relative success of the chemical industry in India owes a large debt to this group of people. Laboratory-scale activity in instrument development is often the realization of a goal with available resources and without worries about the problems of manufacture, reproducibility, serviceability, ease of operation, reliability, long-term stability and, above all, cost. Development-oriented personnel do exist in small numbers in a few national laboratories and in a few instrument manufacturing organizations, but are largely absent in the university sector. It is true that they have not achieved conspicuous success. A major reason for this is the lack of 'moving with the product' on a conveyer belt, to use a phrase common in production engineering. Work on a production shop-floor is efficient when the item being produced is moved on a conveyer belt, with each worker adding his or her part to the item, a method made popular by Henry Ford in his automobile factory. If a researcher who develops a new equipment moves to the product-development area, all the background information,—knowledge of the 'whys', the 'dos and don'ts' and the 'hows'—can be passed on easily, much better than when these can be documented. In a similar way, if a product-development engineer moves with the equipment to the manufacturing phase., the information transfer takes place effectively. We have no method of inducing this movement of people which can catalyse instrument development. In fact, all the present procedures of leave rules, travel rules, daily allowances and other reimbursement of expenses are uniformly against such movement. Why should a researcher move from what is regarded as a more rewarding research work to what is regarded as less rewarding development work by the research community? The only inducement to move is a financial one and can be readily implemented. Many universities, laboratories and organizations will, without murmur, pay air travel and daily out-of-station living expenses at up to Rs. 1500 per day for a technician to come and install new equipment or repair equipment. Yet these same authorities are shocked if a suggestion is made that they pay their own staff at this generous rate when the latter move out for instrument development/manufacture activity. The pat reply that it is not sanctioned under any rule is also given. Therefore we must have a formal scheme under which a person moving from a university/research laboratory to a product-development organization or a person moving from a development organization to a manufacturing factory is paid very generous travel and living-expenses allowances. Then a few persons will move, and usher in manufacture of good scientific instruments, at least for financial rewards if not out of patriotism. Such a scheme can be introduced and monitored by the existing channels of instrument development committees of agencies like DST, DoE, CSIR, etc. This, by providing a priceless resource, namely persons with a mission, will provide a big impetus to the indigenous development and production of high-quality scientific instruments. It is certainly worth trying as a priority programme initially for a five-year period.

Carving a market

All these steps, while promising to motivate, do not answer one question of the manufacturer. Normally, the specialized scientific instruments have a limited market of a few pieces in the country, at least in the early stages. Manufacturers are reluctant to set up production facilities for a small number of units, especially since the route of system integration using readily available subunits is not possible in India because the subunits themselves are not available locally. One can argue that, once a good instrument is available in India, a market for it develops rapidly, as has been experienced in many cases. One can also argue that, besides a domestic market, the companies should be able to compete in the market abroad, especially in the developing countries. All the same, manufacturers are reluctant to embark on the production of a small number of units. At the moment the only solution is that the product-development groups in laboratories/organizations themselves should make two or three units for the use of various buyers. They should associate a manufacturer with the work at this stage itself so that the transfer of technology becomes easy at a later stage. This will give users confidence in the product, enabling the market to be developed. A day must come when an Indian instrument is the first of its kind in the world and aims at a world market.

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The instrumentation imbroglio—Some suggestions for a solution

G. Venkataraman

The health of science in this country is a matter for frequent discussion. While many aspects like funding, proper administrative support, etc. are always analysed threadbare, one item that receives scant attention is the absence of a proper instrumentation base in the country. Perhaps there is a sense of helplessness, considering the deaf ear turned to the numerous suggestions made in the past for improving matters in this respect. What is more dangerous is the complacency that has set in, thanks to the possibility of easy import of instruments. The obvious truth, that our science cannot be strong unless our base in experimental science is strong, and that, in turn, the latter is not feasible without a proper instrumentation base, sems to be slowly slipping from our minds.

The question of what ails our instrumentation has been studied by about half a dozen committees in the past. The present writer was himself a member of an expert group constituted in 1984 by the then Science Advisory Committee to the Cabinet (SACC); S. Ramaseshan was the chairman of the group. Working with great enthusiasm, the group very quickly produced a comprehensive report. However, after a cursory examination by the powers that be, this report soon joined its predecessors in the dusty filing cabinets of Delhi. Three years later, under the promise of a new deal,

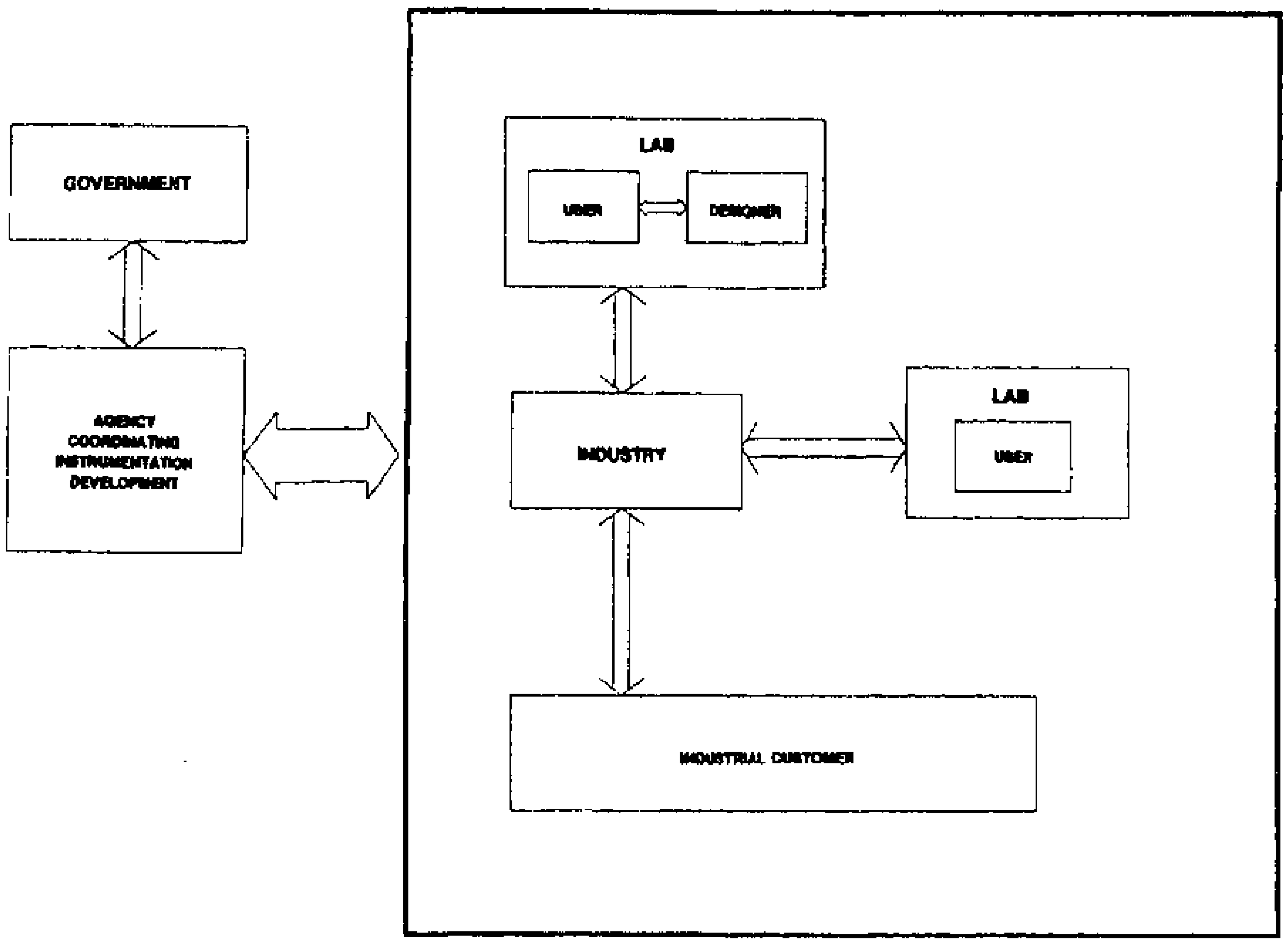

Figure 1.

I reluctantly agreed to head another working group on instrumentation, this one constituted by the Science Advisory Committee to the Prime Minister (SAC-PM). Once again a report was produced, and, despite support from SAC-PM (and, I believe, also from the then prime minister himself), this report too met the same fate as all the earlier ones! Since no one in Delhi appears to be interested in listening, it seems preferable to take the issue to the scientific community itself, whence this article. The focus here is on what can and should be done to improve matters, rather than on cataloguing the ills. One hopes that the views expressed generate a lively debate, compelling the government to take congizance of the seriousness of the matter.

The problem

Figure 1 illustrates some of the linkages pertinent to the problem. Historically, the instrument designer and the user were often one and the same, and it is only in course of time that design became a specialized activity of its own. The fact that experimenters like ready-made instruments was recognized even in the last century, and instrument companies emerged which made thermometers, balances and the like. Components (e.g. optical) also were made available so that, when necessary, the experimenter could configure the set-up to meet his specific needs. There was also an interplay between the user and the instrument manufacturer, leading to better instruments, newer models and innovations. The growth of well-known companies like Adam Hilger, Hewlett-Packard and Varian amply illustrate this evolutionary model.

In the fifties and sixties, when the country went through an intense phase of attempts to achieve self-reliance, scientists in many laboratories were compelled to build their own instruments. For various reasons (too lengthy to recount here), these ventures, barring the odd one, were generally not successful. Even in the so-called successful cases, transfer of technology to industry was shoddy, the net result being that we do not have a viable instrumentation industry today. Today, instruments are used not only by researchers but more so by industry, and, most of the requirement being imported, the instrumentation import bill of the country over the current Plan period is of the order of $ 2 billion. It is clear that, to get out of this mess, we must not only carefully avoid the mistakes of the past but, more importantly, give a strong push to our instrumentation industry.

Incentives

To start with, the government must declare instrumentation a key industry and offer special incentives for rapid growth. There are good reasons to hope that things will improve significantly following such a step, considering the refreshing change that occurred in the computer scene after the measures taken a few years ago.

Unlike consumer electronics, instrumentation is not a mass-production industry; this is true even in the advanced countries. Rather, the core of it is made up of medium- and small-scale industries. What is even more important is that the industry is largely manned and operated by professionals (i.e. scientists and engineers) turned entrepreneurs. One has merely to see the vast number of 'basement' companies that mushroomed in the neighbourhood of the Massachusetts Institute of Technology in the US a few decades ago. The more recent Silicon Valley, California, phenomenon testifies to the continued validity of this model. Given a proper climate, there is absolutely no reason why such a growth phenomenon should not occur here, and why our engineering graduates (especially those from the IITs) and some of the scientists in our various laboratories cannot turn entrepreneurs. Despite the numerous handicaps that exist at present, there are already a few brave souls roughing it out. If only venture capital, which has been talked about for years, becomes more popular, the numbers would rapidly swell. Sizeable additions can also be expected from expatriates anxious to return.

Infrastructure and organization

Something more is needed besides new government policies and capital, especially in our environment. To catalyse growth initially, suitable 'technology parks' must be set up which will provide all the necessary infrastructure facilities for entrepreneurs to function smoothly, efficiently and effectively. The proposed parks should not be a rehash of the industrial estates, which are usually a collection of shoddy sheds. Without being as exotic as, say, Silicon Valley, the park could provide: (i) well-designed modular buildings suited for hi-tech activity; (ii) centralized procurement, marketing and storage agencies; (iii) a centralized display/exhibition area with ante-rooms for customer-vendor meetings; (iv) support facilities, like a precision-machine shop, where machine time can be booked by entrepreneurs by the hour or by the day; (v) documentation facilities that can be shared; etc. The details are not difficult to work out.

A few words of explanation are in order concerning some of the suggestions made above. One of the problems faced by entrepreneurs in our small-scale industries is that they have too many battles to fight—redtape, poor communication facilities, and so on. In the midst of all this, the entrepreneur has to keep up product-improvement activities, maintain customer relations, and attend to marketing. Naturally he is often overhelmed. The net result is that, even though the product he makes might be ex-

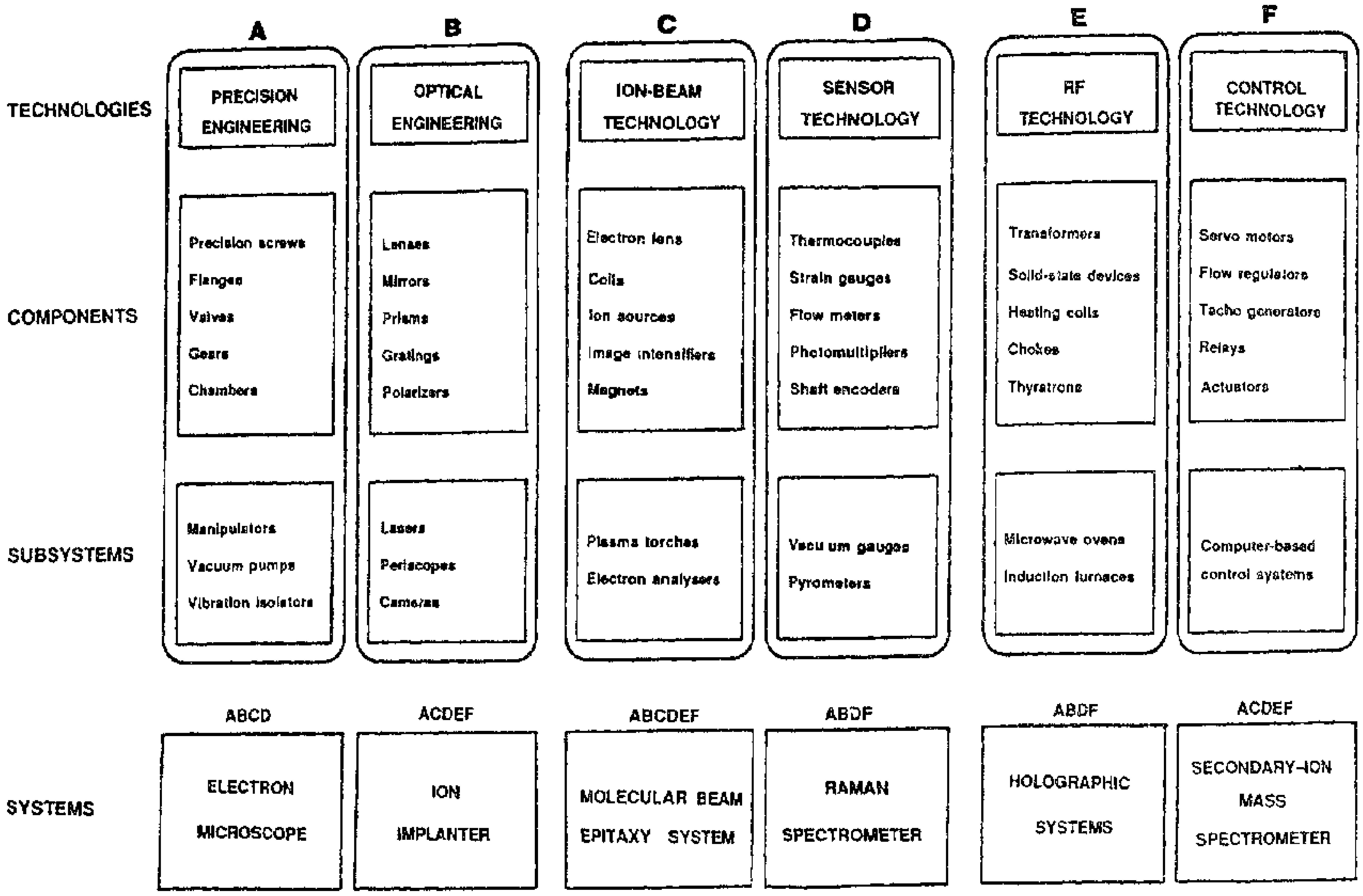

Figure 2.

cellent, often it does not sell well because not much is known about it to potential users. It might be argued that entrepreneurs in Silicon Valley, for example, do not enjoy support of the type proposed above. True, but on the other hand society there is considerably more streamlined, so much so the main obstacle faced is competition, which anyway is part of the game.

To illustrate how a technology park as proposed might be organized and operated, it is useful to consider a specific example. We assume that the park is oriented towards the manufacture of sophisticated analytical instruments like spectrographs, chromatographs, mass spectrometers, ultra-high vacuum systems, etc. Leaving aside the associated electronics for the moment, a little reflection would show that all these instruments can be system-engineered from a basic spectrum of components and subsystems like precision drivers, encoders, feed-throughs, etc. (see Figure 2). While it might be desirable to manufacture locally as many of these subsystems as possible, it is not necessary to do so in the beginning. The more complicated components could be imported and emphasis laid on value adding. There is much that can be done locally in this respect: integrating the subsystems, adding the plumbing (if any), adding the power and the control systems packaging the whole unit, and, last but not least, adding the computer interface (both hardware and software). Thus, the technology park could support small industries specializing in activities like mechanical layout and assembly, electrical power supplies, control systems and computer interfacing. There is considerable expertise available in the country in these areas, though these are somewhat scattered; the park might in fact enable a coming together of these activities. If, in addition, support is also available in the area of precision mechanical engineering, then one can think of slowly venturing into the manufacture of critical components also.

Reference has been made to the problem of marketing. Hre one could follow companies trading in electrical appliances, who buy in bulk from original equipment manufacturers, add their brand name, and then do the marketing, service support, etc. One problem with such a scheme is that the distributing company is often a giant, promptly attracting all kinds of levies by the government. Considering the importance of scientific instruments, at least their distribution should be freed from such taxes, in keeping with the spirit of treating instrumentation as a key industry.

Questions are always raised above the alleged 'smallness' of our market. A careful analysis would show that a structure as proposed above would not be faced with market problems. Consider, for example, the lock-in amplifier (LIA). Today everyone imports LIA. However, skills exist in the country to design and build such units, matching the specifications of foreign vendors. If a manufacturing unit to make LIAs is set up in a technology park, not only can the needs of instrument-makers in the park be met, but one can assert that at least fifty such units would be bought by other users every year, which should be reasonable for a small-scale industry. Experience has shown that the moment a product is made in India, its sale is several times what it used to be when imported. The kind of market thus opened up is quite ample to sustain the nascent industry.

Supporting promotional policies

Several additional measures are needed to ensure that the hi-tech instrumentation industry is not stifled at birth. At present it is possible (at least for an R&D organization) to obtain customs-duty exemption for import of a complete instrument. However, components and subsystems attract duty. What is needed to encourage an indigenous effort in instrumentation is exactly the opposite. If components are more easily available, then there would be greater efforts in value addition.

It is presumed that local industry will rise to the occasion and not offer shoddy products– this is a must. Assuming this is the case, there must be every effort to discourage the import of instruments that are locally made or assembled. There would of course be the tendency of users (supported by local agents of foreign companies) to play the 'specsmanship' game. This should be resisted.

To keep imports to a minimum, industries and R&D organizations seeking to import must first be asked to make matching purchases of local products. A formula could be evolved whereby, unless there is a purchase of Indian products to the value of Rs. X, say, import to the value of Rs. Y will not be permitted. In the case of imported instruments, there should be an additional levy towards a development fund, revenue from which must be available to the agency which co-ordinates and directs the overall national thrust in instrumentation. All this might sound draconian to the user, but national interest demands that we start paying the price.

Reference was made earlier to active interaction between users and manufacturers leading to a cycle of sustained development. This strongly suggests that technology parks as proposed above must be close to major R&D centres, for example the Indian Institute of Science and the Bhabha Atomic Research Centre. The laws of the land must be suitably modified (i) to facilitate professional contacts between scientists of the R&D establishment on the one hand and the engineers of the park on the other (this is so in many other countries), (ii) to gift surplus and unwanted equipment in the R&D establishment to park industries, (iii) to encourage the purchase of products made in the park, and (iv) to encourage the subcontracting of various fabrication tasks to the park. In addition, a golden handshake scheme must be introduced to enable scientists in R&D establishments to quit the lab and turn into entrepreneurs. As a gesture, the R&D establishments should permit such scientists to take out, free of cost, know-how available in the lab, and perhaps also surplus equipment, upto a certain value. In the long run, all this would help in trimming the sizes of some of our labs, which have grown rather unwieldy in the process of trying to build up all kinds of infrastructure.

Simplification of rules as proposed might appear shocking, conditioned as we are to an excessively suspicious and bureaucratic system, but other countries already have such schemes (at least the more important ones); no wonder such technology parks are successful there.

As yet another daring gesture, the government could offer free, say for a period of five years, know-how generated in its laboratories to small-and medium-scale industries. So far the idea has been that the expenditure on R&D must be at least partially recovered through the sale of know-how. The report of the comptroller and auditor-general clearly shows that performance in this respect has been pathetic. If anything, there have been endless disputes between the seller of the know-how and the buyer. If offered free to all and without any guarantees, such disputes will not occur. Moreover, there might be many entrants to the field and thus a healthy competition.

One specific area which definitely needs active promotion is very-large-scale integrated circuit (VLSI) design. Today the trend is toward application-specific integrated circuits (ASIC). Many institutions (e.g. the Indian Institute of Science) train students in this vital area but the training goes waste owing to the absence of a strong instrumentation industry. In fact many migrate, unable to use their skills locally. This trend can definitely be arrested, at least to some extent.

Concluding remarks

There may be other solutions to the problem, different from what has been sketched above. There is obviously no unique solution, but whatever it be, it will surely have to address the questions of how to galvanize our industry, how to stimulate slumbering talent, how to help more scientists and engineers to turn entrepreneurs, how to promote active interaction between designer and user, how to streamline the flow of ideas from lab to industry, how to open up latent markets, and how to overcome prejudices and mutual distrust.

The failure of the past has not been the lack of resources as much as the lack of will on all sides. In a sense, the government is a key player and the ball is really in its court. Both industry and the scientific community have made numerous suggestions in the past but the government (meaning really bureaucracy) has done precious little. Bureaucracy has nothing to lose but science does and so does the country. Will those concerned pay heed?

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BOOK REVIEW

Physics Instrumentation in India. In two parts, as special issues of *Indian Journal of Pure and Applied Physics*, Part I, July–August 1989; Part II, September–October 1989. Publications & Information Directorate, CSIR, New Delhi. 220+xviii pp. (Part I) and 224 pp. (Part II). Rs. 100 each part.

My late learned colleague Prof. R. Srinivasan, an accomplished experimentalist, once made the observation that experimental physicists could be categorized in the class of endangered species. Srinivasan would have been delighted to see these two excellent volumes. As a member of the community of experimental scientists in this country, I welcome the book as a positive effort to save our community. Both parts of the book are professionally done in form and content. The excellent articles do provide a good impression of the state of the art available in the leading laboratories of the country.

The lead article by G. Venkataraman is a must for all, in particular for policy-makers. Venkataraman has made a serious effort to analyse the current situation and has suggested certain solutions. Though I beg to differ from him on some of his solutions (like government involvement *a la* C-DoT), he has done an excellent job. The book provides a blend of small-scale (individualistic but cheaper) condensed matter physics instrumentation with industrial-scale (collective but costlier) instrumentation of large telescopes, neutron spectrometers, pelletron and tokamak. The articles, while clearly bringing out the current state of preparedness in some of the laboratories of national importance, also provide a clear view of the