The Development of Human Resources for the Management of Industrial Technology

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The rapid growth of the industrial sectors of many of the countries of the Pacific rim of Asia has impressively demonstrated that science and technology, not population size or natural resources, are the keys to growth in today's integrated. fast-moving competitive world economy.

Quickly outgrowing the low-skilled assembly work on which their early industry was based, these agile, relatively open economies are using export markets to achieve economies of·scale and to acquire information on markets and technology. They are also making major investments of money and time in order to acquire and absorb foreign technology, and in so doing to develop their own technological capability. Their reward has been the ability to compete in high-technology export markets which elude other developing countries.

More recently, the breathtakingly rapid pace of technological advance in informatics, robotics, microelectrionins, telecommunications, advanced materials, biotech-nology and supercond uctivity, has transformed the world technological landscape, tremendously increasing the technolog ical pressure under which Asian economies must operate. Now ans never before, firms and governments in Asian countries must constantly scan the technological horizon, checking for technologies that are on the road to adoption in the advanced countries and that could sweep them out of the water.

At the same time, these simultaneous technological revolutions have drastically shortened the length of the product cycle, and thus offer Asian countries unprecedented opportunities for transfer and mastery of advanced technology. Innovative products may now be ready for offshore manufacture in developing countries in two years or even less from the time they first appear on the market in advanced countries. In this situation, the race – and what is just as important, the negotiating power and the local value-added – goes to the manufacturer with the capacity to absorb modern technology rapidly.

National Economic Policies and Technological Development

Science and engineering manpower is an essential element of strategy for technological development. But trained manpower is not enough in and of itself. Many countries with huge reservoirs of trained scientists and engineers even today have difficulty in generating enough productive jobs in which to place them, and find large numbers taking positions which do not take advantage of their technical skills, or migrating abroad in search of better opportun ities.

What is more, there are important examples of relatively backward countries which have but a tiny supply of scientists and engineers, but which nevertheless themselves operate sophistica ted infrastructure to a high level of technical efficiency and consumer satisfaction. For example, telephone and airline service in Papua New Guinea and Ethiopia are excellent-for better than those in neighboring countries that might be expected to be much more advanced technologically. Clearly, human resources are important, but so is the system that uses them.

The task facing developing countries, whether advanced or less advanced, is not only the creation of human resources, research capacity, or capacity to transfer or absorb technology perse, but the ability to link science and technology to economic development : to make technology work for the nation.

This objective places a premium on the ability to manage technology : to guide, control, and administer technology as a critical aspect of national development. This capacity takes different forms, depending on whether it is found in a policy making or regulatory body of government, in the management of a private or parastatal firm, or the in staff and management of a financial institution.

At the national level, consideration of technological aspects is an essential input into discussion of regulatory policy and of macroeconomic policies concerning trade, exchange rates. and interest rates – all of which nave key roles in guiding the development of science and technology.

For better or for worse, these economic and regulatory policies often have more influence on the speed and direction of scientific and technological development tnan do explicit policies for support of research, development, technical services and human resources. often laboriously constructed and implemented by officials with deep commitment to and direct responsibility for science and technology. In other words, the influence of implicit, indirect policy normally outstrips that of policy explicitly intended to promote the development of science and technology.

Some examples will make clear the influence of economic policy on technologuical development. If economic or ologopolistic situations, encouraged by public policy, prevent competition, firms will ignore technology that could improve quality or cut costs. If financial authorities overvalue the local currency, firms will have an incentive to import equipment and raw materials rather than draw on locally availavle supplies, and will therefore neglect local sources of technology.

The problem lies in the fact that national and sectoral plicies with critical influence on scientific and technological development are typically formulated in most countries without much input from scientists and engineers. And to ve fair, few people with a broad understandigng of scientific and technological development —or even with a minimal appreciation of science and technology—have taken much interest in these essential aspects of the management of technology.

To cite another example of and area where economic and technological considerations intertwined, consideration of both scientific and technological development should be a key element of discussions of sectoral policies that determine the prices of key inputs and outputs, such as energy, steel, cement, fertilizer, and foodstuffs.

After all, farmers are scarcely likely to make the investments needed to allow them to adopt improved technology for food production if their prospective profits are depressed by low administered farmgate prices. Nor is industry likely to use or develop technology to conserve energy or raw materials whose prices are kept artificially low by government intervention.

In the policy making levels of government, one of the first tasks of technology management is to create a business climate which encourages and facilitates the transfer of technology and at the same time encourages the building of local capability.

Considerations of technological development have long been the basis, at least in theory, for justifying trade or licensing regimes designed to nurture infant industries by protecting them from competition during their early years. Unfortunately, these policies too often inhibit the development of industrial technology by eliminating competitive pressures long after the infants have grown into large, inefficient producers. Similar effects may result from government policies that discourage efficiency by making it virtually impossivle to fire unneeded workers, to go bankrupt or to get out of a given line of business.

Under these condition, management often becomes more concermed with protecting its vested interests and guaranteed markets than with managing ist technology, unless it is committed to technological excellence for reasons going beyond the requirements of business profitability.

Role of Governments in Managing Technology

Most developing countries are coming around to the view that decisions regarding the choice and management of technology are best left to the firm. This is a substantial change from the older view that domestic firms need to be prevented by regulations from importing in appropriate technology on unfavorable terms, even at the cost of a slow and cumbersome bureaucracy.

But even countries that have always relied on international markets for technology do not want the local industry which they have so carefully built up to remain completely dependent on foreign technology or worse, to be reduced to an offshore manufacturing platform

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On the contrary, virtually all developing countries would like to encourage enterprises to improve their own management of technology : to improve their product quality and quality control, to make more intelligent decisions regarding choice and acquisition of technology from abroad, to invest time and money in absorbing, digestiog. adapting and improving that technology, to carry out the product design, engineering, development, and research necessary to be competitive on world markets, and to develop products suited to the unique needs of local markets.

What is more, they would also like to encourage the use of technology that is appropriate to local social and environmental onditions, and to bring science and technology to bear on the problems of disadvantaged groups and remote areas.

These are not obkectives. What is new is the spirit in which they are being addressed.

More and more countries are addressing competitiveness and innovation as a system's problem that involves not only enterprises, laboratories, and engineering firms, but also economic policy-makers, government regulators, banks, and universities.

Older policies in many countries placed bureaucratic obstacles in the path of enterprises wishing to transfer technology from abroad or to enter into a joint venture with a foreign partner. Now, enterprises are being encouraged actively to seek outside technical partners, but to structure these partnerships in such a way as to increase their own technolgical capacity.

Where earlier policies stressed research and development(often carried out in government laboratories) as the key to industrial innovation, newer approaches place equal emphasis on programmatic interventions that share the costs and risks of innovation as a commercial process.

Development of technological Capacity in Industrial Firms

In the more open, export-oriented economies, firms begin the process of developing their capacity to manage technology in a way that is consistent with their status as off-shore manufacturers. For the most part, these firms derive their market information. product specifications, and production technology(often including adaptations and improvements) from their customers overseas. or from purveyors of machinery or turnkey plants.

For this kind of firm, the basic prerequisite of successful operation is the capacity to hold up the local end of a professional and business relationship at an increasing level of technical sophistication and efficiency. For the longer term, the future of the firm depends on its ability to learn quickly : to master the more advanced technology required to meet the increasingly sophisticated demands of the market, and to raise productivity in order to keep pace with the increasing wages of its own employees and to meet the competition from firms with still lower wage rates.

This pattern may obtain regardless of whether the firm is of foreign or domestic ownership, provided that the foreign firm has entered implicitly or explicitly into a strategic alliance with the country and is hence committed to remain in the country and to follow it up the ladder of increasing technological mastery.

The strategic decision to pull up roots or to reman in the country when wages rise will be a product of the particular culture of the foreign company, as will as its policies concerning its international operations. A few companies even maintain a specific policy that all technological functions, specifically including new product development, should be represented in every country in which the company maintains manufaturing operation.

On the other hand, the decision will also be strongly influenced by the company's perception of the business climate in the country concerned, as well as by its judgement of the competitive advantage of the local affiliate in its capacity as fast learner.

Once the firm has shown that it can operate imported production technology chosen in resPonse to customer specifications, the next step is to move through the successive stages of mastery of production technology : direct importation of technology and equipment, minor product and process innovations, and substantial adaptive engineering and research.

If money, equipment, and personnel are specifically invested for the purpose, local and foreign production technology cal become substantially integrated through a cumulative process of adaptation, improvement and innovation. Even so, basic information on markets and on product specification and design continues to derive from outside the firm.

The mastery of production technology culminates when the firm is capable of acting as its own prime contractor in new project investmen ts which involve processes that are the same or closely allied to those it is already using. Such capavility is the basis of most of the substantial volume of technological exports now emanating from the more advanced developing countries, such as Korea, Brazil, India, and Mexico.

Still another critical watershed comes at a later stage, when the firm comes to depend largely on its own resources for information on advances in technology and changes in markets, the critical parameters in product definition. This greatly increases the sophistication required for the management of technology. A number of firms in the newly industrializing developing countries are advancing into this status, and a few are even launching world- wide export drives for their products on the basis of their own brand names and reputations.

By virtue of this transition, these firms take their place as fully-fledged competitors in the world technological marketplace. In this new arena, their competitive strategy is that of the so-called low-cost manufacturer. In advanced countries, such low cost manufacturers compete in international markets, despite their high wage rates, by virtue of their mastery of product design and manufacturing engineering, and(in some industries) by their ability to offer superior service and to change rapidly in response to changes in demand.

Aspects of the Management of Technology

Technology enters into virtually every aspect of the management of a manufac-turing firm. In this section, we review the technological dimension of each of these aspects, as it affects firms in the more advanced developing countries which are typical of the ESCAP region.

Strategic management of technology. In theory(if not always in practice), the management of technology begins with the strategic management of technology, i.e., the blend of technology, market and business forecastiong used to develop strategy for acquiring or generating the technology that will be needed for continuing the business into the future.

Strategic management of technology includes an analysis of the market potential of the various broad lines of business that the firm expects to enter, specifying the product lines in which the firm could be competitive in these markets, and the key technologies required to establish and maintain that competitiveness.

This analysis begins with a careful definition of objectives, and a consideration of alternatives, based on a thorouhg assessment of technological and market constraints and opportunit ies. This process should precede the selection and acquisition of technology – although it is surprising how often it does not, both in actual practice and in technical discussions in the professional literature dealing with technology transfer.

Strategic management of technology also includes the identification of key technologies common to more than one line of business, that could form a nucleus of strategic technological resources, and an analysis of the relative merits of "make or buy,"… i,e., whether to generate the technlolgy by one's own efforts, by licensing or joint venture, or by merger or acquisition of nother that already has the needed technology.

Like other aspects of management, strategic management of technology depends critically on information. Surprisingly, this is an area to which government and industry of newly industrializing countries generally pay insufficient attention. Firms and governments in many industrializing countries still complain bitterly about the unavailability of technological information from abroad. They often seem unaware of the many date bases that are routinely available to commercial customers in advanced countries. Nor are they usually willing to pay a price that reflects the commercial costs of generating such commercial and technological intelligence.

Management of innovation and the product cycle. The second major element of the management of technology, the management of innovation and the product cycle, is perhaps the most critical aspect of management in firms following the technological strategies, discussed earlier, of technological leader and fast-follower. As such, it is the one that receives the most attention in the advanced countries, which by and large look to firms following these strategies to sustain their competitiveness on world markets.

The management of the product cycle goes well beyond the management of research and development, and is a function likely to become increasingly important in the more advanced firms in developing countries. The compression of the product cycle, referred to earlier, is forcing firms in developing countries to manage rapid change in their manufacturing processes, even if theystill receive their information on markets and product design from their overseas customers.

The management of the innovation cycle begins with new product planning. This begins in turn with technologically oriented marketing : the art of identifying specific market niches, and outlining the generic specifications needed to meet these requirements.

Technologically oriented marketing requires a major commitment to gathering information on advances in technology and changes in markets. Free information from customers on markets and technology has been a major element in the success of the export-oriented strategies pioneered by Korea and other Far

Eastern countries.

Now that a few Korean companies aor marketing their own brands overseas against the full weight of international competition, they are forced to take on responsibility for these crucial functions themselves. As we have seen, this is a critical watershed in the technological evolution of the firm, and requires a substan tial investment in maintaining technical staff in close touch with major export markets.

Once markets are defined, the next step in the management of the innovation cycle is product design and engineering. This is the process of specifying the precise product specificati ons, design, performance, and manufactu ring technology needed to meet the markets identified.

The technology for design and manufacture of a new product may come from inside or outside the company, from domestic or foreign sources. These "make or buy" decisions regarding the source of technology are important elements of the management of the product cycle.

Once the technology is identified and acquired, on the one hand, or locally developed, on the other, it must be transferred to the manufact uring line, from the firm's own laboratories or from an outside source. The management of this transfer is another important aspect of the management of the innovation cycle.

The management of an innovation does not end with the successful introduction of a new product. It continues with the improvement of products already on the market, and does not end until the decision to remove from the catalog a product that has become obsolete or has lost its market, a decision which in effect closes the innovation cycle.

Management of production technology. The third element of technology management in firms is the management of production technology : the choice and acquisition of machinery and related know-how (typically by transfer from abroad) : the absorption, adaptation and improvement of product design and process technology : and the management of quality, quality control, and trouble-shooting. In most businesses in developing countries, this is the most important task of technology management, and for this reason has received a great deal of attention in the development literature.

In the advanced countries, management disciplines related to production anr now undergiong a rebirth of interest on businesses, and in instituions of higher learning in business and engineering, as a result of increased international competition based on the extraordinary Japanese concentration and skill on low-cost manufacturing technology. Indeed, many of the most important recent innovations in management, such as the just-in-time inventory system, have taken place in this arena.

Management of technical presonnel and organization. The fourth major element in the management of technology is the management of the people and organizational elements of the firm so as to make sure that people of different skills and in different departments of the company work togetner to respond to changes in marketes, and Technology. This involves intergacating the work of design engineers, maketers, and manufacturing engineers – professioals with very different presonality types, educational backgrounds, time horizons, and(in many cases) career motivations – and ensuring that the conributions of each are suitably rewarded.

The integration of the various echnological functions of the frim with each other and with the broader managemet of the firm requires careful attention to the management of the careers of technically trained personnel. Personnel policis must reward scientists and engineers for their skill at collaborating with marketers and other sides of the business. At the same time, they must reward technical staff for their technical proficiency as will as for their managerial or other business skills. These policies must explicitly encourage scientists and engineers to keep up to date in their professions, and should ofter them the opportunity to do so.

Management of technological facilities and services. The fifth major element of the management of technology is the management of explicitly technological facilities, such as research, development, engineering and testing laboratories, libraries, information services, and education and training facilities.

These may be located within the company, or may be independent institutions run by the government or by private companies as part of the country's scientific and technological infrastra ucture. In the latter case, the management of the relationship between the firm and the outside entity providing the technological service becomes an important element of the management of technology on both sides.

Education and Training in the Management of Industrial Technology

How does this discussion of the complex relations between technology and industrial developm ent translate into a strategy for the development of human resources, which is the topic of this workshop?

Despite the considerable body of literature on the process by which the countries of the Eastern Rim of Asia achieved their remarkable record of economic growth and technological development, there is not, to my knowledge, an authoritative analysis of the strategy for human resources development which supported their overall development.

As is well known, these countries place a high value on education, as witnessed by the high proportion of each age cohort in formal educational institutions, and the remarkable successes of such institutions as the Open Univers·ities of Korea and China. At the same time, the chorus of complaints against the excessively theoretical approach to science and technology typical of most of the schools and universities in the region, leads the outside observer to ask whether the quality of formal training in science and engineering in these countries can have been responsible for more than a small part of their success.

It may offer you scant comfort to know that these problems are not confined to developing countries. I hear some of the same remarks in the United States.

We are all familiar with the complaints of insustry that engineering training in universities is sterile and academic, and provides insufficient practical preparation for work in industry. In developing countries, this criticism is sometimes coupled with the remark that universities too often stress rote learning and may serve only as quality filters that identify bright young men(and rarely women) for recruitment by industry, who must then train them from scratch.

The functions of technological management described in the previous section require a substantial critical mass of technically trained manpower in engineering and in science. There is a major need to expand and improve the quality of such technical training at all levels, and to use modern computer and telecommunications technology to make such trainging available to people who cannot afford the time or the financial costs of training in formal residenti al educational institutions.

But what emerges most clearly from the recitation of technologically oriented business functions in the earlier sections of this paper is the a mix of business and technological skills – and at the higher levels of management, a good dose of policy-oriented economics – is required in virtually every stage of the technologi cal development of the firm. Indeed many of the top managers in advanced countries, both in the public and the private sector, are(and ought to be) trained not in technology, but in humanities or social sciences that prepare them to deal with brodader issues.

As a subiject for higher education, then, the management of technology straddles the traditional domains of engineering and management. Clearly, there is a message here for centers of higher learning in the developing countries.

Unfortunately, engineering and management training at university and graduate levels in developing countries frequently avoids this unfamiliar territory. My impression is stong that most engineering curricula in developing countries are focussed on traditional engineering subjects to the virtual exclusionof management subjects. Most schools of business in developing countries, on th other hand, tend with few exceptions to be focussed on the financial and marketing sides of management, to the virtual exclusion of technology. This means that graduates of both streams are left without formal training to prepare themselves for some of their most critical tasks.

Because fo the gap in past educational programs, there is also a substantial need for mid-career training in the management of technology for mid-level government officials and middle managers in publicly and privately owned industry – as well as for the professors of economics, management and engineering that are likely to inherit the responsibility for teaching mid-career courses.

There is also a continuing need to insure that engineering curricula provide adequate training in low-cost, "appropriate" technologies needed to provide basic social services, such ans housing, sanitation, and public health, to the poor even in some of the most advanced developing countries. To be sure, such educational progrms will be useful only if there are sufficient resources devoteh to solving these problems that people armed with training will be able to find employment on technical tasks that are appropriate to the needs of the country.

Building Human Resources Through Investment Projects

Major investment projects are important opportunities to build up technological capacity within the project unit, in the context of a practical operation and with practical operation and with practical objectives always in view. Such projects provide an opportunity for planning manpower strategy forthe entire sector, or for consultation with local institutions of higher learning regarding the establishment and strengthening of curricula and undergradeate or graduate programs in disciplines related to the sector. Somilar consultations should be held with local vocational schools and technician training institutes, and even with local elementary and high schools.

The specific manpower requirements of the project itself should preferably be met through a focussed training program. If the prepartion of the project involves consultants, the period of project preparation and design affords an excellent opportunity for training the personnel who will ultimately have to manage and operate the project.

Project operation and design should be so structured that personnel who are to manage and operate the project should be involved in, or at least thoroughly knowledgable about, the details of the design and the anticipated running of the equipment. This will greatly facilitate operations and maintenance later on. An explicit training program should be built into the project preparation process and resources should be specifically allocated for that purpose.

Even if the technology chosen for the project is to be imported, the degree to which the "technological package" offered by the foreign supplier is to be "unwrapped", or "made transparent", becomes central to the issue of the building of technological capacity.

This "unwrapping" process may be undertaken in stages. It is rarely, if ever, necessary to accept a totally opaque, totally wrapped package, i. e. a turnkey plant, all aspects of which are proprietary and about which the importer is told only enough to enable him to operate the plant. At a minimum, the purchaser should demand a list of the components of a turnkey project, so that he may judge whether the package being offered is suited to his conditions.

The critical watershed in unwrapping the package comes when the customer becomes his own prime contractor and purchases various parts of the overall project from different sources. He then takes on the responsibility for the interfaces between suppliers and for the soundness of the overall design.

Under these conditions, suppliers will take responsibility only for the proper performance of. their own products, leaving the customer responsible for the overall performance of the system – a particularly important responsibility, since it may be difficult to establish legally just which component is responsible for the unsatisfactory performance of the whole. In the latter stages of "unpackaging", the customer himself manufactures of even designs components of the overall system and purchases only the most sophisticated or specialized equipment or technical services from outside suppliers.

Small-Scale Industry and Technological Development

Up to this point in our discussin, we have implicitly assumed that the bulk of the firms concerned with the management of technology in ESCAP countries are the large, well establis hed firms. On the other hand, a major, and frequently neglected source of innovation in both developing and develped countries, is the samll business.

Some of the small businesses of greatest importance to technological development begin as start-ups by entrepreneurs with ideas generated during their technical or management training at local or foreign universities. Others begin as spin-offs from foregn-owned firms, joint ventures, or larger domestically owned firms.

As they accumulate experience, technical employees from these firms may decide to from companies of their own, perhaps to produce some component or service which, up to that point, has been imported by the industry where they had been working. This decision is a momentous one, both for the individuals involved and for the technological development of the country. In particular, the spining off of new small businesses is one of the most important mechanisms by which skills acquired in export enclaves can be diffused to the rest of the economy.

Governments should therefore ensure that their policies and procedures encourage – or at least do not discourage – this kind of local entrepreneu rship. In praticular, it is important that there be sources of finance in the country that are confident of their ability to assess and accept the risks inherent in the launching of new business(or lines of business) based on local technology.

Government should also encourage – and eliminate any discouragem ents of – both university researchers who wish to strike out on their own, and businessmen who wish to establish close ties with the university, whether as a source of business ideas or as a training resource for their staff.

Recent experiments at the state level in the United States provide a varied and fertile source of ideas for "innovation incubators," designed to encourage collaboration among industry, universit ies, and financial institutions.

Some of these are basically real estate developments, offering subsidized rents to industry willing to locate physically near a university, and providing access to shared confernce rooms, receptionists, photocopying, technical information, and telecommunications services that otherwise might represent substantial financial burdens to small, undercapitalized firms.

On the other hand, many of these incubators explicitly encourage their client businesses to from technical links with the university, and provide a home for selffinancing research consortia, driven by competitive market forces, of private firms and laboratories, universities, bandk, and government.

These innovation incubators are attractive models for developing countries. A program based on their example is being set up in the Indian state of Karnataka, whose capital of Bangalore has the ambition of becoming the "Silicon Valley"of India.

Such incubators should also be attractive vehicles of technical collaboration between private firms in developing countries with private firms in the United States and eventually in other advanced countries. They should be especially useful in helping to identify sources of technology and partners for joint ventures. To encourage such bilateral collaborations between the private sectors of developed and developing countries should be in both the economic and the foreign policy interest of both partners.

Summary

The management of technology offers major challenges ot policy makers responsible for the development of human resources on developing countries. In the early stages of technological development, the chief challenge is to provide firms with trained managers and engineers for the management and operation of production technology, which is largely imported in accordance with the specifications of foreign customers, who provide informaion both on technology and on changes in foreign markets.

As technological development proceeds, firms demonstrate their mastery of foreign technology by adaptations and improvements, and increasing integration of foreign and local technology. This process culminates when the firm can accept the responsibility of prime contractor, and can accept the responsibility of prime contractor, and can expand, duplicate, and re-export the technology it has mastered.

Still later, firms come to rely increasingly on their own resources for information and markets, and take on broader responsibilities for other aspects of the management of technology : strategic management, management of the innovation cycle, the more sophisticated aspects of the management of thechnical personnel and organization, and management of technical facilities, including but not limited to research and development.

This increases the need for integration of technology into the broader operations of the firm, and hence for people trained in both engineering and business. This combined training is frequently unavailable in developing countries, because of excessive concentration on pure engineering subjects in schools of engineering, on the one hand, and excessive concentration on marketing and finance in the schools of business, on the other.

In other words, the last two major transitions in the technological development of the Asian firm depend critically on the development of managerial capability in areas that are sparsely repreented in Asian schools of higher learning.

To a certain extent, training in the management of technology is a by-product of the manager's own unvolvement in the increasingly sophisticated operations of the firm. On the other hand, training in the management of technology is facilitated by a more formal approach than can be transmitted reliably by experience, and is also needed by many people, such as new entrepreneurs, that cannot wait to get it on the job.

The absence of multi-discplinary training in the management of technology is thus a substantial challeng to institutions of higher learning in the relatively advanced countries of the ESCAP region.

거대한 磁石

400만파운드의 비용이 든, 6m 높이의 超轉導 솔레노이드인 이 거대한 강철 원형은, 믿지 못할 정도로 단순해 보인다. 그러나 안쪽 벽에는 0°를 약간 상회하는 온도를 유지하기 위한 복합 냉각 시스템이 삽입되어 있으며, 전기가 통할 때는 磁場이 형성되게끔 되어 있다. 영국 러더퍼드 애플튼 실험실은, 서독 함부르크 교외 지하의 6.3km 길이 터널 안에 비치될 75t급 솔레노이드를 완성했다. 이 터널은 과학자들에게 전자와 陽性子간의 고에너지 충돌에서 생기는 생성물을 연구할 수 있도록 가속장치를 설치해 놓았다. 연구과제는 국제적이며, 영국이 주도 역할을 하고 있다. 솔레노이드는 가속장치 내에서 전자와 양성자가 충돌할 때 생기는 미립자를 휘게 하는데 쓰이는데, 미립자들의 운동량과 電荷를 결정하는 데 쓰이기도 한다.