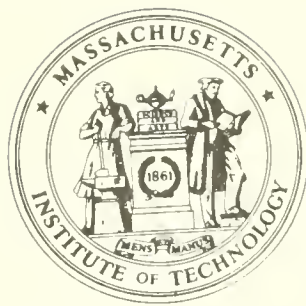
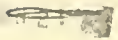


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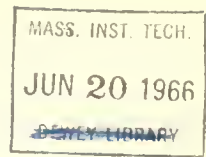
SCIENCE, TECHNOLOGY AND
DEVELOPMENT STRATEGY

April, 1966

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Comments are solicited by the authors who are associated respectively with the Alfred P. Sloan School of Management, Massachusetts Institute of Technology, and the Overseas Development Division of the Ford Foundation.

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SCIENCE, TECHNOLOGY AND DEVELOPMENT STRATEGY

Might there be some value in thinking about economic development as science capacity? In this view, the developed nation is one that has learned to house scientific activity. At some historical juncture, its humanists and practical men moved over and made room for the scientist. At first the new element's contribution was obscure. His theories were difficult and abstract, but their application through technology gained him understanding and support. Science became an orthodox profession with an independent ethos, and the society gained an important monitoring and regulatory capacity which gave new perspective to the issues that the practical men and the humanists had been unable to resolve. It was now possible to systematically scrutinize and up-date current practice. The society became dynamic, venturesome, growth-oriented.

Some underdeveloped societies are without the resources and professional talent that sustained growth requires. Others have them, and yet have not responded to massive resource allocation both from their own bounty and via external aid. Why are the growth processes not now irreversible within these societies? One explanation may be their failure to effectively house scientific activity. Their humanists and practical men - locked in ideological debate - have not moved over to make room for the scientist. Although first-class science may be economically justifiable; it remains second class, the handmaiden of other social factions. Science has not become an orthodox profession. You can't earn a living that way. Young nationals undertaking scientific training abroad hesitate to go back. Those that do, make their peace with the practical men or the equally science-free academic humanists. The society has been unable to make the structural leap forward

and must forego systematic monitoring. Current practice goes un-scrutinized and un-updated. The society remains static, conflict ridden and tradition bound.

This view points to the fact that science is a social phenomenon as well as a technique-gathering mechanism. It is a set of values that, among other things, turn back the harsh edge of self scrutiny and reformulation. It is a manner of discourse by which elements within the society communicate and seek tentative consensus and it also provides a promising system of external communication, cutting at times across ideologic barriers as demonstrated by the fragile, science-based dialogue between the United States and the Soviet Union. Looking ahead a generation or two, it is not difficult to foresee a circumstance in which nations - and bloques of nations with related purposes - will compete with one another, and in this way communicate with one another, not in terms of ideology and philosophic cant, but rather in terms of their ability to generate and apply new technology through science.

It is precisely because it is a social phenomenon that the under-developed societies resist science and deny domestic scientific activity the authenticity required. The humanists and the practical men have correctly perceived that its presence as an independent ethos will spell the doom of a status quo in which they have equity despite their proclaimed allegiance to modernization. Thus, the action-postponing functionality to their purposes in the endless debate as to whether the Soviet or the Western science model is more economic. Thus the decision-avoidance implicit in the protracted discussion as to whether modernization is really worth the cost and the philosophic search for a third route which will be less "dehumanizing," i.e., more traditional-status quo perpetuating.

This is why foreign assistance has had to meet the conditions of the domestically-dominant practical men and humanists. The practical man has been far more interested in importing techniques than the technique-producing mechanisms. He has submitted the returning national with high-order foreign science training to costly and at times brutal resocialization on the premise that what he has learned abroad was not domestically relevant. And the humanist academician has been far more interested in the visiting foreign professor's foreign findings and theories than any proclivity the visitor might show towards analysis of the host institutions. It is the machinery of science that the underdeveloped society fears, not its product; and a whole set of international myths and customs have grown up to perpetuate this unfortunate distinction.

Yet there are signs that these barriers may be coming down, that they are proving too expensive to maintain. The motive force comes primarily from important internal elements, infected by the spirit of scientific inquiry, and willing to risk that, in their time, a domestic scientific career will be possible. Sensitive external agencies have correctly assessed this shift and are beginning to deploy their resources in such a way as to support it rather than be used to prop up arrangements already doomed to obsolescence. Other concomitants conspire towards this end, not the least of which are important break-throughs in the communications and travel industries that promise to slow down if not reverse the trend towards geographical concentration of the international science community.

But the contrary myths and customs will not easily expire, and agencies of change both domestic and external will need to be ever more discriminating in attempting to influence the transition. One useful discrimination

has to do with the category of science undertaken. It has been noted, for instance, that the culture-free sciences - physics is a good example - generate the least resistance to their foreign replication. Unfortunately, they are also the sciences whose partisans are least attracted to duty in the underdeveloped sector. The social sciences, on the other hand, generate the most domestic resistance to foreign participation, and are the areas that have historically proven most attractive to visiting scientists. In the middle of the spectrum are the technologically-oriented sciences bridging both institutional and basic concerns. Here the risks may be more manageable and the basis for a bi-national activity stronger, a possibility which is only beginning to be noted by the technological specialists from the advanced sector who have hitherto absented themselves from activity in the underdeveloped world. It is to this middle area of a broader undertaking that this commentary directs itself.

Our task in the pages that follow will be to consider the institutionalization of technological science at underdeveloped sites with the appropriate level of readiness and raise the question of how a critical size with the characteristic of irreversibility may be achieved. In undertaking this review, we must first inquire into the nature of the critical-size, science-producing entity in the advanced sector and ask how it achieved irreversibility. Next we must consider the fate of similar attempts in the underdeveloped world and speculate on what additional inputs are required to bring these efforts to fruition. One obvious missing ingredient is effective linkage with the international science community. Technological scientists in the advanced sector have not historically been eager to establish such linkage because they have not expected to encounter in the underdeveloped world authentic scientific activity or the means by which it might be rapidly established. We must ask: Are these exclusionary premises still valid? Is

it now possible for the technological researcher from the advanced sector to establish such linkage without career damage? Or - more powerful still - is it possible that the technological specialist without such linkage may soon find himself professionally disadvantaged?

II

The advanced nations long ago concluded that success in keeping pace was a function of their ability to fashion institutional forms capable of generating and applying technological innovation. In our own case, Robert Solow has estimated that capital input and increased labor productivity, taken together, account for no more than 20 percent of the growth in the U.S. economy during the first half of the century. The balance must be attributed to research-generated, technological innovation. The modern world had passed the point where additional inputs of energy produced equivalent outputs of economic advance. Inputs of new knowledge are another matter. Scientific research turns up leads. Some are used, others are not: it is the net impact that counts. Product changes make the product cheaper or longer lasting, releasing resources for alternative consumption or saving. Improved production techniques result in a net saving in the factors of production including materials. Resources are released for other purposes: and the growth processes compound themselves.

The genesis of organizational forms such as those required to house scientific research is beginning to get some theoretical attention. It has been pointed out, for instance, that there has been over time an evolution in organizational form almost Darwinian in character. History has generated tasks requiring revised organizational forms, but these new tasks have been entertained only as and when there existed elements out of which the new

forms could be created. Those with special competency for the new tasks sought to gain legitimacy for their function and the measure of control that its implementation required. The older elements resisted this effort and there followed an unsettled interlude, usually painful in character, which had as its purpose the establishment of boundaries which both parties could accept as legitimate. As a new special-purpose entity achieves critical size and irreversibility, there are three dimensions to watch. The first two have to do with the kind of interfaces the new competency is able to achieve in relating to authority and peer elements. The third is related to the first two. It has to do with the capacity of the new entity to relate to the juniors it attracts in such a way as to assure itself regenerative or self-renewing capacity.

The authority dimension represents the interfaces that an organization is able to develop both with its internal superiors and with external superior organizations. Fortunately for mankind - and for its problem-solving and adaptive capacities - the history of organizational evolution has been, despite occasional setbacks, towards greater rather than less authority dispersion. Thus it has been possible to accord the professionals employed in the research organizations, appearing late on the scene, the autonomy they needed to pursue goals that were not easily communicated and thus difficult to supervise. The modern research-oriented university has proven especially functional in this regard. Private and public research institutes that have rivaled its success have done so to the degree that they have been able to replicate the university's organizational structure. The old German professor of the last century provided the first step towards the resolution of the authority issue. He may have been a crusty character,

but he had achieved relative autonomy in the goals that he set and the manner he went about achieving them.

But he was less than adequate in establishing adequate lateral relationships with others at his level and with adjacent special-purpose organizations. Here the German model required redefinition that was achieved in the course of subsequent experience in the United States and elsewhere. This redefinition accorded the researcher more functional feedback paths with a real world which by this time had become a set of complex productive technologies. The university researcher entered unblushingly into alliance with contemporary technological practice. The factory and the market place became his laboratory as the university campus became the gathering place of the engineer and the manager. This stepped-up inter-action had its effect on both parties. In the course of field work, consultation and research reporting, the university researcher had a chance to test the relevance and quality of his findings; and, as these findings became more relevant and qualified, the practitioner found that he could ignore them only at his peril. An effective education-industry interface had been fashioned and the lateral feedback loop closed.

Yet the gains so achieved would have eroded with time had the new organizational form not acquired capacity for regeneration and self renewal. Under conditions of rapid growth individuals tend to become professionally obsolete and politically defensive and institutions to rigidify as the result of well-understood processes. The adaptive response to these circumstances, where it has been taken, has consisted in the emergence of a value that favors internal change and modification responsive to a changing external circumstance. Thus the research-based university will pride itself upon the

flexibility of its curriculum and internal structuring. One such institution will boast that twenty-five percent of its scheduled courses are being offered for the first time. Another will point with pride to the fact that its knowledge-generating capacities have so outstripped publication that its students find themselves working with unpublished research reports. Concurrently, normal personal preoccupations will have been softened by the value that a man's original work will largely have been accomplished during the first half of his career when his conceptualization is loose and uncommitted and while he is unfettered by administrative burden. Later, when his administrative involvement makes it more difficult for him to test the creative new syntheses, he will have trained himself to encourage them in his juniors, correcting recognizing that the younger men have the lead time to see these new syntheses through the complicated process of theoretical reconceptualization, curriculum change, and inclusion in a redefined disciplinary unit. Thus the two parties have achieved a trade-off. The senior man retains his intellectual vigor and professional centrality by serving as a broker for the new knowledge which his younger associates are turning up, while the junior party acquires the support and shelter he requires to achieve the substantive output that will project him into a power position during the later years of his career.

Thus the university in the advanced sector - and the research institutes that have taken over the academic form - have developed an organizational form adequate to the task of research productivity. This form was of the critical size to assure irreversibility. It has been functional in that it provided the individual researcher the kind of authority relationship that gave him the autonomy required in his work. But this autonomy was not an unlimited one in that his output had to meet an after-the-fact test having

to do with its quality and relevance as it was fed back to contemporary practice. Finally, the form provided the regenerative and self-renewal capacity that was a condition of its survival. With these characteristics of the research-producing organizations in mind, we turn to a consideration of the difficulties experienced by those who have sought to replicate them in the underdeveloped setting.

III

Important resources have been diverted to the establishment of scientific activity at a number of underdeveloped locations, but it must still be reported that the underdeveloped nations themselves and external agencies seeking to be serviceable to them remain conflicted as to the wisdom of such resource deployment. We know that the processes that Solow has identified are compounding themselves in the second half century and that no amount of labor-saving or technique-importation can offset the inability to innovate technologically. Yet we reassure ourselves that the underdeveloped nations' access to cheap labor and our discarded and often obsolete machinery somehow gives them temporary respite from the shifts that are shaking the world. The fact is that the resource-poor underdeveloped nations ignore these shifts at their peril. Gunnar Myrdal concluded an important study of economic growth restriction some years ago with the stricture that only the highest priority to the training of scientists and the conduct of scientific research in all fields could give the underdeveloped countries any real chance of success in economic development.

Granted their resource shortage it may no longer be a question of how much science the developing nations can afford, but how much sacrifice they are willing to make in order to get all that they can lay their hands on.

How many alternative advantages they are willing to forego. Take the example of a public works ministry that is planning an important highway system. The cost of the system - the total resources it will draw from the economy - with planning not yet accomplished, is flexible. It will depend on optimization of route selected according to a complex set of criteria, the economic use of materials and machines granted highly particularistic local conditions and, related to this, the upkeep and maintenance that will be required once the system is in place. Let us further assume that the ministry has two planning schemes, both carrying the same cost. The first involves a small but specially-trained staff, a computer, and a shorter planning period: the second, a larger, less-specialized staff, which is already on hand, no machine, and a longer planning period. At first glance the second plan may seem more advantageous in terms of providing employment and by-passing import restrictions. This kind of planning scheme will be easier to implement, more popular, perhaps even cheaper; but modern planning technology will have been foregone at the expense of greater construction and operating costs over time. A higher net allocation of domestic resources to the project will have to be made because modern planning technology was not employed, and this higher cost the underdeveloped nations are ill-equipped to sustain. Beset with the other disadvantages to which the underdeveloped nations are prey - smaller markets, inefficient natural resource exploitation, poorly formed capital markets, cultural and institutional drag - these nations require the most sophisticated technological approaches that they can acquire and just as soon as they can be brought into reach.

This may be all very true, you say, but there is also the matter of national goals that do not lend themselves to external manipulation. This is only partly true. What we may be talking about is a common human

difficulty which in a way is extraneous to nationality. It is true that giving advice across national boundaries is a difficult business, but the difficulty may reside in the fact that the beleaguered underdeveloped practitioner has not yet acquired the capacity to respond to scientific feedback. Where it is well done, science knows no boundaries. It seeks through theoretical treatment to illuminate alternatives with only a secondary interest in what disposition is made of the alternatives so illuminated. Certainly it took researchers and practitioners in the United States some time and considerable grief to learn to relate to each others' special competencies. If the practitioner in the underdeveloped world wants sympathy or more time, that's one matter. The far greater discrimination would be to attempt to shield him - out of some misplaced sense of national sovereignty - from the beneficent disruption which good science, neutral science, can provide. When and where the underdeveloped practitioner's own nation is able to develop vigorous domestic research capacity, relations will develop more naturally without the need to take refuge behind issues of sovereignty which may be more spurious than abiding.

The question of how much research should be generated domestically is a more complex one. It might be argued, for instance, that most of the required techniques can be imported. This point of view holds that research scientists in the advanced nations have already turned up a backlog of relevant technology. Development costs on this backlog have already been met, giving the underdeveloped nations access at little or no cost. It is far better for them to invest their time drawing upon this existing backlog, rather than attempting to replicate it. Every generation and every regional group needn't repeat the discovery process on its own. Sure, the under-

developed world needs access to technological innovation, but does every underdeveloped nation need domestic access.

This is an impelling argument and in part a correct one. Much research can be done outside of the developing nation and a part of it can best be done in the advanced context where facilities and personnel are more abundant; but not all. There are valid reasons why an important portion of the work - certainly a larger segment that is generally recognized - must be done on site. Environmental differences constitute the most obvious reason. Only as we have attempted to replicate them abroad, have we recognized how complex are the production systems which we take for granted at home. Complex systems that work well under one set of geographical, topographical or climatic circumstances, falter under another or never get off the ground. Furthermore, the weighting of the factors in the system vary with local conditions. One setting may favor capital intensity, a second labor intensity; one, synthetics, another natural materials. The level of capital market formation requires different strategies. Local tastes and preferences - and the hard facts of circumstances of use - effect product design. Perhaps most important of all in determining the health and survival capacity of the complex are the institutional and interpersonal linkages by which technological changes are transmitted from the inventor to the user. As suggested above, scientific feedback from a domestic source obviates resistance clothing itself in charges of external manipulation.

A fairly heavy input of domestic scientific research can be justified on purely economic terms. Sustained national growth requires the presence of a corps of specialists whose task it is to chart the local circumstances into which the production complex is to be set, to design modified systems

that make provision for these circumstances, to monitor the experience of systems once they are in place, and to provide systematic feedback to the practitioners who have the operating responsibility. A part of this specialist corps will address itself to more fundamental problems for reasons that we will suggest later, but unless the research element is operating at a fairly advanced theoretical level, both its efforts and the growth processes of the nation will have been compromised.

There is a second reason why domestic scientific research directed at technological innovation is important. This reason transcends economics but has traceable economic consequences. It arises out of the fact that technology-oriented research is not attracting its share of the corps of theoreticians that is available in the underdeveloped world. Some countries actually have a surplus of university-trained professionals many of whom compete intensely with one another in other over-populated intellectual pursuits, some of whom waste their efforts in endless ideological recrimination and grow dissatisfied because their talents are under-utilized. The fact is that the international science community has been unable to transmit to such circles the intellectual challenge and sense of excitement and adventure to be found in pragmatic, reality-based investigation.

Intellectual circles in most underdeveloped countries feature an intense expressed interest in modernization, a heated debate as to which is the preferred route by which it might be achieved, and an absence of the significant small steps by which the growth processes are triggered. This may be due to a belief that, until consensus on the route to be taken is achieved, no tentative one should be undertaken. The contemporary industrial and political forces are viewed as ideologic power factions. To undertake

scientific research which - however neutral - might be viewed as reinforcing the activities of these "factions" is seen to be an act with political significance. This value has resulted in a polarization among the industrial, political and intellectual segments, militantly enforced by strong divisive codes. One risks his professional career if he brings his scientific competence to bear on activities undertaken by people with whom he does not share complete ideological affinity. Thus the nation is deprived of the scientific monitoring which its technological activities desperately require, theoreticians and practitioners have none of the sense of community out of which true professionalization emerges, and the gentle but powerful spirit of inquiry is overwhelmed by a spirit of advocacy bordering on emotional chaos.

Yet there do exist pockets of professionals ready and willing to undertake scientific activity, and with a preference for undertaking it domestically. If these pockets can be identified and reinforced, there is some chance that they might be able to contend with powerful local forces oriented to other ends. As they survive and achieve critical size, the multiplier effect that research always imparts to its setting will make itself felt throughout the researchers' own institutions, out into adjacent circles, and eventually into the national mentality of the nations that house them.

IV

What forces in the underdeveloped world are tending toward the generation of critical-size, science-producing entities? And how are they faring? Bringing such entities to maturity in a setting that has been traditionally alien to their purposes is a tricky business. It presupposes the existence of certain elements out of which the new entities will be created.

Not all societies have these elements. It further presupposes a state of institutional maturity that grants at least toleration to the new and vulnerable special-purpose activities. This institutional maturity and toleration is not a characteristic of underdevelopment. If a critical review of current effort, domestic and foreign, to locate talent and bind it into functioning activities of critical size shows progress to have been disappointing, this says nothing about the competence and dedication of those who undertook such effort. It may simply be pointing to elements that were not available to them and suggest strategies by which these missing elements may be supplied, possibly with external help. Such a review, however, does lead us to an examination of the entities' interface characteristics which provided the essential productivity and continuity in the advanced sector case.

The semi-independent technological research institutions have most squarely faced the twin issues of authority and research autonomy. The fact that they have typically sought to disassociate themselves from the large government-sponsored universities indicates where they felt the threat to their autonomy lay. The university in the underdeveloped nation - in common with all human institutions - has been a product of its times. It has had more pressing goals than the nurturance of scientific research directed at technological innovation. These goals have had to do with the establishment of a national identity, the resolution of pressing power issues, and the socialization of the young in terms of these identities and resolutions. The fledging research institute had other purposes which it would have had to subordinate to university values had it sought full membership in the academic community. Typically, it struck out on its own; but not completely so because, in escaping one tyranny, it exposed itself to a second.

In seeking to establish their legitimate separate purposes by disassociating themselves from the government universities, the new technological research institutes found it necessary to enter into counter-alliances with industry, the government and, in some cases, with agencies of a foreign government on which they depended for support. The consequences of this move were mixed. Short of conditions of war, direct government action unmoderated by an existing scientific ethos is perhaps the least effective method of achieving the conditions of science. Where the new entity depended for support on a foreign government, it came to be viewed as a pariah and lost its capacity to attract the talent it needed from the intellectual communities both at home and in the nation with which it was allied. Where it turned to industry it gained the required access to current practice, but an entity whose function it is to define the shape of things to come also needs shelter from current practice if it is to generate the flow of technological finding which will redefine and upgrade the techniques which the practitioner currently is employing.

The relationship between the intellectual and the practitioner in the underdeveloped world can best be described as one of unfortunate polarization, and the young research institutes now found themselves caught in a crossfire not of their own making. They had escaped the domination of academia to find themselves confronted with the possibility of domination by industrial practice with which it was at war. In the advanced nations, both the universities and the production organizations have learned to live with a largely autonomous research function which in a sense provides them a common meeting ground and manner of discourse. Not so in the underdeveloped world. The research institute's alliance with industry and the practicing

professions represented an advance of sorts in achieving a functional resolution of the authority issue, but in no sense a final one.

One of the authors was witness to an episode which illustrates this dilemma and sharpens the issues at stake. The organization concerned was a small technological institute affiliated with a large government university, but this is beside the point. The institute had a young, well-prepared and highly-motivated staff which was attempting to develop a cooperative program with a U.S. university. The issue at stake was what might constitute a legitimate problem for joint research. The representatives of the U.S. institution had proposed a project that had important theoretical significance. As individuals, the local people were attracted to the idea. It would have made possible the utilization of their special competencies and have given them visibility in the international science community. Moreover, the importance of the work and the opportunity for association with a respected U.S. school would have projected their institute as an important technical resource, and this projection would have strengthened their relations with the local industrial and professional community. The only thing that chilled their enthusiasm was that it might not meet the test of being in the "national interest" in the sense in which that term was locally used.

A widely-held value in the underdeveloped world that individual professional enthusiasm must always be subordinated to a loosely-defined concept of the "national interest" requires further consideration. Perhaps no value has aborted so many promising starts, driven so much competent young talent to emigration, and made a mockery out of the claim that it is a shortage of trained personnel that is braking economic development. The application of this value may be basically a device by which the power elements

in all sectors of an underdeveloped society maintain the status quo despite their professed devotion to modernization.

Typically the young professional returns from his technological studies abroad with an enthusiasm for and a competence in the sophisticated type of investigation which is the genesis of technological growth. Out of some sense of idealism, or as a normal expression of the male ego, he seeks to implement these enthusiasms and make manifest these competencies through a combination of research and teaching. But an adequate structural resolution of the self-renewing and regenerative issues described above has not been struck. The generation in power will be unsettled by these new inputs without having access to the organizational forms by which such very normal human preoccupations might be softened. It resorts to the "national interest" value as a means of quieting its own fears of obsolescence. The young professional swallows his chagrin and undertakes a project whose quality and form meet the imposed criteria to the point where he senses, perhaps correctly, that he is being used as low-cost backup support for technical work of a mundane sort being carried on by some outside agency. At this point, he must decide whether he should transfer his labors to the outside agency where he will be more adequately compensated, compromise his professional enthusiasms by seeking alternate employment, or migrate to an advanced nation where his special competency is in demand.

The working through of some such function may explain the relative young age and heavy turnover to be found in any number of such bodies which have had their normal growth stunted by other agencies using particularistic interpretations of the "national interest" as their justification. Granted the pressure of events and the shortage of talent, it is understandable that these external agencies should wish to exploit the pools of competence that

technological research bodies represent. Less well recognized, perhaps, is the damage this does to balanced organizational evolution within the nation. Under such circumstances, these bodies can never be considered mechanisms within which a lasting marriage of individual enthusiasm and relevant scientific productivity can be achieved.

In the case of the university institute cited above, we are happy to be able to report that a resolution was achieved. The institute decided to assign one half of its research capacity to the theoretically-stimulating problem which had captured the staff's attention. This allocation promised to keep alive the vision of the institute as an entity with career possibilities for the researcher who aspired to do work at a more advanced theoretical level, a vision with impact beyond the confines of the institute itself. For instance, it provided the local university with a theoretical nucleus around which students with such interests could coalesce. The balance of the institute's capacity would go to the more prosaic activity assigned to it by the outside agency - in this case work on a problem of low-cost housing. In view of the settlement that was worked out, the U.S. researchers in the picture agreed to consult where possible on this second problem which had little professional significance to them.

The visiting professorship represents another method that once held promise of speeding up the structural updating of universities in the underdeveloped setting. The hope was that, in addition to acquiring substantive teaching help, the host institution might be impelled to test some of the distinctive values about the educational role which the visitor manifested and, in the process, acquire expanded capacity for housing scientific research. This expectation underestimated the power of the forces that conspire against

its realization. The basis on which he was accepted and the fact that his stay was a limited one, restricted the visitor's impact to his dialogue with students, and this largely on substantive issues. It might have taken the first half of his stay to realize the contrary lean of the organizational circumstances into which he had been introduced. If he rose against these circumstances, it would take the second half of his visit to realize how powerless he was in effectively countering them. This says nothing about the validity of the visiting professorships as a valuable international institution. It can justify itself exclusively on the basis of the substantive teaching help that it affords. If further justification is needed, note should be taken of the developmental value to the visitor and to his home institution implicit in the arrangement. A man's teaching style will be inevitably altered as the result of years spent abroad. But the fact remains that the visiting professor by and large has not been an economic device for the transmission to the underdeveloped world of the styles of organization capable of housing authentic scientific research. An additional ingredient was required, one which the bi-national research institute has been able to provide at a limited number of locations.

The bi-national research institute typically grows out of the enthusiasms of a visiting professor who has aspired to establish something of permanence, has recognized the limitations of the visiting arrangement, and has returned to make heavy personal investment in the creation of a viable, self-sustaining institution on site. In this sense, it may be considered an occasional by-product of the visiting professional arrangement. Two elements carry it forward. The first is that the foreign professor is accepted as a member of the international science community, not as an agent of a foreign government. He is viewed professionally as a neutral party.

The second is that he puts in the relatively continuing presence of a later-career scientist with professional centrality and without the obsolescent pre-occupations that make senior people less than adequate in most developing nations circumstances. Thus he is in a position to achieve the "trade-off" between the more and the less senior persons, in this instance of mixed nationality, that gives the advanced nations science model its regenerative capacity. The less senior professional is able to engage in theoretical work, subject only to the test of eventual relevance, with the more senior gaining him linkage with contemporary practice, providing the required support and shelter, and serving a brokerage function in transmitting the new knowledge so generated to its appropriate external publics.

The strength of the bi-national institute - the fact that it emerges naturally out of the professional enthusiasms of an authentic scientist during service as a visiting professor - is also its important limitation. The idea of an extended term abroad exerts a screening function according to the scientific area from which candidates are drawn and, to some degree, on the calibre of the people attracted. In some of these areas, extended foreign duty is seen as enhancing one's professional development: in others, not. Thus the corps of top-notch, mid-career professionals that have moved abroad has been slanted to certain specialties and this effect has made itself felt in the bi-national institutes which some of them have helped establish. Moreover, the area of specialization that impelled visiting researchers to seek on-going relationships in the underdeveloped nation may or may not have been the one that the nation required in its development, particularly where the deficiency was in the area of technological innovation. None of this negates the net contribution of the foreign party to the bi-national arrangement. He provided an important demonstration effect that proclaimed the validity of a variant

organizational form, and he reinforced domestic efforts to replicate this form by committing to it his own continuing presence. What was needed was some method of extending the format to other professionals for whom foreign service might, at first glance, seem less relevant. In achieving this extension, we must look first at the career requirements of this second and hitherto largely absent group of specialists.

V

We have now identified linkage with the international science community as an important missing ingredient in the research-producing formula. The continuing presence of first class scientists from the advanced sector has proven an economic and powerful way of achieving this linkage, but the technologically-oriented researcher has hitherto absented himself from this activity. If he can be brought into the picture we will have met the conditions that produce durable, technological innovation-producing entities of a critical size that will attract and sustain young domestic theoreticians and help them to establish functional authority and current practice interfaces.

Why have our own assistance programs not attracted these specialists in the past? The answer is that, for such individuals, a proposed activity has to be on their terms. The competent, up-to-date researcher tends to be rather hard-headed in deploying his time and - working in terms of current perceptions - foreign service has not in the past, and does not now appear to him to be professionally rewarding. Acquired at a distance, these perceptions tell him, first, that it is an extremely difficult business to enter into professional research abroad and that, if it is undertaken, the payback will be extremely limited in terms of his career requirements.

The scientific researcher who has dedicated his time to an examination of technologically-significant problems is a scarce resource in short supply. He is correct in endeavoring to strategically deploy his time using such perceptions as he can acquire for this purpose. The problem is that these perceptions - appropriate to an age now drawing to a close - may be no longer valid. Events have moved so rapidly that the advice he is getting from recent returnees about the nature of foreign research affiliation - advice having to do with the importance of extended foreign residence, the role of language ability and cultural sensitivity, the relevance of his interests to the problems of underdevelopment, and the place of these problems in his own battle against obsolescence - needs reevaluation.

In many cases, extended foreign residence - and extended absence from one's professional and institutional base - is no longer a condition of foreign serviceability; it may have become a block to such serviceability. Let us consider Latin America which happens to be of special interest to the authors. At the beginning of the present decade a trip to a South American country provided a chilling prospect for the first-time traveler deeply committed to important work at home; so much so that the trip was frequently postponed or never seriously considered. There was the matter of finding an adequate block of time, rearranging one's schedule and exchanging correspondence with those to be visited, packing for a different climate and the prospect of a long and tiring trip. This perception is still current; but the fact is that by the end of the decade, the same trip will represent little more than an early-morning flight, lightly undertaken with no more preparation than a phone call to one's Latin associates and the stuffing of an extra shirt and toothbrush into a briefcase. Two of the authors colleagues recently flew to Rio de Janeiro on a Friday evening. Saturday they

participated in a seminar. Sunday they rested before catching a return flight that permitted them to teach class on Monday morning. A few weeks earlier the research staff at one university laboratory flew to Caracas on Thursday night to undertake a full day of conferences with their Venezuelan associates on Friday. That night they enjoyed each others company socially, and by noon the next day the U.S. travelers were at home working in their yards. Travel time will be halved again by the end of the decade, and there will be equivalent improvement in communications possibilities. Research associates at the Massachusetts Institute of Tecnology and Buenos Aires have already linked computers at the two locations by means of teletype and short wave radio. Within a year, a permanent hook-up will be possible via communications satellite. It is already possible to effect continuing research collaboration with foreign associates on a commuting basis and, looked at closely, this may be the more economic way to do so.

A second archaic perception holds that there is no substitute for foreign residence, that language facility and cultural sensitivity are prerequisite to effective service at a foreign location. This value is forwarded most vigorously by those who earlier traded foreign exposure for domestic professional centrality, and who have not recognized the changes that time has wrought. While no longer valid, it still accounts for a proportion of the casualties among the busy professionals who are not about to invest important time at mid-career acquiring language ability and political and cultural sensitivity. The fact is that the professionals with whom they will be dealing abroad speak English and prefer to speak English in the research context. Cultural sensitivity is also a two-edged sword and certainly not something to be acquired in a vacuum. The very cultural differences that the

visitor seeks to repress in undertaking collaborative duties abroad may represent values about work and productivity that might have been his most significant local contribution. To preclude this contribution and hamstringing his substantive input by undue emphasis on cultural sensitivity in the early part of his relationship is poor strategy indeed. It is also patronizing to the local counterpart. There will be differences in the two value structures that the visitor will want to think about, but this is best done in the course of the planning and execution of substantive tasks, and is certainly no precondition to the foreign venture.

A final perception - on which the evidence is not yet in and may not be in until another generation works its way up through the university structure - holds that certain research specializations will never lend themselves to the broader context. This perception holds that the nations on the brink of development may provide a rich and variant laboratory in which one finds different rates of change, different sets of givens, and less inherited blockage to technical and structural experimentation. It may be the only place where certain phenomena of theoretical interest can be studied; but foreign service can be a seductive mistress to one whose focus is a narrow abstraction in which situational variation is denied or held steady. The fallacy in such reasoning is that this kind of a conclusion only the specialist himself is in a position to achieve. What is urged is that he not deny himself or his juniors the opportunity to test it by means of brief foreign exposure, and that he not be denied such exposure by others who prejudge the circumstance.

For the technological totality that we monitor by the instrumentality of scientific research is not what it was when we could satisfy ourselves in

the advanced nations with systematic scrutiny of only our own provincial activities. To this point, travel has been difficult and communication impossible, and it may have been strategic to devote our attention to that which was adjacent and accessible. Travel and communications technology is changing all this. There are coming into existence instant feedback systems of an intercontinental character in which the terms "domestic" and "foreign" lose their significance, and knowledge about a single station in the system is no longer adequate. It may be now more comfortable than strategic to permit oneself the myopia of continuing to ply familiar routines or, worse still, to encourage one's juniors to do so granted the greater lead time that they enjoy.

Yet the old myths endure, vigorously forwarded by those who were partisan to an earlier circumstance. They sustain the technological specialist in his misperception that his contribution is not relevant or currently viable in the underdeveloped sector, even though new communications technology may have rendered this perception obsolete. But the systemic nature of the new linkage, which promises to upend the science structure at the underdeveloped station, could not have been expected to have left parallel structure at the advanced station unscathed. We are only beginning to realize that the change consequent upon binational encounter works in both directions, that international activity invites domestic as well as foreign impact. In the final sense, however, the determination of the career pertinence of a broader research context only the specialist himself can make and, granted our scientific traditions, will make once the issues become clear. The role of administrative support will be to facilitate the clarification process and to mitigate structural modification at the specialist's home base, and our search which took

us from the advanced to the underdeveloped context now brings us back to the starting point.

VI

In assessing the current posture of U.S. institutions vis a vis "international" activity and postulating a revised one more responsive to the new circumstances and opportunities, it should be remembered that our objectives in this discussion, while important, are limited ones. Our conclusions may have nothing to say to programs that have other and, in some cases, complementary objectives. These conclusions treat exclusively of the achievement in the underdeveloped world of critical-size, science-producing entities whose objective is research directed at technological innovation. They identify existing universities and research institutes as the proper setting for such activity. They point to the interface and regenerative capabilities of the research components of such institutions as the prior area for attention. They propose an extension of arrangements that have proven serviceable in the case of certain binational research institutes as an economic method. They isolate the hitherto absent technological specialist from the advanced sector as the missing ingredient. And, finally, they suggest that new circumstances arising out of improved communications technology now make it feasible to bring him into the picture. The role of administrative service at the home base is to bring these elements into effective interaction. This calls for a venturesome, future-oriented, at times outriding type of administrator which all institutions may not possess.

The administrator's first task will be to provide for a reevaluation of a set of myths and perceptions which, although obsolete, are still widely held. Here he must bank heavily on the openness of science and the

capacity of the science community by means of this openness to adapt itself over time. His immediate objective will be to provide the specialist - however irrelevant may seem his interests from a distance - with exposure to the underdeveloped setting. The visiting professor arrangement was an uneconomic way of achieving what must be more directly accomplished. The search for research opportunity and professional linkage abroad has always had to justify itself in terms of other prior purposes - teaching, consultation, tourism. Circumstances no longer tolerate the inefficiency of such subterfuge, and the equation must be reversed so that research becomes the prior purpose of the foreign venture. It will take a sophisticated kind of administrator to accomplish this. Some of the excursions that he encourages will not be productive, others will. With an eye to the stakes, he must feel comfortable playing the percentages.

Where the imprecise dynamics of professional attraction do make a connection - where the traveler encounters problems of sufficient intellectual challenge to unseat other alternatives in his research portfolio - the administrator's second task is to make it possible for the specialist to program his personal involvement on his own terms. Only the individual researcher can effectively deploy resources including his own time, identify, train and influence his associates, determine the pace of the work and generate a high quality research product, especially where he works in a strange and still unfamiliar setting. This calls for a style of administration which respects the conditions of science and yet demands of these conditions a relevant, high-quality product.

The Massachusetts Institute of Technology has an activity of this kind in the field of civil engineering and is planning a second in management.

While the proponents of these programs make a point of their tentative and experimental nature the procedures adopted are illustrative of the kind of activity envisioned. Mid-career faculty with established research competence are encouraged to travel to Latin American sites for the exclusive purpose of meeting people in their field and assessing research activity already underway. Sometimes the travelers bring along junior men in their field or colleagues from related areas. They give no speeches, participate in no seminars, spend little time in ceremonial protocol. No eyebrows are raised if they come back empty handed. In keeping with research tradition, the plans respect the workings of a highly personal special competency and professional wisdom.

Where the juxtaposition of special competency and underdeveloped circumstance does generate professional excitement, the traveler is encouraged to design a program by which the substantive problem may be investigated in terms of his own professional and personal requirements. He selects his own foreign associates, whatever their institutional affiliation. Granted the lead times implicit in scientific research, the chances are that he will select an associate whose immediate work group will be close to critical size needing only the additional impetus that this kind of external association provides or that the associate will have the professional strength and personal stamina to become the nucleus of a new critical-size entity which the international connection will serve to instigate. In either event, no institution-to-institution contract is negotiated. The association is performance based and terminable by either party where output lags. This arrangement enhances the ability of both parties to negotiate the interface conditions that their work requires. Instead of awaiting the conclusion of an institutional contract that commits the parties deep into the future, they are in a position

to employ strategic reinforcement as issues arise. Where a promising international association is at stake, superior elements sometimes find the justification they need in condoning revised authority interfaces that give the research activity the autonomy that it requires, a change that does not go unnoticed by the younger elements to whom the entity looks for regeneration and self renewal. A review of the M.I.T. experience suggests that this kind of project- and performance-based association results in more institutional restructuring than other programs where restructuring is the prior purpose.

The research plan that emerges is task-based and developed by the parties directly involved. It provides them the opportunity to exchange such visits as the planning and execution of the work requires. They determine the duration and frequency of visits to the other partner's base, which may be for a day, a month, or a full academic year. The team becomes the nexus of an effort which may be extended to include graduate assistants, related specialists; it may even take on the character of an interdisciplinary effort. The plan is open-ended with the expectation that the parties will continue their association as long as their research interests converge. One requirement is research reporting, both externally to the appropriate elements within the science community and domestically to contemporary practice by means of a reporting seminar at the foreign site in which both parties participate. This last device is intended to strengthen the domestic industry-education interface and give the local partner and his institution important domestic visibility.

The strength of this arrangement is that it meets the needs of both parties. The domestic partner gains authenticity for his role and legitimacy for his theoretical interests. He also acquires strengthened feedback processes

with contemporary practice and respect from practitioners for his special purposes and requirements. The expectation is also reinforced that, while it may be still in the future, long-range research careers are now possible. The visitor's presence as a representative of the international science community underscores the fact that technology constitutes a legitimate and manageable subject for theoretical treatment; and the important regenerative function begins to make itself felt as blockages with the domestic intellectual community begin to break down.

The visitor enters into the arrangement on firmer grounds than simply the desire to be helpful and to transfer his competencies by means of processes that have only unilateral advantage. He has expanded his data base in a direction that equips him to maintain his professional centrality in a shifting technological circumstance. He has equipped himself to preside more effectively over the activities of his juniors in generating the revised quality of new knowledge that his future circumstance will require. He gains practical experience in the management of the more inclusive research tasks to which the future is directing us. Finally, the M.I.T. experience has demonstrated that this kind of par interchange - broadly undertaken - results in restructuring at the home base at least equivalent to that which is going on abroad. The "international" activity, instead of being an adjunct to largely domestically-oriented organizational structure, becomes an organic expression of that structure's intent to keep abreast of a changing external circumstance, and the extension of a faculty member's research coverage to a more inclusive base - once a luxury - now becomes hard-headed insurance in his battle to avoid obsolescence and to maintain professional centrality.

By virtue of their demonstrated efficiency in technological undertaking, the advanced nations have commanded the attention and acclaim of their

underdeveloped counterparts. The underdeveloped world now knows that it is heir to this advance and the devices by which it is achieved. But it also knows that laying claim to this heritage means important revision in a cherished manner of social relationship. Here it hesitates. Somehow the impression has gone abroad that the condition of social relationship required of technological advance is an inferior one. If there is one massive conclusion in the underdeveloped world, it is that the way that people relate to one another - the meaning of friendship, the dignity of the individual, the integrity of the family - all of the most human values are somehow compromised in the achievement of technological advance.

This is not an impression easily laid to rest. All of our activities to date have not challenged it. Precisely because it is the kind of device by which an old order perpetuates itself, external challenge only serves to reinforce it. Yet work-related associations between technologists from the two settings holds promise. Such association provides the domestic participant an opportunity to observe how his partner - responding to a variant relationship model - goes about his work. He gains immediate exposure to the sense of adventure and excitement that attaches to intellectual search in the field of practical affairs. He comes to understand the organizational forms which make possible a broader range of special purposes and human enthusiasms, and is encouraged to test some of these - at least experimentally - in his own activities. It may be the cumulative effect of these many small starts - undertaken in the spirit of science and for the purpose of scientific activity - that will equip the underdeveloped nation with the quality of relational underpinning which is the basis of equal participation in the modern world.

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