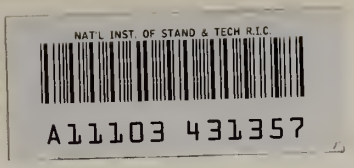

NBSIR 80-1972

Needs and Opportunities in Metrology of the Instituto de Pesquisas Tecnologicas for Effective Support of Brazilian Industry

Robert D. Huntoon
President
Measurement, Evaluation and Management Organization

with an Introduction by
H. Steffen Peiser

Office of International Relations
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Prepared under a Memorandum of Understanding between the National Bureau of Standards and the State of Sao Paulo

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U.S. DEPARTMENT OF COMMERCE, Philip M. Klutznick, *Secretary*

Luther H. Hodges, Jr., *Deputy Secretary*
Jordan J. Baruch, *Assistant Secretary for Science and Technology*

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

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INTRODUCTION

Intensive studies conducted on behalf of the Agency for International Development by the U.S. National Academy of Sciences and Research Council supported by the National Bureau of Standards came to the conclusion that industrial development in Brazil could be accelerated by U.S. assistance in industrial management and technical advisory services to medium- and small-scale industry. AID further decided that such assistance to Brazil should be channeled through the State of São Paulo which was the most advanced in Brazil's industrial structure and which in its own studies of industrial development had come to similar conclusions. In consequence and just before the end in 1973 of the AID assistance programs to Brazil, an AID loan was given to São Paulo State which included a four-year, $730,000 project for assistance and staff training by the National Bureau of Standards for the Instituto de Pesquisas Tecnologicas (IPT) of São Paulo State. As part of this project, NBS awarded a small contract in June 1977 to a company called MEMO, whose President was a retired Deputy Director of NBS, the first Director of the NBS Institute for Basic Standards, and the author of this report. That contract called for a "Report on the needs and opportunities in metrology of the Instituto de Pesquisas Tecnologicas for effective support of Brazilian industry." The "Explanation of Requirements" dated April 18, 1977, states: "IPT is gearing up to handle various Quality Assurance Programs, and Mr. Walter Link is the IPT staff member who will assess the IPT metrological capabilities. The contractor will send a senior staff member to IPT at the expense of IPT for travel and subsistence.

"The staff representative will:

1. Advise IPT upon organizational and system arrangements for the structure of a measurement system capability to provide stable, compatible measurements, including standards, instrument calibrations, and traceability for all needs, including measurement and testing for product standards and quality assurance.

2. Advise IPT and NBS on how to set up long-range objectives for a continuing collaborative program in metrology between the two institutions.

3. During his stay at IPT, the contractor's representative may find it expedient to lecture to small groups of technical people from IPT and other institutes in the São Paulo area, or to conduct a seminar on metrology issues in the context of IPT's links with industry in São Paulo. The aim of such lectures and seminars would be to lead to judgments and opinions of the contractor to be discussed in the report.

4. The contractor will submit a report which will indicate the on-site advice (1, 2, and 3) as augmented by subsequent follow-up studies in the U.S."

The maturity and sophistication of IPT as a well-established and recognized institution in São Paulo posed a unique challenge to the MEMO study. IPT is a respected organization with demonstrated competence, history, and traditions growing out of its years of service to industry and government in the areas of product testing, measurement services, and contract research or development.

This institution, newly chartered as a public corporation in the State of São Paulo, is undertaking to extend and improve these traditional services in a manner befitting a state which is deeply involved in a vast leapfrogging operation. Brazil is committed to national goals which include an industrial development that will lead the nation to a position of prominence as a major exporting country in a time span much shorter than traditional evolutionary processes customarily require.

The new public corporation status and pressures arising out of the leapfrogging operation combine to force IPT into new modes of operation with revised goals and new policy guidelines. Here also a corresponding amount of leapfrogging is required.

Implicit in the award of the contract to MEMO and in this report is the premise that the development of capabilities in metrology is an important and appropriate function for IPT. It was known that this topic was of special concern and interest to Dr. Alberto Pereira de Castro, the IPT Superintendent, and to his special assistant, Mr. Ricardo Florez, who would act as the responsible official in IPT to assist the MEMO study. No one studying the highly industrialized countries can doubt that metrology is a subject without which a country just cannot reach major industrial objectives. However, many countries in their industrialization efforts have chosen to institute one national metrological facility. IPT is not that kind of a national metrological institute. Indeed, Brazil has a very large and ambitious facility (INMETRO or INPM) being built up under the Federal structure. Needs for industrial metrology in São Paulo have preceded the services to be offered by INPM. IPT has the responsibility for providing these services on an interim basis, while also planning to work in support of INMETRO in each metrological field as soon as INPM acquires the primary national capability. IPT should receive reference materials and calibrations from abroad only if and as long as they are needed by industry and only in coordination with the programs of INMETRO. The metrology plan of IPT is not likely to become obsolete when INMETRO has developed fully. The size and

[1] See Appendix I - Early Impressions of IPT.
[2] See Appendix II for an explanation of the term leapfrogging.

diversity of Brazil make it likely that INMETRO will disseminate measurement standards in cooperation with secondary metrological facilities. IPT, with close contact with industry, is capable of becoming a valuable secondary measurement standards laboratory for helping Brazilian industry to choose raw materials, control production, and provide test methodology for quality assurance of products.

H. Steffen Peiser
November 1979

THE CHALLENGE

For assistance in the metrological portion of this pattern of changes, IPT has requested advice and training from a similar, yet different, science-based organization, the National Bureau of Standards (NBS), in the United States. This MEMO study is one aspect of the NBS response.

While the United States has the industrial development and technological base to which Brazil aspires, the United States acquired it via the traditional evolutionary processes. NBS itself grew in this environment of evolutionary change, and its staff and operations take for granted the technological base which evolved with them. Thus, there is available little experience with the complications of leapfrogging.

The challenge is clear. How can the experiences and competences developed in two different cultures with different growth processes and different technological bases be melded into a practical approach which can be expected to yield plans to assist IPT to improve its services to technological industry?

The response to this challenge, which was jointly conceived early in the study, takes the form of an intensive dialogue between the principal investigator and various members of the staff of IPT which, for want of a better name, we call the Discovery Process (DP).

DISCOVERY PROCESS

For the intensive dialogue planned for this process, a Discovery Team (DT) was formed with an IPT member (IM)[1] and a visiting member (VM).[2] The discussions took place in the host laboratory, IPT. This insured immediate access to the staff of IPT and helped keep the discussions and plans practically related to their real-life environment. The IM is presumed to have adequate knowledge and understanding, as they relate to the metrological considerations comprising this study, of:

1. Brazilian culture, goals, aspirations, industrial system, measurement system, and infrastructure of technology.

2. Nature and operations of IPT.

The VM is presumed to have similar background for the United States and NBS.

The DT then proceeds to examine and discuss the operation of the measurement system in the United States with the VM leading the discussion. This discussion should be extensive enough to encompass the sphere of action of IPT both as is and as proposed. The idea is not to use the United States as a model for the solution of IPT problems, which might well be impractical, but to provide a systematic way to cover the field for discussions, in this case, of measurement services. The VM does so, not in great detail, but in a manner which may open new windows and expose new vistas to the IM.

The IM looks through these windows at the new vistas with an understanding characteristic of his Brazilian-based expertise. If these new vistas are presented properly, the IM can be expected to discover opportunities and actions which IPT should and can exploit or take, as the case may be. These might not even be discernible to the VM by virtue of his ignorance of the local situation, while the local knowledge of the IM makes them easily evident. Thus, the DP generates discoveries by both which either alone might not make. In this manner, it provides a sort of bridge across the cultural and systems gaps.

Once the discoveries are made, the IM can then develop practical plans for their exploitation and present them to management as internally devised and proposed actions which should be implemented in the organization. His own presumed knowledge is immediately drawn upon to select approaches suitable for IPT.

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[1] IM - Ricardo Florez

[2] VM - R. D. Huntoon

REQUIREMENTS FOR SUCCESS

The DP is clearly a complex process, the success of which had not previously been demonstrated, and unless certain basic requirements are met, its success is unlikely. In this case, the requirements were met, and the use of the DP appeared justified. As indication of this justification, we examine each requirement briefly and give evidence of fulfillment.

1. The state of sophistication of the host institution and of its IM must be such that there is present an ability to make and recognize the value of discoveries, i.e., to recognize deficiencies and opportunities and to plan appropriate actions.

   Appendix I gives evidence that this requirement is met.

2. The experience of the VM must be such that he can be expected to cover the field in such a manner that he can open "new windows" for the IM to glimpse the new vistas.

   References 1 and 2 display evidence relating to this requirement.

3. The span of the systematic dialogue must be sufficient to cover the field of interest thoroughly.

   Appendix III outlines the structure followed.

4. The IM must be free to concentrate fully.

   In this case he was allowed to spend as much time as circumstances and his judgment required. He worked essentially full time with the VM.

5. The duration must be long enough to permit full coverage with time for discoveries to be made and explored and actions developed.

   The assigned period of four weeks seemed adequate.

6. The management must be fully receptive and supportive.

   In this respect, the IPT response was exemplary. The entire Directorate was accessible and helpful. All division leaders and staffs were fully cooperative.

CONSEQUENCES

Successful application of this DP provided some unique and valuable consequences, not originally intended or necessarily expected.

1. Since the IM is fully involved in the extensive dialogue as the primarily active and responsible member who makes discoveries and proposes actions, he knows fully the considerations which led to his proposals and the management reaction to them at the time. There is no need to report them in detail.

2. IPT is left at the end of the study with a set of self-initiated undertakings which, if sustained by continuing management support, may well be the start of an internal process of self-development which could be expected to lead IPT to an accelerated accomplishment of its goals.

3. An important consequence is that the DP tends to eliminate the "not invented here" syndrome. The discoveries were made by the IM, primarily, and were subsequently examined and developed by the IPT Directorate or appropriate staff. Hence, they are truly IPT accomplishments to be fostered and nourished. They are not recommendations by an outside consultant who may be considered unfamiliar with real life in IPT.

4. There is no need for a report containing a chain of arguments leading to a set of conclusions and recommendations for action. These have already been recognized by the IM as a part of the Discovery Process and have been implemented by his own follow-up actions within the IPT organization.

   A report of the outcome of the DP then naturally takes the form of a listing of the discoveries made and the actions taken or planned with a brief explanation of each. It would force the IM once more to organize his thoughts and to articulate the arguments as clearly and as briefly as possible.

OUTCOME OF THE DISCOVERY PROCESS - SELF-INITIATED ACTIONS

Actions Related to Measurement Services

1. Measurement Assurance - It became evident early in the discussion that measurement is too much taken for granted throughout most of IPT, and that not enough attention is paid to insuring that all internal measurement processes are providing dependably usable products, i.e., reliable and compatible measurements (see Ref. 4). The name of the game is real-life compatible measurement, not equipment or calibration certificates, although these have their necessary place.

It was decided that there should be a Measurement Assurance Officer (MAO), reporting to the Technical Director, with responsibility for establishing organizational arrangements, procedures, policies, and actions which will give assurance that all measurements made in or emanating from IPT will be properly compatible with the world measurement grid.

2. Measurement Awareness - It became apparent that the importance of reliable compatible measurements to all of IPT's outputs and its image among its clients is not sufficiently appreciated within the organization.

It was decided that the MAO should develop a series of lectures and seminars for purposes of orienting new staff and indoctrinating the others.

A guiding principle would be to build a recognition that IPT brings compatibility to its clients directly by its calibration of instruments and reference materials, and indirectly by all the measurements it makes and the certificates it issues. Also, any laxness leading to incompatible measurements is a disservice to the client and damaging to the reputation and image of IPT.

The disservice to the client can be catastrophic. If the client is led astray by non-compatible measurements, his products can be rejected in the world marketplace. This defeats the very goal of Brazil's leapfrogging. Thus, the client is forced to renew his compatibility by himself submitting to judgments on his reliability which in trade often leads to suffering a catastrophe.

3. Compatibility Tie Points - There is at present no systematic structure or set of procedures within IPT to which the staff members who wish to make definitive measurements can turn for assurance of compatibility. It is left to the individual.

It was decided that four compatibility tie point offices or units should be established in IPT. For each, a qualified staff member will

be responsible for providing harmonization services to IPT for those physical quantitites assigned to his office. The level of compatibility obtainable at all range points shall be called periodically to the attention of all staff.

These harmonization services can also be made available to all IPT clients.

4. Compatibility Survey - In planning for the compatibility tie points, it became evident that there is no body of information about the level of compatibility (see Ref. 4) needed for the definitive measurements clearing IPT en route to its clients. Nor is there a body of information available regarding compatibility of the harmonization (see Ref. 4) services now available within IPT. In the absence of this information, the set of four Compatibility Tie Point Stations could not be designed to meet real instead of fancied needs for IPT. Overdesign in these stations would be a disservice to IPT. They should have the capability to meet real and impending needs as an initial objective.

It was decided to have the MAO establish a rapid first-order survey to determine present needs and present capabilities. This could be followed later by estimates of impending needs and plans for any needed extensions of capability.

5. Compatibility Policy - There is at present no clearly stated policy about what level of compatibility IPT should strive for vis-a-vis clients' present needs and estimates of future needs. Such a policy would help the planners of harmonization capability plan for the early and longer term future.

It was decided that the Directorate will work with the MAO to produce and disseminate a policy which will provide an adequate but not exaggerated margin of compatibility.

6. Measurement Control (Analog of Quality Control) - It was recognized that there is no internal policing action which critically examines the quality of the measurement product of IPT to insure that quality levels are being maintained and are not being degraded. Nor is there as yet a measurement tradition which tends to provide corrective action.

It was decided that the MAO should explore the possibilities of a set of editorial controls of various kinds to pass upon the quality of documents of different levels clearing IPT. The idea would be to help police the quality of reports containing definitive measurements (as opposed to qualitative descriptive measurements) before they clear IPT.

7. Measurement Responsibility - It is not at present clear what the policy of IPT is regarding where the responsibility lies for the

quality of any definitive measurements. There is need for policy guidelines, making it clear that the one who makes and publishes or otherwise disseminates a definitive measurement is responsible for its quality. The tie points are a resource available to him but not responsible for his measurement quality. It also needs to be clear that each such staff member who disseminates a measurement outside IPT acts in effect as a measurement agent for IPT and gives, in the eyes of the client, the image of the reliability of IPT.

It was decided that the Directorate should take a policy position making it clear to each measurement agent of IPT that his performance on duty will be judged, in an important measure, by the demonstrated quality of his definitive measurements.

8. Ties to INMETRO - The advantages of redundancy and freedom to tie into the world system compatibility structure in the most effective way was easily recognized. It thus became apparent that coordination with INMETRO should be continuous while INMETRO is developing the central federal master-station capability for BNMS (Brazilian National Measurement System). This will be a prerequisite to insure that a free, not too tightly structured, BNMS will be developed.

An initial meeting with representatives from INMETRO regarding this basic policy was held. It appeared that this need for continuous coordination was recognized in their own planning philosophy. Thus, IPT is free to establish its compatibility ties for world compatibility in the most effective manner, including INMETRO capability, as it emerges. Plans were agreed upon for continuing dialogue for proper coordination actions.

9. Compatibility Ties Through Multi-National Companies (NM's) - It appeared, as a result of additional discussions at CTA (Centro Tecnico Aerospacial), that ties back through U.S. manufacturers will be used when local compatibility ties are lacking or inadequate. This was made as a sort of threat to prod action at IPT, but was then realized to be a possible alternative means to check out compatibility between the two countries and provide a helpful closed-loop redundancy. Then it emerged that similar channels through the multi-national corporations who maintain their own compatibility ties with the headquarters nation might also be available and continuously helpful.

It was decided that the MAO should check things out with CTA as a cooperative venture to close another harmonization loop with the United States. This would be followed by similar attempts with the NM's if it appears feasible.

10. Measurement Assurance Programs for Clients - Those clients who are not large enough to have measurement assurance programs of their own need some connection to provide continuing compatibility through measurement assurance procedures. IPT does not yet have a stated

policy relating to this. It was decided to develop an appropriate policy and disseminate it.

11. Maintaining and Building of Capability - As Brazilian industry grows and the pool of technology supporting it develops, the need for more sophisticated measurement capability at IPT will increase accordingly. To be most effective, IPT should lead rather than follow in this coordinated pattern of improvement.

Experience in many other countries and laboratories shows that metrological services never return enough in fees to show a profit. The costs of improving tie point compatibility increase markedly with sophistication, and at the same time, the frequency of harmonization calls decreases as the client sophistication increases. Yet the tie points must always be somehow available either locally or via some international arrangement.

Good metrological development and corresponding improvement in client services tend to lead to fewer but more sophisticated demands for service. Thus, although the number of requests for service may decrease, the cost and complexity of each increases. Generally, the impact upon the client of a measurement error becomes more devastating. Unfortunately, if the increased costs are included in the fees, the client who needs them most may be unable to pay the bill and be forced to use other less effective channels.

This was recognized as one aspect of a larger problem related to development of general IPT capability growing out of the conversion of IPT into a public corporation. The larger problem is treated in item number two in the next section.

There must be policy decisions in IPT, and in Brazil generally, relating to the level of competence to be developed in-house and how much can be practically deferred by making harmonization ties indirectly through the National Measurement System and directly to foreign national measurement laboratories, such as National Bureau of Standards or National Physical laboratory or Physikalisch-Technische Bundesanstalt.

12. Traceability (see Ref. 4) - It soon emerged that traceability is logically accomplished by means of closed-loop, active harmonization. Passive, open-loop harmonization is at best a doubtful substitute, although state of the art requires its use in many instances.

It was decided that IPT should adopt and promulgate a policy of encouraging and fostering closed-loop harmonization internally and with clients requesting measurement assurance services.

Actions Related to Institutional Development in Support of All Activities

1. The Gap - The staffing pattern at IPT exhibits a significant gap in the middle-management levels. This is attributed to the management policies at IPT and not to the general social behavior patterns. It is partly due to salary policies and partly due to personnel development policies and lack of organized management training to develop people for these levels.

As with most science-based, mission-oriented institutions, there are two main classes of employees: those who work "for" the institution and those who work "at" it. The former meld their personal goals with those of the institution and get their major rewards from the mission accomplishment. The latter have personal goals related to the professional community and go where these goals can be met, staying at IPT only so long as their work coincides with their personal goals. The middle-management people normally come from the "for" class. The top staff of IPT clearly are so motivated. The "gap" seems to be the result of having too many "at" employees who leave for industry once they get some experience. These are not lost to Brazil, and IPT provides a service by training them and benefits from their presence; but IPT is not primarily a training institution and must have a proper quota of "for" staff.

This need has been recognized, if not clearly formulated. There needs to be some policy pronouncement about the training mission of IPT and its balance with the service mission. There also needs to be some management training and indoctrination to help motivate and convert new employees of talent to the "for" class.

The Directorate of IPT is now considering a management training program proposed by one of the directors.

2. Development of Capability - The recent conversion to public corporation status will make IPT strongly dependent upon fees from its industrial clients. While such clients will pay for direct costs of the services they receive, they can be expected to object to markups to provide funds for development of capability to meet foreseeable needs as technology advances and Brazilian industry becomes more sophisticated. Finding the means to grow and develop capability for future needs is crucial for the survival of an IPT as visualized in its present goals. The institution must somehow maintain a leadership position if it is to be ready to serve the needs of clients two to five years downstream. It will not suffice to wait until the need emerges in the form of a client demand. By then the clients will not be willing to wait for development and pay for it, too. IPT must have discretionary resources continuously available for the support of the growth process, and finding them must be a top priority undertaking for the management.

To make the problem even more pressing, the conversion from public funds (presently about 50 percent) to income from fees is accelerating under pressure from the Government. The interval of three years, planned at the time of establishment as a public corporation, has already shrunk to two and possibly less.

The management of IPT is well aware of this crucial problem and indicates that plans are under development to proceed on several fronts, such as:

a. Developing plans for an overhead charge to provide discretionary funds.

b. Planning to sell capability development projects to the Government.

c. Selling the Government on a continuing budget for capability development.

d. Developing a policy to investigate actively the impending developments in industry expected to impact upon IPT, including consideration of a set of industrial advisory committees.

3. Staff Development at Home - Excessive loss of new staff to industry may imply some lacking or even unconscious, unexpressed negative personnel policies. Establishment and pronouncement of positive policies backed by action in support of personal development plans, personal development discussion with supervisors, training for first- and second-level supervisors, procedures for encouragement of ideas from staff to move upwards, and so forth, will help identify and motivate capable "for" employees.

The Directorate is now engaged in consideration of these matters. A new Personnel Committee recently formed will be asked to consider these and similar questions.

4. Staff Training Abroad - Sending a staff member abroad to learn by watching or participating in an ongoing project, while helpful and desirable, can lead to misunderstanding and disappointment unless the visitor understands that he is essentially "piggybacking" on the project he watches. He must be careful to sense and relate what he sees to the realistic picture of supporting systems back home. Appendix II contains a discussion on "piggybacking." More is indicated in Appendix III.

IPT management is planning for more effective counseling for trainees during training abroad. Also, actions to ameliorate the "gap" will lead to more experienced trainees who can appreciate the problem and be more selective in their training activities.

5. Organizational Readiness - It is a common failing in the United States that organizations which send people for training, either technical or managerial, forget that the organization must itself develop to be ready to make use of the training when the individual returns. Failure to make this compensating organizational development is frustrating to the individual, generates an attitude against training, and leads the institution to feel that training is not productive.

The management at IPT indicated that this problem had not been faced, primarily because there has been little management training and the technically trained people are seriously needed when they return. They propose to include organizational development in their actions to provide for personal development and management training.

CONCLUSION

This terminal section is a conclusion in the sense of a closing off, not the conclusions reached as an end product of rational analysis, yet one such conclusion must be stated. Discretionary funds to develop capability and to support the central measurement competence which will not be self supporting must be provided. Without them IPT cannot be expected to meet the future demands of its clients.

It has become clear in the preparation of this report of the MEMO/IPT Project that the product of the Discovery Process resides at IPT in the minds and notes of those who participated actively and in the "ah-ha's" perceived by IPT staff as they sensed opportunities for action and developed plans for implementation.

The Appendices which follow provide:

1. Explanation of some of the terms used.

2. Back-up evidence for some of the statements made.

3. Basis for an overview of the extent and structure of the Discovery Process "Curriculum."

4. Some helpful references. Copies of these have been supplied to IPT and duplicated there as desired.

APPENDIX I

EARLY IMPRESSIONS OF IPT

A preliminary broad-perspective understanding of IPT as an institution in the Brazilian society was an essential input to guide the study. This "first impression" could be corrected later, as and if necessary. It is presented here as a collection of brief statements which generally characterize IPT and will serve to orient the reader. The input for these statements was provided by:

1. Pre-trip briefings by the program coordinators at NBS.

2. The IPT brochure entitled Instituto de Pesquisas Tecnologicas 1976.

3. Early orientation visits provided by IPT upon arrival there.

IPT is a venerable institution of the São Paulo industrial system, starting operations in 1899 (two years before NBS was chartered).

IPT was, for most of its history, a civil service, government-financed laboratory of the State of São Paulo, and it has no federal charter to perform functions at the national level. Some may be assigned.

Within the past year, IPT has been converted to a public company which allows a much freer basis of operation, still, however, under the control of the State Government. In particular, it removes some salary limits of the civil service which were causing serious losses of skilled personnel to industrial competitors.

The mission of IPT is to serve the needs of industry for product testing, contract research and development, product quality control, and measurement services, such as calibration of measuring instruments.

A consequence of becoming a public corporation is that Government funds for support of operations must be replaced, in a major way, by fees from the industrial clients. At present, the mix is about 50-50, but the fraction provided by the Government is supposed to be reduced during an interval of 3 years.

IPT has exhibited a steady growth and a stable management reaching by mid-1977 a level of operation approaching 1600 staff members and an annual budget of about $25 million (Cr$375 million).

As it operates at the time of the study, there are eight technical divisions, two service divisions, and a Directorate consisting of a superintendent, technical director, director of administration, and

legal fiscal director. The superintendent reports to a council made up of Government and industrial representatives.

The operating divisions have extensive autonomy over the work that they undertake for industrial clients. There are no written policy guidelines bounding the freedom of work contracts. However, each division is expected to show a profit from its operations and is not at present required to pay for plant and facilities. IPT will be required to amortize its equipment.

Trainees sent to NBS at the senior level have been reported to be professionally capable, creative, well-motivated, and useful in the programs they joined. In many cases, the NBS units report a desire to have the individual remain to do more.

As would be expected, the stability of management has fostered the development of IPT traditions, social values, and definite modes of procedure (habits of behavior).

The filtering processes, characteristic of civil service days, has left IPT with a dedicated and motivated, but small, top echelon of professionals of real competence. Competent middle management between them and the technicians at the workbench is sparse.

The magnitude of the operation, its continued growth, and the widespread use of its services attest to the competence of its staff and the capable management of the institution.

The growing sophistication of the industrial clients and the complexity of the research problems brought to IPT has caused review of its traditional divisional management. The advantages of some form of matrix management have become apparent, and a beginning has been made to undertake programs which encompass the capabilities of more than one division. The control has been put into the hands of a program manager who assigns tasks and funds to the divisions for appropriate portions of the program.

APPENDIX II

BRAZIL AS A LEAPFROGGING SOCIETY

Every nation is composed of a set of interacting systems of people, institutions, equipment, and procedures each having many interfaces with the others. Examples of the kinds of systems involved are:

1. Political.
2. Religious.
3. Fiscal.
4. Legal.
5. Police.
6. Educational.
7. Transportation.
8. Communication.
9. Industrial production.
10. Measurement.

The latter two systems are prominent in what we call industrialized societies. Such technically based societies have, as an important addition, a vast reservoir or pool of technology from which all the systems draw as needed. Each of them also adds appropriately to the pool through its operations. Thus, a sort of "bootstrapping" (self-sustained enhancement) takes place. The systems which draw upon the technology add to it, in return bringing about a positive feedback to stimulate further growth.

This pool of technology exhibits a form of cascade structure. Later technologies depend upon earlier ones for their development and sustenance. Thus, for example, an illumination technology depends upon the existence of glass technology, metals extraction, wire drawing, powder metallurgy, alloy technology, getter technology, phosphor technology, metal forming, vacuum technology, etc. These in turn depend upon others.

As an industrial society evolves naturally, all of the systems and supporting technologies develop in a mutual harmony with balances roughly maintained. Many small imbalances occur and are remedied by many advances and adjustments so that the whole growing complex evolves to suit the needs and goals of the society in a kind of dynamic equilibrium. A society which grows in this manner, maintaining internal harmony, can be called an evolving society.

If an evolving society, at an earlier stage in its development, undertakes to interact in the world scene with the major industrialized nations and to compete with them in world markets, it must intervene in the slow process of evolution. This intervention takes the form of an attempt to increase suddenly the magnitude and

sophistication of the industrial system by importing equipment and technology and by sending people abroad for training.

Clearly, an increase in the industrial system in an evolving society is accompanied by appropriate changes in the educational, transportation, fiscal, legal, and communication systems as well as the measurement system. Without these adjustments, the industrial system rests on some very insecure and troublesome supports. But the leapfrogging society can't wait for all the evolutionary steps, so it undertakes a series of corrective actions to ameliorate the economically and socially limiting imbalances when the industrial system is stepped up. These can be considered as means to leapfrog over the traditional evolutionary stages into the modern capability. Hence, the term "leapfrogging society" becomes descriptive and useful.

A leapfrogging society has clearly to deal with more complex problems than an evolving one, and it is more difficult to understand and sense the important dislocations. It is beset by a myriad of problems arising from the induced imbalances and the new ones added by first-order attempts to correct the obvious immediate ones.

For the past 20 years, Brazil has been a leapfrogging society and has faced many of the expected problems. This discussion is not an argument against Brazil's leapfrogging, merely a recognition of it, since understanding of what is going on will be helpful in planning the future actions.

However, as a consequence, it is understandably difficult for specialists who have grown up in, and spent their careers in, an industrial society of the evolving type to come to Brazil and exercise their usual skills in the different, more complex environment. Unless they are aware of the fundamental differences, they can give advice which unknowingly subsumes the existence of a level of technology and performance of the other systems which is not yet available. Hence, their advice may be inoperable, unpractical, or even downright catastrophic.

This line of reasoning leads to caution. In effect, it encourages teamwork between the specialist and capable Brazilians who do know the state of their technology and the performance of their other social systems in planning future development.

In this particular case of the MEMO study of IPT measurement services, it rapidly becomes clear that the São Paulo industrial development has progressed beyond the capabilities of the Brazilian National Measurement System (BNMS), and corrective actions both temporary and fundamental are needed. Industry is reaching out to the pool of technology for capabilities not yet in being. In frustration, it turns elsewhere, but not always with success.

To avoid the pitfalls facing the advisor from an evolving society, the Discovery Process was formulated and tried. It seemed to work largely because the state of sophistication at IPT is well advanced and the complexity of the situation is readily understood. Also, there is a good measure of creativity present to recognize the avenues for change and to exploit them.

The discoveries made and the resulting self-generated actions should provide a basis for IPT to bring the São Paulo measurement system into consonance with the industrial needs as they now stand.

More than this is needed, however. As the BNMS catches up to the present needs, they will have, in the meantime, moved further ahead. The planning needs to foresee this forward momentum and plan for it, too. The most effective form of outside assistance will be the kind that leaves a legacy of self-initiated, self-supporting actions which will lead to a growth pattern that will not again fall behind. Leapfrogging should strive to bring the country to a modern position, not just to a new base for an additional repetitive leapfrogging action.

There is, of course, the question, "Is such a course fundamentally achievable?" The growth of technology, depending as it does on positive feedback via the ever expanding pool of technology, tends to increase in proportion to what has already been achieved. A system with a lesser pool to build upon could not then be expected to develop a growth rate which will allow it to overtake an established system of greater development.

Sheer size and complexity or political policies may result in a slowing of the more developed larger system and permit the developing system to catch up. This fundamental question is not clearly settled and may never be.

It does seem clear, however, that every import of technology, if consolidated into the developing system, will help alleviate the differences.

This leapfrogging difficulty tends to work in a reverse mode also. When Brazilians are sent to organizations in a well-developed but evolving society for training, they are accepted into ongoing projects as a part of the team. They, in a sense, "piggyback" the project. By this process they not only become part of the project but also of its environment. They need to be aware that this environment is liable to mislead when the project itself is transferred to their leapfrogging society.

Consider NBS as an example. If the trainees are engaged in watching some ongoing projects, they must realize that these people they watch are accustomed to the presence of the whole pool of technology and of the performance of the other social systems at corresponding

equilibrium levels. Thus, what seems easy and straightforward at NBS may, in fact, be very difficult, if not impossible, back home.

If the trainee is not aware of the leapfrogging actions of Brazil and of the present holes in the structure of Brazilian technology as well as the non-corresponding performance of other Brazilian systems such as transportation, education, or communication, he may well be attracted to the wrong aspects of the projects he is watching. He will learn some wrong things or get priorities reversed.

This argues that already experienced people should be sent as trainee-observers. Yet, at IPT, the people with this experience and maturity cannot be spared from present assignments for a long enough time to make away-from-home training worthwhile.

Three corrective actions can be helpful:

1. Steps need to be taken to fill "the gap". Some are planned.

2. The IPT training coordinator at NBS should be of sufficient stature and experience to counsel with the trainees to insure that they are learning the proper things.[1]

3. The trainees can be given projects of their own to perform at NBS, provided the training coordinator watches that they realize some system performances they are drawing upon do not yet exist in Brazil with comparable performance.

[1]He should also arrange to provide such counseling. The present coordinator clearly has the qualifications. He should review the need for this help for present trainees and adjust his priorities accordingly.

APPENDIX III

DISCOVERY "CURRICULUM"

The material which follows outlines the "curriculum" for discussion which served as a basis for the Discovery Process to function. It is presented to serve two functions:

1. To indicate the scope of the discussions upon which discoveries were based.

2. To serve as a review guideline to IPT for further considerations of self development.

This "curriculum" material was presented with slides in two lectures at IPT. Copies of the slides were made at IPT and kept there. The lectures were taped and detailed notes left at IPT.

I. Universe of measurements

A. Domains

1. Legal metrology (IPT not involved)
2. Technological metrology (vital to IPT)

B. Classes of measurements

1. Interchangeability

a. Materials, parts, systems
b. Equity in the marketplace (legal metrology), data and information science, and engineering
c. Product standards

2. Decision and action

a. Daily actions (flight control, for example)
b. Process control
c. Quality assurance
d. Quality control

II. Fundamental importance of measurement

A. Daily life

B. Science and engineering data

C. Product standards

1. Formulation - based upon realizable measurements
2. Acquisition - based upon realizable measurements
3. Verification - based upon realizable measurements
4. Certification - based upon realizable measurements

D. Quality assurance

1. Product planning and design
2. Materials acquisition
3. Process control
4. Standard verification
5. Performance measurement

E. Quality control - policing

1. Parts verification
2. System performance

F. Economic values

1. Investments in measurement
2. Relation to industrial growth
3. Relation to balance of payments
4. Value in the marketplace
5. Cost benefit considerations

III. Concept of National Measurement System
(References 1 and 4)

A. Measurement station

1. Meaning
2. Operation
3. Operators and integrity

B. Compatibility

1. Meaning

a. Across society (across geographic area)
b. Across time

2. Essential requirement of working system
3. Master slave relations
4. Pyramidal structure
5. Top master stations

C. International compatibility

1. Ties to world grid
2. World infrastructure

D. Main networks

1. Instrumentation
2. Data
3. Techniques

E. Achieving compatitility - harmonization

1. Passive (open loop)
2. Active (closed loop)
3. Absolute

a. Standard reference materials
b. Standard reference things
c. Standard reference data

4. Catastrophe (Manufacturers who depend upon non-compatible measurements make products which are rejected in the marketplace.)

F. Derived units

1. Base units
2. Coherence scheme
3. Coherent derived units
4. Absolute ties to physical constants

G. Range extension

1. Unit definition
2. Top master realization
3. Extension to small and large values
4. Accuracy charts

H. Planning ahead

1. Use of accuracy charts
2. Assessment of present capability
3. Improving the units
4. Profitability

IV. The Brazilian National Measurement System (BNMS)

A. Attempts to sketch the present portions of BNMS

B. Missing elements

1. Federal central core
2. Dissemination chains
3. An example of the missing technological base for the industrial expansion

C. Importance of a free system reemphasized

V. IPT as a functional element of BNMS (black box)

A. Federal role (only as assigned in special cases)

B. Service ties to São Paulo industry

1. Testing
2. Certification
3. Calibrations
4. Measurement assurance needed
5. Process control

C. Interfaces

1. INMETRO
2. Multinationals
3. Industrial clients
4. Industrial ties to world grid
5. World grid (in absence of INMETRO)

VI. IPT from inside

A. Requirements

1. Internal compatibility
2. Measurement awareness
3. Measurement assurance
4. Available tie points

   a. External to world grid
   b. Internal laboratory
   c. External for clients

5. Measurement responsibility
6. Quality control of measurements (editorial policy and committees)
7. Compatibility level requirements - survey

B. Survey proposal

1. Status of compatibility
2. Status of levels available

3. Status of levels needed
4. Estimates of trends

VII. IPT, the Institution

There are fundamentally important factors which affect the accomplishment of the measurement services provided by IPT. However, these affect also, in a broad way, the effective prosecution of all the missions of the institution.

The DP was used in this case, too, using the VM experience at NBS and as a management training consultant as a basis for the discussion. As expected, the IM observed from his background and by joint discussions with the management opportunities for improvement of IPT operations generally.

In this broader based discussion, relevance to measurement services was not a requirement. The "curriculum" of subject matter covered as a basis for this DP follows.

A. General aspects of institutional development

1. Development of staff by the organization

a. Technical training
b. Management training
c. Personal development plans
d. Reward structure
e. Personnel policies
f. Differentiation between those who work "for" IPT and those who work "at" IPT

2. Self development of staff

a. Policy guides
b. Encouragement
c. Financing
d. In technical areas
e. In management areas

3. Self development of organization

a. Awareness
b. Readiness to grow to match staff development
c. Continuing concern for personnel policies
d. Promulgation of policies

4. Development of organization by staff

    a. Awareness that this happens and should happen
    b. Encouragement
    c. Staff initiative to help organization improve

B. Development of capability

1. Sources of funds

    a. What can be done with fees
    b. Needs for discretionary funds

2. The public corporation problem of IPT

    a. Where to get the discretionary funds
    b. Development of institution policy
    c. What can clients be expected to support

3. Trends

    a. Policy regarding forecasting
    b. Passive response to client requests
    c. Active intelligence gathering and forecasting

C. The Gap

1. Observance of middle management gap
2. Accident of IPT or social phenomenon (IPT can control)
3. Procedures for elimination

    a. Is it needed - policy position
    b. Personnel policies
    c. Management training
    d. Treatment of growth of "for" employees
    e. Treatment of growth of "at" employees

D. Training abroad

1. Limitation to "for" employees
2. Remain on duty commitments
3. Consequences of gap

    a. Junior staff too inexperienced to profit sufficiently
    b. Senior staff too committed at home to spare time
    c. How to get out of dilemma

        (1) Management training
        (2) Salary to retain staff

4. Problems of piggybacking

    a. Programs observed are ongoing and based upon technology of the host institution
    b. Result is focussing on wrong aspects in some cases
    c. Remedies - IPT resident coordinator at host institution to help guide the learning of trainees

E. Organizational readiness

1. Management training of staff (training ineffective if organization doesn't develop self to make use of staff training)
2. Organization preparations for returning technical trainees

F. Personnel policies

1. Periodic review
2. Counseling by supervisor
3. Encouraging personal development plan
4. Avoiding the rating confrontation syndrome
5. Value of personnel policy committee
6. Value of division personnel policy committees
7. Keeping control in technical hands
8. Promulgation of promotion criteria
9. Reward structure

    a. Stated
    b. Real
    c. Staff conceptions of each

G. Matrix management

1. Traditional independence of divisions a barrier
2. Difficulties with line managers, understanding
3. Demonstrating the value of matrix management

    a. Efficiency
    b. Prevention of stagnation

4. The transition

    a. Complete or partial
    b. Selecting leaders
    c. Timing
    d. Adjudication

5. Who pays for discretionary funds
6. Role of the resource leader (Division Chief)
7. Role of the program manager

8. Need for goodwill and understanding
9. Use only "for" people as managers and program leaders

H. Integrity

1. Vital to research testing institution
2. Staff awareness
3. Management awareness
4. Impact of organizational changes
5. Reward structure for improving attitudes
6. Policy statements and guides
7. Responsibility of every individual
8. Working for internal social approval

I. Advisory committees

1. Overall operations (now exists)
2. Divisional committees

    a. Client inputs for discussion
    b. Spur to staff
    c. Opportunity for contacts and visibility
    d. Protection against political interference
    e. Stay out of management

APPENDIX IV

THE TRANSFER OF INFRASTRUCTURE TECHNOLOGY FROM HIGHLY INDUSTRIALIZED TO MEDIUM-INCOME COUNTRIES

NBS has gathered some development assistance experience upon which a few conclusions can be drawn which appear to be consistent with this report.

1. Industrialization brings with it an ever-increasing need for an infrastructure in measurement science which in any one country must be carefully tuned to specific industrial needs.

2. Metrology must be carried out under the guidance of a national capability which for different physical, chemical, and engineering quantities could be spread over several institutions.

3. Good dissemination of metrological quantities to industry and test laboratories must be carefully planned and generally involves a multi-institutional structure.

4. Transfer of infrastructure technology tends to be ineffective if not coupled with transfer of management practices and other institution building projects.

5. Transfer of infrastructure technology has to be actively pursued by donor and receiving teams, who in their interplay must be tuned to listen to each other's arguments and be sensitive to wide-ranging issues. This is the principal feature of the "Discovery Process" described in this report. Various descriptions of this Process are possible, but this much is certain: Both sides must actively face it as a challenge.

APPENDIX V

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IPT and NBS are now in the last year of a five-year AID-sponsored joint effort to help IPT accomplish its proper part in the "leapfrogging" industrialization of Brazil. This telescoping of conventional patterns of growth, to reach maturity more rapidly, injects dislocations into the balances between imported sophisticated technologies and supportive subordinate technologies such as, for example, the nation's measurement services. A four-week joint study of measurement services of IPT served as a basis for examining the dislocations in the São Paulo measurement infrastructure. By comparing the activities in IPT with those in a laboratory functioning in a more developed infrastructure, IPT, with its extensive knowledge of Brazilian technologies, was able to identify dislocations peculiar to Brazil and plan for itself appropriate corrective actions. The nature of the comparison and the corrective actions planned are presented in the report.

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