you that I know that the Bureau did very important work for the atomic bomb project on the purification of graphite and uranium, and in the development of analytical methods. With that aside, let me continue with the main thread of our story. Trained as a soil physicist, Dr. Briggs could hardly have been expected to know the ramifications of nuclear fission. But what does a director do when confronted with a problem of this type? Why, he calls in his experts to advise him. And it appears that Briggs did so, for Fred Mohler, spectroscopist-atomic physicist Chief of the Atomic Physics Section, who had worked with Harold Urey on the preparation of heavy water, accompanied him at the first meeting of the original Uranium Committee. But the Bureau had no program in nuclear physics. Indeed, the Visiting Committee had earlier recommended that further research in heavy water be stopped. When one looks at the early experiments that were done to determine the possibility of a chain reaction in uranium, and to the participants in the meetings of the uranium and S-1 committees after the first, one is struck by the fact that no Bureau names appear, except Briggs, of course. The Bureau had simply not kept up with the so-called "new physics." This was in fact centered in the European—and particularly German—universities, and until the great migration of physicists to the United States in the thirties, only a few American universities whose professors had been trained in Europe, could be said to have "kept up."

And what about the Bureau? Its staff had dropped from about 1,100 in 1931 to less than 700 by mid-decade, and by 1939 was only again approaching the level of a decade earlier. It could not afford the luxury of expanding into a new and esoteric field that, at that time, had only a distant connection to its measurement and standards mission. Indeed, a few of our distinguished alumni recall that in the late thirties some noted professors of physics did not have a high regard for the scientific program of the Bureau. Thus, in my untutored view, it is possible that Briggs' dilatory response to the problem the President laid before him was not due solely to his own personal characteristics, but to the fact that his organization could not provide him the support he needed, for it, in turn, had not had the support it merited. Had it received that support, the Bureau, and perhaps the Nation, might have become quite different places. If there is any validity to this speculation, and any moral to this story, it is that if you have an organization that is your principal scientific arm, it is well to be sure that it is properly nurtured.

Now I want to jump again in our historical trek to the post-World War II years. In April of 1948, Merle Randall, Professor Emeritus of Chemistry at the University of California at Berkeley, known to the chemistry world because of his co-authorship with G. N. Lewis of the definitive text *Thermodynamics and the Free Energy of Chemical Substances*, and now a consultant, wrote to George Vinal, Chief of the Electrochemistry Section, about a product of one of his clients. It was a mixture of anhydrous sodium sulfate and slightly basic anhydrous magnesium sulfate which, when added to a lead-acid battery, allegedly improved its performance. Thus began the famous battery additive—or AD-X2—incident.

Now, it is not my intention to subject you once again to a recounting of this episode. But I do want to touch on some salient points. In its testing of battery additives—primarily for the FTC and the Post Office Department—the Bureau had come to the conclusion that none of them was helpful, and specifically stipulated all preparations of sodium and magnesium sulfates in its publications. Moreover, the Bureau had the policy of not naming any proprietary products, and of not carrying out tests for private concerns. Thus a manufacturer could claim that his product was different from the general class, and that by its condemnation without testing, the Bureau was restricting the business of the manufacturer. This loophole in the Bureau policy was brilliantly exploited by Jess Ritchie, an aggressive and charismatic entrepreneur of Oakland, California, whose product, known as AD-X2, was what Randall wrote about to Vinal, and which, in fact, had many satisfied customers in the Oakland area. The Bureau eventually carried out exhaustive tests on AD-X2 and found it ineffective, but could not convince Ritchie.

The AD-X2 affair began in 1948 and ended in 1953. Before it was over it caused the firing of the Bureau's director, Allen Astin, followed by his partial and eventual full reinstatement. It brought the wrath of the scientific community down on Secretary of Commerce Sinclair Weeks because his statement before Congress that in its work on AD-X2 the Bureau had not sufficiently considered the play of the market place, was widely interpreted to mean that science should take political considerations into account in its technical judgments. It made the Bureau front-page news for months and gave political cartoonists a field day. It caused six days of hearings before a Senate Select Committee. It caused a large number of the Bureau staff to threaten to resign. And, most important for our purposes, at the request of Secretary Weeks, who would later become a strong champion of the Bureau, it caused the investigation of the Bureau by a high-level committee chaired by Mervin Kelly, President of the Bell Telephone Laboratories. Another high-level committee, the Jeffries Committee, investigated the Bureau's work on AD-X2 and found it impeccable.

Thus began the fifties, one of the most fateful decades in the Bureau's history. Table 2 shows some of the events of this period.

Table 2. The Fateful Fifties

1950	A new Organic Act, and an unfulfilled vision
1951	A Director resigns under attack
1953	A new Director and his Bureau come under attack
1953	The first Kelly report
1954	Advisory committees formed
1954	A Post-Doc program is instituted
1950	Boulder is acquired
1956	Gaithersburg proceeds toward reality
FY 1957	A new accounting system is instituted, and the Bureau comes out ahead

First, in 1950, a new Organic Act was passed. Despite being considerably more detailed than the original act, it was not greatly different from it, and did not materially change the Bureau's operations and philosophy. But an event that occurred during its evolution is interesting for something that did *not* occur. The revision of the Organic Act came about because Henry Wallace, when he became Secretary of Commerce in 1945, wanted to develop a program for the Department and asked Dr. Briggs to prepare a revision of the Organic Act. In his original draft, Dr. Briggs proposed a new function for the Bureau which, had it been part of the final legislation, would have completely changed the future course of the Bureau. The proposed function reads: "The prosecution of basic research in physics, chemistry and engineering to promote the development of science, industry and commerce." Such a function would obviously have dramatically changed the future of the Bureau. It would have gone from the Nation's measurement and standards laboratory with all of its basic research deriving from that function to an institution with a far broader and more general mandate.

But this was not to come about. On the Visiting Committee at that time was Vannevar Bush, who had just finished writing *Science: The Endless Frontier*, which was to lead to the formation of the National Science Foundation in 1950. Wallace of course sent the proposed legislation to the Committee for their comments, whereupon Bush wrote that he felt the Bureau should do basic research, but ". . . it should be unmistakably clear that the major emphasis should remain on its unique assignment in the field of standards." Briggs' clause did not appear in the final bill.

Then, in late 1951, at the height of the AD-X2 affair, Edward Condon, a great and charismatic scientist who had succeeded Dr. Briggs as Director in late 1945, resigned, a victim of the Nation's obsession with communism. He was succeeded by the steadfast Allen V. Astin, a man with a peerless sense of Bureau mission, and of unparalleled personal and official integrity. Thrust into the turmoil of the AD-X2 episode, he guided his Bureau safely through some of its most trying days, and for 17 years led it to some of its most productive and rewarding times.

But the most important event for our purposes is the Kelly Committee. Formed by Secretary Weeks at the height of the AD-X2 affair to "evaluate the present functions and operations of the National Bureau of Standards," its report was one of the most important documents in the Bureau's history, and its recommendations formed the agenda for a large part of Astin's tenure as Director.

To understand the report, it is well to put it in context. It was written in 1953 at the climax of the AD-X2 affair, which in fact brought it about. As a result of the Korean War, the Bureau, with a staff of some 4,800, attained the largest size in its history. But 85 percent of the work was for other agencies, most of it for the military. A large part of that was weapons development work, and even more of it was what I earlier called unfettered technology development. The work on its basic standards mission had shrunk, and the Bureau was in danger of becoming an appendage of the military at a time when science and technology were growing explosively and clamoring for new measurement methods and standards. Kelly's committee wrote, "Since 1950, the decrease in basic programs must be considered as tragic," and, "The presence of these [weapons programs] in the Bureau is impairing its effectiveness for its primary functions and making it difficult for the Bureau to build strength for the future." While recognizing that much of the other agency work was valuable and of the same type the Bureau would do on its own, the committee recommended the divestiture of the weapons work. At the stroke of a pen, as Jacob Rabinow will tell us about this afternoon, 2,000 people were transferred to the military as the Diamond Ordnance Fuze Laboratory and the Corona Missile Laboratory. Less than a year later, the Institute for Numerical Analysis was transferred to UCLA under the name Numerical Analysis Research. It was left to Astin to find increases in the Bureau's direct appropriation for work on its basic mission, a quest that the launching of Sputnik in 1957 helped greatly. But even with this massive divestiture it was not until 1960 that other agency funds dropped down to 50 percent of the Bureau's total expenditures. The Bureau had been in danger of forgetting its basic reason for existence, and the Kelly Committee brought it back to its true function.

Another recommendation of the Committee was that advisory committees for each division be formed, and this was done in 1954. It is difficult for those of us who came after that date to conceive of a Bureau without evaluation panels, but for more than half its history the Bureau had none, except the Statutory Visiting Committee.

A few other events happened in the fifties. Under the leadership of Joseph Hilsenrath and David Mann, the Post Doctoral Research Associate Program was instituted in 1954, although one person, known as the "zeroeth" post doc came in 1953. She was a woman. Probably no other program has done as much for the scientific competence of the Bureau.

There were also two changes that materially altered the Bureau's fiscal operation. First, it was permitted to retain fees for standard samples and calibrations, fees which were previously sent to the Treasury. This increased Bureau funds by almost two million dollars annually. Second, a working capital fund was instituted, thereby partially lessening the onus of yearly appropriations.

Finally, the Bureau increased in extent, if not in personnel. In the fifties Boulder was acquired, as we shall hear from Dr. Kamper, and the seeds for Gaithersburg were planted, as we shall hear from Mr. Walleigh. The fifties were busy years indeed.

Let us now jump into the sixties, and the last two dates I will discuss before turning over the floor to Dr. Branscomb. Early in the decade, Allen Astin, responding to the urging of the Secretary of Commerce that members of the Department develop and transmit suggestions for strengthening its programs, submitted a bold proposal indeed. I think you will find this proposal interesting in view of the development of NBS into NIST. In agreement with an Academy of Sciences report that I will discuss later, Astin strongly stressed the need for strengthening the scientific activities of the Department. But he felt that report did not go far enough in its recommendations, and that "the great dependence of commercial and industrial growth upon science and technology requires a more unified and dynamic approach." Then, citing scientific activities in the Department of Defense, the Department of Agriculture, and particularly the National Institutes of Health, he finds ". . . no comparable program within the government department entrusted with promoting the Nation's commerce and industry." Astin particularly notes "the serious international competition for technological and economic leadership." Seems to me we have heard those words recently.

To help remedy these various factors, Astin, clearly with the National Institutes of Health in mind, proposed the formation of a major new research and development agency to be called the National Institutes for Physical Science, the subunits of which would have Bureau status. There would be new national research institutes in such areas as new materials, automation and production processes, construction, communication, transportation, fire research, quality control, and engineering standards. Other functions would be the provision of services such as measurement standards and services, the acquisition of precision data, and the operation of scientific information centers. Importantly, the new institutes would support applied research important to industrial economic growth in private institutions through contracts or grants.

The Bureau itself would either become, or provide a nucleus for, or be merged with, a number of new institutes: a National Materials Research Institute, a Communications Institute based on the Central Radio Propagation Laboratory, a National Construction Research Institute. The computer program would become a separate program or be merged with an Automation and Control Institute, and the commodity standards work could be included in a Quality Control and Engineering Standards Institute. Echoes of this organization are clearly found in the NIST legislation.

Astin had plans for all the other agencies of the Department, but to discuss those would take us too far afield.

The plan was immense in its scope and grandeur, and Astin writes the perceptive words,

> To a limited extent the Department and NBS are now attempting to perform a few of the functions of a Department of Science and Technology. NBS has frequently been requested to take on technical activities quite distinct from its central measurement-standards mission and certainly not related to its name primarily because there is no other suitable place within the government for the location of a particular program.

Toward the end of his proposal, Astin shows his personal feelings. He writes,

> [This] proposal . . . is made with mixed feelings on my part since it involves, if accepted, a loss of most of the present programs of the National Bureau of Standards and at least a major part of its present identity.

Alas, Astin need not have feared. His proposal would result in something quite different from what he had in mind.

In 1958, doubtless happy with the Kelly Committee report on the functions and operations of the Bureau, Secretary Weeks asked the National Academy to form another committee to evaluate the functions and operations of the Department of Commerce to ensure that it was fulfilling its responsibilities in the interest of science and technological progress. A committee was formed, again under the chairmanship of Dr. Kelly. On March 1, 1960, the committee submitted its report—a second Kelly report. This 103-page document contained detailed recommendations for all the scientific agencies of the Department, but only a single recommendation that pertained to the whole department. The recommendation was that a position of Assistant Secretary for Science and Technology be formed. This was done, and as we all know, the first occupant of that position was the forceful and dynamic J. Herbert Hollomon of the General Electric Research Laboratory. Now, Karma and I have not yet studied in detail the interaction between Hollomon and Astin, so we cannot trace through its full course. What we do know is that Astin detailed Irl Schoonover to work with Hollomon. What eventually happened was that Astin's proposal for a National Institutes for Physical Science became something quite different. In 1964, the Bureau *itself* was reorganized into three institutes and one laboratory: the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, and the Central Radio Propagation Laboratory. It was the first major reorganization of the Bureau in its history, and made a profound change in its management operations. Rather than having roughly one and a half dozen divisions reporting to him, the Director of the Bureau now had only four Institute Directors, and, of course, a Director for Administration and a Deputy Director. But to show that some of his proposal had inspired the new organization, Astin reported to his division chiefs that while the Bureau would continue to be called the National Bureau of Standards, it would be subtitled the Institutes for Science and Technology, or IST. This was not to be the case. The Bureau would remain NBS until 1988, when NIST was formed.

At various times in this talk I have made reference to the nature and character of the Bureau. What do we mean by this? Let's look at some characteristics of the Bureau. The Bureau has always prided itself on the soundness of its technical work, but this is hardly a unique distinction; all great laboratories do the same. More distinguishing is the fact that in its unique measurement-standards function, after a short start-up transient, it become one of the premier standards laboratories in the world. I believe that can be traced to the freedom the permissive Organic Act gave it, and, of course, wise management leadership at all levels. But perhaps most instructive is to look at how the Bureau describes itself. When doing so it uses adjectives like "objective," "unbiased," "impartial," "neutral," which are adjectives normally used for judges rather than laboratories. This usage can be traced directly to the Bureau's lack of regulatory function. Since the custody of the national standards places it in the position of arbiter in questions of measurement, the court of scientific inquiry forces it to search for scientific truth as its only recourse in rendering judgments, hence these adjectives. And the Bureau has been adaptable. Either because of direct assignment or because of assistance to another government agency, the Bureau has always been ready to undertake work on a national problem, real or perceived.

Perhaps the best way to think of the Bureau is by a corporate analogy, with the Nation it serves as the corporation. That Nation has many laboratories, and many agencies with well-defined missions, corresponding to the corporate divisions. These laboratories cannot be concerned with national problems outside their mission. The Bureau is quite different. While it had a very specific mission, the rest of its legislation was so broad that it could work in almost any area it could justify, and it was called on to work on national problems as they arose. It was allowed to carry out work under contract for other agencies of the government. In the corporate analogy, the other laboratories are divisional laboratories, carrying out work that fosters their agency, while the Bureau is the central, or corporate, laboratory, concerned with all the problems of the corporation and in the process carrying out contract research for the divisions.

Let me close with a comment on the metamorphosis of NBS into NIST. From an admittedly cursory and superficial reading of the NIST legislation, I find that it embodies and formalizes characteristics the Bureau had, and activities it carried out at one time or another. In my view, it represents a confluence, if you will, of trends that were always there. Considering the Bureau's performance throughout its history, this bodes well for the future.

Joint Institute for Laboratory Astrophysics

Lewis M. Branscomb

Introduction by Emanuel Horowitz

For our next presentation we have a videotape of Dr. Lewis Branscomb. He has asked me to express his regret in not being here, but at this moment Lew is on an exciting expedition stomping through the jungles of Costa Rica with an expedition from the National Geographic. We hope to see him when he comes out, of course, but you'll be seeing him on tape today.

Dr. Lewis Branscomb came to the National Bureau of Standards in 1951. He later founded the Joint Institute for Laboratory Astrophysics at Boulder, Colorado. He was appointed by President Nixon as the Director of NBS in 1969. He left NBS in May 1972, to become Vice President and Chief Scientist of the IBM Corporation. He is now a professor and Director of the Science and Technology Public Policy Program at The John F. Kennedy School of Government at Harvard University.

Now, I will take just a moment since we are letting some skeletons out of the closet here, to recall an incident with Dr. Branscomb. I was at a meeting with Jack Hoffman, who was then the Director of the Institute for Materials Research. We were talking about, as John Lyons was this morning, funds and programs, and things of that sort. There arose, of course, a difference of opinion. Jack turned to Lew Branscomb and said, "Well, you tell me what the definition of a standard reference material is." Lew looked him in the eye and he said, "A standard reference material is a material that is a standard when I say it is." At that moment, I grabbed Jack's leg to keep him in the chair. We'll now hear from Dr. Lewis Branscomb.

HISTORICAL PERSPECTIVE: 1969–1973

Lewis M. Branscomb

Thank you, Manny, for that great introduction, and "Happy Birthday" to all my friends at "the Bureau." I'm sorry I can't be with you. I am, at this moment, somewhere in the jungles of Costa Rica or Honduras with the National Geographic Society, making it look like work. I wish very much I could be with you on this ninetieth birthday of the National Bureau of Standards, now the National Institute of Standards and Technology (NIST).

As a name, the "Bureau" sounds strangely archaic, like a piece of furniture. For years, we tried to find a better name, and yet we realized that the Bureau of Standards had earned a level of respect that very few government agencies ever achieved. Now a new world has come to the laboratory with new challenges and new opportunities. The most important goal everyone at NIST should have is to ensure that in time the name NIST also conjures up an image of a scientific and technical institution of the highest competence and of incorruptible values.

It was just 20 years ago, in September 1971, that I asked our legislative committee in the House of Representatives, then called the Science and Astronautics Committee, to recognize the Bureau's seventieth anniversary by undertaking an in-depth review of the Bureau of Standards—the goals, structure, operations, strengths, problems, and opportunities. In a few minutes, I want to recall some of the testimony that I gave at the time. My testimony and that of our Institute Directors is contained in a public report, the 1971 Annual Report.[1] But first, a little stage setting.

When I was Director, John Rooney of Brooklyn, chaired—maybe I should say owned—the Subcommittee on Appropriations for Commerce, State, and Justice. Preparing for testimony before John Rooney was an agonizing affair, though not quite so agonizing as the experience of testimony itself. He ate government officials for lunch. I remember that with the extraordinary help of our budgeting and planning offices, we went to those hearings with two notebooks of about 500 pages each, containing materials which I had, in effect, memorized. In addition, the staff had a lot more back-up material. My theory was that the right way to win over John Rooney was to play an anti-political game. I meant to convince him that, with me as the example, the Bureau of Standards consisted of a group of very serious, very high-minded, very dedicated professionals, who knew what they were doing, knew why they were doing it, and who did it better than anybody else could do.

One piece of preparation for that testimony was particularly essential. I knew that he had harassed Allen Astin, my predecessor, unmercifully ever since the Gaithersburg facilities were built. His leading question usually was an effort to trip up Allen with some piece of knowledge that he should have known but didn't: "How much was spent for the flagpole in front of the main building in Gaithersburg?" I knew the answer. It was $44,000 and some odd dollars. I had it down to the cents. Rooney always took great delight in accusing the Bureau of Standards of profligacy because of that stainless steel flagpole. I suspect that flagpole was a bargain. In any case, it served a useful test of our ability to meet John Rooney on his own terms. And, to anticipate just a bit, in that 1972 appropriation year (the budget prepared in 1971), we got through President Nixon and John Rooney a 36 percent increase in the research funds for the Bureau of Standards. When I finally left NBS in May 1972 to go to IBM with a good conscience, little did I realize that Nixon would be re-elected and would impound every nickel of the increase that we had worked so hard to win. But it was a satisfactory demonstration of what one had to do in order to win the support of a Congress composed of people who had very little understanding of what we were about.

While it was indeed clear that Congress knew little about the agency, the public knew less. NASA had just spent $20 billion going to the moon. The Atomic Energy Commission had spent at least as much learning everything about nuclear science and engineering. Well, almost everything. We knew that we did more for America per dollar spent than either of them, but our problem was how to break out of the constraints of seeming to be an old line agency in a department everyone loved to hate. Larry Kushner was my Deputy. He was an important part of our success. One day when I was in despair about our relationship with the Department of Commerce, Larry Kushner explained to me why we had so much aggravation in our relations with the Department. "The Department of Commerce," he explained, "is the only department of government with a hostile constituency." The business community had not yet learned how severely it was being challenged by foreign competitors in technology who were themselves being

[1] *National Bureau of Standards Annual Report 1971.*

helped materially by their own governments. Our business community was still fighting its government.

The Associate Directors and I changed the program structure of the Bureau so that the Congress, the press, and the public could understand, perhaps, the purpose and value of what we did. All of our program elements were re-defined in terms of the benefits that they would produce. When I was all done, Churchill Eisenhart came to me and showed me the Bureau's Annual Report of 1918. It turned out that I had re-invented the Bureau's program structure from fifty-four years earlier.

In those days, we also established a more collegial system for managing the Bureau of Standards. In addition to Larry and me, our three Institute Directors were Ernie Ambler, Jack Hoffman, and Karl Willenbrock. We had three special program areas. Ruth Davis managed the Computer Center, Ed Brady the Office of Information Services, and Dan De Simone the National Metric Study. Our planning and administration were run by Howard Sorrows and Bob Walleigh. It was a terrific team.

I discovered that, as Director of the Bureau of Standards, I had more clout in Washington than I had realized, primarily because of the agency's extraordinary reputation for integrity. NBS enjoyed a particularly good reputation with foreign embassies. Ministers of Technology and Industry in other countries looked at the Bureau of Standards and identified it as the U.S. agency most adept at providing the underpinning of the technological success of American industry. Perhaps they gave us more credit than we were due. But it gave us a lot of self-confidence that we were on the right track, even if the rest of government didn't fully recognize the power and importance of what we were doing.

I decided it was time to go public with the NBS story. Our team pulled the cloak of obscurity off of the Bureau's vital contributions to the nation. And, by the way, I believe it is time to do that again. In a lecture I gave at a review of the Bureau's history in 1987, I made the following comments:

> The Bureau learned to keep its head down over many years of serving as the arbiter of technical disputes in and out of government. This is a necessary form of behavior for an organization that is asked to make value-free determinations of technical facts, and it's appropriate behavior for an organization that values its integrity above other qualities. But there are other reasons NBS does not follow traditional paths to the development of political constituencies, through which it can increase its budget in pursuit of its goals.
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> First, the Commerce Department has been an uneasy foster parent in most Administrations. [Here again, I quoted Larry Kushner.]

Let me say we had another thing going for us—a record of distinguished leadership unmatched in government, and I'm not talking about me, but about Samuel Stratton, Edward U. Condon, and Allen Astin. Also, the Bureau of Standards had never seen its directorship used for political purposes. I think that's a strong statement, but I challenge you to find another agency to match it.

Remember that after the election of 1972, when Richard Nixon had his staff demand the undated resignations of all 3,000 presidential appointees, Robert Marston, then Director of NIH, was asked to resign. He refused and he was fired for refusing. No NBS Director has ever been replaced routinely after an election to make room for a political appointee. Now, I'll admit we finessed that possibility a few times. I left in May of 1972, so that the search for my successor was already underway before the election, and therefore was not a political choice.

One word about Ed Condon, who would have wanted to be here in this room today. Ed is famous for many things, but I think his most important contributions to the Bureau of Standards lay in two areas. One was his enormous personal courage. He lived his values and he expressed them openly and clearly to the Congress and the public. But secondly, I think it was he, more than anyone else, who put the Bureau of Standards on an irreversible commitment to absolutely first-rate basic science, competitive in quality with the best universities. Look back to the 1930s and think about the NBS alumni of those days. Many subsequent Nobel Laureates and very famous scientists called the Bureau of Standards home.

Ed Condon recreated that capability after the War, and we are still the beneficiaries of it. One of the best examples is the experiment proving the non-conservation of parity in weak interactions performed by the team of Ambler, Hayward, Hoppes, and Hudson. Let me quote just a moment from the testimony that Ernie Ambler gave in those hearings in 1971. After describing the number of projects at the Bureau of Standards that were recognized in Nobel Laureate acceptance speeches as critical to the success of Nobel Prize work, he said,

> We are proud of our participation in these distinguished efforts, and we remember that we were able to contribute

> because good science and good measurements go hand in hand. Once we lose this connection, we regress intellectually and our technical work gradually degenerates. If this should happen, our efforts would be of no use to anyone. I am pledged to assure that this never happens.

Ernie was as good as his pledge.

Allen Astin should be here, too. Indeed, I'd like to propose that an effort be undertaken by John and his staff to persuade the Commerce Department to ask Congress to rename the Gaithersburg laboratory after Allen Astin, or at least to name the Central Administration Building after him. It was he who almost built this with his own two hands.

Secondly, I'd like to suggest that everyone on the staff of the Bureau of Standards who is under 57 years of age, and everyone who has been hired since 1956, should be required to go to a special lecture on the history of the battery additive AD-X2 issue. If there's anyone in this room who doesn't know that story, then "for shame." That was the time Allen Astin maintained the integrity of the laboratory against extraordinary odds. He had been removed from his job by the Secretary of Commerce during the early days of the Eisenhower Administration as a result of a serious political challenge to the technical objectivity of the Bureau of Standards. I'm not going to go back through that story now. All the old-timers here lived through it and remember it well. The Bureau stuck to its guns when it was under heavy fire, when distinguished organizations like MIT did very little to help (that's an understatement). Finally the scientific community and the industrial community rallied to the Bureau's side. The National Academy of Sciences wrote a thousand-page report on the Bureau's technical work, which began with a conclusion that the work the Bureau of Standards had done to prove the correctness of its work in this case has advanced the science of electrochemistry by at least a decade. The report completely exonerated the Bureau of Standards. Mervin Kelly, then president of Bell Laboratories and head of the Statutory Visiting Committee, not only exonerated Allen Astin's management, but helped set the Bureau of Standards on its postwar course, back to good science and to service to American technology.

In view of the fact that NIST (I still have trouble calling the Bureau that) now stands on the threshold of a new era in government technology policy, where NIST will—or should—play a very central role, I want to hark back to what I told the Congress in 1971 about the Bureau of Standard's purpose in society.

> If a free enterprise economic system is to thrive in a modern industrial society, indeed, if it is to survive, buyers and sellers in the market place need to have as much confidence in the quantity, performance, and quality of goods exchanged as they do in the amount of money that's paid. A substantial part of the Bureau's measurement research is devoted to the validation of fair, objective, and useful measurement methods for application to both durable and non-durable goods in trade. A laboratory of this type, with a 70-year tradition of scientific excellence and integrity, finds itself not only in great demand, but acquiring additional major responsibilities that go far beyond the specific research requirements for the national system of measurement.
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> We were established by the Congress to be helpful, and we find ourselves a critical link between the basic research community and those who have put science to work for the benefit of man. [I should have said "of mankind."] As the decades have passed, the Bureau has responded to the country's problems as they arose, in war and in peace, in times of rapid scientific growth, in times of scientific retrenchment and serious domestic problems. Throughout the thousands of useful projects at NBS runs a common thread. The Bureau helps others with applied research services to produce, diffuse, and enhance the value of practical knowledge. Our goal is to strengthen and advance the nation's science and technology, and to facilitate their effective application for public benefit. In short, to make science useful and technology the servant and not the master of people.

That, to me, is still a wonderful statement of what the Bureau of Standards is all about. I closed with these words to the Congress:

> I believe the National Bureau of Standards faces the most challenging opportunity of any large research laboratory in this nation. We have the right competence in the right organization at the right time. We are effectively engaged in a way that I think is unique in bringing science and technology to bear on national social and economic problems, as well as on our scientific achievements. Our scientists understand the complexity

of the social context within which their research must find application. We enjoy a generally excellent reputation among those who know our work, even though we have not been very active in making ourselves known to the general public. I am deeply concerned that disillusionment may follow if government fails to promote innovation in the productivity of our technology, and fails to guide the regulation of technology on the basis of objective evidence in fair and accurate measurement. We see the national measurement system and a system of industrial and engineering standards as dynamic systems, calling not for more stewardship, but for more leadership.

I believe that the disillusionment I forecast twenty years ago has indeed affected the American spirit, the American attitude about our national competitiveness. But, on the other side, after many years of delay, Americans are now beginning to recognize the changed nature of science and engineering, the changed status of the American economy, and the need for a more supportive role by government for industrial competitiveness. The starting point for that recognition is awareness that the spinoff model for commercial benefit from mission-driven Federal technology is not a sufficient view of how the government should help. That is, the AEC/NASA model is not enough. Neither is the DARPA model. In the future the Defense Department will not be in a position to use its budget to support the industrial base, but indeed, will have to work hard to draw upon the industrial base which others will have to support. By the same token, the heroic big science model is also shown to be the wrong approach, for precisely the reason that its benefits, if any, largely must flow through that indirect spinoff.

Back in 1971 and 1972, when I was NBS Director, Bill Magruder, who had headed the SST Project in Transportation, moved over to the White House to work for John Ehrlichman. They made a big effort to establish in the budget a program called the New Technology Opportunities. This was to be a set of multi-million-dollar big engineering developments of heroic technologies. I remember one of the projects was a one-megawatt superconducting motor generator set. I represented the Commerce Department on the White House Committee that studied the NTO. The idea was finally scrubbed, and instead, with virtually no notice, the Bureau of Standards was asked to put into the budget justification for a $44-million program called ETIP (Experimental Technology Incentives Program). With the launch of ETIP, the Bureau of Standards was set on a new path towards the correct government relationship with the private sector.

Last September 26, there was an extraordinarily important event that has almost completely escaped notice in the evolution of the debate about industrial policy and science policy. As you know, the nation is very comfortable with its *science* policy. The nation is, however, quite uncomfortable with the idea of *industrial* policy. Now attention is shifting to focus on an intermediate notion: a national technology policy. Last September, the President's science advisor Allan Bromley sent to the chairmen of the two Appropriations Committees in the Congress an extraordinary document. It is entitled, "The U.S. Technology Policy." Some of my friends at Harvard tell me that the most important part of this document is the title page. The mere fact that John Sununu, Richard Darman, Michael Boskin, and the President have signed off on a U.S. technology policy, with an explicit Federal role, is news in itself. But to me, the really interesting thing about this document is the first one and a half pages. This statement of U.S. goals for its technical enterprise is almost entirely devoted to the concept of diffusion of technology, its beneficial use, and the environment within which innovation is to take place. I believe that this emphasis is much overdue.[2] NIST is very well positioned to carry out such a diffusion-oriented technology policy.

This document also contains an explicit endorsement of the Advanced Technology Program, which was put in place by Congress in the Omnibus Trade Bill of 1988. In a very carefully hedged paragraph, Bromley endorses the precompetitive, generic enabling technology activity to be carried out in cooperation with private industry. If you were the President, how would you go about assessing the value of the nation's $73 billion worth of Federal R&D to the private sector? Once you had considered all of the indirect benefits, which are not insignificant, from the mission-oriented agencies' work, you would have a residue of issues which are not sufficiently well served by spinoff, and that needs to be addressed by some agency.

Most obvious in that list would be areas of technological knowledge of importance to industrial performance but little seen in Federal mission-oriented research. Take, for example, the whole issue of process technology, the characterization of processes so they can be automated, and the

[2] L. M. Branscomb, "The Emerging U.S. Technology Policy," *Issues in Science and Technology* Vol. VII, No. 4, pp. 50–55, 1991.

characterization of materials and determination of their properties, so that both design and production technology can be codified, simulated in computers, and used in automated manufacturing. This is not the world of the future, but of the present for those high-tech industries that are highly competitive. This is an area of strength at NIST.

The NIST is the only government research organization whose technical capability is not constrained by an operational Federal mission. NIST is not defined by responsibility for a particular technology. It is defined instead by the functional requirements of its mission to help the scientific and industrial base as a whole progress technically.

There are three major areas in which the Federal government should move ahead in the direct funding of technical activities meant to be important to commercial industry. My co-authors and I call them "strategic," "pathbreaking," and "infrastructural" technology investments.[3]

In a very limited number of cases there is an industry needing specific help, and where a short-term, relatively low-risk, but probably expensive technology program should be put in place to produce a specific economic result. SEMATECH is an example. This comes as close to industrial policy as anything that the government can or should do. Such strategic technology interventions should be done very selectively. There are times when it's appropriate. That kind of activity may be carried out by any number of agencies, including the Department of Commerce.

Secondly, the government must continue, as it did so importantly right after World War II, to identify the truly pathbreaking, technical opportunities in which the risk and the time required to find out whether or not science will allow the vision to be realized is too great for intensive private investment. Such opportunities may have the potential to create whole new industries. DARPA has been particularly effective at identifying such pathbreaking technologies and probably should continue.

The third type of technology investment is in infrastructural technology, or, if you like, in the diffusion of generic technology. The diffusion process has two major parts: industrial extension, with which NIST is experimenting, and science and technology information policy and services, where the Bureau of Standards has always had an important role. The importance of these activities has been seriously underestimated by those who make national policy.

NIST's research and diffusion services and those of the Bureau of Standards before it, have been of great value to the competitiveness of American industry. I also believe that this value has been severely constrained by the historic restriction of all this work to internal research within a single national laboratory. If we all believe that what the NIST does is the right recipe for an ailing economy, then it is hard to avoid the conclusion that similar work should be supported in industry, universities, and other national laboratories, pursued with the same levels of quality and the same careful relationship with the end user that has characterized NBS and NIST work. I know that if the budgets for those grant and contract programs have to flow through the Commerce Department, there's clearly an opportunity cost for the growth of NIST, but I see no way to avoid it.

My concluding remark is that as we think about what the NIST Advanced Technology Program should be, we have a model that has been successful for 90 years in NBS. The infrastructural investments that NBS has made can, if multiplied in scale by a factor of ten, truly improve the competitiveness of American industry without interference with markets or private business judgements. There is a larger range of technological activity that should be viewed as "public goods" than there used to be. The ATP is in its early stages, feeling its way. The initial grants seem to me to look more like DARPA programs than NIST's traditional work in infrastructural technology. I hope that as the program evolves, the synergy with NIST traditional work will grow stronger.

Finally, let me just say that after 21 years in government, of which I was proud to be a civil service scientist, and after 14 years in industry, in which I learned a great deal that's useful to me, I've been back in the university world for five years at the Kennedy School of Government at Harvard. Ours is a professional school for public service. We hold high in our regard the meaning and importance of public service, especially in science and technology.

My experience in these three sectors of our nation's technological life convinces me that each sector's ability to contribute is greatly enhanced by the contribution of the other two. For NBS and NIST this is not a new discovery, as it may be elsewhere in government. In the next 90 years NIST's role in helping all American institutions contribute to a stronger national capability will be more urgently needed than in the past. I am sure NIST will rise to the challenge.

[3] J. Alic, L. M. Branscomb, H. Brooks, A. Carter, and G. Epstein, *Beyond Spinoff: Military and Commercial Technologies in a Changing World*, Boston, Harvard Business School Press (to appear 1992).

Ernest Ambler

Introduction by Emanuel Horowitz

Our next speaker, Dr. Ernest Ambler, of course needs no introduction to this audience. Ernie first came to the National Bureau of Standards in 1953 as a Special Research Fellow and, as Lew Branscomb reminded us, was a member of the famous team that conducted the world-renowned parity experiment. Ernie served as the Director of the Institute for Basic Standards from 1968 until 1973. In 1978, he was appointed by President Carter as Director of NBS and retired as the Director in April 1989. But he mentioned that he also served as the Acting Undersecretary of Commerce for Technology, a very important post. He's now the Director Emeritus of this laboratory. It is a privilege to introduce Dr. Ambler.

HISTORICAL PERSPECTIVE: 1973–1989

Ernest Ambler

Dick Roberts was sworn in as seventh Director of NBS on February 5, 1973. He remained Director for two-and-a-half years and I was his deputy for two of those years. After he left NBS on June 28, 1975, I became Acting Director. I was sworn in as Director on February 3, 1978, and retired from that position on March 31, 1989, although for the last few months I was acting in the newly created position of Under Secretary of Commerce for Technology with my office in the Commerce Department. Ray Kammer, my deputy, was acting in my place at NBS. I have been asked to cover, therefore, a period of some sixteen years spent in the Director's Office in one capacity or another. These years started in Nixon's second term and ran through the Ford, Carter, and Reagan terms and into the Bush Administration.

In the forty minutes I have available I cannot pretend to do justice to everything that happened, nor can I claim to be as objective as I expect Elio Passaglia will be in his history. I am going to talk about those events that have left an impression on me.

Dick Roberts came to NBS because of Art Beuche. Beuche was head of the General Electric Company's Central Research Laboratory in Schenectady, and Roberts was one of his senior people. Beuche was also a member and ultimately Chairman of the NBS Statutory Visiting Committee. Beuche prided himself on his ability to communicate to top management the nature of the work of his laboratory and its importance and ultimate utility to the company. Roberts was a "whiz" at the kind of "show and tell" that Beuche's method demanded. By comparison Beuche thought we at NBS did an absolutely lousy job in marketing our wares to our bosses in the Government and thought Roberts was just the man to come down and show us how to fix this deficiency. This attitude was held in spite of the fact that government laboratories and corporate laboratories do not operate under the same set of constraints. If anyone had wanted proof of this they needed only look at the FY 1973 budget. Lew Branscomb had obtained a very big increase for NBS; I think it was $22 million although about half of that was for that OMB brainchild, ETIP. Unfortunately that was the year of Nixon's "impoundment," and much of the increase was rescinded or deferred to future years. So the connection between "show and tell" and budgets was hard for most NBS old-timers to swallow.

Nevertheless Roberts came to NBS with this background and with great energy and drive. Dick had an almost insatiable need for personal support, and he knew how to beat it out of the system, and what is more important, he knew good work when he saw it.

Looking back, three things that Roberts insisted on developing stand out in my mind as having been internalized by NBS and serving the institution well in the nearly two decades that followed.

First, the ability to do "show and tell," albeit toned down in "glitz" from the way Dick liked it, beefed up a bit in technical content and executed by a wide range of NBS staff members. Most effective were presentations that many NBS scientists and engineers learned to give in their laboratories to DOC, OMB, and Congressional staff members who seemed to grow yearly in numbers.

Second, the final welding together of the Program Office, the Budget Office and the Accounting Division into one single effective unit called the Office of Programs, Budget and Finance. A great deal of good work led by Howard Sorrows had already been done in this direction, but Roberts wanted more and he entrusted that job to me. In the crucial support, single-mindedness, and perhaps at times ruthlessness I needed, I was helped by Tom Dillon, whom Roberts had handpicked to come to Gaithersburg from the Boulder Laboratories, and Ray Kammer, whom I stole back from the Department of Commerce.

Third, the greater importance attached to the Office of Congressional Affairs to which Roberts had recruited the ever-conscientious Esther Cassidy. The increased activity and emphasis on information exchange with Congressional members and their staff turned out be important in many ways. To give you an idea of the level of activity in the one year 1984 alone, 120 Congressional staff members came to NBS laboratories for briefings.

This last activity contributed greatly to Congress holding 1977 Authorization Hearings, the first held since 1971. This ended their reliance on a "continuing authorization" and began regular annual authorization hearings starting in 1979 with a so-called "field hearing" in the Red Auditorium at NBS with George Brown and Don Fuqua attending.

The holding of annual authorization hearings was, in my opinion, absolutely key later on to saving such NBS programs as Fire, Building, and Computer Sciences, cut by the Administration in each of the fiscal years 1984, 1985, 1986, 1987, and 1988. Congress was also key in giving us a Personnel Management Demonstration Project, an expanded program authority and name change, and helping in many other ways.

During practically all the sixteen years I spent on the 11th floor of the Administration Building, a large fraction, I'd say about a third, of my time was devoted to the budget in one way or another. Most of that effort, until about 1987 at least, was defensive in nature, in the sense that we were constantly under attack, always determined and sometimes vicious. To give you an idea of the level of "jerk-around" we endured, during FY 1982 we were required to do 18 budgets, each with different line items, totals and justifications and many of them with turnaround times of a day or two. In FY 1980-82 we took a personnel reduction of over 400 and had to separate about 150 staff members. Yet during that period NBS continued to do world-class research, to start new programs, to build new facilities and to develop and start implementing a whole new strategy for carrying out our mission. Whether those who judge more objectively than I will agree remains to be seen, but this is the thread that runs through my story of the decades of the seventies and eighties and one I believe worth telling.

Before I get into the story, let me go back a bit and cover a memorable meeting in the Director's Office on March 1, 1976. At that meeting, Elliot Richardson asked me to become Director of NBS and I agreed. I mention this because prior to that time I had made it clear that I really did not want to be the next Director. In fact, I had been formally asked to be Director and had declined. Why did I say "no" then and change my mind later? Dick Roberts had come to NBS as a young, up-and-coming champion from the industrial sector; he stayed only two and a half years. Lew Branscomb, was admired by all of us at NBS for his accomplishments as a scientist and for his part in the establishment of JILA. He was well-known in national science policy circles and clearly Allen Astin's choice to follow him, a choice that met with fairly universal acclaim. He quickly made his mark as Director by getting an appreciable increase in NBS's appropriations but did not stay to see the impoundment. Whatever the reasons for their short tenures, the prospects facing any new Director were not very attractive, especially with the justification of federal budgets getting ever more difficult. Besides, one had the feeling that the scientific and technical community thought that if a real "mover and shaker" were appointed, the forces arrayed against agencies like the Bureau could be overcome. Well, I was not convinced that the "great man" theory was correct, and in any case I knew I was not such a person. I was prepared to hold the fort in an Acting capacity, and indeed I did for over two and a half years with the able and trustworthy Bob Walleigh as my Deputy.

Elliot Richardson convinced me that this was not the way to look at the situation and that, indeed, I was the right person for the job. He viewed government service as honorable. He felt government agencies such as NBS, whose mission he understood quite well, should be led and staffed by people who could bring a high level of professionalism and objectivity to the job. Reliable facts, integrity and character is what he looked for—traits that he, himself, had so clearly and recently displayed. He convinced me to give it a try. I did know what the institution stood for, I believed in it fervently, and I enjoyed working with its staff—they were my friends and my colleagues. I did not relish the thought of working with the government machinery outside NBS, but I was prepared to be patient and take it on, expecting a long struggle and gaining a little at a time rather than a lot of moving and shaking. I guess the highest level of confidence I could muster was that, given the outside circumstances, I could probably do the job as well as anybody else, certainly over the long run, and I felt the long run was what you had to play for.

In having occupied every technical level in the line organization from laboratory researcher to Director, I had learned a lot. I knew that as a practical matter at NBS it took at least five years to get a worthwhile program established. You generally had to start small with what you had. You had to have the right champion. You gradually accumulated bits and pieces from other programs, you worked hard and tenaciously for other agency money and tried to hire some new people, and you pursued any outside cooperation or cost sharing you could get. Above all, in the STRS budget process, you kept coming back and improving your presentation and your own sense of conviction and commitment. "Keep on leaning" became my motto—a far cry from "moving and shaking."

What I have just said is more by way of tactics. As far as strategy is concerned I knew of no approach that convinced me other than that of going to our roots and examining our mission for its uniqueness. The Bureau had done outstanding work and championed causes such as energy conservation, consumer product technology, automotive safety, and environmental protection, only to find the primary mission given to other agencies and to find OMB promulgating the "lead agency" policy, i.e., don't ask us for the money, get it from the lead agency—the one with the primary mission. In addition, Congress, wanting to get us involved in many areas where our expertise would be beneficial, wrote us into fourteen new pieces of legislation over about a ten-year time frame starting in the mid-sixties. Many of these assignments we welcomed, such as those contained in the Fire Safety and Control Act which authorized the right program at the right time to the right agency. But this assignment and many others were never properly funded. Indeed, later on the Administration tried to wipe out the Fire Program as being work inappropriate for the federal government and more appropriate for private industry. In contrast $10 million was put into our budget to fund ETIP, the brain child of OMB. This was to be a program to find ways to stimulate the entrepreneur by removing barriers to innovation. Perhaps it is somewhat uncharitable of me, but I cannot help recalling that the high point of the program was a government procurement standard for safe lawnmowers. The achievement was reported in Dan Greenberg's *Washington S&T Newsletter* under the heading, "ETIP Cuts a Small Swath." ETIP limped along only for a few years after that and then disappeared, I think to everyone's relief. Certainly mine.

But criticism is easy, and finding successful alternatives was not so easy. I wanted to focus direction on the very reasons that NBS was established in the first place. Measurements, standards, and data of technical excellence and usefulness is where I felt compelled to start. Such work served many groups in our society, and I often used the theme, "Everybody uses standards whether they know it or not," as a starting point for talks. I would give examples of such utility to individual citizens, state and local governments, institutions of many kinds, and always very impressive to me, to U.S. industry. But with the prevailing administration philosophy of getting the government out of industry's business, pushing our industrial connection too hard was dangerous. Under those circumstances it was difficult to get really hard-charging—an overall that making presentations on measurements, standards, and data tends to put people to sleep. Our first opportunity came with the publication in May 1983, of the Packard Report on Federal Laboratories.

The findings and recommendations of the Packard Report gave a great boost to my confidence in my own instincts. These instincts stemmed from the Organic Act and the Committee Report establishing the Bureau. Allen Astin had spotted the crucial paragraph in the Committee Report and had it chiseled in marble in the lobby of the Administration Building for all to see. Just to be certain I understood clearly the five recommendations of the report, I made an appointment to see David Packard and spent about an hour talking to him in his office in Palo Alto.

The first of the recommendations on "Missions" and the fifth on "Interactions with Universities, Industry, and Users of Research Results" were particularly confidence-inspiring. Let me quote from the first.

> Of the laboratories visited, those with well-defined missions clearly were better performers than those with poorly defined missions. These laboratories with both well-defined missions and close interaction with the users of their research appeared to be the most effective of all.

Let me also quote from the fifth recommendation.

> The Panel feels that the degree of interactions of Federal laboratories with university and industry varies among laboratories, but has not been strong traditionally. The national interest demands that the collaboration be stronger to ensure continued advances in scientific knowledge and its translation into useful technology.

These two recommendations provided the necessary boost for us to go all-out in assisting economic growth through providing support for U.S. industry and of using cooperation between government, industry, and universities as a major tactic. We began to measure in dollars the support we got through assistance in kind and as a matter of policy to increase it as fast as possible. By 1986 we had 255 Industrial Research Associates at NBS, three times as many as in 1980. In 1987 we had 244 cost-sharing interactions with 174 separate U.S. companies. The loans and gifts of equipment, particularly computers and materials, increased rapidly.

In the decade of the eighties while our STRS budget remained flat, our funding from other government agencies and our earned income through fees roughly doubled, all in terms of constant dollars. Thus the *total resources* available to NBS during the eighties increased about 30 percent in constant dollars, and that gave us the flexibility to start new programs and get things done. For comparison during this same period the NSF budget increased 38.5 percent and total Federal R&D spending increased by 40.8 percent, all in constant dollars.

I should point out that this kind of strategic emphasis at NBS was already being given in a lower key way following my trip with Ed Brady to Japan in April 1980. The relative loss of our industrial efficiency and premium quality of our products was becoming evident in consumer electronics and automobiles as it had been in shoes, textiles, and steel in Hollomon's day. After all, the first U.S. trade deficit occurred in the 1963-64 period. Hollomon's strategy of direct government intervention through such efforts as the State Technical Services Act brought him down in the end. Later on Jordan Baruch's cooperative technology had just gotten started when it was wiped out by the next administration. With the ideology prevailing in the Reagan Administration we had to be careful, and even then we nearly fell flat on our face. Our automation program, which we had been carefully building following the strategy I have described, was visited by Doug Pruitt, Deputy to the President's Science Advisor. He felt this was private-sector work and told OMB to cut it out. Fortunately, by this time Secretary Baldrige had learned to really approve of our programs, especially the one on automation, and he intervened personally with Stockman to not cut the program. The program was saved and continued to grow rapidly, mainly with Navy money.

Before leaving the Packard Report I have to mention two of its other recommendations. The second recommendation on Personnel led directly to our being given the "Personnel Management and Demonstration Project" which was implemented on January l, 1988, as a five-year experiment. This came about because the report praised the China Lake experiment and recommended more institutions be given similar authority. But it was Congress who thought it would be a good idea to give us such authority, and did so over the objections of the Administration.

The fourth recommendation related to management and said that laboratories should rely more on peer review and less on internal government layering and micromanagement. This gave a big boost to the importance of our Statutory Visiting Committee and the NRC Boards of Assessment.

There is one other major event I must describe, because it was an essential piece in the development of NBS. This was the big reorganization that occurred in 1978 when Carter was President and Jordan Baruch was Assistant Secretary. In my own mind the new major feature of the reorganization was the formation of the National Engineering Laboratory and a deliberate change in the emphasis of much of the work that had made up the Institute for Applied Technology. IAT had never really been an engineering organization, nor was it ever intended to be. It was a creature of Hollomon, Schon, and Eberhard, and had a strong orientation to socially oriented problems and solutions. There is no doubt that extremely important problems were identified, and there was a strong emphasis on new ways to look at problems and find solutions. Some programs such as that of the Technical Analysis Division had been very successful and in great demand. Unfortunately they ended up doing a job that the "Beltway Bandits" learned to do equally well and so OMB wiped them out—competition with the private sector again. The Fire Program had finally done a good job on flammable fabrics but only by bringing in leadership from elsewhere in NBS, from universities, and from industry, as our new Director will recall. But most activity in IAT was not my idea of engineering. There were some programs that formed good bases for future growth. Jud French's program on test methods for semiconductor devices, again largely supported by DOD and championed by George Heilmeier then at ARPA, was combined with parts of IBS in both Gaithersburg and Boulder which were in need of closer coupling with users. Thus the Center for Electronics and Electrical Engineering was formed.

A small effort in robotics started by Ruth Davis while Roberts was Director, was combined with work in modern dimensional metrology and a program on the automation of coordinate measuring machines led by John Simpson, to form the Center for Automation and Manufacturing Engineering.

The Building Technology program was focused more sharply on the civil engineering aspects and away from many of the architectural, aesthetic, and social aspects that had been introduced earlier. With these and other changes, I sensed by about the end of Reagan's first term that NBS had achieved a new unity on the right purpose and a level of mutual respect among different parts of the organization that I had not felt before. Even the Boulder Laboratories were drawn into all aspects of NBS programs, and managers in Boulder began to have to manage things in Gaithersburg as well, instead of everything being the other way around. There did remain one exception and that was ICST. ICST suffered because it derived its function from the Brooks Act rather than the Organic Act. The purpose of ICST was to write standards and guidelines for the purchase and effective use of computers in the federal government. Ruth Davis had boldly construed the mission to be broader in computer sciences, but she was alone in that. In fact in 1983 OMB suggested that the logical thing to do was to transfer ICST to GSA which, after all, was the appropriate lead agency for government procurement. It was in that same year that, in my view, the big turnaround came in ICST. The big weakness in the implementation of the Brooks Act was that federal government purchases accounted for only a fraction of the total computer sales in the United States, and administrative-type computing was light years behind the private sector. It is only a slight exaggeration to say that standards for computers in the private sector was basically a proprietary matter and what wasn't could be safely left to CBEMA. What chance did little ICST have?

The day of reckoning came when the big users of computers tried to interconnect their computers and try networking between different companies or different divisions of the same company, all of whom had systems bought from different vendors. The time involved in writing and debugging customized interface software became horrendous, and the banks, the insurance companies, General Motors, and so on got really mad. The ICST staff members were quick to make their acquaintance and to show them how the U.S. Voluntary Standards System worked or could be made to work. At last ICST was in on the big commercial picture and that was a mission that could be derived from the Organic Act as well as the Brooks Act. When ICST began to build testbeds such as the Network Protocol Testing Facility, it began to look like a real NBS operation. In July 1984, along with Boeing Computer Services, the General Motors Corporation, and thirteen computer and communications companies, they organized on the exhibit floor at the National Computer Conference in Las Vegas, a big network demonstration project using the IEEE Local Area Network Standards and the draft ISO Standards for Network Communication. Whether they wanted to be or not, ICST truly qualified to be part of NBS, and as a tangible demonstration we gave ICST three-quarters of a million dollars in precious competence-building funds to start boosting their basic research base in computer sciences. At last I felt I could defend the ICST programs to people in the Department, OMB, and Congress with understanding and conviction.

I do not need to take much more time belaboring "the slings and arrows of outrageous fortune," but I have to mention a few other things that stand out in my mind as rather major trauma. There was the Grace Commission, otherwise known as the President's Private Sector Survey, whose first suggestion was to eliminate four or five of our Centers. There was the attempt by OMB to eliminate our Post-Doctoral Research Program rescued again by Congress. There was a constant drive for "privatization" and "contracting out"; they even went after our library. Then there were the perennial drives to cut travel, printing, reproduction, consulting, and the like. There was a new grand Departmental reorganization proposal called DITI, the Department of International Trade and Industry, in which we were to become part of NSF. There was a move to force our NRC Boards of Assessment to come under the rules for governmental advisory committees. Budget battles went down to the wire. I remember watching on C-Span our Authorization Committee Chairman, Mr. Walgren, debating Mr. Walker of Pennsylvania on the floor of the House. Walker's famous statement was "If we can't cut NBS who can we cut?" and his amendment to do just that lost only by five votes out of the four hundred cast.

Many of these battles could be confined to the 10th and 11th floors of the Administration Building to a large extent because of the work of the Office of Programs, Budget and Finance, and the Office of Congressional Affairs. Vital to me was Peggy Webb, who had taken charge of me the moment I set foot on the 11th floor and Ray Kammer, by now my Deputy and alter ego, who took so much pressure and irritation off me, and whose knowledge of the budget process had been and continued to be indispensable.

I would not want you to think, however, that the marvelous scientific and technical work of NBS went unnoticed by me. Far from it, I took great pride in it. Not the least, I was able to see our international prestige shine in my official capacity as U.S. Delegate to the General Conferences held in Paris under the Meter Convention, in which I was assisted by my friend and international travelling colleague and advisor, Ed Brady. Over a period of some twenty years the meter, candela, volt, and ohm were all redefined using the results of the most exquisite scientific investigation. The leadership in this research and the bulk of scientific data came from NBS. The names and detailed experiments I would love to recount. In the time available, clearly I can't. Let me say I remember the work of Bruce Steiner, Jon Geist, and our Australian friend and Guest Worker, Bill Blevin, in getting the candela based on the physical quantity, energy. I remember Dick Deslattes and colleagues in Gaithersburg; Jan Hall and Dick Barger in Boulder; and Ken Evanson, Don Jennings, and numerous collaborators also in Boulder, and their fantastic experiments that led to the redefinition of the meter, the fixing of the numerical value of that fundamental constant, the speed of light, and a big leap forward in the technology of frequency stabilized lasers. I remember the work of Barry Taylor's Division on the Josephson Effect and the Quantum Hall Effect and Barry's own work on the Fundamental Physical Constants. I also remember the work of Dick Kautz and others in developing the One Volt Josephson Junction array, praised by none other than Barney Oliver of Hewlett Packard as "brilliant."

I hope I never showed partiality toward certain divisions of NBS even though I did have my favorites. The Time and Frequency Division was one, because I always felt that the activities encompassed the full range of projects that IBS divisions should. In particular the work of Dave Allan on

UTC and time synchronization, most recently involving the Global Positioning System, stands out in my mind.

Another of my favorite divisions was the Analytical Chemistry Division for similar reasons. Their series of clinical Standard Reference Materials represent quintessential NBS work, and the use of their analytical organic chemistry program as a springboard to get NBS into biotechnology was forward-looking.

I remember Dick Deslattes' pioneering work on the X-ray interferometer, XROI as he called it, and his obtaining a new value for Avogadro's constant; Mike Moldover's redetermination of the Gas Constant; Jim Faller's work on "g" and his search for the fifth force.

As an old low-temperature man I marvelled at the work of Bill Phillips in Gaithersburg and Dave Wineland in Boulder on cooling and trapping atoms and ions to sub-millikelvin temperatures by shining lasers at them, Jan Hall in JILA "squeezing" light in seeming contradiction to the Uncertainty Principle, and also Jan's work on the tests of the Theories of Relativity.

The work of Bob Celotta and colleagues in inventing the Spin Polarized Electron Microscope and instantly applying it, with people from various industries, to high-density magnetic disc technology stands out as a substantial achievement. I remember this work particularly vividly and somewhat shamefacedly because I did not think it would work. It was Ray Kammer and Karl Kessler who had faith, gave Bob encouragement and provided him funds when they were in very short supply.

John Cahn and colleagues created quite a stir when they found crystalline, or quasi-crystalline, materials with fivefold symmetry. We all learned how you can have fivefold rotational symmetry without translational symmetry and got a big kick out of playing with colors in tiling patterns. We also got a kick out of seeing John debate Linus Pauling and win!

The year 1985 was one of pride when NBS won top place with a record number of eight winners in the IR-100 contest and received a letter of congratulations from the President.

For stamina and the ability to "keep on leaning," Bob Carter, Jack Rush, Mike Rowe, and others at the NBS reactor set a great example. I remember when the reactor was designed at the old Van Ness Street site, the design power was 20 MW and there was provision for a cold neutron source. Twenty years later we finally scrounged enough money to go up to full power and in 1985 received our first appropriation of $1.5 million for the Cold Neutron Source.

I remember in 1984 the Center for Automation and Manufacturing Engineering demonstrating the Interaction Graphics Exchange Specifications and its seemingly never-ending "openhouses" demonstrating the ever-widening possibilities for manufacturing. And then there was its work with CEEE developing SRM 474, the linewidth standard to be used in integrated circuit manufacturing, and the fine workshops that went along with the purchase that were designed to show people how to use the SRM correctly.

NBS has a long record of service in failure analysis, and I believe that is a theme Elio is going to trace in his history of NBS. None was more timely, dramatic, and effective than the analysis of the skywalk collapse at the Hyatt Regency Hotel in Kansas City. Standing out in my mind was the big press conference held in the Green Auditorium to announce our findings. The handling of that by Ed Pfrang, Dick Marshall, Mat Heyman, and others was one of the most professional public meetings I have seen.

As well as the sublime, we also accomplished the ridiculous. In testing the Newman machine, Bob Hebner and others in CEEE deserve our heartfelt thanks. With dead seriousness they followed a court order to test a perpetual motion machine and did a serious and careful job with good humor, putting up with Jake Rabinow's sarcasm—and never cracking a smile!

With a staff capable of achieving the kind of high-level work I have described, we felt our budget labors were worthwhile. We did have some budget successes, and some of them made profound improvements in our situation. We were able to add $15 million to our equipment fund to help modernize our equipment inventory. With a lot of help from our Visiting Committee and Jordan Baruch, we added a total of some $8 million to our long-range research base through the so-called "Long-Range Competence Building Program." We installed a completely new and modern telephone system.

The story of the upgrading of our scientific computing capability is a saga in every sense of the word—a story of heroic achievement and marvelous adventure through the labyrinths of government regulations and administrative controls relating to the purchase of computers in the Federal government. Ignoring rather feeble and unsuccessful attempts in the 1975-76 period, the story does not really begin until long after the days when the Univac 1108 was shamefully out of date and I think not yet paid for. The barriers we faced, mostly outside NBS but some of them inside, in mounting the job of putting together the needed justification and pushing it through the system were mountainous. We needed to go from the level of the 1108 to the level of the Cray, and we needed to put together a requirements study showing why we needed such a big jump in computing power. Scientists at NBS who needed to do a lot of computing had given up on NBS and made deals of various kinds outside. Many had, regrettably, decided to do without large-scale computation altogether. It is no wonder we had the devil's own time getting NBS scientists to respond to our first attempt to do a requirements study. Those who believed we were serious felt, if we were to be successful, the money for the new computer would end up coming out of their program funds. It was a desperate moment when I was left with the only optimist I could find at NBS, namely Eleazer Bromberg. He and I got down into the grubby details and designed a detailed form to get needed information. I made the members of the Executive Board, the Center Directors, and Division Chiefs personally responsible for making sure every scientist and engineer filled out a form and was forward-looking in his or her projections for future computer use. We had to make them go back and do it over several times. Burt Colvin and his Center for Applied Mathematics, at first reluctantly then with stoicism, became the focus of a complicated and ever-expanding effort to do the necessary follow-up work. Glen Ingram was hired as a manager for getting a salable justification together, later Steve White was hired to head up a procurement team, and then Dick Penn was hired to head up a site preparation team. I had all these groups, Guy Chamberlin and his main staff, and many more meet monthly with the full Executive Board in an ADP Policy Committee which I chaired personally. I became a sort of program manager and I am sure a real pain in the rear end to many people. The whole thing started in early 1980 and led to a budget request in FY 1982 of $9.7 million in what was to be a first installment in a five-year, $27 million item for computing capability. The plan was to have a new computer by 1983. But with real money appearing we began to get all kinds of help in how to spend it. The Department decided to combine us into a big DOC Central Facility, Congressman Brooks requested a GAO study, and on and on. We were told to get an interim computer and then to negotiate a lease/purchase arrangement. I really can't remember all the difficulties and disappointments. I do remember Burt Colvin threatening to commit hari-kari on the rug in my office about once every month. The effort was truly Herculean and full of pain and suffering all the way. But we prevailed. A new computer was delivered and accepted in 1985 and became fully operational in 1986. We kept on adding through annual appropriations and in a decade invested about $60 million in scientific computing. There were many concomitant and beneficial effects on the way. Our administrative computing went onto an entirely different and more suitable machine belonging to DOC in Suitland. Our networking became much more sophisticated, new staff skilled in advance scientific computing were attracted to the Applied Mathematics Division, and first-rate mathematical software was made available on the new machine. We also tackled another program that had tied us up in knots and confused and complicated the problem of scientific computing. That was office automation which we approached in a separate way. Here I was helped, not to say pushed, by Patsy Saunders who was then in the Program Office, but who later was set up with her own group to deal with the problems. We knew each office had different word processors and associated software, little was interchangeable, and secretaries and administrative aides were having lots of problems, and many were too scared to ask for help. Their immediate bosses ended up helping because there was nowhere else to turn. Many ended up as what I called Ph.D.s with screwdrivers. Some, such as Merrill Hessel, out of desperation, designed complete administrative systems on their own, and that formed a great source of knowledge and expertise. In principal, the solution was simple: standardize the PCs and word processors; standardize the software; provide training classes, local help groups, a "PC Newsletter," and understanding and sympathetic help from Patsy's group. If you used the standards you got all kinds of help. If you didn't use the standards you were on your own. I think it worked.

That is quite a lot of time to spend on telephones, office automation, and computers, but they took a lot of effort. I should also mention, before leaving this general area, the big help laboratory automation was given by Julian Whitaker's group, for example, in the standardization and stocking of microprocessors and related items in our storerooms.

At a place like NBS there are many non-technical things you can do to support your staff and to try to keep up morale. Some of these can be quite small in terms of cost, such as an annual Christmas visit to all the support groups, which was hard on the Director's feet and even harder on Guy Chamberlin. Others were truly pioneering such as that of the Standards Committee for Women in converting Bowman House into a day-care center. In the same year we opened an exercise facility and encouraged aerobic dance classes, jogging, bicycling, volley ball, softball, soccer, and, in fact, any non-country club type grunt, groan, and sweat exercise. We did this knowing that exercise is a wonderful antidote to stress—and there had been plenty of it at NBS—as well as being generally beneficial to health and, therefore, efficiency. We also converted the modular house, no longer needed by CBT for energy conservation studies, to be the headquarters for NBS Radio Amateur Club. We also let them put up fairly big antennas all over John Brewer's grass. Finally, I am proud to say we encouraged and helped with establishing this Association of Alumni, because so many made such a request following the Allen V. Astin Memorial Symposium in 1985.

I have saved until last a personal view of my last two or three years as Director. Apart from my years as a researcher with Ralph Hudson in the Low Temperature Laboratory, they were my happiest at NBS. During this time there developed a very close relationship first with Bud Brown, the Deputy Secretary, and then Bill Verity, the Secretary. It makes a big difference when you feel your boss understands and likes what you do. You will recall that one of the first things the Reagan Administration did was to abolish the Office of the Assistant Secretary for Science and Technology in DOC. That meant the Director reported directly to the Secretary.

Mr. Baldrige did visit NBS many times; he liked our work, understood our mission, approved of it and went to bat for us a number of times. Mr. Baldrige did meet each year with our Visiting Committee for at least an hour and showed genuine interest in what they had to say. But he did not have time to see us often, and his deputy, Jim Wright, was a financial type who dealt mainly through the budget shop.

I do remember vividly Baldrige's statement to me on departing from NBS after his first visit. "Ernie," he said, "you have the best damned lab in the whole Federal government and nobody knows anything about it." This shook me up no end, especially after all I thought we had learned in Roberts' day. I did try to protest that the R&D side of industry knew us well and that we were well covered in the Trade Press. His reaction was immediate and full of scorn. What he wanted was coverage that would be read by industrial CEO's and the like. So I got Mat Heyman to go to work on Baldrige's request and, after a lot of hard work, I was able to send him in 1987 a box of clippings for the year from such journals as the *New York Times*, *Wall Street Journal*, *Washington Post*, *Business Week*, *USA Today*, and many more. I got a very nice letter back expressing his appreciation for what we had accomplished.

My relationship with Bud Brown got off to a rocky start in a matter connected with the Congressman Walker episode I described earlier. A big change for the better came with the "Emerging Technologies Report" first published in 1988. It all started at one of the quarterly management-by-objectives meetings we were required to attend down at DOC. When someone asked us a question, after a rather long and tedious session, as to how we knew that such and such a technology would be important to U.S. industry, I replied, in a somewhat testy way, that everybody knew what technologies were emerging in this way. Bud seized on this, told me he was setting up a DOC Task Force with me as Chairman to list those technologies and state which industries would likely be affected and what the impact would be on the GNP by the year 2000. I saw this as a great opportunity because I knew we could do the job. I plucked out Ken Gordon from the Program Office to help me. The initial job was really quite easy, so we went further. We listed what we thought would be the barriers to the deployment of these technologies of U.S. industry. Bud was delighted. He got all the Assistant Secretaries and Under Secretaries together several times and had them comment on the report. Only a few minor changes were made in the barriers section, and then Bud decided he wanted to launch the report at a big press conference. Mat Heyman was dead set against it. "It's not news," he said "nobody will show up." We all had made the mistake again that we thought we were dealing with information that was rather obvious and commonly available. What we hadn't figured on was that this was the first time such information had ever been assembled in this way in a short, concise report. Bud had his way, the press conference was a great success, and Bud and I were off on the speaking circuit. I'm glad that these reports are now being updated and improved by NIST and that others such as DOC and OSTP have followed suit.

After Malcolm Baldrige's tragic death in 1987, Bill Verity became Secretary and immediately came out to NBS for a visit. He and I hit it off right away, and I like to think it started on the steps in front of the Administration Building. He had just arrived, and we were trying to look relaxed as Mark Helfer was taking pictures. Trying to make small talk, I remarked that when I was a boy in Yorkshire my father used to take me to see the matches of the champion Yorkshire County Cricket Team. The success of the team was due in no small part to a famous left-handed spin bowler by the name of Verity. Captain Verity, as he later became, was tragically killed in the Italian campaign in World War II. Anyway, I started to tell the Secretary the story and he immediately interrupted and said, "Yes, I know, Hedley Verity from Hebden Bridge." Now Hebden Bridge is one of those small West-Riding of Yorkshire villages nobody who lived more than fifty miles away had ever heard of. And who would know Verity's given name was Hedley? Apparently the Secretary's grandfather, or great-grandfather, I don't remember, came from that area, and Bill Verity himself had been back there as a young man to play in a golf tournament. Everywhere he went the first and only things the locals wanted to know was whether he was any relation to Hedley Verity. Perhaps I attach too much importance to this story, but I think it is worth telling to friends. Anyway, it was a pleasure to work with Mr. Verity, and he helped us in many ways, not the least of them in getting the Malcolm Baldrige National Quality Award off the ground.

The assignment of managing the award came to us very quickly after Congress named the award as a memorial to Malcolm Baldrige. Mr. Verity thought the award was a good thing for the country, wanted it to rival the Deming Award in Japan, and wanted it implemented during his tenure as Secretary. That meant moving very quickly, especially against the difficulty that no funds were provided and most of the work was to be done by the private sector. It was not just a matter of getting the job done, it was a question also of mobilizing the private sector to do it. Fortunately for us, Curt Reimann felt he knew how to proceed. Curt had been trying for some time, but without success, to get the Executive Board to start a program at NBS on Quality Control, broadly construed and going beyond the measurements and standards aspects of it. Curt had made himself very knowledgeable with quality control methods used throughout the world and had made many contacts with the professional community inside the United States. When the Malcolm Baldrige Award came along it provided a good opportunity to get started on quality control methods, and Curt was the right person for the job, in fact the only person. The scope of the job would have stunned most people. Funds had to be raised from the private sector; various professional advisory groups were needed; a large number of qualified examiners had to be recruited; and they all had to be paid somehow. Curt went to work and the response from the private sector, much of it volunteer effort, was outstanding. Sandy McDonnell of the McDonnell Douglas Corporation and John Hudiburg, CEO of Florida Power and Light, agreed to chair the fundraising effort, and many people went to work defining the exact nature of the program and the rigorous criteria for success. Inside the government we all went to work for Curt Reimann. Bill Verity asked for a progress report every week and saw to it that no bureaucratic roadblocks stood in our way. I remember one critical period where we were trying to get a firm commitment from the President to present the awards personally and a firm date at which to do it. Things dragged on with no White House response, so I explained the critical state of affairs to the Secretary. Right away he had Curt and myself go with him over to the White House for a half-hour meeting with Reagan's Appointment Secretary. He let me make the pitch which was one of the most passionate ones I have made in my life—my reputation with Curt depended on it—and we got the commitment. President Reagan presented the first awards on November 14, 1988, and then Vice President Bush and several cabinet officers came also.

Verity was ecstatic. Curt got a bonus, and since I was not eligible for bonuses, Verity gave me the Secretary of Commerce's Medal which was the first time the medal had ever been given to a government official. More important, the award established a very high reputation for thoroughness and objectivity. The application guidelines have now become so well known and highly regarded that they are widely used as a sort of textbook or roadmap to quality control by industry. This year it is expected that some quarter of a million copies will be used for that purpose.

By this time, things had also moved rapidly on other fronts. The Omnibus Trade and Competitiveness Act was passed containing, in Subtitle B, new programs for NBS and a name change. The bill made it clear that NIST had an important new assignment over and above the functions of the Organic Act. The intent was clear to have NIST "... assist industry in the development of technologies and procedures needed to improve quality and modernize manufacturing processes ..." and also implicit that this new function should receive equal if not greater emphasis than that of providing basic standards and measurements. Congress was tired of the mission of NBS being narrowly construed. Congress wanted to expand our vision, our influence and our funding and help us achieve our full potential in the way we worked with industry, small as well as large. To duck such a challenge, even if we could, would not only be faint-hearted but foolish; we would have become the mother of yet another agency by starving ourselves.

On another front, Secretary Verity wanted to enhance the role of technology in the Department. He believed the use of technology was vitally important to the U.S. economy, indeed his own company had thrived on it. He wanted to create a position of Under Secretary of Commerce for Technology and he looked for support for this idea. The Patent and Trademark Office and NTIA did not want to stop reporting directly to the Secretary. That left us, NTIS, and what was left of OPTI. What to do? We would have another level of reporting inserted again and I didn't like that idea much; all the new Under Secretary might have to do would be to manage me. But the principal I thought was overwhelmingly important, namely the principal of having the state of civilian technology a major concern of the Commerce Department. Herbert Hoover believed this to be a vital role and, in more recent times, Herb Hollomon and Jordan Baruch had tried to revive that idea. The fact that recent efforts had not flourished did not indicate to me that they were wrong, but rather that one had not found an acceptable way to go about it. So at that stage we threw our energies into trying to help Verity pull it off. He was successful and the position was quickly established. He tried to get someone from industry to come in to do the job, but at that late stage in Reagan's second term it was hopeless. Accordingly he asked me to do the job and I agreed, but only on an acting basis. I knew I would be retiring the following March and I wanted to retire as Director of NIST, not as Under Secretary. After all, I had been at NBS nearly thirty-six years, and I wanted to leave the association of a working lifetime with some affection and feeling of intimacy with my colleagues. During the few months I was Acting Under Secretary and working in the Commerce Department, I saw quickly what Verity saw and I am sure what Hollomon and others saw, and that is the potential of DOC to become a much more powerful force in supporting the U.S. economy. DOC has so many connections and pipelines to companies throughout the United States, and many formal Advisory Committees representing all industrial sectors. The broad range of activity in economic data, trade statistics, trade issues, exports and imports, and many areas of technology are all broad and impressive when you get close enough to see them. But the connections with industry are not used in any coordinated way. When a situation becomes important nationally it is seldom that DOC becomes the lead agency; more often it is State or Defense or Treasury, or the Special Trade Representative or the White House itself. DOC operates more like a conglomerate than an entity with an overall unified goal. I had always supposed, and I think most people suppose, that DOC is rather weak and just needs stronger leadership. I found that this was not the reason for the prevailing situation, after all Baldrige and Verity were very strong leaders.

In my opinion resistance comes from two sources. The first is from industry itself. It doesn't want government meddling in its affairs—government can only screw things up. A strong, coherent Department of Commerce intimately and powerfully involved in all issues that affect industrial enterprises is the last thing industry wants. The second source of resistance resides in the basic Administration's belief in the free market system and a total rejection of any notion of an industrial policy. I do not see any reason to believe that this situation is going to change. It is true that there is increasing concern for the state of the economy, but government action is centered on the White House, not the Department of Commerce. That being the case, it seems to me that NBS/NIST is forced to plan strategies and tactics based solely on Administration and Congress support for R&D generally and civilian technology in particular, bearing in mind always the need to be as clear as possible about the accepted and respective roles for industry and government and by following these roles scrupulously. But this is good for NIST; we know how to do it, it is the way we were brought up. So what we have to do is to keep the faith and keep on leaning.

Boulder Laboratories

Robert A. Kamper

Introduction by Emanuel Horowitz

Now, to tell you about how the West was won, we have Dr. Robert Kamper who is Director of the NIST Boulder Laboratory. Bob joined the Bureau of Standards in 1963 as a physicist in the Cryogenics Division. In 1978, he became Chief of the Electromagnetic Technology Division, and in 1982 he put another hat on top of his Division Chief hat and became Director of the Boulder Laboratory. So he's doing double duty. Whoever is taking care of payroll here, please note that, O.K.? For those of you whom are not familiar with the Boulder Laboratory, at least not to the extent that you should be, we are going to hear from Dr. Kamper about some of the interesting things that go on there. Bob.

HISTORY OF THE BOULDER LABORATORIES

Robert A. Kamper

This brief description of the origin and achievements of the NIST Boulder Laboratories does not pretend to be a scholarly work of history. It is my personal view of the story, based on direct observation in the period from 1963 to the present, and on the really scholarly works that describe events before then. The examples I have chosen to illustrate the technical achievements of the Boulder Laboratories reflect my own sense of what was significant.

To any reader who wants more than this, I recommend reading *Achievement in Radio* by Wilbert Snyder and Charles Bragaw, which tells a large part of the story with meticulous attention to accuracy in every detail. I have also seen parts of unfinished manuscripts by Elio Passaglia and by Brickwedde, Hammel, and Keller, that I would recommend as fascinating reading if ever they are published.

The story started after World War II. Microwave radio had proved its military significance during the war, and in the ensuing Cold War there was a large national program to refine its application to surveillance, navigation, communication, and so on. The Bureau was to mount an expanded program in radio propagation and standards to support all this, but could not accommodate it on the site it occupied on Connecticut Avenue. The Director of the Bureau at the time was Edward Condon, and guided by a policy of the time that all new Federal buildings should be outside Washington, he took up the search for a site on which to expand the Bureau.

The policy probably intended that new buildings should be in the outer suburbs such as Gaithersburg, but Condon took it as a mandate to search nationwide for the ideal location for radio research. His top three candidates were Palo Alto in California, Charlottesville in Virginia, and Boulder in Colorado. His choice of Boulder was probably based on many considerations, including personal preference, but one strong factor was a vigorous campaign by the Boulder Chamber of Commerce, organized by its manager, Frances Reich, to attract the Bureau to Boulder. The campaign included an offer to donate a 217-acre site for the new laboratory campus. The offer was accepted, and in one week the Chamber of Commerce raised the $70,000 needed to buy the land by public subscription.

Funds for the new building were appropriated in 1950 and construction began. The NBS Boulder Laboratories were dedicated by President Eisenhower in 1954.

But meanwhile another project, to build a large hydrogen liquefier, began in much greater haste. In 1949, somewhat earlier than expected, the Russians had successfully tested a nuclear bomb. The response in the U.S. was to give high priority to the development of the deuterium fusion bomb. At the time, this was thought to require a copious supply of liquid hydrogen, and the Bureau received a contract from the Atomic Energy Commission to assemble a team of low-temperature physicists and engineers to design and build the world's largest hydrogen liquefier at the Boulder site, to supply liquid hydrogen for the development effort at Los Alamos. The project was completed in little over a year by a major feat of engineering. The liquefier was capable of a producing 350 liters per hour and was housed in a building designed to survive an explosion. It was never tested in this respect. The whole cryogenics program had an outstanding safety record.

Soon after the completion of the hydrogen liquefier it was discovered that liquid deuterium was not the best fuel for a bomb. Lithium deuteride was better and did not require liquid hydrogen for its production. Overnight the liquefier lost its original purpose, but the whole field of cryogenic engineering was about to enter a golden age with the advent of the space program. To design large rockets burning a mixture of liquid hydrogen and liquid oxygen required the establishment of a whole new field of engineering, and the Cryogenic Engineering Laboratory that was established with Russell Scott as its first director played a prominent part in that. The original NBS hydrogen liquefier has been dwarfed by the plants that now supply the space program. A single launch of the space shuttle would have taken nearly a year's production from it.

The Cryogenic Engineering Laboratory had other big projects besides developing engineering data for the space program. It made a major contribution to the development of the large liquid hydrogen bubble chamber at the Lawrence Berkeley Laboratory. It established the quantitative basis for custody transfer of cryogenic fluids, first liquid nitrogen and later liquefied natural gas. It contributed to the development of new refrigeration technology, including a miniature high-speed expansion turbine that ran on gas bearings, and the most recent accomplishment: the "Coola Hoop," a refrigerator with no moving parts that can reach

65 K. It consists of a pulse-tube refrigerator driven by thermal oscillation, developed in collaboration with Los Alamos.

As the space program matured, most of the Cryogenic Engineering Laboratory was absorbed by the Center for Chemical Engineering and turned its attention from cryogenic fluids to the great variety of fluids and processes used in chemical engineering. The new challenge in developing thermodynamic data was to encompass mixtures, which was done using a combination of measured data, empirical correlations, and theoretical equations of state. This work depends on a large amount of numerical computation. It came into its own with the search for a substitute for chlorinated fluorocarbon (CFC) refrigerants that would be more benign to the ozone layer. Another field that was taken up was the study of basic chemical engineering processes, particularly separation of mixtures. Various projects studied separation through semipermeable membranes, immiscible liquids, and with supercritical carbon dioxide. These projects in chemical engineering are still in progress now.

Another program that started in the old Cryogenic Engineering Laboratory was the study of structural materials. This was of great importance to the space program, because at low temperatures many materials suffered phase transformations that caused them to become brittle. This program later evolved into the study of the strength and reliability of welded joints and into nondestructive testing of materials and structures. The staff of this program became involved in testing the welded joints in the Alaska oil pipeline and in investigating the causes of several catastrophes in which buildings had collapsed.

In 1958 the Radio Standards Laboratory was completed and opened with due ceremony. It mounted an ambitious program to develop and refine the basic standards and measurement techniques for all the quantities that affect the performance of microwave components and systems: power, voltage, attenuation, impedance, and so on. An extensive calibration service, which at first served mainly the procurement and maintenance functions of the armed services, was offered.

Many of the standards developed at that time have served to this day. The microcalorimeter, the micropot, the piston attenuator, and standard waveguide sections are still in routine use. But measurement technique has evolved through several generations. At first microwave measurements depended upon tuning out the imperfections of the measurement system at each frequency at which a measurement was to be made. This was a laborious process requiring good hands and much patience on the part of the measurement technician. The result was very accurate measurements but a very low rate of production. The first venture into automation was made in the early '70s. A commercial automated network analyzer was bought and modified by the addition of inductive voltage dividers to provide a reference that would upgrade its accuracy to the level required to provide a national calibration service. The result was a very complex system that was prone to partial and total failures that made it difficult to operate routinely, but it remained as the workhorse of the calibration service for many years. It was then superseded by the fruits of another project that started at about the same time: the six-port. This was invented by Cletus Hoer in the early '70s and slowly developed into a superb calibration system that is simple to calibrate and checks its own stability and errors, under full computer control. This is the new workhorse of the calibration service.

Another project, which started in the early '60s, was the measurement of the velocity of electromagnetic waves using a microwave interferometer. The idea was to measure the frequency and wavelength and deduce the velocity. The problem was to correct for the small distortion of the waves caused by diffraction at the edges of the beam. This correction was calculated by David Kerns and Paul Wacker, who then realized that the same calculation could give the relationship between the distribution of fields close to an antenna and the radiation pattern in the far field, where plane waves have developed. The accurate measurement of the radiation patterns of antennas has become an important matter with the development of the antennas with very high performance used for radar and satellite communications. Alan Newell was in charge of building a near-field antenna scanner to make the measurements from which a computer could calculate radiation patterns using Kerns and Wacker's method. This facility has been heavily used, and about a dozen copies have been built in various companies around the United States.

The Time and Frequency Service came to Boulder with the Radio Standards Laboratory. The first atomic clock, an ammonia maser, had been developed by Harold Lyons in Washington. Strictly speaking this was not a clock, but a frequency standard. It was superseded by a standard based on a resonance of the cesium atom, which is detected by a change in the deflection of a beam of cesium atoms projected through a nonuniform magnetic field. The first cesium beam standard, NBS-1, was built in Washington and then moved to Boulder. It was then succeeded by several generations of improved models, culminating in NBS-6, the present standard. Its successor, NIST-7, is already under construction. It will also use the cesium resonance, but will detect it by an optical technique. This will eliminate some sources of error in NBS-6 and create a standard about an order of magnitude more accurate. The next generation of frequency standards will take several years to develop and will be radically different. It will be based on a resonance of the mercury ion, suspended in an electromagnetic trap and controlled and monitored by a laser. The action of the laser cools the mercury ion to a very low temperature, at which it hangs, suspended and almost motionless, resonating with extremely low external perturbation. This already exists as a spectacular scientific demonstration, and David Wineland and his group are working to refine it into a frequency standard that may be a thousand times more accurate than NBS-6.

The resonance of the cesium atom that is used for a frequency standard is at a convenient microwave frequency. The resonance of the mercury ion lies in the ultraviolet. Some time ago the Time and Frequency Division won a place in the 1974 *Guinness Book of World Records* by bridging a similar gap to measure the frequency of a visible (iodine) laser. This feat required a large team of people and won much acclaim. It established the basis for a new definition of the meter, in terms of the second and the velocity of light. It will need to be repeated routinely when the mercury ion is adopted for a frequency standard.

The national time scale is maintained by a set of about a dozen small, commercial cesium beam standards that are designed for continuous running. They are calibrated annually against NBS-6. The time scale must also be coordinated with those of the other nations that maintain frequency standards of similar quality. The mathematical problem of finding the best weighted average among a collection of clocks, all prone to small fluctuations, was solved by David Allan and James Barnes. Their solution depends on a measure of stability known as the Allan variance, which is used in all serious time keeping.

The middle '60s saw several major events at the Bureau. The headquarters moved from Connecticut Avenue to Gaithersburg. The Radio Propagation Laboratory was spun off to become the nucleus, in Boulder, of the Environmental Science Services Administration (ESSA), which later became the National Oceanographic and Atmospheric Administration (NOAA). The Institute for Telecommunication Sciences (ITS) was also spun off and later became part of the National Telecommunications and Information Administration (NTIA). And the Joint Institute for Laboratory Astrophysics (JILA) was formed.

JILA is shared by NIST and the University of Colorado (CU). It was established in 1962 with Lew Branscomb as its first Chairman. It occupies a building on the CU campus. The permanent staff consists of about a dozen NIST employees (the Quantum Physics Division) and an equal number of CU faculty members. Then there are Visiting Fellows, Postdoctoral Fellows, graduate students, and so on, to make up a total of about 150 people. JILA's mission in laboratory astrophysics is very broadly interpreted, and its staff has made many distinguished contributions to science and to instrumentation. To take a few examples: Jan Hall and Dick Barger were pioneers of the frequency stabilization of lasers, one of the advances that took these devices from being "a solution looking for a problem" to become the superb tools for metrology that they are today. Jim Faller and Peter Bender took prominent parts in designing the experiment to monitor the distance to the moon, using a laser ranging system that included a reflector placed on the moon's surface by the Apollo astronauts. Jim Faller developed an instrument to measure the acceleration of gravity with an uncertainty of only a few parts per billion, which also eliminated the need for a vibration-free platform. This instrument made a radical change in the whole business of measuring gravity. In this diverse program there are also people studying astrophysics.

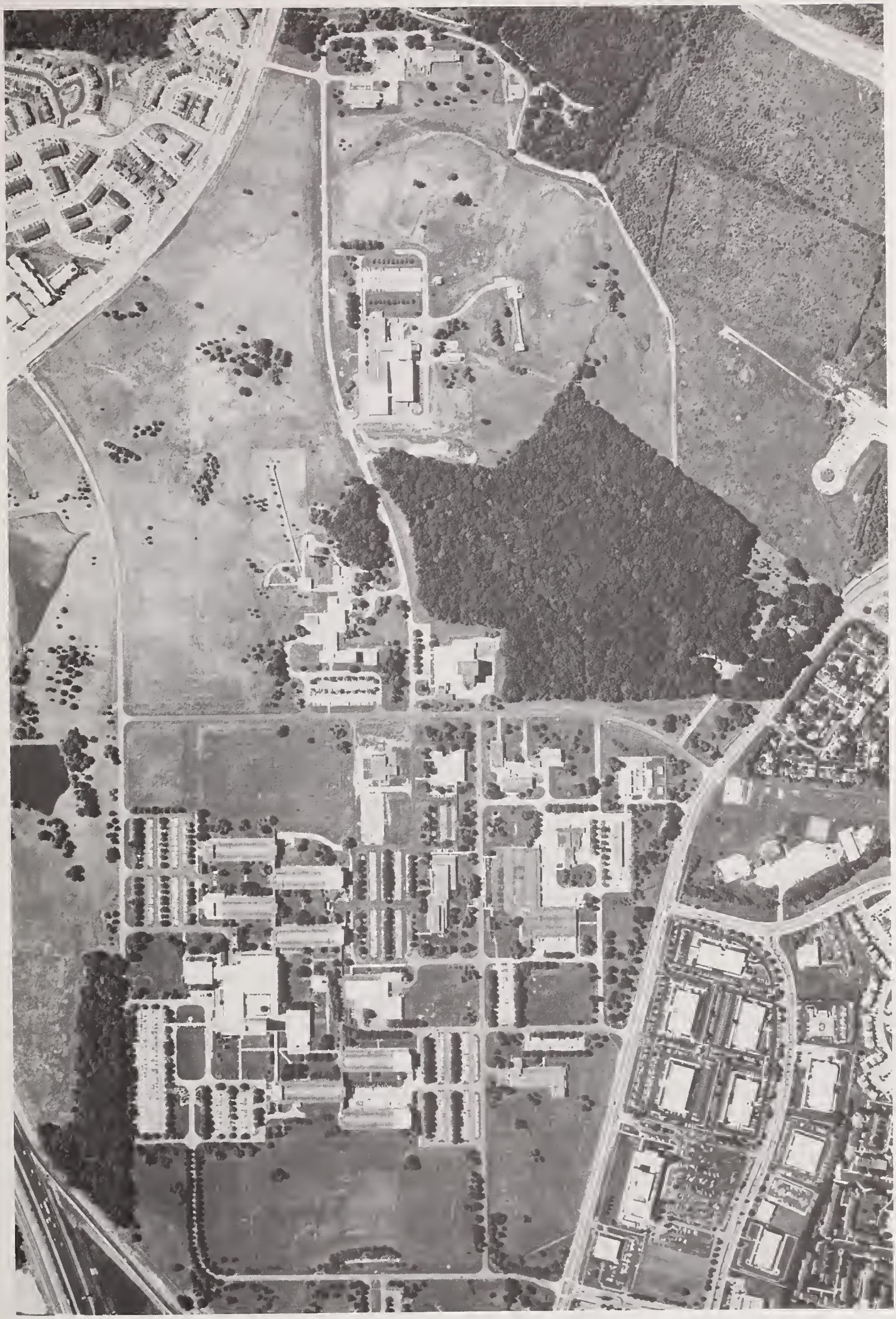
To return to the main NIST campus in Boulder, the early '70s saw an extension of the radio standards program into lasers and optics. The program to measure the frequency of lasers started then. So also did a program to establish the consistent measurement of laser power. This enabled lasers to be categorized for safety regulations and met some interesting challenges from the Department of Defense at the extremes of the range of power. At the high end was the challenge to measure the power of high-energy lasers. These were intended to be all-destructive weapons, but the measuring instrument had to survive. At the low end was the challenge of measuring the energy of pulses at the femtojoule level at which the receivers for laser target designators ("smart bombs") and range finders operate. These challenges have all been met.

The mid '70s brought the spectacular rise of the optical fiber telecommunications and a program at the Bureau of Standards to establish the necessary measurement techniques. At first the transmission characteristics of the fibers themselves were the limiting factors in telecommunication systems and received greatest attention at the Bureau. Later, the program expanded to encompass the lasers, detectors, amplifiers, and integrated optical components of the increasingly sophisticated systems being developed by the industry. One prominent aspect of this work is the measurement of very short pulses of light. This has led to the development of a sampling source, using mode locking and soliton compression in optical fibers, that has been built into a complete and surprisingly simple all-optical sampling system.

The last major program I will mention is in superconductivity. This started in the early '60s in the flurry of excitement generated by the discoveries of the high-field superconductors, that made big magnets feasible, and the Josephson effect, that opened up a new field of electronics. The superconductivity program at the Boulder laboratories of the Bureau has its roots in both the cryogenics program and the radio standards program.

Superconductors have been used in some impressive engineering successes, such as the Tevatron at the Fermilab in Chicago, the experimental magnetically levitated train in Japan, and magnetic resonance imaging. But they have unique and tricky engineering characteristics that have also led to some expensive and embarrassing failures. One part of our superconductivity program is exploring, defining, and measuring these characteristics, to enable reliable engineering data to be generated. One of the accomplishments of this part of the program was Jack Ekin's discovery and exploration of the drastic effect of elastic strain on the current-carrying capacity of superconductors. A specialty of this program has been the refinement of magnetic measurements on superconductors. This has become the nucleus of a new program to develop magnetic measurements and standards for other fields of technology, particularly magnetic recording. With the discovery of the high-temperature superconductors, the field of measurements and standards has become wilder country, and the group has a fine opportunity to pursue the Bureau's traditional function of taming it. The larger part of the superconductivity program is in electronics. It was started to improve the art of electrical measurements and physical standards and has remained among the leaders in the development of superconducting electronics. The technology has evolved dramatically from the early days, when Josephson junctions resembled the crystals and cat's whiskers of early radio, to the present when the group has a complete facility to fabricate microcircuits containing many thousands of nearly identical Josephson junctions using equipment and methods similar to those of modern semiconductor electronics. The accomplishments of this program include some of the early pioneering of magneto-encephalography, a radically new voltage-measuring system, that is its own standard, and a new principle for radiometry. The program is advancing into high-temperature superconducting electronics, single-flux quantum logic, and single-charge tunneling.

It is not only during working hours that our staff members bring fame to the Bureau. NIST has the distinction, unique among Federal agencies, of having a newly discovered dinosaur named after it. Two members of our chemical engineering staff, Jim Filla and Jim Siegwarth, are amateur paleontologists. They spend their weekends digging among the copious dinosaur quarries of Colorado and Wyoming with Professor Robert Bakker of the University of Colorado. Recently they discovered a new, small dinosaur whose existence has thrown interesting light on the mystery of why the dinosaurs disappeared. Professor Bakker named it Drinker Nisti, the genus in honor of a famous paleontologist and the species in honor of NIST.



National Institute of Standards and Technology—Gaithersburg, MD

Robert S. Walleigh

Introduction by Emanuel Horowitz

The move from Van Ness Street and Connecticut Avenue in Northwest Washington, D.C., to the Gaithersburg site was both a momentous opportunity and a unique experience for those of us who went through it. The planning was largely in the hands of Bob Walleigh, the NBS Associate Director for Administration. Bob spent 35 years at NBS, having come to the laboratory in 1943, and he retired in 1978. He is currently a Consultant with the Institute of Electrical and Electronics Engineers. Bob told me during one of our planning sessions, "There are some things I'm going to be talking about today, but there are others I will remain silent on." I think we all know what he means. For some special insights into the move to Gaithersburg, Bob Walleigh.

THE GAITHERSBURG SITE

Robert S. Walleigh

The decision to build new laboratories for the National Bureau of Standards was made in September 1955. Prior to that, Bureau Directors had tried for many years to get appropriations for an Administration Building which would house the Director's Office and the service activities. The records of the Bureau show that a well-developed plan for an Administration Building had been used as a basis for a request in 1934 for funds from the Works Project Administration (WPA) in the days of Franklin Roosevelt, but the funds were not forthcoming. Even in those days, much of the Bureau staff was located in substandard temporary buildings, some of which had been built for special-purpose experiments in World War I.

The problem was made worse during World War II when other temporary buildings were erected for activities related to the war effort. Thus, following World War II, there was a serious problem in managing the Bureau's work. The employees of every division were scattered in several buildings, the worst example being a division which was housed in 17 different buildings. There were about 100 buildings in all; one third of the space was temporary and another third was substandard. The efforts continued to get major improvements on the Bureau site to eliminate temporary buildings and to build an Administration Building and some laboratory facilities. One request for such a development with a $30 million price tag got nowhere. Some relief came when the guided missiles work of the Bureau was relocated to a former hospital facility in Corona, California. The next real relief came with the approval of a new building for the Bureau's radio work. However, the Congress stipulated that the work must be out of the Washington area. Boulder, Colorado, was selected as the site for this laboratory which was dedicated in 1954.

In the meantime, Congress had approved $2 million for the renovation of the electrical system at the old site on Connecticut Avenue. This was a very welcome improvement. Unfortunately, it came at a time when the effective application of the more modern instrumentation was requiring a stable control of the operating environment and a variety of special supporting services. This resulted in more and more demands for air conditioning equipment to control the heat and humidity in laboratories, thus adding greatly to the electrical load, and this had not been factored into the modernization of the electrical system. Incidentally, no provision was made for air conditioning for the comfort of the employees. In those days this was called "creature comfort." The number of requests for air conditioning to control the laboratory temperature and humidity, but which were in whole or in part intended for creature comfort, began to grow, and it became necessary to require that the approval of air conditioning be made at the highest level in the Bureau.

I have often thought that the attention which was directed at the National Bureau of Standards by the AD-X2 incident may have been a major factor in finally causing the Administration to direct some serious attention to the Bureau and to its need for a new laboratory and office facilities. The firing of Director Allen Astin and the anger which that generated in the Bureau staff led to a threat of wholesale resignations from the Bureau and to a subsequent rehiring of Dr. Astin. This was followed by the study by the Kelly Committee, some of the most prestigious scientists in the United States who were asked to look at the validity of the Bureau's work and who subsequently made a number of recommendations concerning the Bureau. The national attention brought to the Bureau by the firing and rehiring of the Director, front-page headlines, and the study by the Kelly Committee, kept the Bureau in the limelight for quite some time. It also brought to the attention of the Administration a realization that the National Bureau of Standards was indeed a national resource whose scientific work was of the highest caliber. This total vindication and support by an objective group from outside the National Bureau of Standards was a message to the Administration and to the Congress which could not have been made as effectively by the Bureau itself.

When the decision was made in 1955 to relocate, action was begun immediately to begin preparations for a budget request, for an estimate of costs and for a decision on a recommended location. The General Services Administration (GSA) was called upon to assist in this effort. Since the total area in all the Bureau's buildings approached 1 million square feet, it was decided that we would seek about 1 million assignable square feet to house some 3,000 employees. The GSA developed an estimate of $40 million for a "monolithic block-type structure," in essence a cube which was the smallest possible configuration and the most economical to build. The Bureau developed an estimate of $23 million in addition for equipment and for the relocation. Armed with this information, NBS sought and got an appropriation of $930,000 for site acquisition and preliminary planning.

The decision as to where the laboratories should be built was based on many factors. First of all the Administration, in offering the Director the opportunity to plan new laboratories, had made a determination that the Bureau did not need to be in Washington D.C. This decision was made at a time when the atom bomb was having a serious influence on the locations of facilities. The Bureau was told that it had to relocate if it was going to build new laboratories and that the location had to be at least 20 miles from the White House.

In considering a new site, the first concern was for the Bureau's primary resource, its staff. In that period of time, the demands for scientists and engineers were very strong, and Government salaries were quite low as compared with those in private industry. Therefore, we had to be very careful in the selection of the site since, if the staff did not like the location or were too inconvenienced by it, they could easily get jobs elsewhere. We had lost one-half of our staff in the move of the guided missile work to Corona and in the move of the radio work to Boulder, Colorado. Taking this into consideration, the Director decided on the following criteria for a new site:

1. The site should be reasonably accessible by automobile from the homes of the majority of the Bureau's professional staff.
2. The site should be near high-speed roads for ready access to Washington and its airports.
3. The site should contain at least 400 acres in order to provide freedom from sources of vibration, noise, and radiation from potential neighbors, as well as to allow for expansion.
4. The terrain should be relatively flat and high.
5. Utilities should be reasonably accessible.

In order to meet dispersal criteria, the relocation site had to be at least 20 miles from the center of Washington and could not be in the Washington/Baltimore corridor.

When the original site for the old Bureau had been selected in 1901, it had been chosen to provide a rural location and the city had subsequently completely surrounded it. The prospect for the relocation to a new rural site had a special appeal. A task group containing NBS and Public Buildings Service employees considered nearly 100 locations and narrowed the list to about five for detailed examination by the Bureau's management. I can remember taking Dr. Astin out to see this site. Route 240, which subsequently was renumbered Interstate Highway 70S and which now is called Interstate 270, was still under construction. We climbed a slight incline at the northwest corner of the site and looked over a barbed wire fence. Almost the entire area that we had under consideration and the surrounding areas were farms. Since the growing season had not started, there were no crops visible and the only signs of life were a few cattle. There were a few farmhouses and farm buildings on the proposed site and on surrounding farms, but other than that, no development whatsoever.

Both Clopper Road and Quince Orchard Road were very narrow country roads. The site was exactly 20 air miles from the center of Washington. Except for the southern boundary, the site was bounded entirely by roads. It was 550 acres. Dr. Astin agreed that this was the most desirable site from all those that had been considered.

Not long after that Dr. Astin called me into his office. With him was Dewitt Hyde, the Congressman for the area of Maryland in which the proposed site was located. He said that he had been asked to intercede on behalf of some homeowners who lived on the site which we were proposing as the new Bureau location. It seemed that it had been the practice of the Diamond family, who were the principal landowners at the site, to give to their sons and daughters an acre or so for a home along Quince Orchard Road. There were about six such homes on a small enclave. A member of one of these families actually worked at the National Bureau of Standards and he had learned that the Bureau had this site under consideration. Congressman Hyde said that those families were in favor of the move of the Bureau to that site, but asked that consideration be given to omitting their properties. A subsequent decision was made to leave out this enclave, the decision being made at least in part because the cost of those few acres and their homes would have driven up the entire cost of the site.

However, because this information of the site had leaked to this one Bureau employee, it was feared that land speculators might also have heard of this recommended choice. For that reason it was decided that we would use the authority of the Secretary of Commerce to take the land through a Declaration of Taking and let the courts decide on the value. As soon as the appropriation was made for the acquisition of the site, a Declaration of Taking was filed July 6, 1956. The price for the 550 acres was subsequently determined to be about $500,000. (Incidentally, we had to acquire an additional ten acres in 1961 when the Reactor Building was added to the planning.)

Shortly thereafter an architect was chosen for the preliminary plan. The Bureau recommended the firm of Voorhees, Walker, Smith, and Smith, a New York firm which had experience in designing many modern laboratories following World War II. The firm had designed Bell Telephone Laboratories, the DuPont Research Laboratories, the Ford Laboratories, General Foods, and many more totalling more than 10 million square feet of laboratory space.

The GSA received proposals from several architectural engineering firms, but when the several proposals were reviewed by a panel of GSA and NBS employees, the New York Firm of Voorhees, Walker, Smith, and Smith was selected. The architects placed a number of members on their staff at the Connecticut Avenue site to collect information on the needs of the Bureau for the new facilities, working directly with the Division and Section Chiefs. They also made preliminary studies of the site at Gaithersburg. During this period several members of the top staff of the Bureau, along with members of the architects and Public Buildings Service, made visits to other laboratories to see how such laboratories had been constructed, and to take advantage of the good ideas and reject the bad ideas which had evolved from their construction experiences.

In the early spring of 1957 a visit was made to the offices of the architect in New York for a report on the planning preparatory to appropriation hearings. The Public Buildings Service and the NBS officials were stunned when the architects gave an estimate of over $100 million for the new facilities plus the $23 million which the Bureau had estimated the year before as the costs for new equipment and relocation. The architects had provided 30 percent more space than the 1 million square feet which had been agreed to in the original request. The plans were reviewed and major cuts were made to reduce the size of the facility to 1 million square feet, and to reduce correspondingly the cost of the facility. Despite these cuts, the Bureau was in the embarrassing position of having to go before the Congress in the certain knowledge that the estimates which had been developed by GSA the year before were grossly understated and could not possibly produce the laboratories which the Bureau needed. The hearing was one of the most difficult which Dr. Astin was to have. He had established a reputation with the Congress for being a good administrator and for being honest and open with the Appropriations Subcommittee. It was difficult for him to be placed in the role where his word was open to question because of the prior gross underestimate of the facilities cost.

Following the hearings, GSA, NBS, and the architects worked jointly to devise means for further savings in the costs of the proposed new facilities. A decision was made to make all laboratory spaces windowless, making it possible to place laboratories back to back. Thus the buildings could be doubled in width more closely approaching a cube, an ideal in terms of minimizing the cost of building construction. This modification alone made it possible to save about $4 million. Also eliminated from the planning were a proposed railroad spur and helicopter landing facilities.

The Director had appointed a committee of NBS scientists[1] to make recommendations on desirable criteria to be considered in the development of the designs for the new facilities. The report of the committee made in September 1957 included recommendations that the space be flexible so that laboratory changes could be made quickly; that suitable conference rooms, dining rooms, library, cafeteria, shops, and administrative divisions be located centrally and be conveniently located with respect to laboratories. It also made some specific recommendations with respect to the size of doorways, lighting levels, and ventilation. Most of the criteria were adopted in the planning.

I have mentioned earlier that I had thought the AD-X2 incident and its attendant publicity had been a significant factor in causing the Administration to support new facilities. However, the outside support for the program had slowed almost to a halt after the hearings which reported on the stunning increase in the estimated cost of the facilities. But, on October 4, 1957, an event occurred which shook the confidence of the American public in its beliefs that America led the world in it's scientific achievements. On that date Soviet scientists launched Sputnik I, the first man-made satellite. It made headline news around the world. It is my opinion that this event was a significant factor in making it possible for the National Bureau of Standards to obtain a supplemental appropriation of $3 million for the planning of the new facilities.

The first efforts were directed to another study of a general plan which would incorporate all or most of the facilities in a single structure. The study concluded that it was neither feasible nor economical to do this, but out of this planning there did evolve the basic concept that placed the Director's Office and staff, the central support activities, conference rooms, dining rooms, library, and shops at the center of the site, surrounded by general-purpose laboratory buildings, which would accommodate all of those laboratory activities which did not require truly special-purpose space. The general-purpose laboratories would be connected with each other and with the central support facilities by full height, all-weather corridors. While the Bureau and the architects were engaging in their efforts to consolidate the buildings,

[1] Herbert Broida, Allen Franklin, John Hoffman, Ralph Kotter, Lawrence Kushner, and Leo Wall, with Lewis Branscomb as Chairman.

Dr. Wallace Brode distributed a humorous bulletin showing a number of suggested configurations, each with appropriate comments. I can remember his comment on a five-sided figure saying that he abandoned that idea because it might be mistaken for the Pentagon in time of war.

It was first thought that NBS could rely on its existing administrative structure for developing NBS requirements for the new facilities, but it was soon found that neither the architects nor GSA could provide the backup services which they had assured would be available, and a Gaithersburg planning group was established within the Plant Division. This group was given the responsibility of working with the divisions and developing their requirements, conveying those requirements to the architects, reviewing plans and specifications, and preparing and supervising contracts for the move and occupancy. One of the first steps was to assign to each technical division space for its general-purpose laboratory and office needs. The special-purpose laboratory needs were considered on an individual basis, and assignments of space were made only after a thorough review to justify the need.

Despite the fact that a site had been acquired and that an appropriation had been received for planning, there was still a large percentage of the staff which did not believe that the Bureau would ever move, and it was difficult to get them to place the priority needed to keep the planning going forward at a reasonable rate. In fact, there were many on the staff who were strongly opposed to any thought of leaving the Washington site. Partly for this reason it was decided to designate a Gaithersburg planning representative for each of the Bureau's 15 technical divisions and for each of the support divisions to expedite and coordinate input from the staff. A questionnaire was devised which would be helpful in determining requirements on a room-by-room basis. In all, the questionnaire provided for 11 pages of detailed information on each laboratory module. By June 1960 planning had progressed to the point where the architects were able to produce and deliver to NBS a model of the facilities. This model was presented to the Associate Directors on June 1, 1960, and to the press on June 2. Pictures appeared in the newspapers the following day. An *NBS Standard* article showing a picture of me pointing at the model appeared a few days later. Someone at the Bureau sent me a copy of that *NBS Standard* with a notation beneath the photograph "Walleigh's Falleigh."

It should be mentioned that Bureau scientists had been asked at an early stage to make measurements at various points on the new site of the existing levels of radiation, of vibration, and of noise. I can remember that one such report stated that the vibration of the earth from the rustling of the leaves in the trees caused more detectable vibration than the motion of the passing of the automobiles and trucks on Highway 70S. The health physics scientists measured radiation at the site, including soil and water samples. They also measured radiation in wells in the vicinity of the site. Those measurements have continued although the number of wells which are now monitored has been reduced because many of them are now capped off since water and sewage utilities have been installed in the communities. At one time there were 40 dosimeters installed along our five miles of perimeter fence. Today there are 16, the new ones being much more sensitive than the old ones. They are checked quarterly. Grass samples are checked every two weeks in growing season, and soil samples are checked monthly.

We have continued to be very sensitive to any developments in the area which might cause problems to our sensitive measuring devices. I remember a few years back, when we were apprised of possible expansion of the Gaithersburg Airport, that we commissioned fly-over tests of our site by both propeller planes and jets.

In the planning of our facilities, serious consideration was given at all stages to protect ourselves from our own sources of noise and vibration and radiation. Our steam and chilled water facility was kept distant from other buildings, as was our electric substation. In our buildings, the necessary fans and transformers were isolated from the building structure through three levels of isolation. Wiring in the building was placed in metal conduits. An electromagnetic interference specialist was named who was authorized to provide advice and solutions to individual cases as they arose in the planning.

We have also worked closely with local Government bodies in the development of zoning standards which would protect the environment not only of our site, but of the county in general.

Following the approval of the site model by the Director, we went through a series of reviews of our plans by Government bodies. We made a presentation to the National Capitol Planning Commission which approved the planning, but also directed that a large part of the site be preserved in what they called a "green area," that is, an area which is not to be developed. Our approved master plan has a line across it marking that green area.

When we went before the Fine Arts Commission, we were admonished not to use our rooftops for experiments. Members of the Fine Arts Commission noted that the roofs of many of our buildings at the old site on Connecticut Avenue had been used for many types of experiments and that the roof lines were generally quite unsightly. They directed that the roof lines be kept clean. In consideration of that direction, we planned our roofs at Gaithersburg so that they do not lend themselves readily to experiments. So far as I know, the only items which have been mounted on any roofs are the two or three antennas used for communication on the top of our Administration Building.

As the planning progressed, it was soon decided that it was not feasible to proceed with construction in one large package. Some buildings were more urgently required than others. Some facilities were more difficult to design than others. Furthermore, additional facilities and additional requirements continued to be added, and these required changes in the planning as it proceeded. One facility was even dropped. Consequently, the decision was made to proceed in phases, and appropriations were sought one phase at a time. As we went before the Congress each year for our appropriation, it was necessary to explain that the costs of construction were escalating because of inflation which in those days was running at about 3 percent per year. On a facility with a total cost of more than $100 million, that amounted to an escalation of more than $3 million each year.

When it was announced that we were going to proceed in several phases of the construction, some Bureau employees and some managers expressed dismay thinking that we might end up with only part of the construction completed and with some of the staff in Washington and some in Gaithersburg. We were fortunate in that we were able to get the appropriations needed to keep the building programs going forward, once construction was begun.

The first phase of construction included the Engineering Mechanics laboratory, the Steam and Chilled Water Plant, and the Substation. The long-awaited ground breaking occurred on Wednesday, June 14, 1961. After arriving by helicopter, the Secretary of Commerce, Luther Hodges, turned the first spadeful of earth. The gold-plated shovel used for the ground breaking had been used originally to break ground for the Chemistry Building in 1915 at the old site.

With the beginning of construction, some of the skepticism of the staff concerning the reality of the construction of such facilities was abated. To stimulate interest, group visits to the site were arranged, and staff was also encouraged to go out and make visits on their own. The employee newspaper, the *NBS Standard*, contained one or more articles on the progress in each issue, and there were occasional talks to staff in the East Building Lecture Room. The planning for the remaining phases of construction proceeded more rapidly, and the Congress, despite some problems, appropriated funds which made it possible for construction contracts to be let as planning for a phase was completed. The first occupancy of Phase I at Gaithersburg was in 1963. The second phase of construction included the Administration Building, Radiation Physics, Supply and Plant, Shops, and Service. Construction of Phase II began in 1962.

The move of the Director's Office to the Administration Building was in 1965, about one year before the dedication. There is a little story connected with the move of the Director's Office. Dr. Astin had decided that when the Director's Office was moved to Gaithersburg he wanted the flag to be raised over the site. We asked GSA to put out a contract for the flagpole. They said that they had not planned to erect the flagpole until the end of construction and they suggested that NBS put out a contract, which we did. GSA had provided us with set of drawings and specifications. Each year when appropriation hearings are held, it is necessary that the agency submit a listing of all of its contracts. This list is usually reviewed toward the end of the hearing. At the particular hearing at which the contract for the flagpole was listed, the Congressman from West Virginia asked the Director, "What is this item for a flagpole for $45,000?" Unfortunately, I had to be elsewhere for another hearing, so I was not present at the appropriation hearing. While Dr. Astin had been briefed on the contract list, he could only remember that we had contracted for a flagpole and that it was 90 feet in height. The Congressman soon did some dividing and said, "Dr. Astin, that is $500 a foot." Dr. Astin had forgotten that the contract also provided for the removal of a small farm building, the leveling and sodding of the site in front of the administration building, and the provision of a granite walkway. The flagpole itself had cost $9,000. It seemed almost every year after that Congressman Rooney of Brooklyn took delight in asking about the flagpole. It was all in good humor, but the printed records of the hearings sound more ominous than they were. How many of you have ever looked at the base of the flagpole? Incised in the granite base is a quotation from George Washington at the Constitutional Convention in 1787, "Let us raise a standard to which the wise and the honest can repair." Dr. Astin chose that quotation as appropriate for NBS.

As I look back, there are many interesting incidents which come to mind, unusual occurrences which left an impression on me. One of these was the early discovery on the site of some field stones which seemed to be markers for three graves. It was decided that this was the case and arrangements were made for reburials in a cemetery. In the process of the reburials, it was found that there were actually seven graves. In the reburial, prayers were said by a Catholic Priest, a Protestant Minister, and a Jewish Rabbi.

In another incident as construction proceeded, the water main burst at night near the center of the site, and before the water could be brought under control, it had washed away earth, leaving a hole almost an acre in size. Incidentally, to provide flexibility water comes onto our site in two 20-inch mains, one from the east and one from the north. Either main is capable of supplying all of our needs.

In still another incident, the 550-volt switch gear at our substation exploded and burned. An investigation followed. The investigation concluded that a mouse or a squirrel had gotten into the switchgear. The switchgear standards were changed to provide more space between the elements. Incidentally, to assure continuity of electric power service to our site, the power to our substation is fed in by three separate power lines, each of which is more than capable of supplying all of our power needs.

There were two separate occasions which I recall quite clearly when recommendations were made to the Secretary of Commerce that I be fired. One came from the office of a Senator after I told the Senator's aides that I could not make an additional million dollars available for the construction of a special facility because the funds for that facility were separate from those of the general construction facilities. They did not believe me.

In another case a Senator tried to coerce us into giving a move contract on a noncompetitive basis to the contractor who had developed the specifications for the move. The contractor, who was well qualified, had taken the contract with the full knowledge that it contained a provision that the contractor who prepared the move proposal could not bid on that proposal because the contractor would be in a favored position. In both cases the Secretary of Commerce was completely supportive of the position I had taken, and I was not fired. I did suffer some nervous moments, however, on both occasions.

In another incident connected with the moving, I was visited by two young men from the Teamsters Union. They looked like husky football players, who advised me not to let our first move contract to the low bidder who was a non-union contractor. They said that if we did, the Teamsters would picket the site so that the union members of the construction crews could not come upon the site. We did let the contract and, as luck would have it, their pickets appeared on a day when Secretary of Commerce John Connor was on the site. When I gave him the message about the pickets he told me he had no concerns with crossing the picket lines. We were fortunate that the other unions found some loophole for bypassing those picket lines and they were soon removed.

The Administration Building was a part of the second phase of construction. We had planned to have a cornerstone laid at the base of the Administration Building, a cornerstone to commemorate the construction of the entire site. We had a cornerstone prepared with the names of President Kennedy, Secretary Hodges, Assistant Secretary Hollomon, and Allen Astin. President Kennedy was assassinated before that stone could be laid. A second stone was then prepared for President Johnson, but the Administration decided that he should make fewer public appearances because of increased fears of assassination. As some of you know, there was no formal cornerstone ceremony, and instead a simple date stone was then placed near the entrance to the Administration Building. A metal plaque placed on the interior wall of the Administration Building near the entrance was unveiled when the dedication of the site took place in 1966, 25 years ago. Those two cornerstones, bearing the names of Presidents Kennedy and Johnson, were still stored somewhere in the recesses of the Supply and Plant Building when I left here several years ago. The dedication in 1966 represented the culmination of the planning and construction of facilities, but the actual construction of the final phases continued somewhat beyond that.

There had been five principal phases of construction in all for the Gaithersburg facilities. The largest of them was Phase III, the seven General Purpose Laboratory Buildings. Phase III was actually divided into two parts, Phase IIIA for the footings and foundations and IIIB for the structures. In addition to the five major phases, two additional separate contracts were placed, one for the Reactor and the other for the Non-Magnetic facility. Construction of the last of the buildings in the Gaithersburg Relocation was in 1969. In all, the buildings contained over 2.2 million gross square feet, with over 1.3 million assignable. The total cost exceeded $120 million.

The ten years that I spent on the planning and construction of these facilities were certainly some of the busiest and most rewarding of my career. Thousands of decisions had to be made in those years, and it was very gratifying that there were so many well-qualified people at the National Bureau of Standards to assist in or to make those decisions. The services of the Gaithersburg Planning Group, the division representatives, the committee of scientists who established the criteria for the laboratories, the Laboratory Services Committee, the Laboratory Furniture Committee, the Office Furniture Committee, the electromagnetic interference coordinator, and many others provided services which cannot be adequately recognized in words. The work of each of these would be a story worth hearing in itself. Finally, I want to acknowledge the confidence and support I received from Allen Astin throughout this period. Whenever I went to him for advice or for a recommendation, he was always thoughtful and considerate and prompt in his response. These laboratories are a memorial to him.

Lawrence M. Kushner

Introduction by Emanuel Horowitz

We now come to a very special part of the program, which we call "Spinoffs from the NBS Laboratory." Dr. Larry Kushner will be the moderator of this session. He joined the NBS in 1948 as a physical chemist in the Chemistry Division. In 1961, he became the Chief of the Metallurgy Division, taking over from Dr. James Hoffman, Jack Hoffman's father. It is interesting that two chemists, Jim Hoffman and Larry, headed the Metallurgy Division for about 10 years. In 1969, Dr. Astin appointed Larry as the Deputy Director of NBS. For a time, he also served as the Acting Director of this laboratory. He then received a presidential appointment as a commissioner of the Consumer Products Safety Commission and served there, according to those who followed his work, extraordinarily well, until he returned to NBS. Almost all roads lead back to NBS. On his retirement from NBS, he joined the MITRE Corporation and became a consulting scientist. Since his retirement from the MITRE Corporation, Larry has undertaken a very serious task. He's trying to improve his golf game, so that he will no longer be humiliated by his champion golf partner and wife, Shirley. Larry Kushner.

SPINOFFS: AN ADDITIONAL MEASURE OF SUCCESS

INTRODUCTION OF PANEL

Lawrence M. Kushner

Never mind the Teamsters. One of the panelists has threatened me with bodily harm if I take too much time in the introduction here. I'm going to try to move expeditiously. The final portion of today's program is devoted to organizational spinoffs from the Bureau, several of which went on to become important laboratories in their own right. This panel discussion actually reflects a special pride in this uniquely NBS mode of operation, which has been commonplace throughout the Bureau's history. After all, for most of the first half of the Bureau's existence, it was undeniably the Government's principle multi-disciplinary physical science and engineering laboratory. As situations arose in which a Government agency's responsibilities required the rapid initiation of a laboratory program, the Bureau was invariably turned to. As that agency's requirements subsequently grew, the work was enlarged, and the agency itself became better able to manage its own technical work, the performing groups at NBS were transferred, often taking on their own identities as important laboratories.

We have three panelists this afternoon who are going to talk about three of the very well-known spinoffs from the Bureau, but without attempting to be complete, I'd like to mention just a few others. In 1953, the Bureau's Guided Missile Laboratory in Corona, California, was transferred to the Navy, becoming the Naval Ordnance Laboratory, Corona. The Bureau's Institute for Numerical Analysis, then working on Navy and Air Force problems, was transferred to UCLA in 1954. In the late 1960s, several long-standing product testing operations at the Bureau were transferred to GSA, the Government Services Administration, nucleating that agency's own in-house testing laboratory. In 1973, several groups were transferred to the newly created Consumer Products Safety Commission, as the nucleus of that agency's Product Safety Laboratory. There have been many, many other spinoffs. As I say, I can't possibly list them all. There are problems of definition as to what constitutes a legitimate spinoff, I guess. But Steffen Peiser reminds me that while no spinoffs as such were involved, the Bureau, through individual staff members acting as consultants, had a profound influence on the establishment of the Korea Standards Research Institute, the Taiwanese Centre for Measurement Standards, the Turkish Standards Institute, and the Japanese National Research Laboratory of Metrology. In retrospect, we may have been too helpful for our own good.

Jacob Rabinow

Introduction by Lawrence M. Kushner

I'd like to introduce the first speaker, one of the Bureau's more colorful members over the years, Jake Rabinow. Jake was born in Russia, educated in New York City, with a bachelor's and graduate degree in electrical engineering. After a few jobs during the Depression, he ended up here at the Bureau in 1938 as a mechanical engineer. His talents were very quickly recognized. He rose quickly, ultimately becoming Chief of the Electromechanical Ordnance Division. In 1954, he was a personal spinoff from the Bureau. He left and formed his own company, which was subsequently taken over by the Control Data Corporation, of which he became a vice president. In 1968, he also formed an additional company of his own, which was subsequently acquired by Harmon Kardon Corporation. In 1972, he rejoined the Bureau, and in April 1989, he finally retired from Government service and is now a consultant to NIST in connection with the evaluation of inventions. Jake is one of the nation's most highly honored inventors. He holds over 200 patents, several fistfuls of important national awards and recognitions, and it is a pleasure for me to introduce the person who threatened me physically, Jake Rabinow.

DIAMOND ORDNANCE FUZE LABORATORY AND NATIONAL INVENTORS COUNCIL

Jacob Rabinow

I asked you to make a short introduction. You're cutting into my time. As a matter of fact, if Chet Page is here I'd like to tell about the time he and I were arguing. We both speak very fast. Cledo Brunneti came over and listened to us and said, "You people speak too fast." Chet stopped for a moment and said, "You listen too slowly," and kept going. Please listen fast.

My first story is not about a spinoff, but about a spin-in. It's about the National Inventors Council (NIC). It's worth telling but I have only five minutes for it. In August 1940, the Secretary of Commerce, who was then Harry Hopkins, at the suggestion of scientists, engineers, and others, felt that we had to get the lay inventors (that is, the non-professionals, and perhaps the professionals who are not part of large organizations) to submit inventions to the Government to help the war effort. This was based on the philosophy and the fact that most of the great inventions for military use were not made by military people but were made by civilians. If there were time I would give you a long list, but it's interesting that it's the civilians who do this. This relates to something I'll talk about later. Anyway, the way it operated, the Secretary of Commerce would invite famous inventors, engineers, scientists, physicists, and chemists to serve the country by giving advice to him or to his subordinates. The technical people served without pay. Eventually they had a staff to help them.

The first chairman of the NIC was Charles Kettering, Director of Research of General Motors. After his death, Dr. Stark Draper became the chairman.

It would be a revolving kind of organization, so every year there would be some new members. I joined this outfit in the 1960s. It was a very great pleasure to work with people who were much smarter than me. I was once asked the definition of a genius. I said, "A genius is a guy you meet at a cocktail party. He asks you, 'What do you do for a living?' You say, 'I build reading machines.' He says, 'What are they?' So you start explaining, and five minutes after you start he knows more than you do."

Anyway, this system existed for quite a while. I'll give you just a few numbers. By the end of the war the Council had received over half a million submissions. Most of them were junk, as you'd expect to get from amateurs: perpetual motion machines, enclosed turbines that have no outlet, accelerations produced without ejecting any material, all kinds of wonderful things. Of these, some 500 were considered promising, and they were sent to various Government agencies to get support. By the end of the war, 106 of those were actually in production. The reason I tell you this story is because the Bureau of Standards was very much involved in this work. The Committee used the Bureau to evaluate inventions. Of this quarter of a million, some 700 were evaluated by the staff here.

I wish I could tell you some of the stories about some of the inventions, silly and otherwise. The overall mail that this group received over its lifetime was 625,000 submissions. Many of them were not considered inventions because we would get a postcard saying, "I have a perpetual motion machine that will win all the wars," or "I have a weapon that doesn't require anything, but it kills everybody." But the thing that was interesting is that some of the ideas were good. For example, the mercury battery was one of the submissions. This is the little battery that went into hearing aids, and eventually led to the development of many other small batteries. It was invented by Sam Rubin, who eventually became a member of the Council. The production of those things was so enormous that if you compute only the taxes on the profits, they would have certainly paid for the Inventors Council many times over. The National Inventors Council was a wonderful group of people, and it was a most exciting thing to work with them.

In 1974, Betsy Ancker-Johnson who was Assistant Secretary of Commerce for Science and Technology, decided that this organization should be abolished. The Bureau of Standards, by that time, was handling the paperwork, the publishing of documents, handling travel, etc. We published a couple of books. She decided to save some money, so she abolished the National Inventors Council. She felt that it had run its course and she had enough advice without it. She thought that she could save six jobs (which she didn't). The jobs continued, because the Bureau's Council people were not working on this project anyway.

At the same time, Congress in its wisdom knew that we were helping inventors, so it wrote us into a bill called the Federal Nonnuclear Energy Research and Development Act of 1974. There's a paragraph that says the Bureau of Standards shall evaluate promising inventions submitted by individual inventors and small companies for the purpose of obtaining direct grants from the Administrator. So, instead of six jobs, which we were going to save, we now had some 28. George Lewett manages this work. We evaluate inventions again, only this time the Government does give grants to inventors. The way it works is that we receive the submission; we evaluate it (I say we because I work there as a consultant); we decide that some of them are good; we send them to the Department of Energy with a recommendation to support the invention. This takes a book about an inch thick because everybody wants documentation so they won't be caught ignorant of how the device works and how much it will cost. We have looked over some 30,000 in the last five or six years, of which about 500 have been considered good enough to get grants. The grants produce industrial products and I'm told that so far the total production has produced some $400 million worth of business. The taxes on this would certainly pay for our work.

The only thing I want to say to this audience is that it's hard to say whether such efforts are worth doing except for these statistics. But it does give the individual inventor a feeling that the Government can do something good for him. George Lewett would like to expand the work so that not only energy-related inventions would be evaluated. By the way, that's a pretty sloppy limitation. Almost anything can be assumed to be energy-related. But George would like to support all kinds of inventions, because many people do have good ideas. As a matter of fact, all my friends are inventors. They always come to me with the statement that they have a million-dollar invention. Someday, somebody will come to me and say, "I have a $100,000 invention," and I'll drop dead.

Now I have to tell you about the Harry Diamond Ordnance Laboratories, which was an NBS spinoff. In 1940, the President issued an Executive Order to set up a group called the Office of Scientific Research and Development (OSRD). This group was to no longer use the lay public. It collected scientists who could really help, and people from industry. The Government also set up the National Defense Research Committee (NDRC) which a year later became part of the OSRD. The purpose of this effort was to set up facilities (in laboratories, universities, and private industry) where there was any hope of helping the war effort which was already coming. There were some 12 committees organized to coordinate the work. Vannevar Bush was the first chairman of the OSRD, and Dr. James B. Conant became chairman of the NDRC and served from 1941 to 1945.

The way I became involved in this work is probably worth telling. I had two degrees, as you heard, in electrical engineering. I came out of school in 1934, and I worked in radio factories for $12 a week. That was before President Roosevelt did a terrible thing and made the minimum wage $14 a week. My boss at that time complained that he couldn't make a living by paying people $14 a week. Occasionally when I lecture, I mention this to students and they ask, "Do you mean a week, or do you mean an hour?" I say, "I mean a week."

I took some competitive exams and did very well on the electrical engineering exam. I got 99, and Izzy Rotkin here in the audience got 100. After I came to the Bureau (and I think this is also worth telling) one of the men with whom I worked said, "I marked your exam paper." The Bureau of Standards was marshaled to mark the papers because 80,000 people took those exams. I said, "Thank you for giving me a 99." He said, "You didn't get a 99." I said, "But I have a paper from the Civil Service Commission saying I got 99 on the competitive exam." He said, "You didn't get it. What happened is that the people in New York City and other northern places did very well, but some southern states didn't get a single engineer with a mark of 60, which was required. Since it is a competitive exam, we just raised everybody by a formula. Then some unfortunate people finally passed, but not in sufficient numbers, so we raised it by another formula." I said, "What did I really get?" He said, "I have no idea." Anyway, I did much worse on the mechanical engineering exam. At one time in 1938 I was looking for my civil service papers, and through a series of accidents, I became a mechanical engineer at NBS, which I still am, I suppose.

I got involved with ordnance work after being here for a couple of years. I was a P-1, which is the lowest rank. My boss was Mr. Stutz. He was a Section Chief. Above him was Dr. Hugh Dryden. One day in 1941 Dryden said to me, "Come." I said, "Where?" "Come." If Dr. Dryden could use one word, that's all he would use. If he could use no words, he would just motion. He took me to another building, opened a door, and there I saw a beehive of activity. A better way to put it is to say it was a madhouse. This was the ordnance group. He called over a young man and said, "Bill, this is Jake. He has some mechanical aptitude." That's the highest compliment I ever got from him or from anyone. He walked out and thus I was introduced into the proximity fuze work.

Bill was Bill McLean, who was a Ph.D. in physics. He was also the best engineer I ever knew. He eventually invented the sidewinder missile. He really was quite a guy. I said, "What do you do here?" He said, "You'll see." We worked on all sorts of things at the same time. We had no organization—no sections, no divisions, no nothing, no paperwork. Somebody paid for whatever we did.

Who paid, I have no idea. If you wanted something, you picked up the phone and called Bell Labs, Eastman Kodak, Zenith, Philco. They all worked for us. "I want the following," and you got it, usually without paying for it either because they were patriotic or because it was too much trouble to charge. The swindles that developed later (the racket of writing proposals, evaluating proposals, competitive bidding for R&D, which is nonsense to start with) simply didn't exist. We worked on everything at the same time. After half a year of this I stopped Dr. Dryden and asked, "Dr. Dryden, who is my boss? For whom do I work? What is the organization?" He said, "Jake, don't be stupid. I have no idea."

I'll tell you some of the things we worked on. We worked on proximity fuzes, which are gadgets that trigger a bomb or a rocket when it gets close to the target. We worked on toss bombing, which is a technique of throwing bombs, not simply dropping them. That's the way all big bombs are thrown now. You can throw a bomb one way and you go the other way. That's very useful when you're throwing an H-bomb or an A-bomb. We worked on guided missiles, which were the first completely automatic weapons of that type. We worked on trench mortar shells and fuzes for them. As a matter of fact, printed circuits were invented for these fuzes by a contractor and Harry Diamond loved the idea, so we revolutionized the making of electronic devices. We worked on hand grenades; we worked on rockets. We actually made rockets that were loaded at the Bureau and then fired north of Van Ness Street. Bill McLean and I used to fire rockets in among the trees behind the Hot Shoppe on Connecticut Avenue. North of Van Ness Street were woods. There were very few buildings. In those days, nobody cared if there were explosions. People pretended they didn't hear them. We used to fire three-inch rockets among the trees there. One of the rockets got away from me and it was going for the Hot Shoppe. The rocket hit a high tree and it never hit the Hot Shoppe. These rockets didn't have any warhead; they were dummies. But it would have made one hell of a hole in the roof of the restaurant.

We had wonderful bosses: Astin, Hinman, Diamond, Condon, Ellett. Ellett, by the way, was my first boss. He was a professor of physics from Iowa State University. The people were not only our bosses, but one of the wonderful things about the people was that they were personally involved with what we were doing. That is, they would come and watch the test. Sometimes they would go to the proving grounds with us. They also permitted us to do a lot of bootleg work. The result of that bootleg work was that we could do many interesting things. We had a lot of money so there was no question about having to justify the work. For instance, I worked on record players. How does a needle track a groove? If Edison had known how complicated that was, he would never have invented the record player. We built a reading machine here. We built the first magnetic disk file for computers because we worked with the Census Bureau, helping them buy the first UNIVAC. What happened was the Census Bureau wanted to buy the first UNIVAC for the 1950 census (to get rid of some of the punchcard problems) and they didn't know how to order it. Nobody else did, so they asked the Bureau to help them. We helped them to write some of the specs. One of the wonderful things you do when you are trying to buy something so new, is that you write the specs after the developers do what they do. You keep modifying the specs as they modify the machine, and in the end, the specs agree with the machine. It's really quite wonderful. This is the way most research is done.

For examples of more such work I built a heart pump for a group at George Washington University. Henry Kalmus, whom was with me one day watching an operation on a dog, was told by the doctors that they would like to know how fast the blood flowed through the veins and arteries. So Kalmus invented an ultrasonic system of sending sound waves through the blood, without cutting into the organ. He could tell by the phase shift and the frequency shifts how fast the blood flowed. I walked into the guided missile laboratory one day and saw water pipes all over the floor. I said, "What's that?" He said, "My boss is having a fit. I'm testing the ultrasonic flowmeter, and he doesn't think that flowmeters belong in a guided missile laboratory." But in those days, we got away with it.

As a result of this there's a Rabinow Law: Everything you do illegally, you do efficiently. I think I don't need to explain this to you. The paperwork is zero when you do this kind of work. There's one other great virtue that people don't realize. When you do formal work, if it doesn't work you keep doing it. You hope that you can drag it out long enough to be a success or long enough so you will not get blamed. When you do things illegally, if it doesn't work, you bury it real quick. You don't drag it out.

The organization grew. We were very rich. In 1952, the national election was coming (I debated whether I should really name the party that won, and I decided that you people know it was the Republican Party). We heard an interesting rumor before the election, that if the Republicans won, the Ordnance Labs would be broken away from the Bureau and given to a private company, which I will not name, as a prize of war. There are a few laboratories which are run by industry for a "dollar a year," and this was going to be one of them. We didn't like that very much. Of course, the election was won by the Republicans, and as you heard this morning, the battery additive hit the fan. I use the analogy carefully. Then we heard another rumor that we would not be given to private industry, but we would be taken over by the Department of Defense. The way that was to happen was that the Kelly Committee (that you heard about this morning), said that we were the tail of the dog, and the tail was bigger than the dog. We were very rich. We had by this time some 1,600 people, mostly in Washington, some in Corona. Apparently, the Kelly Committee, perhaps because they really felt that the Bureau should do more basic work, more scientific work, and less technology like we were doing (or partly maybe to get the Secretary of Commerce off the hook), felt that the Bureau should be split.

I had worked in many arsenals during the war. We often traveled to arsenals to test weapons. A military laboratory is a very formal institution. They're very worried about improper explosions, which happen. The directing officer is rotated every two or three years. He never knows who his successor will be, so the officers don't like to criticize each other. Generally, the administration of arsenals develops a stiff and formal attitude, certainly not good for guys like me. I heard General Simon, head of Army R&D, once tell us that "you cannot do original research in a military establishment. You have to have a civilian laboratory with whatever craziness it has."

Next rumor we heard was that we would become a military laboratory. One fine morning, Harold Goldberg, who was Chief of one of the divisions, Mike Domsitz, who was another, and I, who headed a third, were called into a conference with General Simon and Allen Astin. They informed us that after all due consideration we would become a military laboratory. I said, "But General, I have a couple of questions to ask you. You know that that's not a good thing to do. Why can't we be some kind of civilian lab?" He said, "I'm sorry, Jack, but rules are rules. I have to live with the Government. We decided to do this as the best thing, if we don't want to give you to the private industry that wanted to have you. I don't think they deserve you. We spent a lot of money forming you. We like the organization. We'll take you over and do the best we can with you." I said, "General, how many bosses will I have in the next 20 years?" He said, "Six or seven." I said, "What are the chances they all will like me and tolerate the way I operate?" He said, "No chance at all." I said, "Yes, I know. I'm quitting because I've been offered more money than I get here, and because I want to develop my own inventions. I want to try to do some consulting." The other two Division Chiefs also quit at the same time.

By this time, I was a P-8. I had started as a P-1. You have to understand what a P-8 is. Some of you know. By the time I was a P-8, God was a P-9, and I could get three times as much in salary. But I didn't do that. I decided that I'd open my own company with one mechanic, and since I had offers to do consulting work, I decided on that. What happened was, of course, the ordnance work of NBS was transferred. But these Division Chiefs were asked to stay for 6 months to smooth over the transfer, which we did. Harry Diamond Laboratory stayed physically at the same site for some time.

I was a spinoff. So was the Harry Diamond Lab. Spinoff is a crazy word when you get kicked out. There was another spinoff at the same time. Bruno Weinschel, who worked in the Ordnance Laboratory, left in 1952 and formed Weinschel Engineering in Gaithersburg and was very successful. He and I differed in what we did. I did only industrial R&D and no production. I did no military work at all. That wasn't because of any moral commitments. I was very proud of my military work. I remained an unpaid consultant to the Pentagon for many years. But I wanted to know if I could still do something where a dollar was a dollar. In ordnance work, in military research to this day, you lose all sense of value. If you want to use diamonds for a bearing, you use diamonds. If you want platinum, you get platinum. If you want to make a device that should cost two bucks and it costs two thousand, nobody objects, because nobody knows. I wanted to know if I could still do engineering—after all, I'd been an engineer once—where a buck was still a buck. So I worked for private industry. I did get involved with the Post Office some years later, but even here a buck was very tight and competition was tough. I found it was a different world. I have nothing but contempt for much of the way ordnance work is done now. Not the technology, but the pricing and the competitive bidding, and the nonsense about evaluation by another bidder, and the Government engineer sitting at a desk and handing out money. The half-life of an engineer today is five years. If he hands out money, after five years he doesn't know what he's doing, so that the work is always done on contract. I don't understand why we don't fight wars on contract and give it to highest bidder.

The spinoff was the Harry Diamond Labs, Rabinow Engineering, and Weinschel Engineering. That's all I can tell you. I wish there was time to answer questions, because I skipped so much. Oh!

I have to tell you one sequel to this tale. People later said, "That rumor about the company taking us over was only a rumor." That was a fact. The way it happened is very interesting. I asked General Simon if it was true. He said, "Yes, the story is true." And then, as the years go by, who should become a client of Rabinow Engineering but that same company, and I got to know the Chairman of the Board, who was a very nice guy. They wanted us to build some robots for them. He said to me one day at lunch, "Jack, where did you work before you had your own company?" I said, "I worked at the Bureau of Standards." He said, "What did you do?" I said, "I worked in the Ordnance Department." He said, "Oh! That was the thing we were going to take over and run for the Government for nothing." I said, "Why would you want to do that?" He said, "Patriotism." And for all I know, he meant it.

Paul J. Brown

Introduction by Lawrence M. Kushner

Our next speaker is Paul Brown. Paul is going to talk about the transfer from NBS to the Department of Transportation, of a good bit of work here that had to do with automotive safety that was initiated in the period after World War II, and grew at the Bureau as the Department of Transportation was established and put money into the Bureau to conduct research and testing on important automotive components. Our speaker, Paul Brown, is an engineer. He received his B.S. in mechanical engineering and a master's degree in engineering administration from Washington University in St. Louis. He joined the Bureau in 1966 after having a number of engineering management positions in industry. At the Bureau, he headed up the automotive safety work. In 1972, the entire package of automotive safety research and testing at the Bureau was transferred to the Department of Transportation becoming the technical arm of the then new National Highway Traffic Safety Agency. I regard this spinoff as in the classic mold, that is, the Bureau taking on some early work when an agency didn't have its own technical capabilities, building it up to a point at which it was viable, and then when the other agency was ready to accept it, transferring it to the agency.

I'd like now to call on Paul Brown, who when leaving the Department of Transportation, went to the Department of Energy, where he became involved and very much interested in electric vehicles. Now, in his "retirement," is the Executive Director of the Electrical Vehicle Association of the Americas. Paul Brown.

AUTOMOTIVE SAFETY LABORATORY

Paul J. Brown

Introduction

It is indeed an honor and a privilege to be part of this Symposium in Celebration of the Ninetieth Anniversary of NBS/NIST. Some 24 years ago, in 1967, the National Bureau of Standards established an automotive safety laboratory at the old site at Connecticut and Van Ness in Washington, D.C.

Accompanying me today is my close friend and colleague, Dr. F. Cecil Brenner. As a scientist-engineer team we recruited the staff, planned the programs and fought for funding each year from the Department of Transportation. Dr. Brenner also was directly responsible for the management of the Tire Division's research programs. Representing the staff of that laboratory, we can state that we were proud to have been part of the history of the National Bureau of Standards.

Let us go back in time to the fall of 1966. There was a concern over the growing number of fatalities on our nation's highways that had reached over 50,000 a year, as well as some 3 million serious injuries a year, that led to the passage of the National Traffic and Motor Vehicle Safety Act of 1966. On September 9, 1966, when President Lyndon Johnson signed the Act, he stated that this effort was second only to Vietnam in the priorities of his Administration.

1. Laboratory History and Mission

The Office of Vehicle Systems Research in NBS was established by a Memorandum of Understanding signed by the Secretary of Commerce, Alexander Trowbridge, and the Secretary of Transportation, Alan Boyd. Boyd had been the Undersecretary of Commerce for Transportation under Trowbridge and became the first Secretary of Transportation when the Department was created by Congress in 1966.

The Office of Vehicle Systems Research (OVSR) was funded by the interagency transfer of funds from the Department of Transportation until the transfer into the National Highway Transportation Safety Administration (NHTSA) in 1972 in accordance with the original Memorandum of Understanding. In March 1972 the entire laboratory facility and professional staff were transferred to the Department of Transportation, and our name was changed to the Safety Research Laboratory. The laboratory was located in the Industrial Building of the old NBS until we were relocated during the Nixon Administration to leased facilities in Riverdale, Maryland.

The objectives of the laboratory were to provide the scientific and technical bases for motor vehicle safety performance standards in three areas: tire systems, braking systems, and occupant restraint systems. An additional important and challenging task was to provide the technical basis for a Uniform Quality Grading System for Tires.

2. Occupant Restraint Systems

Prior to the passage of the National Traffic and Motor Vehicle Safety Act of 1966, the National Bureau of Standards was responsible for the implementation of a seat belt law. That law did not require that the auto industry install seat belts in cars, but if they elected to install seat belts, the belts had to meet or exceed the design standards promulgated under the seat belt law. The specifications and methods of testing the design standard for seat belts were developed by NBS in consultation and consensus with seat belt companies and the auto industry. The testing of seat belt assemblies was done on the OVSR Instron. Important design standards for strength, elongation, flexing, stain and moisture resistance, and retractor performance were established to ensure that seat belt restraint systems installed in motor vehicles operating on U.S. highways would protect the motoring public.

One of the major tasks of OVSR/NBS was to improve the dynamic performance of the available anthropomorphic dummies to better simulate human reactions in the automotive crash. A unique and very economical sled was designed and fabricated by OVSR to provide a dynamic test of occupant restraint systems and to evaluate anthropomorphic dummy performance. The impact pulse of the vehicle is simulated by a belt over a cam that pulls the sled in reverse.

On the Daisy Decelerator at the Holloman Air Force Base, the Air Force and the NBS conducted human volunteer experiments on car seats with lap belts alone, and lap belts and shoulder harnesses in levels up to 16g which represents a 17 mph auto crash into a barrier. With identical tests on dummies we could determine what changes in dummy design were necessary to improve the human fidelity of test dummies. The high-speed motion pictures and test data were shared with the automotive safety community in a special meeting in the NBS Red Auditorium in Gaithersburg. Some 200 members of the automotive safety community, including overseas guests, attended this meeting. Our human volunteer test data were used and cited in the *Federal Register* as justification for mandating shoulder harnesses in motor vehicles.

The discomfort and inconvenience of seat belts and shoulder harnesses were early issues that contributed to the low usage rates. OVSR conducted a study of existing and experimental restraint systems with a number of different-sized male and female volunteers to make recommendations for improvement in retractor location and the use of inertia reel retractors.

3. *Braking Systems*

A dual-end inertial dynamometer designed and built to the OVSR specification was used to test and evaluate braking systems of automobiles and trucks. On the dynamometer, inertia discs were used to simulate any vehicle from a small compact passenger car to a large truck or bus up to 80,000 pounds gross vehicular weight.

In a cooperative agreement with the U.S. Army at the Aberdeen Proving Ground, we were able to conduct tests using a number of instrumented tractor-trailer rigs for wet pavement performance in straight-ahead stopping, lane changes, and braking-in-a-turn maneuvers. In these tests on the Aberdeen 11-mile strip and skid pad that NBS installed, we were able to test and evaluate the effectiveness of the new anti-skid braking systems.

The braking system performance for repeated stops, fading, and brake lining or disc wear can be evaluated on the dynamometer. The ducts over the test specimen simulate the cooling of the brakes that occurs in the wheel well as the vehicle travels over the road.

Correlation of the laboratory dynamometer tests with vehicle road braking performance was obtained through instrumented vehicles on test tracks. Laboratory and vehicle test methods for safety performance standards for vehicle braking systems and brake components such as lining and disc pads, cups, seals, and cylinders, were developed by OVSR. A chemical laboratory at OVSR also developed the safety standards for hydraulic brake fluids, and pioneered by field and laboratory tests the determination of the adverse affects of water pickup by brake fluids over time on lowering the reflux boiling temperature.

4. *Tire Systems*

Tire research at NBS preceded the Motor Vehicle Safety Law by many years. Early in automotive history, an "NBS Tire Test Wheel" was developed to evaluate the strength of various materials for tires. The test wheel was being used by the tire and auto industries to determine the load-carrying capacity of pneumatic tires at different velocities. OVSR ran a large number of tire tests in the laboratory and in vehicle tests to verify the load ratings for the initial tire safety standards.

Skidding on wet pavements was determined from accident statistics to be the predominant tire-related safety issue particularly with worn tires. Skid trailers were used to measure the coefficient of friction of pavements using a standard tire. OVSR used and modified a skid trailer for the measurement of new and used tires. The laboratory also tested tires on vehicles in spin out maneuvers on a Standard J Turn at Texas A&M. One of the results of this research was the requirement to place treadwear indicators in the bottom of the grooves in tires, which required replacement of the tires when the tires were worn to 1/8 inch of the bottom of the groove.

The laboratory also developed a Mobile Tire Traction Dynamometer to measure braking, driving, or cornering traction over a wide range of driving conditions. The dynamometer is a towed trailer similar to the skid trailer with watering capability to measure wet pavement performance but with the added capability of changing the steering, camber, and braking during road operation.

5. *The Uniform Tire Quality Grading System*

One of the biggest challenges to the Safety Laboratory was the development of the controversial Uniform Quality Grading System for Tires mandated by the law. From a host of tire performance attributes, treadwear, traction, and temperature resistance were selected for the grading system. To measure treadwear, the laboratory established a prescribed test on the public roads in Texas. For wet traction, the laboratory constructed standard concrete and asphalt skid pads. To measure temperature resistance, the laboratory tire test wheels were used.

It is significant to note that the tire industry was opposed to any quality grading system for tires from their marketing point of view. They spent considerable resources in fighting the rulemaking all the way to the Supreme Court where the Government's position was sustained in large part due to the technical and scientific basis provided by the laboratory. However, one of the tire companies that strongly opposed the rulemaking is now citing the grading of its tires under the Government system in its advertising.

Operating out of the Goodfellow Air Force Base in San Angelo, Texas, the Safety Research Laboratory developed the test procedures for measuring treadwear on this course. Convoys of vehicles with test tires were run over Texas public roads to determine the treadwear after a day's run. Wear measurements were made by a laser device developed by the laboratory to measure and record precisely to within ten-thousandths of an inch the wear of the day's operation. Tests were completed to tire wearout. This data determined that comparative treadwear ratings could be made after 6,400 miles and a break-in of 800 miles of operation over the NHTSA prescribed course.

To measure wet traction performance, two standard skid pads were constructed at the Goodfellow Air Force Base, one concrete and one asphalt for the comparative testing and grading of tires.

On the sidewall of your tires, the treadwear, wet traction, and temperature resistance properties are graded in accordance with the test procedures and the test facility established by the laboratory at the Goodfellow Air Force Base. We believe that the tire grading system will enable you to make an informed choice in your selection of replacement tires.

Summary and Conclusions

This then has been a quick overview of the Office of Vehicle Systems Research that was spawned in the National Bureau of Standards. We are convinced that the laboratory made a significant contribution to the development of safety performance standards for motor vehicles that have resulted in the saving of lives and reduction of injuries on our nation's highways. Thank you for inviting us back today to participate in your 90th Anniversary.

C. Gordon Little

Introduction by Lawrence M. Kushner

Our final speaker this afternoon is Dr. Gordon Little, who is going to talk about the Central Radio Propagation Laboratory and its spinoff from the Bureau. Dr. Little was educated in Manchester, England, where he received a bachelor of science degree in 1948, and a Ph.D. in radio astronomy in 1952. In 1953, he came to the United States, where he became Deputy Director and Research Professor in the Geophysical Institute at the University of Alaska. He was there until 1958, at which time he left to join the Central Radio Propagation Laboratory at Boulder. He transferred with the CRPL to the Environmental Science Services Administration, that is ESSA, in 1965. It subsequently became part of the National Oceanic and Atmospheric Administration in 1970. Dr. Little resigned from NOAA in 1986, and since 1987 he has been with the Navy, based in Monterey, California, but he is a Senior Fellow at the National Center for Atmospheric Research in Boulder. Dr. Gordon Little.

CENTRAL RADIO PROPAGATION LABORATORY

C. Gordon Little

Fifty years ago, at the outbreak of World War II, the United States combined Chiefs of Staff were faced with many technical problems. One of the most important of these was how to communicate with aircraft, ships, and armies overseas. The only known way to communicate with such locations beyond the horizon was by reflecting high frequency (HF) radio waves off the ionosphere—that is, off the electrically conducting ionized layers of the upper atmosphere. The range of radio frequencies effective for this purpose was known to be very variable. Over the previous 10 to 15 years, the NBS had identified strong diurnal, annual, and sunspot cycle variations, which depended also on latitude, and less strongly on longitude. Moreover, these "irregular" variations were at times greatly disturbed by ionospheric storms triggered by activity on the sun. However, by 1939, NBS had begun to prepare predictions of ionospheric radio wave propagation conditions one to three months in advance. With the onset of war, NBS was asked by the Joint Chiefs of Staff to accept the wartime responsibility for providing the armed services with radio communication research and services.

In response, then, the National Bureau of Standards formed the Interservice Radio Propagation Laboratory (IRPL) in the summer of 1942. Its activities included the regular radio standards activities of the Bureau of Standards. IRPL served the war effort very successfully. Even before the end of the war, it was recognized that there would be a peacetime need for continued, centralized radio propagation and radio standards research and services to support the civilian as well as the military establishment. So, with interagency and Congressional approval, the wartime IRPL was replaced in May 1946 by the NBS Central Radio Propagation Laboratory.

CRPL grew steadily, then, within the National Bureau of Standards in Washington during the late 1940s, rapidly straining the facilities at the Van Ness site. During this period, CRPL made many important contributions, especially in developing ionospheric and tropospheric forward scatter systems, which greatly expanded the range of frequencies available and the reliability of communication beyond the horizon. In 1954, in response to the overcrowding at the Van Ness site, and influenced by a policy of decentralizing the Government functions from Washington, CRPL completed the move to Boulder, Colorado. There it had, of course, access to much more space, to a much more varied terrain and climate, and to a major university.

In the period 1954 to 1965, CRPL continued to expand its radio standards and radio wave propagation studies within NBS, Boulder. But then, in 1965, a major reorganization occurred within the Department of Commerce. Studies initiated by Dr. Hollomon, the Assistant Secretary of Commerce for Science and Technology, had identified many important similarities between three of his science agencies; specifically, the Weather Bureau, the Coast and Geodetic Survey, and the Central Radio Propagation Laboratory of NBS. And so, in 1965, a new Department of Commerce agency, the Environmental Science Services Administration (ESSA) was formed by merging these three organizations, with the notable change, of course, that the radio standards activities stayed with the National Bureau of Standards' Institute for Basic Standards.

In ESSA, the Central Radio Propagation Lab was renamed the Institute for Telecommunication Sciences and Aeronomy (ITSA) and joined three sister institutes from the Weather Bureau and the Coast and Geodetic Survey, namely the Institutes for Atmospheric Science, for Oceanography, and for Earth Sciences. Together then, these four institutes formed the ESSA Institutes for Environmental Research (IER). These institutes were headquartered in Boulder, although scattered in different locations across the country. They reported to Boulder, and through Boulder to the Director of IER, located in Boulder, who reported to the Administrator of ESSA in Washington.

The creation of a single, geophysically oriented research organization from four very different research components of greatly different size and with quite different histories, stature, and traditions, was quite an important challenge. To this challenge, CRPL/ITSA was very influential. It was much the largest unit in terms of size and it had grown up within the National Bureau of Standards—that is to say, within a research organization—whereas the other three institutes had grown up in operational agencies, whose prime mission was not research. I personally count myself very fortunate to have spent the formative years of my Federal research and research administration career within an excellent organization, the NBS. NBS, and NIST, of course, is an agency which understands that its research products are produced low in the organization by its scores of Section Chiefs and hundreds of Project Leaders, and not, of course, by top management. They recognize that effective upward and downward communication of new results, new needs, new priorities, is extremely important to the vitality and success of the organization. Therefore, it is extremely important that the number of levels in the hierarchy be kept at a minimum. This is true not only because such levels consume valuable resources, but perhaps more especially because each level inevitably delays the upward and downward flow of signals, and typically, unfortunately, to some extent each level distorts, attenuates, and masks the signals flowing through it. Perhaps one of the most important contributions CRPL/ITSA made to the process of forming the research arm of ESSA was to ensure that in 1967 we succeeded in persuading the ESSA administrator to abolish the Institute Director level. So the four Institute Director offices and the associated staffs were dispersed. One or two left, but in many cases they went down into the research labs. This allowed the lab directors to report directly to the Director of the Environmental Research Laboratories. I must admit that this had the additional, though unadvertised, advantage of ensuring that the Director of IER would be so busy that he would not have time to micromanage the ten labs. This was a significant hazard when we had one Director and four Institute Directors and their associated staffs.

The single goal traditionally uniting CRPL/ITSA was to study, understand, model, and predict the interaction of waves, acoustic and electromagnetic, with the propagation medium and its boundaries. But just as there are two sides to a single coin, so there are two reasons why we needed to study these interactions—first, to understand their effects on telecommunication systems, and second, to use these interactions to provide information about the propagation media. In other words, to exploit the interactions, not for telecommunication purposes, but for environmental remote sensing—a typical example, as the telecommunication people would say, of "One man's signal is another man's noise."

The move of CRPL/ITSA into the Environmental Science Services Administration accentuated rather than softened this dichotomy between the two sides of the CRPL coin. Considering first the telecommunication side of the coin, studies within the Department of Commerce, stimulated by ITSA, concluded that the telecommunication policy formation and research needs of the United States Government were not being met. And so, in 1967, the Department of Commerce formed within itself the Office of Telecommunications, and within IER, the two telecommunication labs were united to form the Institute for Telecommunication Sciences (ITS), still remaining within ESSA. In response to continued studies, in 1970 the Office of Telecommunications Policy (OTP) was formed in the Executive Office of the President. At that time, ITS was transferred from ESSA to the Office of Telecommunications of the DOC. Then in 1977, a further reorganization combined the policy formation functions of OTP with the policy implementation and supporting research functions of the Office of Telecommunications in the Department of Commerce into a new single agency, the National Telecommunications and Information Administration (NTIA). Currently in 1991, ITS is still performing some propagation research, especially to extend radio telecommunications to the higher millimeter wave frequencies, i.e., the shorter millimeter wavelengths. But its mission has expanded to include research in support of telecommunications policy formation by OTP, telecommunication standards (both national and international) technology for telecommunication system evaluation, and technology transfer to industry. Thus, 25 years after leaving NBS, ITS is very much alive and hard at work.

Turning now to the environmental science side of the CRPL coin, 1967 also saw evolution of the environmental science component of CRPL/ITSA. A new lab, the Wave Propagation Laboratory, was formed to develop new remote sensing techniques applicable to research and services in the Earth's atmosphere and ocean. Then in 1970, a further Federal reorganization added some non-DOC activities, chiefly from the Navy, to ESSA, and ESSA was given the new name National Oceanic and Atmospheric Administration (NOAA). With the simultaneous transfer of ITS from ESSA/NOAA to OT/DOC, the Institutes for Environmental Research were given their present title, the Environmental Research Laboratories (ERL) of NOAA. Their headquarters continue to be in Boulder.

For the past two decades, the environmental science components derived from CRPL have flourished in ERL, initially in the form of three labs. The Aeronomy Laboratory has conducted research on chemical and physical processes in the Earth's atmosphere to advance the capability to monitor, to predict, and to control its quality. Currently, their major focuses are research on air quality and climate, with special emphasis on such areas as stratospheric ozone depletion, tropospheric ozone production by pollutants, and the greenhouse effect, acid rain, and climate change. So a very broad range of air quality and climate change studies are continuously pursued within the Aeronomy Laboratory. The Space Environment Laboratory performs research and services directed towards understanding, monitoring, and forecasting solar and geomagnetic events. These can have undesirable, harmful, and costly effects on activities on Earth or in near-Earth environments. They may even be health- or life-threatening. As part of these activities, the Space Environment Laboratory operates in Boulder, jointly with the U.S. Air Force Weather Service, the Space Environment Services Center. This Center provides solar terrestrial prediction services 24 hours a day, year in and year out, for users in the nation's military and civilian organizations. The Wave Propagation Laboratory is NOAA's remote sensing lab. It focuses on studies of the interactions of acoustic and electromagnetic waves with the atmosphere and the ocean, with particular reference to their use for remote sensing purposes. It develops and evaluates new geophysical remote sensing concepts and systems, and applies the unique advantages of these newly developed remote sensing techniques, which typically provide two to six orders of magnitude more data than an individual thermometer or wind sensor. It seeks, through the transfer of these new remote sensing technologies to others, to advance the nation's atmospheric and oceanographic research, and its atmospheric and oceanographic forecasting and warning services.

Spinoffs from the Wave Propagation Laboratory, specifically the PROFS (Program for Regional Observing and Forecasting Services) and the Profiler Program, a clear air Doppler wind profiling system, helped form a fourth laboratory, the Forecast System Laboratory. This lab focuses on the development and transfer of new forecast systems for the nation's weather services or for the National Ocean Service.

In conclusion, I believe that the National Bureau of Standards/NIST may well be proud of the impact achieved over the years, and still being achieved, by its 1965 spinoff child, the Central Radio Propagation Laboratory.

LETTER FROM FREDERICK J. SCHLINK

In early years, around 1900, before a Bureau of Standards was conceived, buying and selling were completely uncontrolled by public authorities. The basis for the vitally needed controls was established in March 1901 with passage of the law creating a National Bureau of Standards. The Bureau's Weights and Measures Division came first. It performed newly established pioneering services for the ultimate consumer by checking the accuracy of weights essential in industry and trade. The newly created Federal weight, length, and volume standards were put to widespread use by officers known as sealers of weights and measures. Their work provided protection in all the states against short-weight cheating by thousands of grocers, butchers, and other retail merchants.

Before weights and measures testing administrations had been developed in states, counties, and cities, a large proportion of scales in use were found inaccurate to a degree that caused millions of dollars of losses to consumers.

One of the Bureau's most important services for consumers was the convening of conferences, which began in 1912 and were held annually (except in wartime). These conferences were attended by weights and measures officials, whose duties included tests that prevented fraud by merchants in their use of inaccurate scales, and dry and liquid measures. These well-attended conferences established tolerances or permissible errors (unavoidable in all commercial measurements).

Frederick J. Schlink (NBS 1913–19), celebrated his 99th birthday last October 20, 1991, and is the oldest NBS alumnus. In conjunction with the 90th anniversary of the Bureau, he was invited to attend this Symposium. Although he was not able to do this, he wrote some recollections of NBS in the teens and of his subsequent career. His letter is reproduced here.

* * * *

I graduated in 1912 from the University of Illinois. I had majored in physics and mechanical engineering and received a B.S. degree. I worked at two engineering jobs in the Chicago area before I came to the Bureau of Standards in 1913. At the Bureau I worked with Mr. Louis Fischer, Dr. Arthur Pienkowski, Roy Ferner, Fay Holbrook, and Clarence Briggs. I was testing scales and writing about scale design and accuracy.

About 1913, track scales, which accounted for more than $2 billion in freight revenues, had become notorious for inaccuracy. In 1915, very large errors were reported, and 75 to 80 percent of the scales tested were found completely unfit for service in establishing charges to shippers of every kind of product transported by rail.

In 1918 I was one of a team of three men using specially designed equipment built into a box car, capable of placing on a railroad track scale large iron weights weighing 10,000 lb. each, to a total of 105,000 lb. The railway scale testing equipment was moved into the states of New Jersey, New York, Connecticut, and Vermont. A second test car was built; it traveled to the Midwest and southern states. Of ordinary scales tested in one nine-year period between 1902 and 1911, errors were common with huge losses for consumers.

Around 1918 my paper on variance of instrument readings was published as the Bureau's *Scientific Paper No. 328* and by a leading engineering and scientific journal, *Engineering*, of London. At that time it was unusual that an American technical article would be republished in full in a foreign journal. *Engineering* was the most influential of English technical and scientific journals of the period.

I also wrote a number of articles on scales of several types and their design, causes of errors, and other subjects of interest to engineers. Gene Gressley, Professor of History at the University of Wyoming, has filed copies of my articles, estimated at about 75 in number. They have been placed in the University's American Heritage Center Archives.

In about 1916 I was assigned to an important task in Chicago. There I worked for several months at a factory where I conducted acceptance tests for the Post Office Department on 42,000 postal scales of a novel type. To reduce costs and weight, these scales were made chiefly of a sheet metal. Also tested for accuracy at the same factory were several hundred thousand auxiliary weights that were part of the scale assembly.

In one period, the Bureau of Standards took steps to provide information and printed matter directly useful to consumers. The Bureau published three major Circulars: *Measurements for the Household*, *Safety for the Household*, and *Materials for the Household*, (1915–1918). These three books were an outstanding success, with large sales through the Government Printing Office. I had a modest part in the work reflected in these books.

The Bureau received large sums of money from Federal agencies, for which it conducted hundreds of tests. One Congressman objected to these financial arrangements on the grounds that they decreased the dependence of the Bureau's projects and equipment purchases on funds appropriated, directly, by Congressional action. Another legislator was disturbed by the fact that large appropriated sums were all coming from "a little two-page law" (the Bureau's Organic Act).

The National Bureau of Standards' policy of not publishing the names of products which it had found ineffective or misrepresented, reflects the hard times which the Bureau had with AD-X2 (an ineffective chemical product alleged to revive "dead" storage batteries). The summary dismissal of Director Astin by the Secretary of Commerce was universally condemned, with the result that Dr. Astin was soon reinstated.

Several states and some professional societies have felt that the public interest warranted bringing facts about undesirable or unsafe products to public notice. Connecticut and North Dakota, and the American Medical Association follow a policy of naming names where the public interest warrants this (as it often does).

An officer in the Adjutant General's office of one of the military services announced that it was absolutely illegal for any Government agency to participate (as many did) in the operations of private non-governmental bodies such as the American Standards Association. Their "mixed memberships" made cooperation by official Government agencies quite improper, he asserted. The Bureau of Standards remained active in the work of the American Standards Association and continued Government representation on the ASA board and on working committees under the auspices of the Association.

In 1917 I was appointed Technical Assistant to National Bureau of Standards Director, Dr. Samuel Stratton. In the same year I received the M.E. degree at the University of Illinois. At the Bureau, and subsequently in my work as Technical Director and President of Consumers' Research (a non-profit consumer product testing organization founded in 1928), my greatest satisfaction was finding inexpensive ways of building devices usable in testing products for accuracy and reliability (postal scales are an example). I wrote several papers on mechanical hysteresis as a factor in instrument calibration, and explained how one could minimize accuracy-disturbing effects of friction. Several papers growing out of these findings were published by the Bureau of Standards, and also by the Franklin Institute.

In 1919, while engaged in research at the National Bureau of Standards, I was awarded the Edward Longstreth Medal of the Franklin Institute of Pennsylvania, for the design of a novel type of weighing scale of improved precision. While at the Bureau, I developed certain specialized weighing and measuring instruments, for which patents were assigned to the Bureau for free use of the public. I was responsible for the design of several novel testing instruments and devices used in the product-testing activities of Consumers' Research. A number of these have been duplicated by industry for use in their laboratories, with CR's permission, and without charge.

In 1919 I organized an instruments control department for a major manufacturer's numerous pressure and temperature instruments. I prepared and published specifications for recording thermometers and for pressure gauges. These instruments are vital in the control of manufacturing processes, and likewise essential for the safety of persons living or working in close proximity to equipment operating at high pressures and temperatures.

After leaving the Bureau, I was employed from 1920 to 1922 by Western Electric Co. in New York City. My duties were chiefly as a test engineer on the new automatic telephone equipment being developed for the Bell System.

In 1922 I was appointed Assistant Secretary of the American National Standards Association, where I was engaged in assisting Secretary Paul Agnew in numerous administrative duties relating to many aspects of the national voluntary standards movement.

For many years I served as a member of the Underwriters Laboratories consumer advisory council and reviewed safety requirements proposed for adoption by the National Standards Institute (UL is the world's outstanding testing laboratory concentrating on products related to public safety).

Beginning around 1980, I served for several years on a screening and review committee of the American National Standards Institute. I retained an active interest in this committee's work until 1990. I was awarded Honorary Life Membership in the Institute and was named a Life Fellow of several professional societies, including the Franklin Institute and the American Society of Mechanical Engineers.

After 1927, I lectured often on consumer subjects, including a short course for graduate home economics students at the University of Tennessee.

I was co-author of two best-selling books. The first, *Your Money's Worth*, was published in 1927. The second book, *100,000,000 Guinea Pigs*, published in 1933, led to the development of badly needed Federal food and drug regulations. The earlier book attracted much attention to the public importance of the work of scientists and engineers in the Bureau of Standards. It discussed the possibility that the results of the Bureau's research, testing, and standards activities could be applied to the great benefit of consumers in their day-by-day dealings in the market place.

I am honored in having been able to play a modest part in the early days of NBS, and to record some facts of interest in the origins and evolution of a great Federal agency. NBS has been unique in productivity and service to science and engineering over a period of nine eventful decades. It has been my good fortune to achieve the title of the oldest living practitioner of physical science and engineering in the operations of a great and indispensable Federal institution.

NIST-114A (REV. 3-90)

U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

BIBLIOGRAPHIC DATA SHEET

1. PUBLICATION OR REPORT NUMBER
NIST/SP-825

2. PERFORMING ORGANIZATION REPORT NUMBER

3. PUBLICATION DATE
April 1992

4. TITLE AND SUBTITLE
NBS/NIST, A Historical Perspective: A Symposium in Celebration of NIST's Ninetieth Anniversary, March 4, 1991

5. AUTHOR(S)
Karma A. Beal, Editor

6. PERFORMING ORGANIZATION (IF JOINT OR OTHER THAN NIST, SEE INSTRUCTIONS)
U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
GAITHERSBURG, MD 20899

7. CONTRACT/GRANT NUMBER

8. TYPE OF REPORT AND PERIOD COVERED
Final

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (STREET, CITY, STATE, ZIP)
National Institute of Standards and Technology and Standards Alumni Association, NIST, Gaithersburg, MD 20899

10. SUPPLEMENTARY NOTES

11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

This publication contains the proceedings of NBS/NIST, A Historical Perspective: A Symposium in Celebration of NIST's Ninetieth Anniversary, held March 4, 1991, at the National Institute of Standards and Technology. The symposium, co-sponsored by the Standards Alumni Association and NIST, highlighted the NBS/NIST contributions to industry over its 90-year history. The nine papers provide new and interesting insights on significant historical events and personalities that shaped and influenced NBS/NIST. Papers include: "Current View," John W. Lyons; "Historical Perspective: 1901-1970," Elio Passaglia; "Historical Perspective: 1969-1973," Lewis M. Branscomb; "Historical Perspective: 1973-1988," Ernest Ambler; "History of the Boulder Laboratories," Robert A. Kamper; "The Gaithersburg Site," Robert S. Walleigh; "Diamond Ordnance Fuze Laboratory and National Inventors Council," Jacob Rabinow; "Automotive Safety Laboratory," Paul J. Brown; and "Central Radio Propagation Laboratory," C. Gordon Little.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)
Automotive Safety Laboratory; Boulder Laboratories; Central Radio Propagation Laboratory; Diamond Ordnance Fuze Laboratory; Gaithersburg Site; JILA; National Bureau of Standards; National Institute of Standards and Technology

13. AVAILABILITY

- [X] UNLIMITED
- [ ] FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NATIONAL TECHNICAL INFORMATION SERVICE (NTIS).
- [X] ORDER FROM SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, DC 20402.
- [X] ORDER FROM NATIONAL TECHNICAL INFORMATION SERVICE (NTIS), SPRINGFIELD, VA 22161.

14. NUMBER OF PRINTED PAGES
78

15. PRICE

ELECTRONIC FORM

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National Institute of Standards and Technology
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