LEAPFROGGING THE SCIENTIFIC AND TECHNOLOGICAL GAP:* AN ALTERNATIVE NATIONAL STRATEGY FOR MASTERING THE FUTURE

Roger Posadas

While all of us agree that our nation is in crisis, not all of us agree on the nature, cause, and solution of this national crisis. Thus, this crisis has been diagnosed by different groups as either a political crisis, an economic crisis, or even a moral crisis.

Most of our people, however, have failed to recognize the scientific and technological dimensions of our national crisis despite the fact that this crisis has exposed the almost total dependence of our production system on the importation of our means of production (i.e., industrial and agricultural inputs) and the almost total inability of our science-and-technology (S & T) system to meet the major technological requirements of our production system.

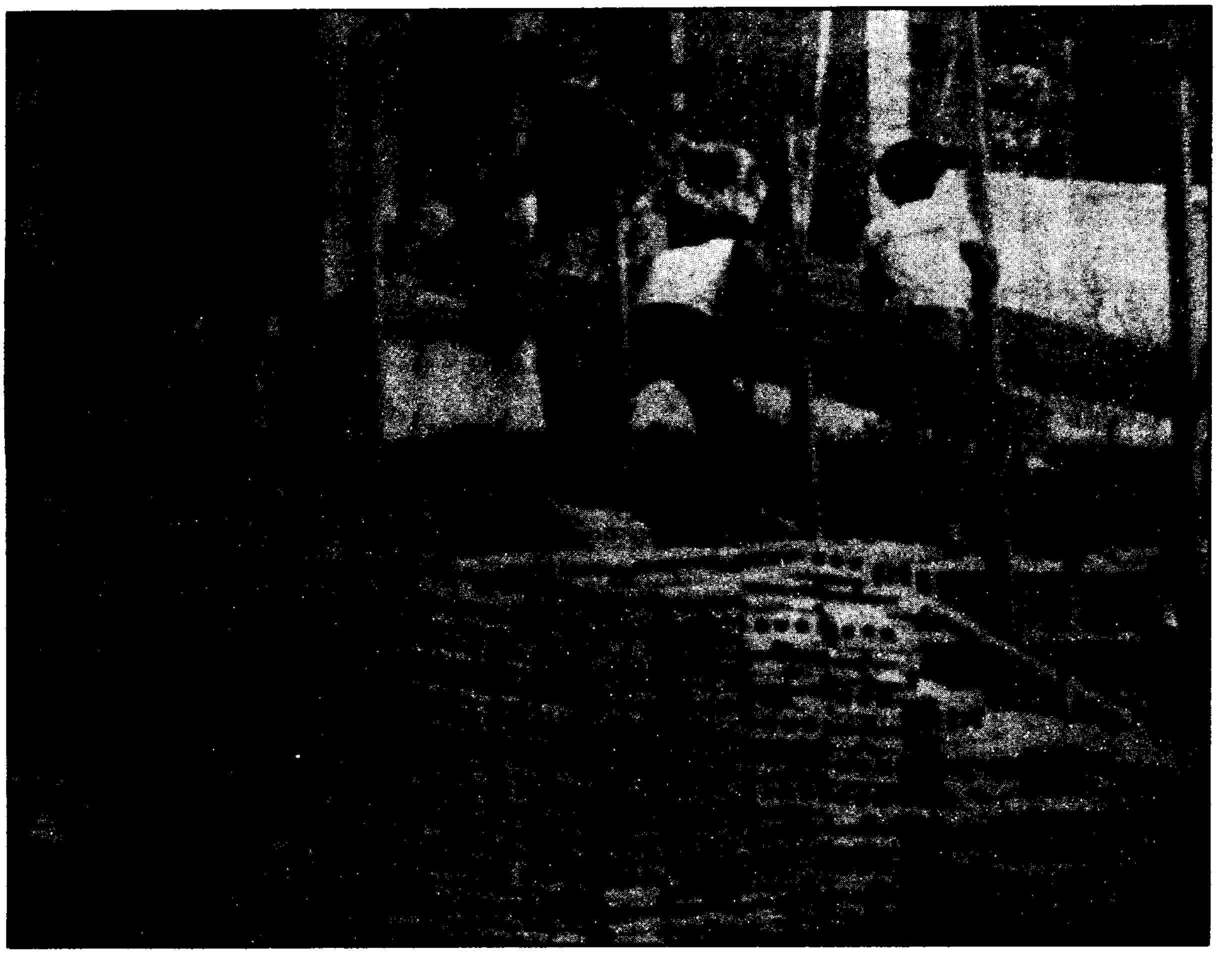
The Scientific and Technological Roots of the Crisis

In my view, the present crisis is but a symptom of the underlying, systemic weaknesses of our society -- its scientific and technological backwardness, its dependence on foreign technologies and capital to sustain its economic life, and its subordination to foreign dominance, exploitation, and control.

Because of our S & T backwardness, our country cannot process its own natural resources or produce the equipment and tools needed to transform raw materials into manufactured goods. As a consequence of this S & T incapacity to produce our own means of production, our economy has to depend on the importation of foreign technologies in the form of manufacturing processes, producer goods, and even complete production facilities in order to meet the consumer needs of the domestic market.

To finance our country's technological dependence on imported foreign technologies, our economy in turn has to produce and export as much of the goods that our scientifically and technologically backward production system is capable of, namely, coconut oil, sugar, copper, logs, handicrafts, and other low-technology products. But no matter how much of such products our country exports, our earnings never seem to match the cost of our imports. And so our economy has to depend on foreign loans to make up for its chronic trade deficits and support its technological dependence.

*Paper presented at the colloquium on "Alternative Scientific and Technological Development" held on 13 September 1985 at the College of Law, U.P. Diliman as part of the University of the Philippine Colloquium Series, "The Nation in Crisis II: Inquiring into the Future".



RP's cheap labor: its comparative advantage?

The International Division of Labor

As a result, our economy finds itself locked into the international division of labor, playing the role of exporter of primary commodities and importer of production technologies and subordinating its development to the loans and dictated of the international capitalist system.

Not surprisingly, the technocrats of the government as well as most economists see nothing intrinsically wrong with our economy's subordinate role in the international division of labor and even try to rationalize this by citing the "law of comparative advantage". Even now some of them are loudly advocating a back-to-agriculture reorientation of our economy at the expense of our fledging manufacturing sector and urging our people to plant all sorts of crops for export.

Not being an economist, I cannot see any comparative advantage in an unequal international division of labor that has perpetuated and aggravated the underdeveloped, agricultural, technology-dependent, loan-dependent, and foreign-dominated character of our economy. On the contrary, our nation's economic history tells me that acceptance of the international division of labor has only mired our economy in a worsening condition of comparative disadvantage and locked our development efforts into a Sisyphean cycle of crisis after crisis of such the present one is only the worst so far.

The Vicious Circle of S & T Backwardness and Dependence

While our S & T backwardness may have been the underlying cause of our country's technologically dependent and economically disadvantaged position in the international division of labor, our economic dependence in turn has been a major factor in the perpetuation of our S & T backwardness, as I shall explain more fully later.

Thus, our country is trapped in a vicious circle of S & T backwardness leading to technological dependence, which in turn places our economy in a dependent, dominated, and disadvantaged condition that in turn reinforces and perpetuates our S & T backwardness.

Under this condition and alternative national strategy for S & T development must therefore address itself to the problem of how to transcend this vicious circle of S & T backwardness and economic dependence and liberate our nation from the subordinate position to which it has been consigned by the international division of labor. Before I can expound my proposed alternative strategy, however, I need to discuss first the state of science and technology in our country.

Nature of Science and Technology

Science is a system of activities which seek to describe, understand, and predict natural phenomena in terms of a cumulative body of experimentally verifiable laws, principles, and theories. It is usually classified into the *basic sciences* (biology, chemistry, physics, mathematics, and earth sciences) and the *applied sciences* (agricultural sciences, engineering sciences, and health sciences). The core activities of science consist of ***research and development*** (R & D). *Research* — classified as pure or fundamental, oriented basic, or applied depending on the researcher's orientation — aims to acquire new knowledge. *Development*, on the other hand, involves the transformation of research findings into prototype inventions of new materials, devices, and processes.

Technology is a system of hardware (tools, equipment, machines, materials) and sofware (processes, techniques, organization, and management) which are used in the production and distribution of goods and services. The core activity of technology is *technological innovation* which seeks to transform the prototype inventions of R & D into a commercial product or process. Technological innovation comprises the following chain of activities: pre-investment studies, investment decision, engineering design, tooling and construction of manufacturing facilities, manufacturing start-up and marketing start-up.

Types of Technologies

We may classify technologies into the following basic types:

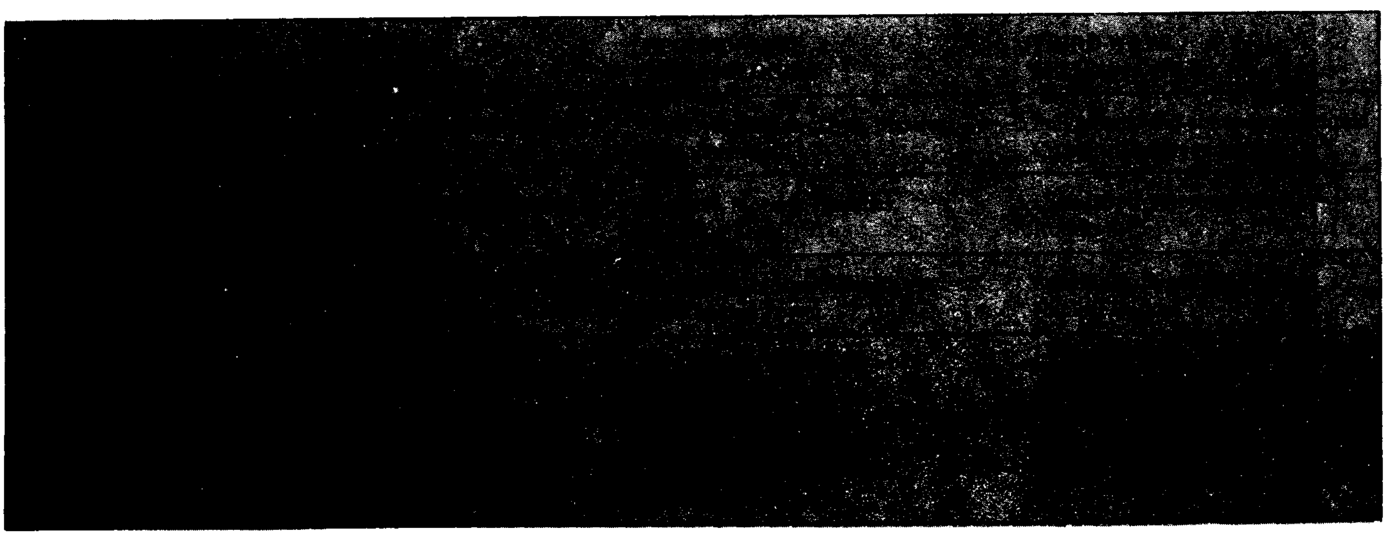
1. *Materials Technologies*, which deal with the extraction, processing, fabrication, combination, and synthesis of materials;
2. *Equipment Technologies*, which deal with the design and fabrication of tools, instruments, devices, and machines;
3. *Energy Technologies*, which deal with the generation, conversion and distribution of various forms of energy;
4. *Information Technologies*, which deal with the collection, storage, processing, retrieval, transmission, and utilization of information;
5. *Life Technologies*, which deal with the preservation, repair, maintenance, reproduction, and improvement of living systems; and
6. *Management Technologies*, which deal with the planning, organization, mobilization, coordination, and control of social activities.

Following Alvin Toffler in his book **The Third Wave**, we may also categorize technologies, according to their levels of scientific sophistication, into the following classes:

1. *First-Wave Technologies*, comprising the pre-industrial technologies which are labor-intensive, small-scale decentralized, and based on empirical rather than scientific knowledge. The *intermediate appropriate*, or *alternative* technologies based on the Schumacherian philosophy of "small is beautiful" also fall under this category.
2. *Second-Wave Technologies*, comprising the industrial technologies which were developed since the time of the industrial revolution up to the end of World War II. These are usually capital-intensive technologies which are essentially based on the principles of classical physics, classical chemistry, and classical biology.
3. *Third-Wave Technologies*, comprising the post-industrial or *high technologies* which are called science-intensive because these are based on our modern scientific knowledge of the structures, properties, and interactions of molecules, atoms, and nuclei. Among the important high technologies are micro-electronics, robotics, computers, laser technology, opto-electronics and fiber-optics, genetic engineering, photovoltaics, polymers and other synthetic materials.

Some of the representative technologies under the First-Wave, Second-Wave, and Third-Wave classes are shown in Table I below:

Table I. Types and Classes of Technologies



Endogenous and Exogenous Technological Innovations

The acquisition of a new technology can be carried out through either of two modes:

1. *Endogenous Technological Innovation,* which entails the local generation, development, and utilization of knowledge via the chain of activities: research –– development –– engineering –– production –– distribution; or
2. *Exogenous Technological Innovation,* which entails the importation of an existing technology, developed elsewhere, through commercial or non-commercial *transfer of technology.*

Technology may be transfered in the form of sofware (technical expertise or information) or hardware (machines, materials, or factories). Most transfers of technology are carried out through commercial arrangements between domestic firms and transnational corporations (TNCs) or other foreign firms. Such arrangements may take the following forms:

1. Marketing agreements for the domestic sale of foreign machineries, equipment, and parts;
2. Licensing agreements for the domestic manufacture of foreign-brand consumer products;
3. Direct investment of a TNC in the domestic market through the establishment of a local subsidiary;
4. Joint venture agreements between a local and foreign firm;
5. Service contracts or management contracts involving a foreign firm's sale of technical servives to a local firm; and
6. Purchase of complete industrial facilities from TNCs on a turnkey basis.

Our Country's Scientific and Technological Potential

The state of science and technology in our country can be gauged, in the first place, by our national scientific and technological potential (STP). Among the indicators of a country's STP are the quantity and quality of its R & D scientists and engineers, the adequacy and quality of its system of scientific and technological institutions and facilities, and the amount of its expenditures on R & D.

Based on international comparative statistics of these indicators, our country's scientific and technological potential turns out to be awfully and shamefully weak and negligible by the standards of the advanced countries. It is also the weakest among the ASEAN countries with the obvious exception of Brunei.

In fact, I estimate that our country is 10-15 years behind the other ASEAN countries (excluding Brunei) in key areas of science and technology; 20-30 years behind South Korea, China, India, Taiwan, Brazil, and Mexico; and 50-75 years behind Japan, US, and the other advanced countries. These estimates are based on the number of years it would take our country to build up our STP to the STP levels of these groups of countries, assuming the most ideal and favorable conditions of national scientific and technological development.

Our Country's Stage of Technological Capabilities

While the STP indicates what a country's science-and-technology system can possibly accomplish, it does not say what our S & T system can actually accomplish. The latter is gauged by the country's stages of technological capability with respect to the aforementioned types and classes of technology.

There are five main stages of technological capability:

1. *Operative Capability,* which is the ability to put an imported technology into actual operation and carry

J. F. Bartolome

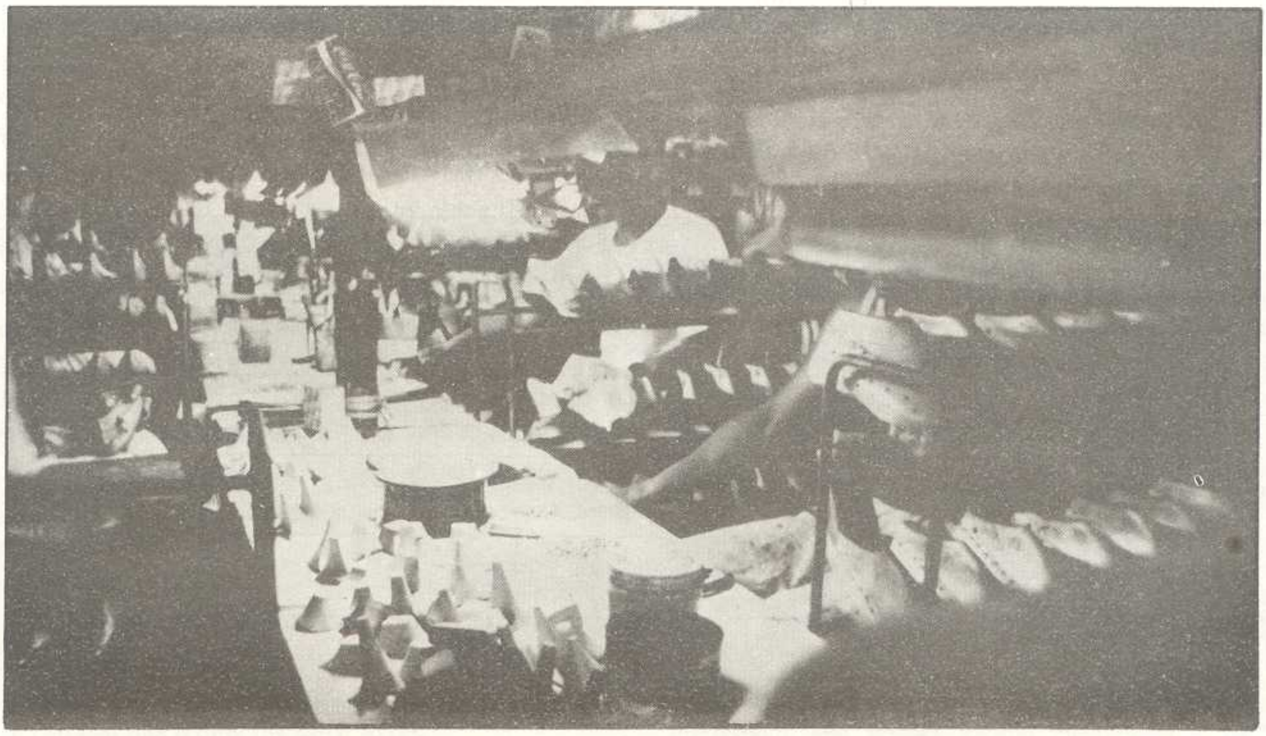


Table II. Stages of Filipino Technological Capabilities

[illegible]	[illegible]	SECOND-WAVE TECHNOLOGIES	THIRD-WAVE TECHNOLOGIES
[illegible]	[illegible]; Adaptive in Some	Operative in Some; Adaptive in Others	Pre-operative in Most; Operative in Some
[illegible]	[illegible]	Operative in Most; Adaptive in Some	Pre-operative in Most; Adaptive in a Few
[illegible]	[illegible] in Most; [illegible] in Some	Adaptive in Most; Replicative in Some	Pre-operative in Most; Operative in Some
[illegible]	[illegible]	Operative in Some; Adaptive in Others	Pre-operative in Most; Adaptive in Some
[illegible]	[illegible]; Innovative in Some	Adaptive in Some; Replicative in Others	Pre-operative in Most; Adaptive in a Few

out routine maintenance and minor repairs on components of the technology;

2. *Adaptive Capability,* which is the ability to adopt a foreign technology through a modification of its scale or a replacement of some of its minor components to suit local conditions;
3. *Replicative Capability,* which is the ability to reproduce most, if not all, the major components of a foreign technology through endogenous technological innovation;
4. *Innovative Capability,* which is the ability to make major significant modifications and improvements in the basic design of an existing technology; and
5. *Creative Capability,* which is the ability to develop, design, and produce an entirely new and revolutionary technology out of R & D findings.

Regarding our country's technological capabilities, I can safely say that, on the whole, while we may have reached the replicative and even innovative stages of technological capabilities as far as first-wave or pre-industrial technologies are concerned, we are still largely at the operative and adaptive stages with respect to second-wave or industrial technologies and at the pre-operative and operative stages with respect to third-wave or high technologies as shown in Table II.

To dramatize the technological gap between our country and the advanced countries, I can describe our present stage of technological capabilities as follows: while the advanced countries are busy creating revolutionary high technologies for the 21st century, our poor country has not yet even acquired any significant ability to replicate obsolete 19th century industrial technologies.

R & D Achievements of the NSTA

Our country's pre-industrial stage of technological capabilities is borne by the fact that we do not yet have a genuine endogenous chemical industry, metals industry, machine tool industry, pharmaceutical industry, automotive industry, and electronic industry. It is also underscored by the following list of major R & D achievements of the National Science and Technology Authority (NSTA) in agriculture, industry, and health during the past few years:

1. Development of high-yielding crop varieties, post-harvest techniques, alternative livestock feeds, better fertilizer formulas;
2. Commercialization of low-cost dryers, shellers, kilns, fermentors, power tillers, and construction materials; production of activated carbon, gas-fired laboratory furnaces, and gasifiers; improved production of "toyo" and "suka";
3. Development of pharmaceutical preparations from local medicinal plants; development of an oral electrolyte solution and new food formulations.

Of course, the NSTA has also a few exceptional achievements of fairly advanced technological sophistication but its main R & D thrusts are still directed towards the attainment of either innovative capability with respect to pre-industrial technologies or adaptive and replicative capabilities with respect to industrial technologies.

Inadequate Government Support for Local S & T

Thirty years ago, our country was on a par with, if not a little ahead of, the other countries in Southeast Asia and East Asia (excluding Japan) in scientific and technological development. Now we find ourselves lagging behind most of our neighboring countries in science and technology.

Why has our country failed to develop its science and technology as fast as the rest of our neighboring countries during the past 30 years?

I believe that there are two principal reasons for the very slow development of science and technology in our country: (1) the lack of a strong government push for scientific and technological development and (2) the lack of an effective economic demand for local R & D and innovations.

The perennial lament of the local S & T community about inadequate compensation, research facilities, and research funds reflects the inadequate government support for national scientific and technological development.

The NSTA reports that national expenditures on scientific and technological activities amount to less than 1/2 of 1% of our GNP of which amount less than 20% is spent on R & D proper. In other words, our country's yearly expenditures on R & D have been less than 1/10 of 1% of our GNP. On the other hand, the target set by the United Nations for national expenditures of developing countries on R & D proper is at least 1/2 of 1% of GNP. It should be noted that the advanced countries' expenditures on R & D range from 2% to 4% of GNP. The per capita expenditures of most of our neighboring countries on R & D are much larger than ours.

Because of the low priority and inadequate support given to national S & T development by successive national administrations for the past 30 years, it is not surprising that our national S & T development has lagged behind those of our neighboring countries. The kind of high-priority, long-term national commitment to S & T development that has been largely responsible for the rapid development of S & T in most of our neighboring countries is simply absent in the Philippines.

Lack of Effective Demand for Local S & T

At the same time, the lack of an effective demand for local R & D findings and inventions has made it almost impossible for the market to pull up local S & T development and rendered the local S & T system almost irrelevant economically.

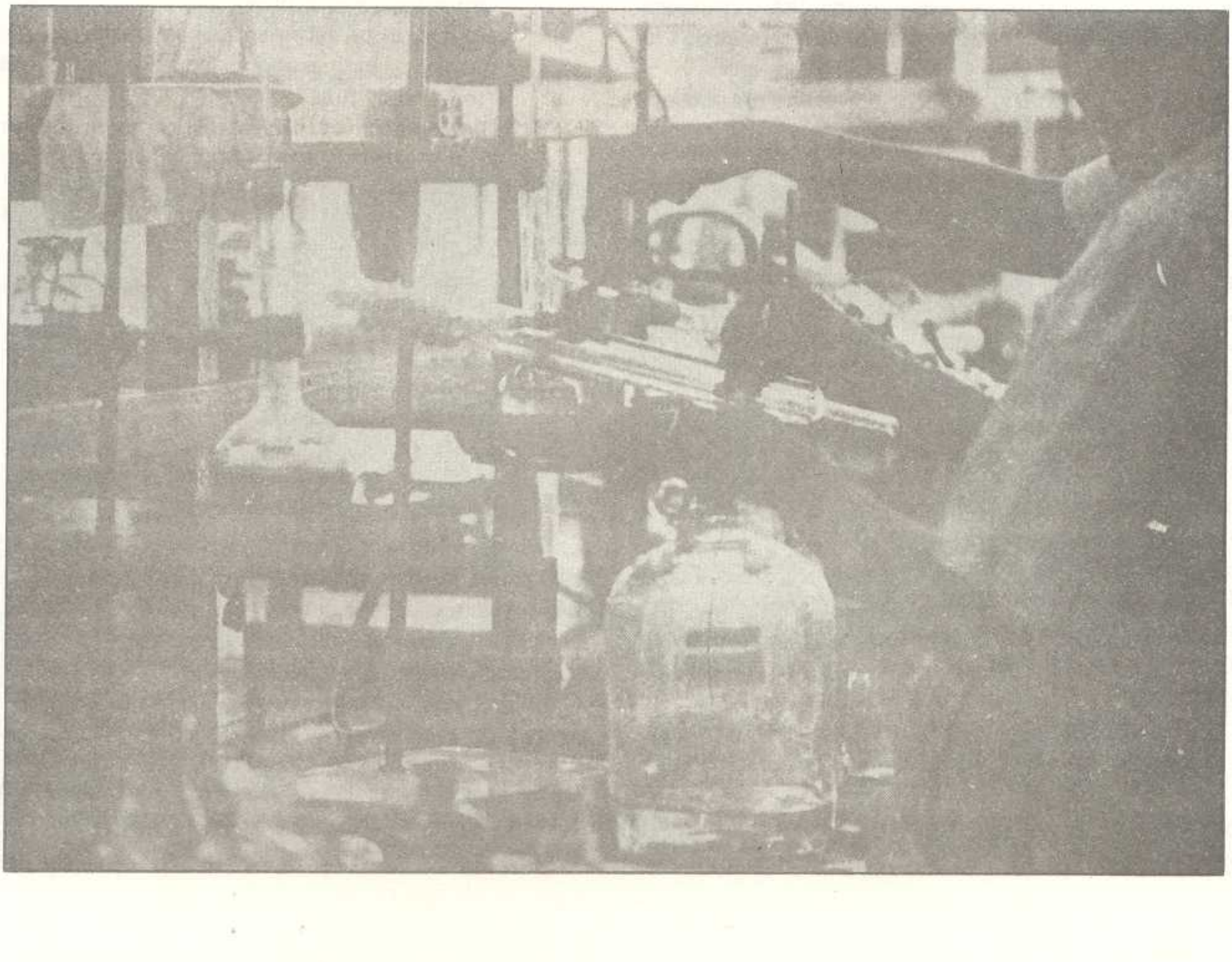
This absence of an effective demand is, of course, due to the technologically dependent character of our economy which manifests itself in the general preference of local firms to meet their technological needs through commercial technology-transfer arrangements with TNCs rather than through investments in domestic R & D and endogenous technological innovations. In fact, there is hardly any R & D activity or endogenous technological innovation in most local industries.

Analyzing the state of S & T in our country in terms of supply and demand, we have a situation in which there is an inadequate supply of good-quality R & D products and services from the S & T system due to its backwardness and a lack of effective demand for local R & D products and services from the production system due to its technological dependence.

In the ultimate analysis, the backwardness of the S & T system and the technological dependence of the production system are both due to government economic development strategies and policies that have kept our S & T system and production system trapped in the vicious circle of backwardness and dependence.

Flaws in NSDB Development Strategies

The basic flaws in all previous S & T development plans, strategies, and policies of the National Science Development Board (NSDB) since its establishment in 1958 stem from (1) lack of full recognition of the vicious circle of technological backwardness and dependence, (2) lack of central national



S & T goals in relation to the development of our country's scientific and technological potential and capabilities, and (3) lack of a political commitment to S & T development on the part of the national government.

For example, during the period 1976-1981 the NSDB adopted a "mission-oriented" research strategy to meet perceived national needs in agriculture, industry, health, and other sectors. This strategy, however, was hardly able to take off because it overestimated the supply of, and demand for, local R & D products and services. Moreover, it was a mission-oriented approach without any central national mission vis-a-vis the vicious circle of technological backwardness and dependence.

The NSTA's Demand-Pull Strategy

With the reorganization of the NSDB into the National Science and Technology Authority (NSTA) in 1982, the new NSTA administration has put forward a new "strategy" which is called the "demand-pull strategy" and which is basically a policy of orienting and prioritizing R & D activities along the demands of the local production system as contrasted to a "supply-push approach" where the R & D needs of the production system are determined by the S & T system.

Again the problem with the "demand-pull strategy" is that it tends to overestimate the demand for local R & D products and services and the supply capabilities of the S & T system. In a highly innovative and competitive market environment such as those of the advanced capitalist countries, the demand-pull approach is an effective mechanism for stimulating and supporting the S & T system as shown by the strong linkages between University S & T departments, government laboratories, and industries in the US, Japan, and Europe. Unfortunately, in an underdeveloped economy like ours which is almost totally dependent on imported foreign technologies and which hardly makes any demands on the local S & T system, the adoption of a demand-pull approach can, at worst, stifle local development of advanced technologies for which there are no current demands in the domestic market and, at best, generate such low-level technologies as soy sauce, vinegar, and citric acid.

My major criticism against the "demand-pull strategy", however, is that it is simply an R & D policy and not a strategy for achieving a definite national S & T goal. The demand-pull approach attempts to link the S & T system's weak supply capability with the production system's weak demand for local R & D without attempting to overcome the vicious circle of technological backwardness and dependence.

Given the government's low priority for S & T development and its policies of economic and technological dependence, the NSTA's pursuit of the demand-pull approach is nevertheless a valiant attempt to make the local S & T system responsive and relevant to the local production system.

Alternative S & T Development Strategies

Returning now to the choice of an alternative national strategy for S & T development, we can classify the different alternative strategies into three major ones which differ from one another according to the relative importance assigned to the two modes of acquiring technologies, that is, endogenous and exogenous technological innovations.

The first strategy, which I call the *strategy of technological dependence,* adopts the approach of importing most of the major technologies needed by the country and generating only a few minor, low-level technologies. This approach is usually justified by its adherents on the grounds of "cost effectiveness" and "quick results" and "minimal investment risks".

This strategy, which is actually what the government is pursuing notwithstanding the NSTA's "demand-pull strategy", accepts the country's subordinate role in the international division of labor and ignores the vicious circle of technological backwardness and dependence. At most, such a strategy can only succeed in raising the technological capability of the country to the adaptive stage and giving the economy the semblance of industrialization, but it will never enable the production system to reproduce its own means of production. Therefore, this strategy has to be rejected as inimical to national S & T development.

The second strategy, which I call the *strategy of technological autarky,* takes the approach of generating most, if not all, the major technologies needed by the country and importing, if at all, only a few technologies. This strategy, which is advocated by some local nationalists in reaction to the strategy of technological dependence, rejects the international division of labor by delinking the country's production system from the international market and avoids technological dependence by rejecting imported technologies and attempting to develop needed technologies from scratch or from the stock of indigenous, traditional technologies.

While the autarkic approach can possibly raise the country's technological capabilities to replicative and even innovative levels of self-reliance with respect to the production of its basic needs and its means of production, this strategy can only succeed in reproducing or improving obsolete, inefficient technologies, as the experience of pre-1978 China has shown. Moreover, the successful implementation of this strategy involves a very slow, trial-and-error process that requires a great deal of national discipline, sacrifice, and perseverance. And so, while it may be preferable to the first strategy from the criteria of technological self-reliance and economic independence, I also reject the strategy of technological autarky because it will maintain our country's scientific and technological capabilities in a state of inferiority and obsolescence.

The Strategy of Technological Leapfrogging

The alternative national strategy for S & T development, which I advocate for our country may be called the *strategy of technological leapfrogging.* This strategy would attempt to liberate our country from the vicious circle of technological backwardness and dependence by importing selected high technologies for the purpose of acquiring adaptive, replicative, and innovative mastery of these advanced technologies.

The basic approach of this strategy is to couple selective, strategic transfers of high technology with local R & D and innovation activities in order to absorb, assimilate, develop, and improve the scientific and technological knowledge embodied in these imported technologies. Unlike the strategy of technological dependence, technological leapfrogging would see selective transfer of technology to narrow the technological gap and attain technological self-reliance. Unlike the strategy of technological autarky, technological leapfrogging would develop technological self-reliance from state-of-the-art technologies rather than from indigenous and low-level technologies.

If this technological leapfrogging strategy is to be successful, however, the following conditions must first be in place:

1. A science-and-technology system with fully developed R & D resources, particularly in the basic sciences and engineering sciences which hold the keys to the mastery of high technologies;
2. An extensive, internationally linked information system for technological monitoring, forecasting, assessment, and intelligence;
3. A mass-based educational system reoriented towards the provision of international-quality scientific and technological education and training at all levels;
4. An economic system reoriented towards self-reliant, self-sustaining, and innovative production mainly for domestic social needs, importation of only the most essential producer goods, and exportation primarily of high value-added goods;
5. A cultural system reoriented towards the promotion of originality, creativity, inventiveness, excellence, and passion for learning in addition to the values of nationalism and humanism; and
6. A political system fully committed to the national and social emancipation and progress of our people and the fullest development of our scientific and technological capabilities.

In short, the successful implementation of the strategy of technological leapfrogging entails the overhaul of our present system and the establishment of an entirely new social system. This, of course, is to be expected since national S & T development is inextricably linked to the political, economic, cultural, and social conditions of a country.

Mastering the Future

The national S & T goal which is intended to be achieved by the strategy of technological leapfrogging is already implied by the strategy itself. This goal is *national technological mastery* of selected key high technologies in the areas of equipment, materials, energy, information, and living systems for the purposes of fully developing our productive forces, adequately meeting our society's various needs on a self-reliant basis, and closing the scientific and technological gap.

I have preferred to adopt the term "technological mastery" instead of the term "technological self-reliance" because the former not only contains the idea of self-reliance but also connotes the following:

1. National expertise in scientific and technological knowledge;
2. National ascendancy in the international S & T arena; and
3. National and human control over advanced technologies.

Our country's long-term S & T objective should be technological mastery at the level of the advanced countries within 50 years, its medium-term objective should be technological mastery on a par with that of the newly industrializing countries (NIC s) within 20 years, and its short-term objective should be technological mastery on a par with that of our ASEAN neighbors within 10 years. Thus, by such stages, our country should be able to leapfrog the scientific and technological gaps within the span of two to three generations.

Though the pessimists and pragmatists among you may find my proposed strategy of technological leapfrogging as an impractical visionary path, I strongly believe that what our people badly need today is a vision for a better tomorrow. And so I offer my strategy of technological leapfrogging towards the goal of mastering high technologies as a long-range vision for designing, building, mastering, and insuring our future as a nation in the 21st century.