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SCIENTIFIC POLICIES IN MEXICO FOR THE DEVELOPMENT OF MATERIALS

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PRESENTATION

At the end of 1988 the new president of México, Carlos Salinas de Gortari, took possession for the period 1988-1994. Due to this change in administration, a new National Development Plan (Plan Nacional de Desarrollo) was drafted for the period 1989-1994 and as a consequence all government institutions had to elaborate their development programs in agreement with the overall guide lines of the National Plan. The government institution that is in charge of scientific policies in the country is the National Council of Science and Technology (Consejo Nacional de Ciencia y Tecnología, CONACyT for short), whereas the Institution in charge of all public higher education is the Secretariat of Public Education (Secretaría de Educación Pública, SEP). Both of them drafted their respective programs for the period, programs that would guide all the actions of both institutions for the reminder of the six-year period of the present government administration.

CONACyT started out with an administration that began working while formulating the National Program of Scientific Development and Technological Modernization (Programa Nacional de Desarrollo Científico y Modernización Tecnológica, PNDCMT) and by the time it was finished there was a change of administration. The first CONACyT administration started out accepting the recommendations set forth by the Organization of American States (OAS) in the areas of priority for the development of the country, which are: new materials, biotechnology, electronics and informatics, ecology and environment, water and extreme poverty. During this period the science and technology of materials was a priority area. By the time the PNDCMT was finished, which coincided with the change in administration in CONACyT, it had become clear that the present-day problems of the country required a different approach and the priority areas were abandoned.

On the other hand, at the end of 1989 I was approached by the Secretariat of Exterior Relations (Secretaría de Relaciones Exteriores, SRE) to elaborate a program in Materials Science that contained recommendations for bilateral and multilateral international cooperation both for scientific projects and for technological cooperation. The development of this task was undertaken in 1990 and completed at the beginning of 1991, in close communication with the personnel of SRE. The group which I coordinated included the following specialists: Dr. Alberto Correa and Dr. David Ríos for metals, Dr. Roberto Escudero and Dr. Liberto de Pablo for ceramics, Dr. Ricardo Vera for polymers, Dr. Enrique Sansores and Dr. Ricardo Zermeño for semiconductors, with Dr. Jesús Heiras acting as Secretary.

The document that follows has been so structured that section I contains a discussion on the science policy in México that is relevant to the development of Materials Science. Section II contains information regarding the demands and the problems for materials in the country together with a discussion of my recommendations for possible solutions to these problems. In Section III a prognosis is made concerning the development of scientific and technological policies, and Section IV includes the recommendations for international linkage and cooperation taking into account the modes, the areas and the scope of these actions. Finally Section V contains some comments that I consider pertinent to the subject.

Dr. Ariel A. Valladares C.
México, D. F. November 27th, 1991

I. MATERIALS POLICY IN MEXICO

Historical Background

Science Policy in México started officially in december 1970, when the Federal Government created the National Council of Science and Technology, which in spanish is called Consejo Nacional de Ciencia y Tecnología, or CONACyT for short. Before that there had been attempts that gave way to the founding of CONACyT, and they will not be mentioned here.

CONACyT was born under the administration of Luis Echeverría Alvarez, president of México for the period 1970-1976, with 27 functions defined in the second article of the law that created it. The first article says that CONACyT is founded to be a consultant and a support to the Federal Government for establishing, implementing, executing and evaluating the national policy of science and technology.

At the beginning, this newly created Council was faced with a heavy centralization of scientific activities, since more than 90% was located around Mexico City, or metropolitan area as it is called. That was the origin of a dichotomy that has become recurrent as administrations of CONACyT come and go: Should they support scientific activities guided by a criterion of excellence regardless of the geographical location of the groups that carry them out or should they foster a more balanced development of science all over the country applying different criteria for different institutions?

When first created, CONACyT had a very limited choice of scientific institutions to finance since only those in the metropolitan area had reached a reasonable degree of scientific development. Gradually the state universities (more than 30 public institutions located in the states of the Republic) and the centers created by the Council itself, mostly located in the states, developed scientific groups. In spite of this, funds were still channeled mainly to the metropolitan community largely due

to inertia and also to a limited knowledge by the metropolitan community of the changes that were taking place outside México City. The CONACyT centers also received substantial support that allowed them to flourish although most of them did not have graduate studies and therefore were unable to form Ph. D.'s to promote the growth of other groups. Moreover, they did not have close links with the local state universities either, which made their usefulness for the formation of human resources very limited.

For many years the state universities have received more than 80% of their budgets from the national government through what is now called the General Direction of Higher Education (Dirección General de Educación Superior, DGES) of the Secretariat of Public Education (Secretaría de Educación Pública, SEP), which has existed under a variety of names for several decades. The rest is obtained through state funds and a very small part from student tuitions. Since México has experienced a rapid population growth in the last decades, the government found it useful to channel funds to the state universities through two different General Directions: one was DGES, mentioned above, and the other was the General Direction of Scientific Research and Academic Improvement (Dirección General de Investigación Científica y Superación Académica, DIGICSA), both originated in December 1976, only six years after the creation of CONACyT. They were formed to promote the academic development of the state universities. DIGICSA assumed a complementary role to that of the Council and for almost 15 years science has grown in the state universities due mainly to the support of SEP.

By law CONACyT is the instrument of the government for setting the policies for the development of Science. At the end of 1988 with the change of presidential administration for the period 1988-1994, the Council changed General Director. The new administration adopted as its own the policies recommended by the Organization of American States, among which the area of new materials was priority, together with biotechnology, electronics and informatics, water, environment and extreme poverty. These

priority areas were also adopted by the Secretariat of Foreign Relations (Secretaría de Relaciones Exteriores, SRE) to define the areas in which bilateral and multilateral cooperation should be undertaken. Because of this an International Cooperation Program in New Materials for the SRE was developed under my coordination. This Program has been completed and delivered to the SRE for the purposes that they consider fit.

Meanwhile the administration of CONACyT changed at the beginning of 1991 with a consequent change in policy. For one, there are no longer priority areas. For pure science excellence in the projects is the main requirement. For technological development a strong participation of Industry is required, both economically and academically. All in all the present policies tend to strengthen and develop existing areas of excellence. Existing incipient projects are being left out in order to maximize the benefits of the financing supplied. Thus certain areas that are relevant for the development of the country but are only in the beginning stages may not be covered. No doubt, one of the urgent requirements in México is the establishment of policies that respond more to a long term idea of what the country needs for its development, regardless of the individuals that put them into practice.

Recently some of the policies for scientific development have been clearly stated:

i) As far as basic science is concerned quality is the main requirement. There are no specific priority areas, on the contrary the main reason a given person or group is financially supported is the quality of the project presented.

ii) For applied science or technological development participation of an industrial group is essential for any project approved by CONACyT.

There is an underlying logic in these policies. For one thing, it is clear that for basic science there is no substitution for excellence and attention must be paid to this aspect. Nevertheless I believe that fomenting the creation and growth of certain areas

that are strategic for the development of the country should not be overlooked. This requires a congruent effort among all the different government institutions that have to do with the development of science both in research centers and in institutions of higher education. It is also necessary to establish and maintain policies beyond the period of a given administration. The only manner in which this can be accomplished is by planning in such a way that all long term programs associated to the development of the country are sustained.

For technologically oriented research it is fitting to point out that when the industrial development of a given country is incipient, as is the case for practically all of the third world nations, it seems pertinent to make political decisions to launch the areas that are considered relevant for the progress of the country. To leave the evolution to the market forces is to overlook the power of political decisions and, as an example, I would like to remind you of the political decision of the Kennedy administration which decided to put a man on the moon and all the collateral industrial development this decision brought to the USA. The power of political decisions must not be overlooked, especially when they span many administration.

There is another aspect that gives educational and scientific policy making in México a special dimension. Due to historical reasons, most public institutions of higher learning are autonomous. This means that even though the government finances these institutions almost completely , they have freedom to decide how to use the budget and when to use it. The origin of such status can be found in a political struggle back in 1929 within the National University of México, which in that year became the National Autonomous University of México (Universidad Nacional Autónoma de México, UNAM). As a consequence, most public institutions founded later were declared autonomous from the start with all that this implies.

To finish up I would like to mention the program called National System of Researchers (Sistema Nacional de Investigadores, SNI),

launched by the Federal Government in December 1983 through SEP, that has undermined the relevance of the salaries obtained by researchers in the public universities, but has contributed to maintain and even increase the number of researchers in the country through the hard years of the national inflationary problems. The SNI grants salaries that range from 3 to 8 minimum salaries to researchers that work in the Federal District (more or less the metropolitan zone) and one extra minimum salary to the researcher that work outside the Federal District. The idea is to foster the scientific development of the groups located outside the Federal District to provoke a descentralization of academic activities. The concept of minimum salary is not easy to grasp; it is the minimum amount of money that any employee must receive for his work anywhere in the country. In order to become the recipient of these compensations in SNI it is necessary to be evaluated by peers who determine the quality of the work and therefore which level a given individual deserves. So far the criteria used for the evaluations do not have any element of preference based on the type of research done; that is, there are no priority areas involved in these evaluations.

The Making of a National Policy

As mentioned above, CONACyT is the institution in charge of establishing the national policies in science. Nevertheless, due to the autonomous character of the public universities it is necessary to negotiate any policy and convince the participants to put it into practice. Also, due to the fact that there exist other financing institutions, like SEP that supports both the universities ordinary budget and its extraordinary one oriented to the activities that directly represent scientific improvement, it becomes evident that the "economic boss" for higher education is precisely SEP. This is even more so since this Secretariat also economically supports the so-called Technological Institutes, approximately 40 in number which are located throughout the country and are dedicated to the technological areas in higher education.

It should thus be clear that making a policy and putting it into practice require negotiations among all the above-mentioned participants. Nevertheless, as I mentioned before, the present policies are not area-oriented, but are quality-oriented for basic science, and usefulness-oriented for applied science and for technological developments.

As can be seen the agencies and institutions involved in the development, formulation and implementation of a scientific policy in the area of materials are: CONACyT, SEP, UNAM and the public state universities, the technological institutes, industrial groups and some selected groups of society. It is important to emphasize that every time there is a change of presidential administration, and this occurs every 6 years, a new Development Plan is drafted and this implies that all the government institutions have to elaborate their specific programs in accordance to the Plan. At present there is a National Development Plan for the 1989-1994 period and CONACyT has the National Program for Science and Modernization of Technology 1990-1994 (Programa Nacional de Ciencia y Modernización Technológica 1990-1994). It would be reasonable to establish long term programs beyond the period of a given presidential administration

CONACyT has established a close relation with industries during its existence. Even though it is a tremendous task to reconcile the interests of the industrial groups of the country with the scientific community, some progress has been made to the point that presently there are many more links between the academic world and the technological groups; nevertheless, what promises to change this relationship in a radical way is the political decision of the mexican government to sign the Free Trade Agreement with the USA and Canada, matter that will be the subject of further discussion later in this work.

The formation of personnel at the Ph. D. level is an important task endowed to the Council. Presently assistantships are granted to those students who are accepted in any university that is included in a list elaborated by the Council in collaboration with

the scientific community. In the case of the basic sciences, the list of recommended universities includes the most prestigious ones all over the world in the different disciplines. There are also mexican universities included in this list and such a classification is useful for students that plan to get a degree.

Materials Policies and Environmental Issues

The Mexican Government has given top priority to environmental protection and restoration. There is a firm will to act vigorously in this area to ensure the necessary respect for nature and recognize in practice what can be done and should be done to preserve our resources and protect the environment. The intention to carry this forth is clearly stated in the National Development Plan (Plan Nacional de Desarrollo, PND) for the period 1989-1994, the document that provides the guidelines for the country's planning process.

The Plan gives the environment an essential role in México's modernization process, and promotes a new type of socio-economic growth that deters pollution and deterioration of the environment. It also establishes a general framework for environmental policy that seeks to lay the groundwork to achieve a balanced growth.

In many stages of the country's development, environmental variables were not taken into account thus giving rise to the deterioration that is of concern to many Mexicans today. Presently, one of the important points is the concept of energy efficiency to reduce the emission of pollutant gases. In addition, enterprises producing goods and services are becoming convinced of the desirability of installing anti-pollution devices, thereby avoiding payments to repair the damage caused to the environment.

In March 1988 the General Law of Ecological Balance and Environmental Protection (Ley General de Ordenamiento Ecológico y Protección Ambiental) went into effect. In this law four broad regulatory instruments are considered:

i) The ordering of the nation's territory.

ii) The evaluation of the environmental impact of large works, projects or activities.

iii) The analysis of industrial, commercial and service activities with high environmental risk.

iv) The elaboration of laws, regulations, technical standards and ecological criteria that constitute the body of environmental standards.

Beginning in 1990 the Ecological Ordering Program for Priority Regions with Productive Activities (Programa de Ordenamiento Ecológico para Regiones Prioritarias con Actividades Productivas) was set up in close coordination with the office and agencies of the federal public administration in conjunction with state and municipal governments.

Within this framework, in 1988 the environmental impact of 600 forest projects and 934 projects of different types were evaluated. In the industrial sector the principal projects approved were: 19 chemical industry plants, 3 iron and steel plants and foundries, 1 petrochemical plant, 1 tannery, 2 oil pipelines and 8 electric power plants that met all the regulations established by the government.

As can be seen, México is seriously concerned about ecological problems and since 1938, has signed and ratified, 35 international agreements, treaties and protocols. This indicates that any industrial activity must comply with the ecological laws without exception and also with the concept of energy efficiency to reduce the emission of pollutant gases; technological projects in materials science are therefore also subject to these regulations.

II. PROBLEMS AND RECOMMENDATIONS

In order to adequately describe the demands and problems that I believe exist in México as well as some recommendations for overcoming them, it is necessary to analyze the national situation considering the two main actors in the scenario, the academic world and the industrial sector. Even though their interplay is essential, for the purposes of the analysis it is better to separate them. This separation leaves out the institutions that support and foster simultaneously the development of academic and technological areas, like CONACyT and SEP, which were mentioned above.

The Academia

In México there are public universities and public technological institutes, all economically dependent on the Federal Government to a large extent. These institutions are at different stages of development and therefore the problems that they face are qualitatively similar but quantitatively different. Without doubt the National Autonomous University of México, UNAM, is the most developed of all the educational institutions. Some of them carry out sciencific activities in materials science and others are still struggling with more basic problems, without being able to develop research in any area, although it should be mentioned that in the last 15 years SEP has fomented the necessity of scientific activities to improve basic educational aspects.

The number of researchers in the country in the area of materials is no larger than 300 which evidently is insufficient for the size and the necessities of the nation. In UNAM there is an Institute of Materials Research (Instituto de Investigaciones en Materiales, IIM) to which I belong. It is the largest institution in the country dedicated to materials and has only a little over 50 researchers and some 40 tecnicians. Altogether I would say that UNAM accounts for about 100 researchers, while other universities have some 50 more. The rest are distributed in the public institutions on the technological side and in what we call the

sectorial Institutes, where those created by CONACyT are included together with others associated to the Federal Electricity Commission (Comisión Federal de Electricidad, CFE), to the Mexican Oil Company (Petróleos Mexicanos, PEMEX), the Mexican Institute for Research on Iron and Steel (Instituto Mexicano de Investigaciones Siderurgicas, IMIS), and groups associated to mexican industries.

It can be seen that the formation of human resources for academic institutions is an *urgent* need. However until a few years ago the situation for academic personnel in institutions of higher education was quite critical since salaries had not kept up with the inflation phenomenon that the country experienced in previous years. The possibilities of equipping research laboratories were also almost non-existent. Consequently many bright students of the country looked for careers more promising than academic life and until recently the tendency still exists.

Another problem that occurred was that a large percentage of the students that were studying in foreign universities decided not to come back to México due to the infamous conditions in which institutions and personnel found themselves. This was a typical case of "brain drain" that had never occured in México before the economical crisis from which we are now emerging.

The Industrial Sector

México has an incipient industrial development. Up until recently the mexican industrialists had been largely concerned with buying obsolete technologies since the government policy had been to protect the industrial infrastructure that existed, providing them with a period of time to become competitive internationally. This protectionism lasted for more than four decades and instead of taking advantage of it to develop their own products and techniques the industries, with few exceptions, kept on buying obsolete technologies and since most Mexicans did not have any other option, they continued acquiring obsolete products.

Recently, the present administration has undertaken a tremendous task, that of signing a Free Trade Agreement (Tratado de Libre Comercio) both with Canada and the USA. If this is accomplished it will provoke a commercial revolution in the mexican economy since it will be possible to have options in the selection of consumer goods and mexican industry will have to be competitive or it will perish. Only a few industrial groups are prepared to cope with competence, those that took advantage of the several decades of protectionism; the rest are quite preoccupied and are doing everything imaginable to survive.

Some industries have research and development centers. For example, there are centers in the area of polymers and metallurgy, but not in ceramics. Semiconductors are a very special subject since, as is well known, only the big international companies do research in this area and have a monopoly in the subject. On the other hand, there is room to do research in the academic institutions, but this is very incipient in our country.

I believe that the existence of academic research in materials is a very decisive factor for inducing the industrial sector to take a more serious stand in this matter. By this I mean that at this stage it is very difficult for any company to start developing its own technologies; they must look for support from any institution that guarantees them the competitiveness they lack. As a corollary, were the academic institutions better prepared they could help the industrial sector bridge the gap of free trade; if industry does not have farsightedness, someone else has to have it. I am convinced that the universities and technological institutes should develop it, with the support of a policy established and guided by the government.

How to Overcome these problems

As a scientist I think that the development of science has a special place in every nation that pretends to be independent, understanding that this should not be a synonym of self-sufficiency; quite the contrary, international cooperation is

essential. Nevertheless for international cooperation to be useful, it is necessary that the participants are mutually benefited; otherwise it is not cooperation.

In México, it is necessary to redefine the role that science should play in the country. By this I do not mean to have a 100% "utilitarian science" that would only serve the necessities of the industrial sector; quite the contrary, I believe that quality in science should be the most important criterion, but close to it there should be the political will to preferentially support those areas that the country considers strategic for its development. In the study that we carried out for the mexican government, SRE, it became clear that the following recommendations are relevant:

1) Establish a well-defined policy as to what scientific areas are more important for the development of the country and foster them in the academic institutions.

2) Do not deviate from these objectives with every change of administration.

3) Establish an intensive program to develop human resources in these areas and, in parallel, improve the financial status of the academic personnel that deserve it in all public institutions.

4) With the participation of the private sector define a policy to develop those industries that are considered strategic for the independent evolution of the country, industries that should be in private hands and not in the hands of public institutions.

5) Promote a better linkage between the academic world and the industrial one.

III. MATERIALS POLICY DEVELOPMENT: A PROGNOSIS

For a long time, México has been concerned with having an articulated, well-sustained scientific policy that attends the necessities of the country with efficiency and opportunity. In spite of the variations that may occur when new national development programs are drafted, for some decades now science has been a subject that different governmental administrations have included in the national programs. Like everything else, the first step has been taken and gradually the country is approaching a more integrated scheme.

The present situation, without doubt, points in the right direction. As mentioned before there is no substitution for academic excellence. Present policies are oriented to the formation of human resources in the best institutions of the world, to the financing of the scientific projects of better quality, to the recovery of mexican "brains" that remain outside the country after finishing their studies, to the strengthening of scientific laboratories by acquiring new equipment to substitute the obsolete and to establish special chairs for the most renowned scientists in the country to improve their salaries and as a recognition to their many years of work for the nation, to mention just a few.

As can be seen, all these policies are on the right track for improving the badly battered scientific community of the country. From my view point what remains to be done is the following:

-Formulate a national plan that clearly defines the lines of industrial development of relevance for the country.

-Establish priorities so that some areas relevant for the development of the nation are fostered without upsetting the policies of academic excellence.

-Link activities that would lead to an improved development of scientific areas with particular emphasis on those that México

urgently requires.

The situation on the national level can be described as follows.

Ceramics.-The national industry is oriented towards the production of conventional ceramic materials. At this moment they are not producing new or advanced ceramics. The number of institutions of higher education that offer a program at the B. Sc. level or at the Ph. D. level in the area of ceramics is quite limited. Training outside of México is also very limited due to the fact that this area does not have an appeal either in industry or in the academic life, since the Institutes and Centers that carry out basic or applied research are practically non-existent; the only one worth mentioning is IIM-UNAM (Instituto de Investigaciones en Materiales of the Universidad Nacional Autónoma de México). Ceramics is one of the lines that needs to be developed urgently, specially because of the advances that are taking place on the international scene.

Metals.-This industry in México is essentially traditionalist and there are about a dozen Institutes and Centers dedicated to this area. Some of these Institutes like IMIS (Instituto Mexicano de Investigaciones Siderúrgicas) are dedicate to the important field of special steel alloys; others like IIM-UNAM are dedicated to the study of non- ferrous materials. Industrial activities encompass mainly obsolete technological processes, although it is important to emphasize that there have been some technological developments that are being exported. As an example I would like to mention the developments generated by HyLSA (Hojalata y Lámina, Sociedad Anónima), a mexican company that has created a new process for producing iron starting from junk iron. As far as the institutions of higher education are concerned there is a tradition in the extractive metallurgical aspects at the B. Sc. level that needs to be supported and modernized, whereas at the Ph. D. level there are some programs with an excellent level.

Polymers.-The consumption and production of polymers in México is increasing rapidly. The industries have very little vertical

integration in the production chain of polymers, even though the oil resources of México allow for the production of monomers and intermediate polymers required by industries. This is the area where more programs exist both at the B. Sc. and the Ph. D. level and the number of institutes and centers, both private and public, has increased considerably in the last decade, to approximately 20 throughout the country. The Centers associated to private industries are mainly dedicated to solving production problems. The most important Institute in the country in this area is IIM-UNAM. In spite of all this, the formation of human resources inside and outside the nation is still inadequate and does not satisfy the existing scientific and technological needs of the country.

Semiconductors.-The industrial aspects of this area are poorly developed in México due to the well-known fact that the knowledge of this subject has become a monopoly of a few international industrial groups that control and define the evolution of scientific and technological research. In spite of this there are about 5 scientific groups that work in this area mostly in the institutions of higher education. As far as the development of human resources is concerned, the number that graduate, nationally or internationally, is very limited even for the demands of the scientific groups.

In short the recommendations that were set forth in the above-mentioned Program are the following:

i) To increase the development of academic personnel at all levels, from technicians to Ph. D.'s, in numbers and in areas, both within the country and in other countries where institutions of excellence can be found.

ii) To support the scientific and technological activities that are under way in different Institutes and Centers in order to consolidate them, and to sponsor the creation of new institutions that carry out research and technological development.

iii) To support the national industry, establishing in collaboration with the different private groups an overall development plan for the evolution of production groups, in order to evaluate the immediate and long term needs and plan accordingly, fostering the collaboration of scientists and industries.

As far as the particular areas in materials that should be financed and fostered, based on the academic and industrial infrastructure and the opportunities that presently exist, both nationally and internationally, our study for SRE indicates the following specific lines, in order of priority:

- Structure and properties of structural ceramics
- Ceramic processing
- Powder metallurgy
- Solidification
- Corrosion
- Amorphous metals and semiconductors
- Recycling of polymers
- Composite materials
- Structural plastics
- Structure and properties of glass and optical fibers
- Special steels
- Light alloys and superalloys
- Polymer synthesis
- Superconductors
- Memory shape alloys
- Biopolymers
- Semiconductors II-VI, III-V and $I\text{-}III\text{-}VI_2$,

to mention the most relevant.

I am convinced that a more precise definition of the priority areas for the country will be decided upon in the future and that Materials Science shall be one of them. The continued improvement in these policies will bring about a new start for the scientific community, a boost that is badly needed especially since the

economical problems that have plagued us in the last couple of decades have nearly disintegrated the already small community.

IV. INTERNATIONAL LINKAGE AND COOPERATION

When talking about the modes of international cooperation, bilateral and multilateral schemes come to my mind. These are the ones most frequently used by experts in the field. For both cases it is important to analyze the relevance of three scenarios: the linkage with nations that are more developed than we are; the linkage with those with more or less the same degree of development and finally the linkage with nations whose development is less than ours. It should be clear that these three groups of countries define the emphasis and the characteristics of the cooperation.

Based on the general conclusions of the 1991-1994 Program for International Cooperation in Materials Science and Technology that was elaborated for the SRE of México under my coordination, where the three scenarios were analyzed, I would like to present a condensed version of the recommendations that were proposed in that document for the cooperation between México and more developed nations. In order to better emphasize the nature of the situation, the presentation is made based on two very important aspects: i) research and formation of human resources, and ii) industry and formation of human resources. This presentation was done according to the classification of the traditional areas of materials science.

Research and Formation of Human Resources.

International cooperation with developed nations should be oriented towards establishing the necessary mechanisms, official and non-official, for fostering the interaction with individuals, with groups and with institutions. It is important to look for collaborative projects in areas and in institutions of interest for the country; by this I mean that the areas should be those that already exist in México and need to be strengthen or the new ones that need to be developed for the benefit of the country. The institutions should have the capacity to form Ph. D.'s with the abcve-mentioned criteria. The nations considered in our study are:

USA, Canada, England, France, Spain, Germany and Japan. Language is an important factor since this is the way to benefit from the collaboration.

Ceramics.- Among the institutions that were recommended for possible collaboration are:

USA: Alfred University, The Universities of California at Berkeley, Stanford, Harvard, Pennsylvania, Rutgers, Case-Western Reserve, Cornell, Northwestern, Ohio State, Illinois and Florida. Others recommended are MIT and CALTEC, Los Alamos Laboratories, Lawrence Radiation Lab. and the National Institute of Standards and Technology.

ENGLAND: The universities of Oxford and Cambridge and the Imperial College.

GERMANY: The Max Planck Institute.

JAPAN: The Universities of Nagoya and Tohoku.

Metals.- In this area the following institutions were recommended:

USA: The Universities of Stanford, Harvard, Case-Western Reserve, Northwestern, Cornell, Illinois, California at Berkeley, Washington State. Others recommended are MIT, CALTEC, The Carnegie Mellon Institute and the Sandia National Laboratories.

CANADA: The Universities of Toronto and Mc Master.

ENGLAND: The Universities of Oxford, Cambridge, Sheffield, Birmingham, Salford and the Imperial College.

FRANCE: The School of Mines and Metallurgy at Nancy and the Polytechnic at Grenoble.

SPAIN: The National Center for Metallurgical Research.

GERMANY: The Max Planck Institute and the University of Göttingen.

Polymers.- Here the institutions recommended are:

USA: The Universities of Case-Western Reserve, Michigan, Stanford, Northwestern, Cornell, Illinois and California at Berkeley. Also MIT, the Carnegie Mellon Institute, and the Polytechnic Institutes of Virginia and New York.

CANADA: The Universities of Mc Gill and Toronto.

ENGLAND: The Universities of Oxford, Cambridge and the Imperial College.

FRANCE: The Center for Research of Macromolecules in collaboration with the University of Strasbourg.

GERMANY: The Technical School of Darmstadt

JAPAN: The Universities of Tokyo, Kyoto and Osaka.

Semiconductors.- For this area the recommendations are:

USA: The Universities of Stanford, Oregon, Princeton, Delaware, Cornell and North Carolina. Also with MIT and with the Solar Energy Research Institute, which recently has become a National Laboratory.

FRANCE: The Laboratory of Studies of Electronic Properties of Solids.

GERMANY: The Max Planck Institute.

Also, with the Korean Institute of Electronics Technology in South Korea, and with the Industrial Technology Research Institute of Taiwan, ROC.

Industry and Formation of Human Resources.

In this section emphasis has been laid on the existence of certain developments in mexican industries and also on the areas that we consider relevant for the development of the country, whether the interest exists or not within the industrial mexican community. In addition, it is important to mention that there are certain industries whose requirements are at the undergraduate level (the technical level to be precise) since they need to solve problems in plants and not in the research laboratories. Other industries however, are more developed and are working at the research level.

Ceramics.- Among the industries that are most active in glass, Corning, Inc. should be considered. For electronics, optoelectronics and fibers the following are recommended: AT&T, Bell Labs., Sandia National laboratories, Dupont, IBM, Westinghouse and Mitsubishi.

In superconducting ceramics the following were quoted: AT&T, Bell Labs., Biomagnetic Technologies, General Dynamics, GE Research and Development Center, IBM Research Division, Westinghouse, TRW, Superconductor Technology, Fujitsu, Hitachi, Mitsubishi Electric, NEC, Nippon Telegraph and Telephone and Oxford Instruments.

Metals.- In the area of steel manufacturing, the companies with which cooperation is recommended are US Steel Co., Bethlehem Steel Co. in the USA, British Steel Corporation (BSC) in England, Institute de Recherche de la Siderurgie Francaise (IRSID) and the integrated group SIDMAR-SACILOR in France. With August Thyssen in Germany and with the Nippon Steel Co. and the Nippon KOKAN Co. from Japan.

The most important industries in special alloys and superalloys are: August Thyssen and Salzgitter in Germany, BSC in England, IRSID and SIDMAR-SACILOR in France, Sandia National Laboratories and US Steel Co. in USA, Nippon Steel Co. and Nippon Kokan Co. in Japan and National Research of Metallurgical Research (Centro Nacional de Investigaciones Metalúrgicas, CENIM) in Spain.

For non-ferrous materials the recommendations are as follows: For aluminum, ALCOA from USA, ALCAN from CANADA, Kaiser Aluminium Co. from Germany and PECHINEY from France.

The copper industry is a very well integrated industry in México, but nevertheless cooperation with groups like the British Non-Ferrous Metals Technology Center would be highly beneficial.

For the development of applications of gold and silver to the electronic industry, cooperation with IBM, AT&T, Texas Instruments and Hewlett Packard from the USA, and Mitsubishi and Hitachi from Japan should be sought.

Polymers.-This is a very active industrial area all over the world. Some lines are more active than others due to, for example the ecological impact of plastics. In what follows we will present a very condensed resume of the recommendations.

For plastic recycling collaboration should be established with groups like Plastics Recycling Foundation from the USA, The Laboratory of Plastic Technology of Technologisches Geberwemuseum and the Association for the Promotion of Plastics Technology from Germany.

For the development of engineering plastics the following groups are suggested: Imperial Chemical Industries (ICI) from England, Ciba-Geigy from Switzerland, Reichold from Germany and Rohne-Poulenc from France.

Also, groups like DuPont, BASF, Bayer, Celanese, GE, would be important for the purposes of establishing industries in the country in the lines of interest for Mexico.

The development of polymeric alloys and mixtures will greatly benefit from collaboration with companies that are leaders in the subject: DuPont, Monsanto, Dow Chemical and Union Carbide from USA, Shin Etsu, Mitsubishi or Toray from Japan.

Semiconductors.- Here the competition among the different companies is impressive. Technological secrets are not shared readily because of the impact that the semiconductor electronic industry has, but nevertheless the following international industries were recommended: From Japan, Sanyo Electrical Co., Hitachi Ltd., Mitsubishi Electrical Co. and Sharp Co. From USA, Solarex, Energy Conversion Devices, IBM-Almaden, Bell Labs, Texas Instruments and the RCA Labs. From Germany, Messerschmit and Siemens. From South Korea, the Korean Institute of Electronics Technology and from Taiwan, ROC, the Industrial Technology Research Institute.

We should be careful not to overlook the relevance of the collaboration with the other two groups of nations, collaboration that becomes more important as the world becomes better integrated in an effort to remedy the consequences of an unbalanced growth of all the nations.

V. FINAL COMMENTS

Developing science policies in a country that is in need of human resources in practically all areas of science is not an easy task. It is understandable that such a broad range of necessities makes one oscillate between trying to foster the development of everything or selecting a very well-defined group of areas that may be, according to some criteria, the most adequate for the country. The scientific administrations of the country have felt this dichotomy.

Nevertheless, it should be recognized that in México both the government and the scientific community have established very strong links that has made everybody more aware of the relevance of science in the development of the nation, and this link is to me our most important accomplishment, since in this manner the interaction benefits the country as a whole.