

**STRATEGIES AND A ROAD-MAP
FOR
DEVELOPMENT OF INSTRUMENTATION
IN INDIA**

*Report by a Committee constituted by
Indian National Science Academy, New Delhi*



June 2004

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SUMMARY

The instrument-building scenario in India has been a cause for concern for last three decades. To study this in depth, President of Indian National Science Academy (INSA) appointed a Committee whose composition is given later in this Report. The Committee was to work out a strategy and provide a road map for encouraging development of instrumentation in India.

The Committee deliberated in five meetings during which the industry viewpoint was also heard. To increase the quality and quantity of innovations, so essential for development of new instruments, a general improvement in the state of science and technology in India is imperative. This may require a substantial increase in R&D expenditure both by government and industry. It needs to be raised to beyond 2% of GNI in near future, comparable to that of some developed countries. The instrument industry requires more interdisciplinary research between physicists, other scientists and engineers etc. The science departments in universities should function in “Science Parks” mode for this. Like some foreign companies, the national labs /universities may also out source on contract to industry the development and fabrication of an instrument needed by them, as it will be beneficial to both parties. Both academia and industry should exploit the newer trend that even the instruments based on earlier concepts will require to be converted to more software and MEMS/NEMS oriented ones. A mission mode approach may be adopted for some sectors like medical instrumentation, where there is a huge demand in the country.

The Committee submitted its report to INSA President in June 2004. The full Report is given in subsequent pages. The key recommendations of the Committee are as follows:

	Key Recommendations	Government	Academic Institutes/ Universities	Industry	Academies	Scientists
(i)	In all instrument related projects, industry–academia partnership should be ensured right at the proposal formation. IP rights will then have to be shared.	*	*	*		
(ii)	Sharing IP rights by funding agencies with the developers of instruments will help marketing of instruments. Funding agencies should put in place a practical mechanism to serve this purpose.	*				
(iii)	Government should create a separate fund that would provide an incentive or tax credits to the industry that purchases indigenous instrumentation technology and brings it to the market. It can also be used to help companies in creating a brand for their instruments by enabling them to exhibit their instruments abroad etc.	*				
(iv)	Some of the innovators are turning entrepreneurs in some of our S&T institutions like IISc, Bangalore and IITs. The above fund should provide venture capital to spin off companies formed by these scientist entrepreneurs	*	*			
(v)	For a technology transfer to be successful, there should be continued association between the technology developer and technology buyer till the latter has successfully absorbed the technology.	*	*	*		
(vi)	While recommending procurement of an instrument it should be ensured that specs are drawn-up to include those of the locally made ones. Companies and institutions, which buy	*	*	*		*

	locally produced instruments may be given tax credits.					
(vii)	A website containing a list of instruments being manufactured in India and a data- base of professors and scientists with expertise in instrumentation, who are willing to interact with the instrument industry should be maintained.		*	*	*	*
(viii)	'Technology Parks' and 'Incubation Centres' in proximity to R&D institutions to exploit the S&T strength of the R&D institute may be created.	*		*		
(ix)	The government may set up a few component and subsystem development technology parks.	*		*		
(x)	Accreditation centers should be setup/ augmented for certification of instruments conforming to international norms like ISO, CE, UL, and QS etc.	*	*	*		
(xi)	Government should establish some centers of excellence in electronics and encourage the industry to use them.	*				
(xii)	Academies and science administrators should give due credit to instrumentation scientists in promotions, awards and election to Fellowships.		*		*	*
(xiii)	The S&T institutions may help to upgrade the skills, knowledge and technical manpower in industry by organizing short-term courses, seminars, etc. INSA and other academies and CII may play a proactive role in this regard.		*	*	*	
(xiv)	Some Indian universities may start multi-disciplinary courses involving S&T and business management and also take steps to produce manpower required for particular skills needed by the industry. Similarly the industry may do more for training of students at their plants, as this hands on training will be an important step to develop entrepreneurial skills in them.		*	*		
(xv)	Some instrumentation linkage companies should provide rapid prototyping services for converting innovations into products.			*		

1. INTRODUCTION

In January, 2003, Prof. M. S. Valiathan, President of Indian National Science Academy, New Delhi set up a committee to prepare a report on **Instrumentation in India in about a year's time**. The mandate given to this committee **was to work out a strategy for developing instrumentation for science laboratories, universities, hospitals, industries, etc., and to provide a clear and innovative roadmap for the Government, Industry, etc., who would be obliged to implement the strategy**. Prof. Valiathan had noted that several attempts were made in the nineteen eighties to promote instrumentation development through Government initiatives and the setting up of an Instrumentation Board was also contemplated. These were in addition to the CSIO and other efforts by the National Laboratories for instrument development. Unfortunately the progress achieved was very little and India continues to depend on imported instruments - perhaps up to 95% of our requirements - except in sectors such as Defense and Space where the technology denial regime obliged us to perform. Meanwhile, instrumentation technology has changed dramatically at the global level with the advent of extensive computerization, miniaturization, green technologies, etc. The entire field is dominated by MNCs with limited, but not insignificant, space being claimed by smaller firms - especially in Europe - who specialize in specific instruments. It is important that in the globalised context of our economy, we should base our instrumentation strategy on forging partnerships with MNCs who may outsource a part of R&D to Indian institutions or industry and agree to India retaining the domestic market. It may also be possible to attract the smaller firms of Europe who are threatened by MNCs to locate their operations in India on mutually agreeable terms with Indian industry. The strategy we adopt should be highly flexible and should draw upon the strengths we have in the public and private sectors.

1.1 Composition of the Committee

1. Dr. S.K. Sikka, Scientific Secretary,
Office of the Principal Scientific Advisor to the GOI
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Maulana Azad Road, New Delhi - 110 011
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2. Dr. Krishan Lal, (Former Director, NPL),
Director Grade Scientist,
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3. Prof. S. Mohan, Professor,
Faculty of Department of Instrumentation &
Chief Executive, Innovation Centre
Indian Institute of Science, Bangalore - 560 012
Email: smohan@isu.iisc.ernet.in Member

4. Shri A.V. Ramani, Senior Vice-President(R&D),
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5. Dr. K.R. Rao, (Former Director of Solid State
& Spectroscopic Group at BARC),
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3rd Main Road (Margosa) Road,
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Email: krrias@yahoo.com Member

6. Shri V. H. Ron, (Former CMD, ECIL),
Scientific Consultant, O/o the PSA to the GOI,
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Email: vhrn_43@rediffmail.com Member

7. Dr. Amit Roy, Director,
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8. Dr. V.C. Sahni, Director, Member
Physics Group BARC, Mumbai - 400 085 and
Director, Centre for Advanced Technology,
Indore - 452 013
Email: vcsahni@magnum.barc.ernet.in
9. Dr. R. P. Gupta of O/o the Principal Scientific Advisor to GOI was
coopted to assist the committee.

1.2 Meetings of the Committee

The Committee held five meetings. The dates and places of these meetings were as follows: -

1. June 13, 2003 Indian National Science Academy
Bahadur Shah Zafar Marg
New Delhi
2. August 27, 2003 Innovation Centre,
Indian Institute of Science
Bangalore
3. December 4, 2003 Innovation Centre
Indian Institute of Science
Bangalore
4. February 11, 2004 Indian National Science Academy
Bahadur Shah Zafar Marg
New Delhi
5. April 8, 2004 ELICO Ltd.
Sanathnagar
Hyderabad

1.3 Special Invitees

The Committee heard the views on the instrumentation status in India from the following industry representatives: -

1. Shri P.C. Goliya
(Representative of CII)
Chairman & Managing Director
MECO Instruments Pvt. Ltd.
Mumbai
2. Prof. K. Jayaraman
Academic Programme Manager
National Instruments
Bangalore
3. Shri D.T. Patil
Honeywell Technology
Solutions Lab Pvt. Ltd., Bangalore
4. Dr. Pradeep Desai,
Director, Phillips Research, Bangalore
5. Dr. K. Nandakumar
(Chairman, Instrumentation Division of CII)
CMD, Chemtrols Engineering Ltd.
Amar Hill, Saki Vihar Road
Powai, Mumbai
6. Dr. T.V. Shiva K. Rao
(Vice-President, Instrumentation Division of CII)
ELICO Limited
B-90, A.P.I.E. Sanathnagar, Hyderabad
7. Shri S.G. Roy
Deputy Director
Confederation of Indian Industry
23, Institutional Area, Lodi Road, New Delhi
8. Dr. Ramesh Datla
(Vice-Chairman, CII-AP)
Managing Director, ELICO Ltd., Hyderabad
9. Prof .M. Ramakrishna

1.4 Survey

The Committee also carried out a survey by writing to about 50 eminent scientists in the country. Replies from 15 were received. A summary of these is presented in Annexure -I to the Report.

1.5 Some resource documents

Very few reports prepared in the past on different aspects of instrumentation are available. However, the following reports, papers and books were consulted.

1. SWOT Analysis of Instrumentation in India - TIFAC report of early nineties.
2. "Instrumentation in India" by G. Venkataraman - Indian Journal of Pure & Applied Physics, 27, 303-310(1989)
3. India: The Hardware Opportunity by Manufacture's Association for Information Technology (MAIT-2003)
4. Electronics Industry of India by R. Sharma, D. Bansal, P. Srinivasan and M. Pecht, CALC EPSC Press, University of Maryland, College Park, Maryland (2001)

1.6. Status Papers

Some members were requested by the Committee to prepare sector-wise status papers. These papers are included as Annexure -II. A paper by Dr.R.Datla giving an industry viewpoint is given in Annexure -III.

Sr. No.	Area	Authored by
1.	Instrumentation for Industry	Dr. K. R. Rao
2.	Electronics Instrumentation	Shri V. H. Ron
3.	Educational Instrumentation	Dr. V. C. Sahni
4.	Medical/agri/bio Instrumentation	Shri A. V. Ramani
5.	Analytical Instrumentation	Dr. Krishan Lal
6.	R &D Instrumentation	Prof. S. Mohan

1.7 List of some instrument makers in India

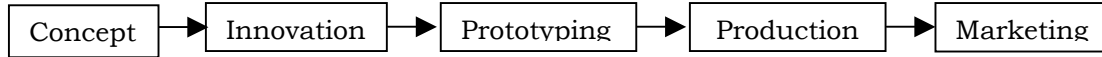
In order to gauge the type of instruments being manufactured presently in India, the Committee had requested Shri Goliya of CII to give a list of all instrument manufactures in the country affiliated to CII Instrumentation Division. Out of the 35 members, ten are involved in the manufacturing of instruments for measuring, checking and testing and eight for instruments meant for industrial process control. Only three firms manufacture medical equipment. Rest of them are just traders.

1.8 Scope of the report

A very large variety of instruments are used in each and every human endeavor for a variety of applications like for the characterization, control and measurement of a variety of properties of inputs and products. Therefore, it was not possible for the Committee to consider every type of instrument. The members decided that the deliberations would focus more on scientific/analytical instrumentation and medical instrumentation. However, it may be stressed at the outset that the recommendations of the committee will apply to most of the areas as the field of instrumentation cannot be treated in isolation from others like hardware manufacturing, consumer electronics goods etc.

1.9 An ideal scenario

A typical instrument development chain is shown below.



The instrumentation development integrates many sciences, is technology intensive and capital intensive. The technological strengths needed include those in electronics (e.g. for controls, embedded systems), software (e.g. data processing), optics, sensors (MEMS and NEMS), detectors, sources (e.g. lasers), special materials and precision mechanical fabrication etc. For creating concepts and innovations, a good infrastructure for R&D is required. This may depend on the amount of funding for scientific research. For prototyping and development; one needs a good interaction between scientific community and industry, a flexible mechanism for transfer of technology, and a sound infrastructure for hardware manufacturing. Here, the role of spin off and link companies may be important. Modern instruments involve system integration of a large number of components and sub-systems. We visualize a future in which an experimenter or a technologist in India like in West should simply be able to assemble together an instrument system by using commercially available components and subsystems and is able to easily outsource servicing for his equipment.

1.10 Acknowledgements

Thanks are due to Shri N. Srinivasan , Director General, Confederation of Indian Industry (CII) for arranging briefing of the committee by CII Instrumentation Division officials. We are also grateful to Prof. S. Mohan and Dr. Ramesh Datla for arranging meetings at Bangalore and Hyderabad.

2. SOME SUCCESS STORIES

- 2.1** In India, the mission-oriented agencies have designed and built nuclear reactors and accelerators, satellites and space launch vehicles, missiles and Light Combat Aircraft (LCA) etc. These mission critical equipments involved the highest level of system integration.
- 2.2** Besides these, a few large facilities for R&D exist in India. These include the CIRUS and DHURVA reactors in Bhabha Atomic Research Centre (BARC), Mumbai for Neutron Beam Research, variable energy cyclotron (VEC) at Calcutta, Pelletrons at Nuclear Science Centre, New Delhi and Tata Institute of Fundamental Research (TIFR), Mumbai and folded tandem ion accelerator at BARC all for Nuclear Physics related research, Synchrotron radiation source at Centre for Advanced Technology (CAT), Indore for Atomic and Materials Research, Vainu Bappu optical telescope at Kavalur, Giant Meterwave Radio telescope (GMRT) in Pune, γ -ray telescope at Mount Abu and the Hanley Optical telescope for astrophysical research.
- 2.3** The instrumentation for operation and utilization needed for above facilities have been built indigenously and continuously upgraded from time to time. Using these facilities, the researchers have been able to carry out advanced research in various fields and to publish results of investigations in high impact international journals. Some of the instruments developed indigenously have also been installed at research reactors and accelerators in other countries. Typical examples are installation by BARC of a 'day one' instrument at ISIS Spallation Neutron Facility at Rutherford Appleton Laboratory in UK and various types of

advanced detectors for high-energy experiments at CERN by VEC in collaboration with some Indian universities.

2.4 In 1960's entities like Electronics Corporation of India (ECIL) - Hyderabad, Bharat Electronics Limited (BEL) -Bangalore, Instrumentation Ltd.-Kota and Central Scientific Instruments Organisation (CSIO)- Chandigarh etc. were created to meet some of the instrumentation needs in country. These entities and some others have developed and built many types of instruments and have also catered to the needs of mission oriented agencies .A recent notable example is the "Electronic Voting Machines" developed by ECIL and BEL and used so successfully in the 2004 general elections, that even the outside world seems to have noticed the achievement! Some other prominent examples include the following:

- Spectrophotometer (ECIL, ELICO)
- Gas Chromatograph (TOSHNIWAL)
- Mass Spectrometer (BARC, IISc)
- X-ray Diffractometers (NPL, BARC,IUC for DAEF)
- Electron Microscope (CSIO, CEL, IIT)
- Ion Implanter (IGCAR, BARC, VEC, Univ. of Pune, IIT/ Kanpur)
- Auger/ESCA spectrometer (IISc, IOP)
- Thin film deposition system (IISc, CSIO)
- Molecular Beam Epitaxy facility (CSIO)
- Atomic Force Microscope (Univ. of Pune, CSIO)
- Scanning Tunneling Microscope (Raman Res. Inst., IISc)

2.5 India has been denied many high technologies under various dual technology control regimes and sanctions. This has spurred Indian scientists and technologists to design and make equipments denied to

them. A prime example of this is the development of super-computers by different agencies (C-DAC, DRDO and BARC and others). This has demonstrated that the country has the innate capability to build high tech instruments provided right inputs and impetus are given. It is also observed that when a particular product has been developed indigenously, the technology denying countries remove the restrictions.

3. SOME REASONS FOR LACK OF PROGRESS IN INSTRUMENTATION

- 3.1** In spite of the above success stories, the instrumentation scenario in India is a cause for concern. What we see is that today most of the instruments built by various laboratories have not been commercialized. This is despite our large domestic market [+ one billion population, large economy (4th at present on price parity purchasing (ppp) power basis), a large pool of trained and skilled scientific manpower with a natural advantage of the knowledge of the English language etc.]. Some of the reasons for this state of affairs are given in the following:
- 3.2** It is alleged that the scientists in India do not innovate much in the instrument field at present. To find the truth, we carried out a survey of the instrument related publications and patents originating from India. For publications, we chose the journal 'Review of Scientific Instruments'. A paper in this journal may be regarded as pertaining to an innovation. Only 32 papers from India out of about 2000 papers have appeared in the period 2001 - 2003. A look at the patents statistics is also revealing. The number of patents, related to instruments, granted in 2003 as per United States Patent and Trademark Office are shown in Table 1 This is very disturbing. Also the contribution in IP generation from universities here, which is the dominant one in West, is almost absent. This may perhaps, explain the near absence of spin off technology companies formed by academia in India.

Table 3.1 Granted patents in USPTO* (United States Patent and Trademark Office) in Instrumentation in 2003

	Japan	S. Korea	China	USA	India
Medical equipment	882	61	5	4997	3
Measuring instruments	1722	105	5	5639	6
Industrial process control equipment	319	19	0	N.A.	1
Optical instruments	2172	135	5	N.A.	0
TOTAL	5095	320	15	N.A.	10

3.3 The instrumentation industry in developed countries is mostly physics based and is based on interdisciplinary research between physicists, other scientists and engineers etc. Except in mission-oriented labs in India, there is a general lack of this culture, especially in universities where the division into departments is very rigid.

3.4 In India, the Industry, so far, has almost lacked a global vision. This was fine as long as the imports were restricted and the demand of locally made products within the country was large. Industry has also not sufficiently exploited, markets of the neighboring countries where conditions are very similar to ours. With liberalization and globalization currently Indian users need not depend on locally manufactured instruments and this has a negative impact on the growth of indigenous industry, unless the latter is competitive in global market in terms of quality and modernization. All this is reflected in the rather low percentage of high technology exports. As of 2001, the figure is 6% for India compared to more than 25% for developed countries (UNDP, Human Development. Report, 2003)

3.5 In other countries, especially in USA, sectors like defence, space and aeronautics have acted as engines of growth for the instrumentation

industry. In India, this has not been very significant. Here, the mindset seems to be –whether be it defence, public health or research in academia - that we need modern, state of the art, gadgets to defend ourselves, to cure ourselves and also to do international quality research. Nothing wrong with this in the absence of corresponding indigenous effort, but it has encouraged an import culture especially after easing of foreign exchange situation in the country from mid seventies onwards. While deciding to buy the instruments, specs are sometimes laid down in such a fashion – whether required or not -, that the locally developed products are eliminated from competition.

3.6 One of the other main factors has been the poor interface between industry, research institutions and academia. The industry perception is that:

- (i) Scientists in India at the most have carried out reverse engineering of non-patented instruments till now. The industry is not interested as these are not state of the art instruments as they were developed in the West much earlier and have undergone several stages of developments based on extensive and useful feedbacks from user community. The industry feels that they can not compete with foreign vendors selling these instruments
- (ii) Scientists take so long to develop an instrument that the industry obviously loses interest because the product is considered outdated by the time the development is complete.
- (iii) The product is also not usually user-friendly and there is no proper follow up and monitoring of the quality (exceptions have been DAE, DRDO and DOS, who had handheld the

industry for development of critical products needed by them in-house).

- (iv) There is a dearth of trained S&T manpower in certain critical fields like optics.

3.7 The academia viewpoint is that:

- (i) Before the liberalization era, the Industry did not care much for local technology, as they were able to import freely available, albeit, second grade technology and Industry was able to sell its products based on this technology in a captive market.
- (ii) In India, due to absence of component industry, the disincentive for scientists has been that they have, sometimes, to make their own components. This has rendered instrumentation development a very long and tedious job.
- (iii) Indian industry has not made a very serious effort for international brand building of indigenous instruments. The industry representatives pointed out that for doing this they have to display their instruments in trade fairs abroad and be a part of trade delegations. Without government support this is not possible as costs involved are too high.

3.8 Another reason advanced for our backwardness in instrumentation is the lack of state-of-the-art electronics industry so far. The Bhabha blue print for developing this has not been implemented satisfactorily. It is often said that in India we have missed the first silicon (microelectronics) revolution. There has been no unique Centre of Excellence to support electronics R&D. Apart from some undertakings like ECIL, BEL etc., there are no

major success stories. (the success of ECIL and BEL is also attributed to the consumption of their products in-house, i.e. by DAE or Defence) In all our electronics goods, the crucial component, the chip is imported. We have two medium sized foundries: Semiconductor Ltd. [SCL] in Chandigarh and SITAR in Bangalore. They can make Si CMOS of only about 1 μm feature size while the rest of the world is generally moving towards less than 100 nm size. The capacity utilization of these Indian foundries is only about 20 per cent.

4. ROLE OF FOREIGN (MULTINATIONAL) COMPANIES

- 4.1 A majority of foreign instrument companies in India are represented through local agents and they act only as conduits for selling the instruments manufactured abroad by these companies. The after-sales service provided by the local agents is either very poor or non-existent. Many a time, spare parts are not available and it is also alleged that sometimes, there could be a 'managed' obsolescence!
- 4.2 Besides this the prices of lab equipment and materials are frequently inflated. According to a recent survey by Nature (vol.428, p.453, April 2004), scientists in poorer countries have to pay up to 70% more than their counterparts in richer countries for identical supplies. This is attributed by suppliers to them not having control over pricing by local distributors.
- 4.3 Lately, it has become rather difficult for Indian industry to get technology from abroad. This is because foreign companies can themselves locate their manufacturing facilities in India or elsewhere and are therefore less willing to share technologies. Presently, the preferred choice of Multinational Companies (MNCs) for such locations seems to be China. During the discussions with a representative of a multinational, he was asked to rate various attributes that make China an attractive country vis-à-vis India on a 10-point scale. His responses are given in Table 4.1.

Table 4.1 Attributes governing choice of China over India for out sourcing manufacturing industries.

Attribute	Country	
	India	China
Governance	5	7
Infrastructure	4	6
Creativity of people	6	4
Discipline	5	8
Skills	6	8
Government subsidies	3	8
Language (English)	7	5
Salaries	6	6

There is also a feeling among MNCs that Intellectual Property (IP) is better protected in India. This points out that infrastructural, procedural and logistical issues etc. need to be further addressed so that MNCs find it cost effective to manufacture instruments here . However, given our large base of creative manpower, lower manpower costs than in the developed countries and IT prowess, some of the MNCs are already outsourcing/shifting/setting up their R&D and design activities to India (according to Business World, Feb.11 2003, about 100 MNCs have set up research centers in India recently). In order to sustain this important activity, emergence of manufacturing base in India is inevitable.

5. INSTRUMENTATION MARKET IN INDIA AND OPPORTUNITIES

5.1 According to estimates by Industry Chambers, the total cost of production of instrumentation related products in India at present is around Rs. 5000 crores per annum. Sector-wise breakup is shown in Table 1. The growth rate is 10 to 15 per cent per annum. This production is about 15 % of the total demand; the rest is met by imports. Except for a handful of them, all companies are operating in low end products. In 2002-2003, the consumer electronics goods production stood at Rs.37500 crores. According to the MAIT report (see section 1.5), this is expected to grow by about 10 times in 2010. For medical hardware the market size is Rs.6500 crores (see Table 2). Compared to this the market size in China was Rs.11500 crores in 2001 with import component being about 50%. Even if these numbers may be disputed, the growth potential in India is huge.

Table 5.1. Cost of annual production of instrumentation related products in India (in Rs. Crores). The data is taken from CII .

Process Control Instruments	1400
Analytical Instruments	650
Electrical Test & Measuring Instruments	1450
Survey & Geo-Scientific Instruments	750
Medical Instruments	1150
Total	5300

Table 5.2. Indian market size for medical hardware (2001 estimates)

Segment	Market Size (in Rs. Crores)
General Surgery	3065
Imaging	1110
Clinical Instruments	570
Critical Care	320
Cardiac Surgery	260
Self Care	300
Ophthalmology	240
Urology	150
Others	515
Total	6500

Source: UK Trade and Investment (www.tradepartners.gov.uk)

5.2 The trend in modern instrumentation is that more and more functions of the hardware are being taken over by software (also called ‘virtual’ instrumentation*). The hardware part is also shrinking in size. Newer miniaturized sensors and detectors are coming into the market. The instruments are also becoming application specific. In analytical instruments; the concept of ‘lab-on chip’ is beginning to be adopted. This means that most of the older instruments have to be upgraded. Here, our software skills will become very handy. Both academia and industry could exploit this.

* A virtual instrumentation system is computer software that a user would employ to develop a computerization test and measurement system, for controlling from a computer desktop an external measurement hardware device, and for displaying test or measurement data collected by the external device on instrument-like panels on a computer screen. Virtual instrumentation extends also to computerized system for controlling process based on data collected and processed by a computerized instrumentation system.

- 5.3** As per an assessment of projected demand/ prospects of the Indian hardware sector, that appeared in Business Today (Feb. 29 2004), the business prospects in next few years in electronics consumer hardware goods in India is expected to be nearly Rs. 750,000 crores. The pharmaceutical industry is booming and it is now investing significantly in R&D to meet its demand of newer molecules. There are possibilities that there will be more indiginisation of defence equipment. All these sectors along with our huge health care needs require instruments and thus could act as drivers for instrument development.
- 5.4** K. Sahin (Technology Review, December, 2003/January, 2004,pages 56-57) classifies universities, national and corporate laboratories as R&d (big research and small development organizations) and most companies with their production and marketing arms as d&D (small development and big delivery) enterprises. Linkage companies are rD&d (small research, big developments and small delivery) organizations. To quote him linkage companies “have some research capability in order to link to the sources of innovation, and a delivery component that helps get products to the market, but their main activity is in developing innovations for market”. Some companies in India should predominantly play this role. They can also serve as “rapid prototyping servicing” companies, which will bridge this gap and also help reduce drastically the time from concept to productionisable prototype.
- 5.5** A mission mode approach for development of instruments may be adopted similar to that of the ‘CAR’ Group (Core Group in the R&D Automotive Sector) of the Office of the Principal Scientific Advisor to the Government of India. The task of the CAR group was to identify frontier

technologies in the automotive sector on which R&D can be carried out in order to acquire Intellectual Property Rights (IPR) for the products developed. The target will be the global market. This group set up six panels consisting of 150 leading experts from industry and academia for preparing reports and identifying projects in - Embedded Control Systems, Telematics, Advanced Materials, Hydrogen, Safety and Recyclability. They have completed this work now and identified the projects, which will be jointly implemented by industry and academia. Departments of Science and Technology and Heavy Industry of the Government of India and Industry will provide funding and resources.

- 5.6** The instrumentation field is very vast. So to start with, a mission mode approach like that what is described above for CAR group can be adopted for a few sectors like medical instrumentation for which the demand in the country is large. However, for success of this approach, large companies will have to be associated.

6. SPECIFIC RECOMMENDATIONS

- 6.1 In developed countries, there is a well established link between instrumentation industry and the quantity and quality of innovations. In general, these are related to the state of R&D in a country, which among others is correlated with the total spending on R&D as a component of GNI. In 1999, it was 0.6% for India compared to 3.8% for Sweden, 2.5% for USA, 2.8% for Japan, and 2.7% for South Korea (UNDP, Human Development. Report, 2003). It is only now that government has increased this to 1.2% in 2003. According to the new Science and Technology Policy announced in 2003, it is expected to go up to 2% by the end of 10th Plan. This needs to be raised further.
- 6.2 As mentioned in section 3.6(iii), the mission-oriented agencies have involved Indian companies to develop and fabricate the critical components needed by them. The participating companies, apart from financial aspects, have also enriched themselves in expertise and skills. National labs and others may exploit this situation. After the design of a required instrument, they can outsource it for fabrication (including hardware, electronics and software as one package) in a time bound contract by one of the interested company^{*+}. The advantage will be that the company will recover its investment and the labs will not have to create infrastructure to do the prototyping/manufacturing.

*An example here should clarify. Indus 2 synchrotron is being set up at CAT, Indore. A number of beam lines have to be built for using X-rays from the storage ring. These have to be built in India, as it is difficult to import them. Scientists have already designed the beam line instrumentation.

+Some foreign companies are already doing this outsourcing.

6.3 There are many Government Departments, which fund projects for development of instruments. Following changes in procedures adopted by such departments are suggested:

- i) Most of the project - proposals for development of instruments are submitted by Academia. It is suggested that in all instrument related projects, industry -academia partnership should be ensured right at the proposal formation. The academia-industry partnership could be in sharing of cost and manpower. Any Intellectual Property (IP) resulting from successful implementation of the project will thus have to be shared. Sharing IP rights with the developers will be in the interest of the latter to carry out commercialization. Of course, this has to be done flexibly keeping in view the relative contribution of the partners. A practical mechanism for doing so needs to be put in place by the funding agencies.
- ii) Establishment of 'technology parks' is being done/contemplated by some funding agencies, so as to exploit the S&T strengths of R&D institutes. In fact, it would be desirable to locate these 'Technology Parks' right adjoining R&D institutions, where industrial units could be invited to set up enterprises in niche areas consistent with the S&T strength of the R&D institute.
- iii) The industry representatives have pointed out that the industries are sometimes disadvantaged as some R&D labs, in order to generate a significant amount of revenue, price their innovations and services costlier than those from abroad. It is suggested that as the instrument industry is still in a nascent state of development, a different mechanism for recovering the costs incurred by R&D labs

should be worked out. For example, this recovery may be done after the company involved has marketed the product successfully.

- iv) For a technology transfer to be successful, there should be a continued association between the technology developer and technology buyer till the latter has successfully absorbed the technology, rather than as a one time transfer as is being practiced at many instances at present. Technology transfer agreements by DAE already do so for a specific period of time after the technology transfer. Other scientific departments may also adopt a similar procedure.

6.4 Government ought to set up a separate fund for instrumentation technology development and implementation. This fund could be utilized for providing an incentive or for tax credits to the industry that acquires indigenous instrumentation technology and fructifies by commercialization. It can also be used to help industries in creating a brand name for their instruments by enabling them to display these exhibitions abroad, etc. In Western countries and Japan, many of the innovators also become entrepreneurs (this is also beginning to happen in some of our S&T institutions like IISc, Bangalore, a few CSIR labs and IITs). The above fund should provide venture capital to spin off companies formed by these scientist entrepreneurs. Technology Development Board (TDB) in the Dept. of Science and Technology already operates this scheme. However, out of about 100 projects funded so far, hardly any one is instrumentation related. The Government should extend the same fiscal and tariff incentives to the instrumentation industry as it is doing for IT and consumer electronics sectors.

6.5 One of the handicaps that the industry faces is that entrepreneurs very often do not know with whom to interact in academia for development/improvement for value addition of their products. It is suggested that maintenance of a website containing a data-base of professors and scientists with their areas of core competence and expertise, who are willing to interact with the instrument industry - be taken up. Besides this, this website could also serve as a repository of the list of instruments already developed and marketed. Many a time, the buyers are not aware that an indigenous product is available. The funding agencies while recommending an instrument should ensure that specs are drawn-up, just not to exclude the locally made ones. Companies and institutions, which buy locally produced instruments should be given tax credits.

6.6 The S&T institutions may be encouraged to provide training in relevant fields by organizing short term courses, by holding of seminars, etc. for continuous up gradation of skills, knowledge and technical workforce of industries. Special training on modern quality control techniques will be highly beneficial. INSA and other academies and CII should play a proactive role in this respect. Similarly, industry has to encourage academia to get involved at the industry work place as this exposure will greatly help them to become entrepreneurs.

6.7 It has been pointed out above that most of the industries in the instrumentation field are small and can be classified as small and medium scale enterprises (SMEs). Large enterprises are beginning to have their own R&D centers. But SMEs do not have adequate resources for setting up these for experimenting with new ideas and products and for carrying out R&D. Thus, there is a need to set up 'incubation centres' in the

proximity of some clusters of SMEs with modern testing and quality assurance equipments. It may also be necessary to augment /setup accreditation centers for certification of instruments conforming to international norms like ISO, CE, UL, QS etc.

6.8 It is suggested that the government may set up a few component and subsystem development technology parks. For this the industry has to follow the example of automotive sector and keep the global market in view for their products. For component and subsystem manufacturing, tie ups with MNCs may be more forthcoming as can be seen from some recent trends in IT sector for PC components, cellular phones and other consumer goods. Recently, some global electronics majors have started investing heavily in India for contract manufacturing of the systems and components required by them (see for details: Business Today, Feb.29 2004 issue). In these technology parks, it may also be possible to attract the smaller firms of Europe to locate their operations in India on mutually agreeable terms with Indian industry.

6.9 For building a strong electronics base in the country, government should establish some centers of excellence and allow the industry to use them. The centers are expected to have design, prototyping capability and association with large scale chip manufacturing. They should lay emphasis on human resource development, research on sensors (both MEMS and NEMS), embedded systems, and software based devices etc.

6.10 Instrument building needs a combination of science and engineering disciplines. One needs also to unite this with some aspects of business management. The universities in West and Japan are devising special curricula to train students to have such required skills. It is recommended

that some Indian universities should start multi-disciplinary courses involving S&T and business management for providing entrepreneurship training to S&T graduates. Here business people may be required to give lectures and they may not have the required degrees. If required, the rules of the academic institutions should be amended to permit this.

- 6.11** One needs to recognize the contribution of scientists and researchers involved in instrumentation. It is high time that one gives due respect to instrumentation scientists in promotions, awards and election to fellowships.

The above recommendations are schematically shown in figure 6.1 below.

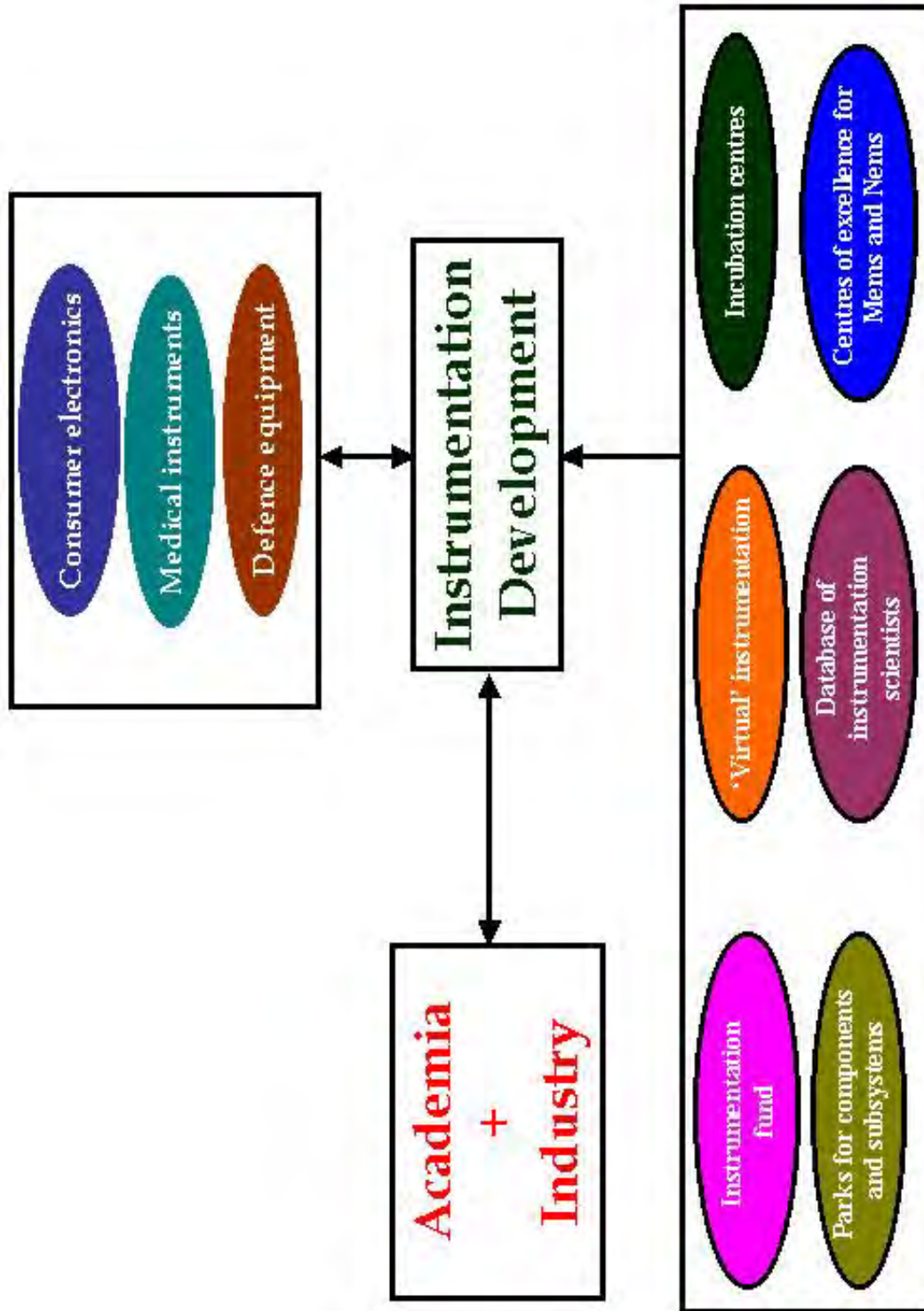


Fig. 6.1 A roadmap for instrumentation development strategy

ANNEXURE - I

Summary of comments received from some scientists

- I.1 The instrumentation development requires the partnership between the industry and the institution even before the project is being considered for funding. There is sometimes a problem, but this scheme should be considered, where feasible.
- I.2 The requirement of the research equipments within India may be limited and hence it may not be economically viable to support manufacture of such equipments unless export potential is exploited. For that to happen, indigenous instrumentation has to be technically of highest level, better than what is currently available.
- I.3 One of the many reasons for the failure of the past attempts appears to be our shying away from the global requirements and markets. Often products were made keeping in view the volume of Indian requirement. Unless this volume is large, one cannot be competitive.
- I.4 Although many instruments have been developed in the country, considerable efforts will be needed to make them user-friendly, economical and internationally competitive.
- I.5 Those involved in instrumentation should be accorded the same prestige and provided with similar avenues of career advancement to those that are available to scientists. There should be adequate appreciations for those who take up career in instrumentation in scientific institutions and universities.

- I.6 Funds from different agencies, DST, DBT, MIT, MMES, CSIR, DAE etc. be pooled together to be managed by one agency /group like the Planning Commission with liberalized rules for purchases and services.
- I.7 In order to generate competence in the field of instrumentation, we must have a cadre of technicians, who develop ideas into reliable components for instruments. The present method of funding does not give enough freedom for the project leaders to recruit technical assistants. The academic staff must be encouraged to have multi-disciplinary qualifications.
- I.8 We can start with the indigenisation of defence and other strategic equipments.
- I.9 There is an electronics aspect and that is inevitably present in the control aspect of instrumentation and the material related aspect that goes into the everything else other than the electronics part. Therefore, it is absolutely essential to strengthen these areas.
- I.10 Develop a breed of machine-physicists which is highly respected group of scientists elsewhere in the world, which does not exist in this country. Also the reward system or the evaluation system is unfairly harsh on activities pertaining to instrumentation and this must change if we are to attract young and motivated person to work in this field.
- I.11 Unless one pays close attention to market reality, the strategy of the competition, the psychology of the investor, the guarantee of the market share etc., we will most likely end up as before.

- I.12** Real gains come entirely from design of new instruments which may result in the creation of new IP. This culture needs to be soaked into our research institutions. There is very little mixing of disciplines in our groups. Perhaps, set up a laboratory - industry consortium for this purpose with a reasonably large venture capital.
- I.13** There is a need to stop importing the highly expensive commercial instruments if the indigenous technology has to catch up. It goes without saying that all state-of -the-art instruments available internationally, have undergone several stages of developments based on extensive and useful feedbacks from the user community. In India, all the users want to buy the best available instruments in the world markets, and specify the most stringent specifications regardless of the fact they need them or not !!. Quite often, these costly instruments remain unused or improperly used, as the users are not well aware of the subtleties associated with such instruments and unable to fix even the minor malfunctioning problems!. Of course, getting to know the instrument subtleties and fixing instrument problems does not get them any credits. Nor do people sweating to develop indigenous instruments get the recognition they deserve. In this situation it is difficult to attract people for such activities.

ANNEXURE –II – Status Papers

II.1 INSTRUMENTATION IN INDUSTRY

(K.R. Rao)

Instrumentation is used in industry to monitor and/or control industrial processes. Modern industry cannot exist without instrumentation. In a refinery, instruments control dozens of process variables. Without instrumentation it would take dozens of workers, each of whom monitoring one or two items to make the refinery work. Even then, they would probably be too slow to do an effective job.

II.1.1 General aspects

The simplest instrumentation is a status indicating system. For example a high level switch turns on an alarm to alert the operator that a tank is full. Instrumentation cannot only report status; it can control the process itself. Systems that control the process are referred to as loops. The basic features of loops are (i) a process variable; sensed by a sensor it is converted to a signal which is sent to a controller (ii) the controller has a set point which it compares to the process (iii) the controller activates a control element (For example, a valve) actuated by an error signal which is the difference between the process signal and the set point and thereby the set point is reached

Sensors can be categorized into four basic groups: (i) level detectors say in tanks, process vessels, hoppers, etc., (ii) pressure sensors in, say, in pipes, vessels etc. or across an orifice (iii) flow meters and (iv) temperature sensors like thermocouples, RTDs, capillary bulbs or infrared detectors

The controls loops are implemented using electronic (hardware and software, analog or digital), hydraulic or pneumatic technologies. -However, some of these pneumatic, hydraulic and allied instrumentation schemes have given way to electronic schemes in recent years thanks to the rapid strides in electronics and allied areas. At present classic digital measuring is considered

outdated, being replaced by others with built-in computers or assisted by computers

Microprocessors, embedded microprocessors and VLSI supported devices are found in modern instrumentation. The main types of microprocessor-driven measuring instruments are frequency counters, multimeters, power analyzers and digital oscilloscopes. The digital measuring systems involve data-conversion components for data acquisition and control, such as: sampling circuits, digital-to-analog and analog-to-digital converters. The main types of measuring systems for industrial or laboratory instrumentation involve built-in microprocessor (or microcontroller), and computer- driven systems, along with basic electronic transducers for temperature, strain, force measurements

Automation and continuous process operations are expanding both the scope and the use of individual instruments and systems for automatic control and measurement of the variables encountered in manufacturing and process facilities. The increased scope and expanded use of instruments has made the business of building, operating, maintaining, and calibrating these instruments a large and vital part of economy.

II.1.2 Medical instrumentation

The Biomedical Engineering associated with hospitals and the related medical instrumentation has increased in complexity and in numbers rapidly in recent years; preparation for service in this field is challenging. The emphasis in this program is on patient-care equipment, and medical imaging equipment like electrocardiographs, pacemakers, defibrillators, ventilators, and imaging devices such as x-ray, computer tomographic scanners, ultrasound, etc .

II.1.3 Automobile industry

In automobile industry, from 1995 'immobilizers' are installed in cars. 'Immobilizer' is a microcontrolling system, that controls almost everything: the

proportion of air and fuel, engine starting, ABS-breaking system, navigation, air-conditioning, etc.” It may sound silly if we tell a car mechanic that in a year or two he will have to know a great deal of electronics, in order to fix the car, but it is so obvious. Those who will start out among the first, and fetch the necessary equipment and instrumentation, will definitely gain the largest part of the profit”.

II.1.4 Microcontrollers

Most of the washing machines in India are still mechanical ones. However the world-over trend is to replace them by microcontroller-controlled ones. The latter are more efficient and cheaper and come with intelligence built-in..

Cameras, photo cameras, phones, pagers, ID cards, industry control, automation, home devices, military technology, medicine and much others use larger and larger quantities of microcontrollers as they are small, fast, efficient, reliable and cost-effective. Microcontrollers from Intel, Motorola , Siemens etc are quite popular for several applications. However several other companies like Microchip, Atmel etc have chipped in. In a country like India where the software support is readily available there is scope to go in for our own microcontrollers. The PC-on-a chip is the next revolution in this scenario.

II.1.5 Instrumentation in semiconductor industry

Instruments in semiconductor industry, especially in semiconductor metrology, X-ray based measurement tools are routinely used for thin film and materials characterization. XRF, XRD and XRR metrology tools help to measure critical process parameters of thin film like: thickness, composition, roughness, density, porosity, and crystal structure.

II.1.6 Instrumentation in textiles

As far as Instrumentation in Textiles is concerned, Nodal Centre for Upgradation of Textile Education (NCUTE) has been setup by Ministry of Textiles, Govt. of India, in 1998, with the aim of enhancing textile industry's performance by improving manpower training necessary to meet the challenges of emerging technologies and product quality requirements as well as to increase productivity and export capability of our textile products.

Textile Technology is a very capital-intensive production means for producing a variety of clothing using the most modern machinery. In a relatively narrow field like spinning itself one finds that raw material represents about 50 - 65% of the production cost of a short-staple yarn. There are a number of fibre properties, which can influence the quality of the yarn. A textile fibre is a peculiar object. Fibre properties vary very much within the lot. Optimal conditions can be obtained only through the mastery of the raw material. Therefore fibre testing is very important. It involves, for example, study of [effect of fiber length on yarn quality](#), [cotton stickiness](#) and so on. Basic characteristics of the fibre like fibre length, fineness, strength, maturity, rigidity, fibre friction and structural features have to be assessed. Following are some methods of determining fibre fineness gravimetric or dimensional measurements, airflow method, vibrating string method . This example shows the ramifications of instruments involved even in a very small component of spinning which in turn is only one small component of the production of textiles of one type. It is neither feasible nor advisable to go into the varied ramifications of this one industry unless specialists are consulted.

II.1.7 Instruments for pharmaceutical industry

A large variety of instruments are continuously getting evolved in Pharmaceutical Industry . The processes and instruments are patented regularly..

A wide range of Rapid Microbiological Methods and their applications in the Pharmaceutical Industry is a very important aspect of the demands on the industry as one has to be aware of the challenges involved in the assessment of microbial hazards and risks to ensure product and consumer safety. One has to take into account microbial growth in pharmaceutical environments, Influence of Environmental Conditions on Microbial Survival. Labor-Saving Devices and Automation of Traditional Methods is one activity. Among Traditional and Automated Rapid Methods for Species Identification and Typing, one finds techniques like Genotyping, Chemotaxonomy, Electrophoretic Protein Typing. Techniques for Detection of Specific Organisms have explored Potential use for DNA-Based Technologies. New Technologies for Microbiological Assays include Immunological Tests, Microchips and Instrumental Techniques

II.1.8 Instruments in food technology

Instrumental methods of analysis form an indispensable aspect of any R&D programme. Keeping in view the growing demands of R&D departments for sophisticated analytical instruments, and the necessity for an organised operation and maintenance system for the optimal utilization of such instruments, the Central Instrument Facility and Services was set up in 1989 at the CFTRI, Mysore. The facility is equipped with state-of-the-art analytical instruments for advanced research and development in food science and technology, and for stringent quality control of food products. Besides serving the scientific community to run the in-house projects, the facility provides analytical support to sponsored R&D/consultancy projects.

The focused areas are : Instrumental analysis of food materials, Study of texture and rheological properties of foods, Development of analytical methods for food analysis, Electronic instrumentation for food analysis, Automation of food industry, Maintenance of a Standard Reference Laboratory for calibration of

analytical instruments, Food texture measurement system, Colour measurement system · Controlled stress rheometry

In the food processing industry , one of the important objectives is to enhance the shelf-life of food or beverages. There are many methods and technologies used for this purpose . One of the important is based on ultraviolet radiation and is referred as Ultra-violet disinfection It is a simple technology.simple to understand, simple to install, simple to maintain, simple to run.

II.1.9 Flow rate measurement in industry

Finally, purely as an illustration, this example illustrates the wide spectrum of instrumentation involved in measurement of flowrates alone, a requirement one comes across in many an industry. As many as ten different technique- based flowmeters are in vogue. They are referred to as :Coriolis, magnetic, ultrasonic, vortex, DP, positive displacement, turbine, open channel, thermal, and variable area flowmeters.

II.1.10 Conclusion

The above provides a very random selection of role of instrumentation in various industries. It has to be emphasized that this list is not exhaustive but only illustrative. The vast arena covered by modern instrumentation spanning various human activities from Agriculture to Chemicals to Fishing to Mining (off-shore or on-shore) to Petrochemicals etc is mind-boggling. It is neither prudent nor possible to select one or more instruments selectively to be able to make a wide social impact.

II.2 ELECTRONICS INSTRUMENTS AND INSTRUMENTATION IN INDIA

(V.H. Ron)

Historically the real growth of electronics in India started with the report by the committee headed by Dr. Homi J. Bhabha (1966). The committee prepared a comprehensive report covering all major areas of electronics including computers, communications, components and consumer electronics. A ten year growth plan profile, investment and manpower needs and product and application priorities and guidelines for organising the industry in a systematic manner were evolved.

Based on this report, Department of Atomic Energy started Electronics Corporation of India Limited (ECIL) and after that practically every state started in their respective states, electronics Development Corporation like WEBEL, KEONICS, ELCOT, KELTRON etc. Also in Instrumentation field Instrumentation Limited, Kota was established. Central Electronics Limited was established by the Department of Science and Technology to productionize instruments and systems based on the know-how developed in the National Physical Laboratory.

Many of these units also went into collaboration with foreign vendors and did quite well during the initial period. Later foreign vendors were allowed to establish their own units either fully owned subsidiaries for Indian operations or joint ventures. Once this happened, these companies started feeling the pinch of new business models. After liberalisation in 1991, most of the units went sick because they could not adapt themselves to the changed business environment with the exception of ECIL (though it went into deep troubles, but bounced back with spectacular turn around and consolidation) and BEL.

Meanwhile TATAs established a joint venture with Honeywell of USA in the name of TATA-Honeywell and Blue Star with Yokogawa of Japan under the name of Yokogawa- Blue Star. BHEL also started its own Electronics Division at

Bangalore to meet the requirements of electronic instrumentation in the area of power projects.

II.2.1 Present status

As on today major players in India are ECIL with a turn over of Rs.1,000 Crore in the filed of Nuclear Instruments and Detectors, Analytical Instruments, limited medical instruments like Gamma Camera and Elisa Reader and Nuclear Control & Instrumentation and SCADA for Oil Pipelines and Antenna Control Equipment. BEL with a turn over of more than Rs.2,500 Crore manufactures special test equipment for defence (custom built, non-standard) and other defence equipment. BHEL Electronics Division with a turn over of Rs.500 Crore manufactures Control and Instrumentation for power plants and earlier in collaboration with ABB and now in collaboration with Max Controls. Their Electronic Meter Division is almost closed because of competition from private sector and Chinese products. Instrumentation Limited, Kota, now a sick Company waiting for dis-investment. TATA Honeywell with a turnover of Rs.260 crore, basically dealing in instruments for process controls and oil pipe lines, and building-automation. They are also sole selling agents for Honeywell products in India. Yokogawa Blue Star with a turnover of about Rs.130 Crore basically dealing in process automation and enterprise integration and also undertaking application software for Yokogawa, Japan. Some minor suppliers like APLAB, Toshniwal, Elico etc., are basically suppliers to the major OEMs. Almost all the firms are basically serving the domestic market with very little export. All are finding it very difficult to survive in competition with global suppliers even in domestic market except where there is a captive consumption.

II.2.2 R & D institutions engaged in instrumentation.

BARC & ECIL Nuclear Control & Instrumentation

DLRL & LRDE Defence related Electronic Instruments and Instrumentation.

These are basically engaged in indigenous development to achieve self-reliance to face possible embargo problems. By and large the methodology followed so far by most of the institutions as one of import substitution and reverse engineering. As a result product development rarely becomes state-of-the-art. & rarely results in creation of Intellectual Property. Normally the R&D institutions in India stop at the state of proto-type or technical development and ignore the several further steps needed to be taken to make "Market worthy products".

Domestic demand is very limited, and more over there is overcapacity in the domestic suppliers. Generally in India customers have preference for imports except where the technology is denied especially in strategic sectors.

Except where it is entirely unavoidable, Indian purchasers (whether in private or public sector) fear to try local designs. So, except when foreign technology is not available in strategic sectors like defence, atomic energy and space, Indian designs do not get a chance to prove their worth.

II.3 EDUCATIONAL INSTRUMENTATION

(V.C. Sahni)

After independence, both Central and State Governments have been giving fairly high priority to education. As a result, the number of schools (upto plus two level) – supported by government departments or private organizations - in the country has increased at a remarkable pace. In addition, hundreds of Universities, Institutes and Colleges imparting higher education in various fields, including professional courses, have been setup across the country thus meeting the demand of skilled, technical and professional persons both within the country as well as globally. For a good scientific and technical training, educational instruments of proper quality are essential and making these available to our institutions is a challenge. Here the private manufacturers have played a significant role and a review of present state of affairs would be in order. For convenience, we can divide instrument industry into five broad categories:

1. Instruments for School Labs
2. Instruments for College/University Labs
3. Instruments for Technical Education
4. Instruments for Medical/Higher Level Bioscience Education
5. Instruments for Research Labs

II.3.1 Instruments for school labs

Upto plus two level, the equipments are essentially required for Physics, Chemistry and Biology laboratory experiments. In Physics the equipments/tools are required for experiments pertaining to the mechanics (levers, shear force measurement etc.), heat (e.g. linear thermal expansion apparatus, pyrometers for radiation/temperature measurements, thermal conductivity apparatus etc.), optics (e.g. mirrors, lenses, prisms, traveling microscope, spectrometers, Newton ring apparatus etc.), sound & waves (e.g. tuning fork, vibrating bar, Melde's

experiment, resonator etc.) magnetism (e.g. induction coils, solenoids, inductors, electromagnets etc.) and electrostatics & electricity (e.g. galvanometers, current and voltage meters, rheostats etc.). All such equipments/tools needed for physics experiments are being manufactured in the Country and the number of manufactures is quite high (<http://www.indiamart.com>). These manufacturers not only cater to the vast requirement of the country, but also export many items. Similarly, the county has large number of manufactures for chemistry labs (e.g. thermometer, balances, centrifuges, pH meters, burners, spatula, glass and plastic wares, laminar flow benches, magnetic stirrers, ovens and furnaces etc.) and biology labs (e.g. slides, forceps, scissors, moisture meter, seed germinating chambers, microscopes, magnifiers, etc).

While indigenous manufacturers are doing well, there is tremendous scope for the growth of this sector, since a large number of schools still do not have adequate science labs. If the MHRD of Govt. of India, and the educational departments of the State Governments are contacted to get some assessment of the existing gap between what the school science labs actually possess, to what they should have at a minimal level, one will be able to quantify the expansion opportunity for this sector. The committee suggests that matter can be brought to the attention of Minister/Secretary, MHRD for follow up action.

II.3.2 Instruments needed for colleges/university labs

Although some of the equipments required for undergraduate and graduate level education in science disciplines are similar to those used in school labs, for postgraduate education, several higher accuracy and high precision instruments are required. While the equipments in the former category are being produced indigenously, these often require up-gradation; however, equipments for higher education are either not manufactured in the country or are of inadequate quality. Luckily, this trend is changing and already manufacturers in Ambala, Bangalore, Coimbatore, Delhi, Hyderabad, Kolkata, Mumbai, Nasik, Pune

etc. are moving up in the quality and range of products they are producing. We feel, here again by pursuing the idea proposed above of establishing a link with MHRD (in the case of school labs) an accelerated growth of this sector is also feasible.

II.3.3 Instruments for technical education

Technical education in the country is provided at different levels, such as, Industrial Training Institutes, Polytechnics and Engineering colleges in various disciplines (i.e. mechanical, electrical, electronics, chemical, metallurgy, civil, computer etc.). Most of the instruments required for the technical education are also being manufactured in the country. For example, for electronics discipline the frequently required instruments (such as, amplifiers, oscillators, function generators, timers, digital multimeters, power supply, transformers etc), are manufactured in the country, but specialized instruments are not being produced indigenously. This is an area where more efforts can be devoted to bridge the gap between demand and availability.

II.3.4 Instruments for medical/higher level bioscience education

For medical/bioscience education, instruments needed are ovens, incubators, water stills, dissecting equipments, slide boxes, stirrers, hotplates, medical microscope, fiber models (e.g. human torso, eye, heart, skin, nervous system, DNA model etc.), eye and ENT equipments etc. All these are manufactured in the country. However, all specialized instruments are still being imported.

II.3.5 Instruments for research labs

Research being pursued in the country is multifaceted and multi-disciplinary. It is therefore very difficult to fully catalogue the manufacturing

activity of all types of research instruments in the country. However, following instruments are not being manufactured in the country:

- (i) High accuracy and high precision measurement equipments (e.g. nano-voltmeters, LCR meters etc).
- (ii) The instruments dealing with extreme conditions (e.g. cryostats working at mK temperature range, very high magnetic fields, very high pressures etc.).
- (iii) Sophisticated analytical instruments (e.g. Scanning electron microscope, tunneling electron microscope, atomic force microscopes, X-ray photoelectron spectrometers, NMR, EPR, XRD, IR, Raman etc.).
- (iv) Electron and ion accelerators.
- (v) High power lasers.

It may be noted that some of these instruments have been developed by leading research institutes in the country for their own programmes. So the way forward is to take the development of such instruments (at whatever stage they may be) to a more robust and reliable level. For this, a strong linkage between industrial units and R&D institutions is desirable. Of late, Indian manufactures have found a distinct growth opportunity in the area of advanced instrumentation. For instance, vendors now make custom designed instruments related to UHV and thin film deposition. A new trend has been that several engineers/scientists, after working for many years in US, have returned to India, and have set up manufacturing bases at advanced levels. For instance Advanced Processing Technology (APT) and Milman India in Pune provide custom made fully automatic multi-target sputtering units for multilayer depositions, and in fact can export these items. This generation of entrepreneurs needs to be encouraged.

In summary, one can say that for educational equipment sector, India has a large number of manufacturers who cater to its schools, universities and

technical institutions as well as to some extent to its research labs. Many instruments are also being exported to various countries, such as, Malaysia, Philippines, Egypt, UK, USA, France, Germany etc. On the other hand, the country lacks in the manufacture of high accuracy, high precision and state-of-art instruments because of insufficient base of specialized component industry that is required by manufacturers of such equipments. In addition, high quality manpower, which the country produces, moves out to developed world, so that potential developers of state-of-art instruments in the country are in short supply. In a way, if the environment is more congenial, their staying back in the country and contributing to this sector would happen quite naturally.

II.4 ANALYTICAL INSTRUMENTATION (Krishan Lal)

II.4.1 Introduction

The term Analytical Instruments refers to a large collection of instruments with an enormous range of capabilities. These are used to analyze materials in respect of major constituents (composition), minor constituents (trace impurity analysis) as well as real structure (ideal crystalline structure and defects). All or some of these aspects are of vital importance to practitioners of Physics, Chemistry, Materials Science and Engineering, Engineering (all specializations), Medical Sciences, Biosciences, Geosciences and Environmental Science and Engineering. The demands of users lie in an extremely large range. For example, on the one extreme scientists and engineers engaged in design, development and manufacturing of microelectronic devices continuously pose new challenges for analytical instrumentation in terms of detection limits and speeds and on the other end for routine analysis of metals and alloys only fast and reliable analysis with modest sensitivity is sufficient. The material to be analyzed may be a solid, a liquid or a gas. In the case of solids different techniques are required to characterize surfaces and the bulk of the materials. For elemental analysis chemical, spectrochemical (atomic absorption and emission techniques), mass spectrometry (including isotope dilution MS), chromatography (analysis of vapour phase and liquids), and X-ray fluorescence spectrometry (X-rays and electrons induced fluorescence) methods are the principal techniques. For determination of elemental composition of solid surfaces techniques like Auger electron spectrometry (AES), secondary ion mass spectrometry (SIMS) and electron spectrometry for chemical analysis (ESCA) are widely employed. One of the first tasks in structural characterization of solids is to find out if the given material is amorphous, polycrystalline or single crystal. Next, the phase of the specimen (if crystalline) is to be established. The defects in crystals seriously affect their properties and, therefore, observation and characterization of defects

is an important activity while dealing with single crystals and polycrystalline materials. Powder X-ray diffractometry, electron diffraction and neutron diffraction methods are extensively in use for determination of crystalline phase of materials. With the availability of crystal phase data (X-ray diffraction) of solids on CD-ROMs it is possible to make automatic phase analysis with several commercial powder X-ray diffractometers. For characterization of crystal defects one can use a wide range of techniques like chemical etching, high resolution X-ray diffraction (diffractometry, topography, diffuse X-ray scattering), electron microscopy and diffraction (SEM and TEM), scanning tunneling electron microscopy and atomic force microscopy.

The state-of-the art level capabilities of techniques for different types of analysis are as follows. It is possible to analyze some trace impurities with parts per trillion level sensitivity under favourable conditions of low interferences. However, in such cases the uncertainty in measurements is quite high. Most impurities can be analyzed at parts per billion levels with reasonable uncertainties. However, these high sensitivity techniques are destructive in nature. The sensitivity of non-destructive techniques like X-ray fluorescence analysis is comparatively very low. Atomic number of the impurity and the composition of the matrix are also important. Defects like boundaries and dislocations can be directly observed and characterized by high resolution X-ray diffraction topography. Point defects and their aggregates in nearly perfect single crystals can be characterized by high-resolution diffuse X-ray scattering measurements. Important crystallographic parameters like orientations (surfaces and straight edges), biaxial stress in thin film-substrate systems, lattice and orientational mismatches between thin epitaxial films and substrate single crystals can also be determined accurately.

II.4.2 Present status in the country

Several leading laboratories of the country have been engaged in design and development of analytical instruments. These include some of the CSIR laboratories (notably, Central Scientific Instruments Organization, Chandigarh and National Physical Laboratory, New Delhi), Bhabha Atomic Research Centre, Trombay, Indian Institute of Science, Bangalore and a few universities. Several Indian industries have been manufacturing a variety of analytical equipments. These include M/s Electronic Corporation of India, Hyderabad, M/s Elico Industries Hyderabad, M/s AIMIL Ltd., New Delhi, and M/s Toshniwal Bros. Pvt. Ltd., New Delhi. A wide range of instruments are being manufactured and sold by these industries in India and abroad. However, these equipments do not come up to the state-of-the-art level in terms of technology employed and the specifications.

The real challenge is to develop infrastructure for design, development and manufacture of international quality instruments, which can sell in most competitive markets of the world. This can only be achieved by pooling the best of the intellectual, the entrepreneurial and the manufacturing capabilities in the country. A strong financial back up above the critical level is vital. Therefore, if well worked out projects aimed at developing world-class equipment are encouraged there are good chances of success. To begin with attempt must be made to develop a few analytical equipment, which can be used for societal benefit or for advanced applications.

II.4.3 Proposed plan

For the success of instrumentation projects one of the key elements is networking of skills in all aspects. Capabilities in the following fields need to be pooled together: (a) design of advanced equipment; (b) fabrication; (c) electronic controls; (d) detectors with suitable electronics; (e) software and computer control; (f) output infrastructure; (g) testing; and (h) quality control. Fig 1 shows

schematically all these components. The specifications of any equipment planned for development have to keep in view major developments at the global level. Aesthetics is a vital ingredient of design. Fabrication requires major infrastructure including numerically controlled lathe and milling machines, high precision tool rooms, and machines for quality cutting, controlled grinding, precision lapping and polishing. The tool room should serve as vital component of quality control in fabrication. Electronics is also a very important part of modern analytical equipments. Advanced digital electronics must be utilized keeping in view the international trends. Facilities to develop equipment specific Printed Circuit Boards is most desirable. A variety of detectors particularly for different radiations and their controls are important components. For the time being we should import the best possible detectors. Computer software required to efficiently perform all specified functions of the equipment must be developed indigenously. The software should be able to acquire experimental data and perform all the functions required to run the equipment. Also, it will analyze the experimental data and display the results and control output devices like printers.

Some basic expertise is required in development of practically all analytical equipment. These are the linear motion tracks, angular motion producing modules, data acquisition and analysis and graphic display of experimental results. For linear and angular motion devices provision has to be there for measurement as well. Some components like air bearings may be imported, if necessary. In general, computer control of analytical equipment should be an integral part of all the equipments.

As mentioned above it would be highly desirable to create a network of R& D institutions and industries with expertise in different aspects of equipment development. A database may be created for this purpose in association with industrial bodies like Confederation of Indian Industries. Before initiating the developmental work on any equipment a market survey of current and future

demands may be made. If the industry gets associated in the beginning the R&D Team may be constituted of personnel from the industry and the concerned R&D laboratory. Quality management in the process of manufacturing, calibration for ensuring traceability to national standards (and through them to international standards) and rigorous testing at all stages should be integrated with the development and fabrication process.

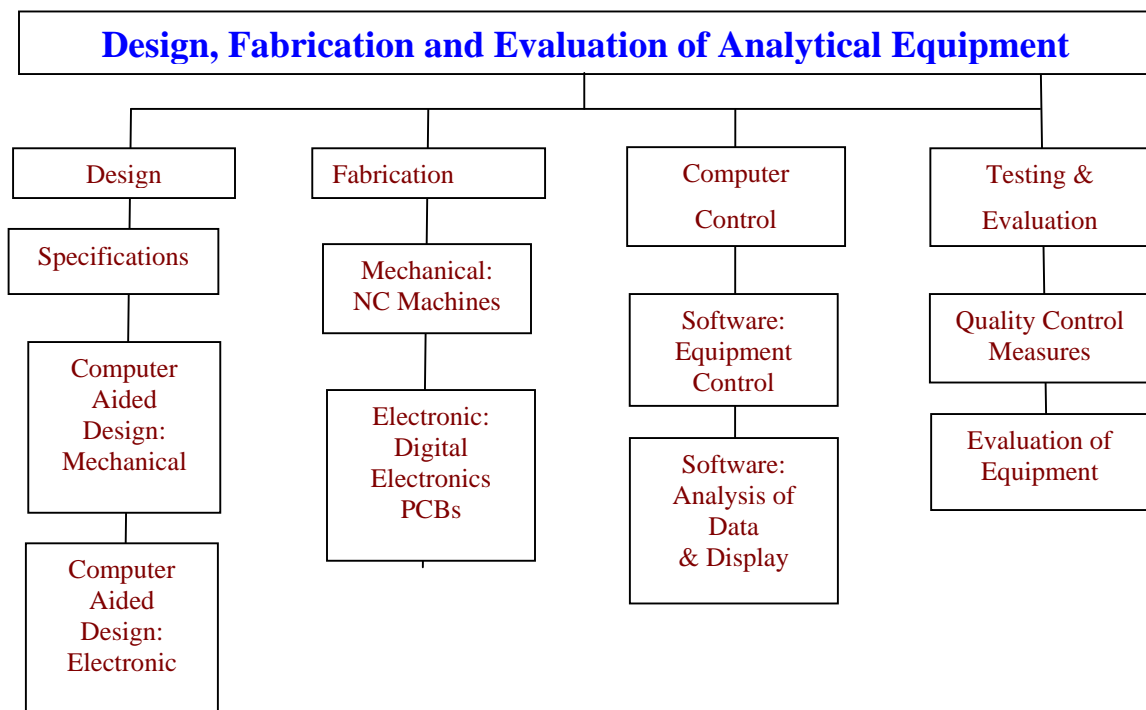


Fig. II.4.1 A chart showing all aspects of development of an analytical equipment.

II.5 INSTRUMENTS FOR MEDICINE AND BIOTECHNOLOGY (A.V. Ramani)

II.5.1 Introduction

With the dropping of trade barriers, India has become part of the Global Village. This means that every kind of instrument is available for a price, which is sometimes quite competitive. There is still need in India for some lower end instruments for use in education, medicine, and biotechnology. While a lot of biotechnology requirement is for high-end instruments, there are niche areas like instruments for fermentation technology, thermal cyclers, and CO₂ incubators, which can stand improvement and lower cost end products.

II.5.2 Current status

On the medical front there is a need for developing diagnostic and therapeutic instruments, which are simple enough to operate by Primary Health Centre technicians and in the home. These would cover instruments for blood banking and biochemical analysis, therapeutic devices for fetal and neonatal care, cardiac care, hypertension and diabetes.

Today, India imports about Rs.7.5 Billion worth of high-end instrumentation covering CT, PET, MRI, and ultrasound scanners, Auto analyzers, as well as miscellaneous instruments. There are very few Indian players in the organized sector. No one makes high-end devices like Imagers, and pace makers. At the lower end, low cost, low quality Chinese homecare devices are flooding the market.

The reason for this is the usual demand and supply mismatch. Many of the major players had to close down because of lack of demand in the initial years. It was a case of too many pieces of too small a pie. The industry was capital intensive with poor return on investment. Indigenous products were of a lower quality than the imported. After sales service was poor.

The situation was compounded by the poor quality of Indian made components. Import duty was high on components but less on the finished instruments imported as such. Foreign Instruments had a built-in obsolescence. Products were continuously upgraded at a lower cost. Spares for the indigenous instruments were high.

II.5.3 Available options

India has a huge software base. This can be leveraged to make India an outsource for high-end imaging and therapeutic Device manufacturers. India will get money, and some employment generation of the IT kind. One merit is that this can take off at once.

India also has a wealth of light engineering/electronic hardware base. Indian industries can have many JVs with global majors for manufacturing of their products in India for the global market. This would again generate wealth and jobs. It is essentially 'farming out' but can start at once. The latest products will be available for the local market. Prices could be lower than for imported instruments.

One of the major strengths of India, which is unfortunately not exploited properly, is its R&D base. India can be very cost effective in R&D. There is an urgent need to set up 'Technology Incubators' like the one demonstrated in IISc, to develop cost effective, cutting edge products to suit third world needs. This is a long haul option. This will need commitment, investment, time, and infrastructure. The sooner it is initiated the better. Components import could still be a problem. The delivered price will be very low.

II.5.4 Recommendations

1. We should start with lower end educational and analytical devices.

Revisit Healthkit and Mckee Phederson Instruments laboratory kits. Develop kits specific for individual course modules in chemistry, physics, electricity and electronics. All kits should preferably work on rechargeable power packs so that they can be used even if there are power interruptions.

Develop instruments for the lower end biochemical analysis for primary Health Centres. These would include calorimeters, Haemoglobino meters, and urine analysers based o reproductive index.

2. At the next level Blood Bank devices for component separation, ELISA readers, Thermal cyclers, infusion devices, and devices for use in ICU have to be developed.
3. IITs and CSIR should take up the initiative to start 'Technology Incubators' like the one at IISc.

CSIR, DST, and DBT should streamline and speed up funding start up companies that take up indigenous R&D products for productionising.

4. All import substitutions should be given all benefits given to direct exporters, avoiding hassles. Market will be small at start. Small-scale option may be the best, provided harassment by Sales Tax, Excise, and Labour departments, which is currently the bane in this sector. Exemption from ET and ST will give a boost.
5. We should not ignore new areas for development. India is slated to have the world's largest geriatric population. There is going to be lot of morbidity. Diabetes, Hepertension, and movement disabilities are on the

increase. Instruments and devices for all these areas as well as for portable oxygen, resuscitation, and external cardiac support have to be developed. Nuclear, small families have thrown up a need for low cost movement monitoring for the very young and the infirm are needed. Fetal, Neonatal, and infant mortality is still very high in India. Devices for care in these areas are urgent.

II.5.5 Acknowledgement

Many people in industries and institutions gave helpful inputs. H.Vijaykumar, CEO, SIDD, Chennai, is a very vocal proponent of indigenous medical devices. Santhosh Janardhan, Director, Clinitron, Bangalore, is a manufacturer of medical instruments. His inputs are in Annexure II.4.A-1.

Medical Instrumentation

Following table shows the list of analytical and blood bank instruments with their market size. This report is based on the inputs from C&F agents and major Distributors of leading manufacturers/Importers of these instruments.

No	Instrument	Market Size (INR)	Manufacturer	Technology
1	Colorimeter	7-10 Crores	ECIL Systronics, Elico,	Indigenous
2	Spectrophotometer Includes 1. Visible 2. UV - Visible 3. Atomic absorption 4. X-ray diffraction	50 Crores	ECIL / ELICO	Indigenous
3	Flame Photometer	3 Crores	ECIL Systronics, Elico	Indigenous
4	Blood analyser Semi - auto	30 Crores	Transasia, Ranbaxy	Transferred Technology
5	Blood analyser Fully - automatic	25 Crores	Hitachi, Borehinger, Bayer	Imported
6	Cell counter	20 Crores	AVL	Imported
7	Electrolyte analyser	15 Crores	AVL, Transasia	Imported Transferred Technology
8	ELISA reader application includes Blood Bank, Agriculture, Pathology, Bio-Tech	10 Crores	Hperion Bio-Tek Transasia	Imported Imported Imported
9	Blood bank instruments Deep freezer Blood bank refrigerator Refrigerated centrifuge Plasma thawing system Plasma expressor	60 Crores	Penpol J Mitra Baxter	Transferred Technology Imported Imported

Market Size is estimated by adding previous financial year's turnover of the major players in their respective fields. Actual size of the market may be much more than this estimate.

II.5 R&D Instrumentation **(S. Mohan)**

II.5.1 The instruments required for carrying out R&D in the country are mostly used in

1. Universities, IIT's, IISc, NIT's and Engineering colleges offering doctoral & master's programs.
2. CSIR laboratories
3. Defence laboratories
4. DST, DBT, MIT and ICAR sponsored laboratories
5. R&D labs associated with public and private sector industries.

II.5.2 These instruments could be broadly classified into :-

- (a) Highly sophisticated and expensive systems
- (b) Routinely used instruments, which are not expensive but still need modern technologies so that they can compete with the imported systems.

II.5.3 Some of the systems which could be listed in category (a) are: -

1. High resolution electron microscopes, Atomic force and scanning tunneling microscopes for structure investigation.
2. Surface analysis systems such as ESCA, Auger, SIMS, ISS and Rutherford Backscattering spectrometer, Nanoindenter, Surface profilometers
3. Synchrotron, Pelletron, Molecular beam epitaxy systems.
4. Ion Beam deposition, Etching and Reactive ion etching systems, Ion accelerator
5. Plasma based systems for surface Engineering.
6. Laser based systems for medical applications, metrology etc.
7. Synthesis and characterization systems for semiconductor industry.

II.5.4 In category (b) the following systems / instruments could be identified: - Spectrophotometers, Gas chromatographs, Atomic absorption spectrometers, ellipsometers, optical microscopes, lasers & optics based instruments, Thin film deposition and characterization systems, optical emission spectrometers, Xray diffractometers, scanning and transmission electron microscopes.

II.5.5 At present, most of these systems from both the categories are being imported and it requires making suitable road maps for building these instruments.

II.5.6 It should not be difficult to fabricate and market the systems in category 'b' if the following methods are adopted. However addressing the instruments in category (a) requires a better R&D in both R&D labs and industries.

II.5.7 Let us now look at the infrastructure required in the country to make high technology instruments which can not only compete with imported systems but also understand the changing technology scenario and get adopted to it.

II.5.8 For developing these systems with in the country, there is a need to have centers of excellence in the following areas:

1. Sensors - Conventional sensors and MEMS further leading to research in Nanosensors. B-Smart program is an ideal example.
2. Microelectronics Fab facility as well as prototype fabrication centers with the necessary MEMS and VLSI design software.

3. Software design and development centers including R&D in embedded systems.
4. CAD/CAM design centers with facilities for rapid prototyping and Reverse Engineering (Ex: Center for Manufacturing Technological Instruments CMTI)
5. Laser centers in the same model as center for advanced technology at Indore.
6. Optical fabrication facilities including aspherical optics-fabrication and characterization and links with CIPET centers specializing on plastic moulding.
7. R&D centers / Industries with established infrastructure already existing in the country for High Vacuum and Ultra high vacuum system fabrication.
8. Centres specializing in ion beams, electron beams and plasma generation, design and fabrication of beam guiding systems. Ex: - VEC, Calcutta, IOP-Bhubaneswar, Plasma Research Institute - Ahmedabad.
9. Materials Research centers such as ARCI, Hyderabad with networking with academic institutes on one side and industries on the other to interact and set up incubation centers.

II.5.9 All the centers should have direct links with agencies such as space, defence and atomic energy on one side and industries on the other.

- These centers should be driven by industry and should work as institutes of Industrial Research. Ex: - Sri Ram Institute of Industrial Research Bangalore, New Delhi, Industrial Research Institute, Taiwan.
- Instruments projects should not be sanctioned in the present PAC mode – Though TIFAC mode is considered to be better there are still better

methods. Mission mode is the best one. CAR is a model, which is worth following.

- A website with a complete database of experts, infrastructure available, center of excellence, prototype facilities available for industry, national and international requirements is a must.
- With right vision, expertise should be identified and encouraged.
- Virtual centers which networks the centers of excellence, industries and funding agencies with SID/IISc as a model is worth following

II.5.10 Collaboration with foreign countries involving not only their R&D institutes but also their industries for natural benefit should be encouraged.

II.5.11 One of the best examples for development of R&D instruments is the “Design and Development of MEMS based miniaturized mass spectrometer” at University of Washington, Seattle USA involving scientists from different disciplines of science, engineering, business management, marketing and funding agencies, entrepreneurship centers and industries.

II.5.12 CSIR laboratories should play a key role for which they are created. This should not be done in isolation but only with proper interaction with academic institutes on one side and industries on the other. Networking is the answer, which solves this problem.

ANNEXURE - III - AN INDUSTRY VIEWPOINT

III NATIONAL ANALYTICAL INSTRUMENT POLICY-MAJOR ISSUE (Ramesh Datla, MD, Elico Ltd. Hyderabad & Chairman, CII-AP)

III.1 Introduction

No longer can market forces be driven by objectives that are different from the demands made by the people from the government they have elected.

No longer can government deliver the goods without using science and technology intelligently. Similarly, no longer can scientists and technologists pursue their objectives without harmonizing them with the needs of the market and the people.

Atal Behari Vajpayee, former Prime Minister of India

In this backdrop it is very clear that for any economy to grow it is very essential to have a strong science and technology base.

Electronic and IT Hardware industry is the fastest growing industry in the world and is the worlds largest and most strategic industry. The approximate size of the industry now is about US\$ 1.5 trillion

With the signing of WTO-IT agreement in 1997 by Government of India there is a gradual reduction of duties and removal of quantitative restrictions, and the Zero Duty regime for IT industry will be coming into effect from year 2005.

In a free and open global economic environment, the industries will face even stiffer competition. In order to increase competitiveness, the Government will be compelled to further deregulate and globalise the flow of money, manpower, resources, and information. In light of this trend of increasing liberalization and competition, one of the greatest challenges will be to enhance national competitiveness through providing conducive environment and the right policy framework.

Governments in developed and in most developing countries have shifted their attention towards policies that improve the environment in which business functions, that remove impediments to trade and investment, and that deregulate or regulate more effectively. The focus of industrial support policies have changed, with sectoral support giving way to economic wide measures, such as support for research and development, environmental protection, and start-up and growth of new businesses.

The Government of India and the respective State Governments should take immediate steps to implement a comprehensive policy for the Analytical Industry to see that the domestic industry is geared up to meet this challenge and at the same time create a conducive environment for foreign/local companies to set-up new design & manufacturing facilities in India.

III.2 Objectives

The objectives of the Policy are

1. To create a high technology vibrant instrument Industry enabling to compete with the best in the world.
2. To attain 5% market share of the world instrument industry by year 2010.
3. To create world-class infrastructure and attract the best to set-up manufacturing base in India.
4. To encourage Government-Industry-Institution partnerships
5. To encourage creation of industry clusters and cross collaboration.
6. To set-up centres of excellence in design, quality, manufacturing, HR etc.
7. To encourage setting up of advanced technology research and development centres.

III.2.1 To create a high technology and vibrant analytical instrument industry that enables to compete with the best in the world

The contribution of labour and capital accumulation to the growth of average productivity is less than ten percent, and that the source of economic growth is, therefore, technological progress. by Nobel Prize winner Professor S. Kuznets

Traditional natural resources and capital are no longer the main elements of economic superiority in today's fiercely competitive global market. by Michael Porter in his book "The Competitive Advantage of Nations"

Technology confers an artificial competitive advantage and will be the foundation of competitiveness in the next century. by Lester Thurow, in his books "Head to Head" and "The Future of Capitalism,"

Although Japan is small in land area and lacking in natural resources, its high-tech products were so successful in world markets throughout the 1980s that even the United States felt threatened. The chief factor for Japan's success was the great attention paid to research and development by both government and the private sector.

In Taiwan High-tech exports have grown to a quarter of total exports in recent years, and it has become the leading maker of several high-tech products.

These facts demonstrate the contribution technology makes to competitiveness. Because of this, technological development will play a vital role in maintaining the nation's future competitiveness.

In globalised business environment, policy strategies should enhance the ability of industry to become more innovative, flexible and competitive, thereby leading to increased productivity and job creation. Such strategies should be efficiently designed and delivered with a view to ensuring the development of the emerging knowledge-based economy. A healthy business environment will foster entrepreneurship and encourage industries and individuals to exploit new opportunities and move into high-value-added activities.

A new economic paradigm is thus emerging: the mastering of information and the introduction of knowledge-intensive means of production have become key to competitiveness, and even survival. This calls for fundamental changes in the way government policies promote industry.

III.2.2 To attain 5% market share of the world instrument industry by the year 2010

The aim of the policy should be to create an environment to achieve the above goal.

Electronic and IT Hardware industry is the fastest growing industry in the world and is the worlds largest and most strategic industry. The approximate size of the industry worldwide at present is about US\$ 1.2 trillion. In India the size is about US\$ 6 billion, which is approximately 0.5% of worldwide share.

2000 Statistics in US\$ billions (approx figures)

Item	World Wide	India
Components	365	1.20
Computers	377	0.60
Consumer	96	2.60
Control& Instrumentation	130	0.87
Telecom & Broadcasting	250	0.93
Total	1218	6.2 *

* Strategic Electronics not included

Source: Electronic Business

III.2.3 To create world-class infrastructure and attract the best to set-up manufacturing base in India

One of the main factor, which is essential to the growth of the industry is proper infrastructure.

Special Electronic Zones or Hardware Technology Parks have to be created which provide the following

- a. Uninterrupted power
- b. Clean water

- c. Sewerage facilities
- d. Waste treatment facilities including incinerators for disposal of solid waste
- e. Roads
- f. Air and Rail Connectivity.
- g. Communication facilities
- h. Training Centers
- i. Conference and trade centers
- j. Shopping Areas
- k. Police control rooms
- l. Commercial and Residential areas
- m. Schools.

For creation of these parks in line with those existing in countries like Taiwan (Hsinshu Science Based Industrial Park), Singapore (Singapore Science Park), Malaysia (Kulim Hi-Tech Park), China (Beijing experimental zone for development of new technology industries and Guangzhou Electronic Industrial Park), Philippines (Subic Industrial Park) etc. Government should implement policies to encourage Private participation in such projects.

III.2.4 To encourage government-industry-institution partnerships

With opening up of the economy and increase in competition there is an urgent need to seriously look into the issues affecting the growth of the industry so as to de-bottleneck and help the industry to thrive in the global market. To achieve this government and industry should work jointly as partners to minimise the operational hurdles and cumbersome procedures, which inhibit the smooth functioning and growth of the industry.

- a. Government-Industry partnership: or public private partnership is the joint initiatives between government and industry. The following are the key joint activities that can be taken up
 - 1. Policy framework
 - 2. Setting up of Industry Standards
 - 3. Infrastructure development
 - 4. Business Development
 - 5. Setting up of Training centres.

b. Industry-Institute partnership: are the joint initiatives between Industry and academia. As competition increases more and more industries are moving towards what they are best at or their core competencies. One of the most important element in this is the contribution of the Knowledge worker. The more an industry can attract a knowledge worker the better is its competitiveness and growth. Hence to improve on the quality of the worker it is very essential for the industry to closely work with the academia.

1. Curricula committees
2. R&D funding & incubation Centres
3. Joint R&D projects
4. Industry training programs.
5. Faculty training programs
6. Summer training programs

III.2.5 To encourage creation of industry clusters and cross collaboration

The presence in the nation of related and supporting industries is one of the major determinants of a nation's competitiveness. Successful innovation is highly determined by the extent of learning-by-interacting between parties connected together by flow of knowledge, skills, and services. *by Philip Kotler, The marketing of Nations.* Industrial clusters to be promoted for greater efficiency in terms of resource use and inter-industry and inter sectoral linkages

III.2.6 To set-up centres of excellence in design, quality, manufacturing, HR etc

An important element in the growth of developed economies like the US and Japan has been the contribution of the Knowledge Worker. A Knowledge Worker is an individual with specialised knowledge and skills in the respective field.

Analytical Instrumentation been a multidisciplinary hi technology industry requires continuous training of their workers, hence there is a requirement of excellent training centres specialised in relevant fields.

The centres of excellence can be defined based on the set of standards. These can be existing centres in universities, industry, Government or new centres, which meet the set requirement.

- c. Evolve uniform standards for training.
 1. Manpower standards
 2. Curricula standards
 3. Teacher standards
- d. Mandatory accreditation of all training institutions.
- e. Compulsory audit of training institutes.

III.2.7 To encourage setting up of advanced technology research and development centres

In order to maintain competitiveness of products in the world market, many developed nations have poured more and more resources into both private and government research and development. Identifying key technology areas in Hardware and putting emphasis on it.

- a. Microelectronic & MEMS Research Centre
- b. Sensor Research Centre
- c. International Cooperation in basic research and joint developments
- d. Emphasis on developing Intellectual Property.
- e. Mandatory requirement for industry to spend on R&D so as to avail any kind of benefit or incentive from the Government.

ANNEXURE - IV - SOME CASE STUDIES

IV.1 ISSUES INVOLVED IN DEVELOPMENT OF ANALYTICAL INSTRUMENTS IN INDIA

(Ramesh Datla, Managing Director, Elico Ltd, Hyderabad)

IV.1.1 Development of FTIR

Indigenous development of FTIR (Fourier Transform Infrared Spectrophotometer) can serve as best example to demonstrate the issues and intricacies involved in the design and development of new technologically advanced product in the field of analytical instrumentation in India.

IV.1.2 What is FTIR?

FTIR spectroscopy is used primarily for qualitative and quantitative analysis of organic compounds, and for determining the chemical structure of inorganic compounds.

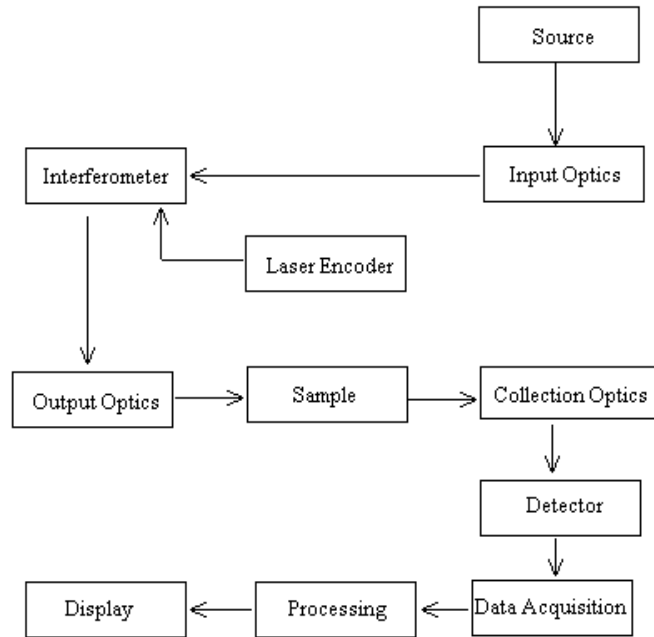
IV.1.2.1 Principle of operation

Spectroscopy is the study of the interaction of electromagnetic radiation with a chemical substance. The nature of the interaction depends upon the properties of the substance. When radiation passes through a sample (solid, liquid or gas), certain frequencies of the radiation are absorbed by the molecules of the substance leading to the molecular vibrations. The frequencies of absorbed radiation are unique for each molecule, which provide the characteristics of a substance.

Because chemical bonds absorb infrared energy at specific frequencies (or wavelengths), the basic structure of compounds can be determined by the spectral locations of their IR absorptions.

FTIR is a non dispersive technique. It is based on interferometry principle where all the wavelengths are recorded simultaneously.

IV.1.2.2 Block diagram



Block description & constituent elements

- Source - emits the required IR radiation. It consists of coiled filament of an appropriate material
- Laser Encoder - serves as a reference. It consists of HeNe Laser, Visible Detector
- Interferometer - produces the interferogram. It consists of Germanium Coated KBr beam splitter, Compensator, Retroreflectors, Moving mechanism (voice coil motor)
- Input Output and Collection optics - direct the optical beam - consist of Off axis Parabolic mirrors.
- Detector - acquires the optical signal and converts to electrical form - consists of IR sensitive Pyro electric detector or Mercury Cadmium Telluride detector enclosed in a Dewar for liquid nitrogen cooling or PbSe detector depending on the range of operation.

IV.1.3 Design issues

FTIR requires advanced optics and specifically IR elements, Retroreflectors, KBr beam splitter and compensator, Off axis paraboloids. These components are not manufactured in India all of them have to be imported.

Mirror moving mechanism is the most critical part of the instrument, as it requires very precise and smooth movements. *Voice coil/linear motor* are generally used to meet these requirements. This needs to be imported.

Vibration control is a key aspect in recording accurate data. Vibration Isolation pads are employed to isolate the effect of vibration. These vibration isolation pads need to be imported.

For the validation of the instrument wavelength accuracy standards (NIST traceable standards) need to be imported.

IV.1.4 Issues involved in sourcing material locally

Efforts for indigenous development led to the sourcing of material locally, but it involves lot of intricacies.

IV.1.4.1 Off axis paraboloids

Efforts have been made to initiate the development of off axis paraboloids at the CSIR labs (CSIO Chandigarh), which have the best facilities and equipment to do the work. But

1. They are not willing to take up the work until total developments costs are paid upfront even though requested them to amortise the cost on the finished components supplied.
2. Cost quoted is very high, greater than the imported components - the very purpose of going for indigenisation cannot be met

IV.1.4.2 KBr beam splitter

Steps have been taken for the development of KBr beam splitter at IISc Bangalore. Intricacies involved

- 1 Time taken very high

- 2 Failed to reach the required accuracies in processing and component specifications

IV.1.5 Issues involved in sourcing material from other countries

As most of the components cannot be obtained locally, it requires sourcing the material from other countries.

The IR components (IR source, beam splitter, detector) used are difficult to import. We are supposed to clarify as to why we require that material i.e. for what purpose. Some companies even do not supply such elements saying that these are restricted items.

More over all the advanced optics (Retroreflectors, off axis paraboloids) need to be imported. The intricacies involved in importing material from outside are

- High import duty
- Overall development cost of the instrument becomes high
- The process is time consuming

IV.1.6 Availability of expertise within the country

Initially BARC and NPL have done some work on FTIR instrumentation this but there is no commercial outcome. Many years back ECIL was funded for this project by DST but nothing has been developed so far. In general very little IR instrumentation work is done in the country. As far as we know no organisation developed this instrument. All users import.

IV.1.7 Conclusion

The above example illustrates the complexities involved in the development of Analytical instrumentation in India. Hence centres of excellences have to be developed in various areas of instrumentation for the industry to grow and for the country to have a strong base for indigenous instrumentation.

IV.2 Development of Four-Circle Single-Crystal Diffractometers at BARC (M. Ramanadham, Head, Solid State Physics Division, Bhabha Atomic Research Centre, Mumbai 400085)

IV.2.1 Background

A single crystal diffractometer is used for collection of intensity data for Bragg reflections from mono crystals of substances for determining their crystal structures. A schematic of this instrument is shown in Fig. IV.2.1. It essentially consists of a source of radiation, a four-circle goniometer, a detector with counting electronics for recording scattered radiation, a hardware for positioning of the four-circles (2θ , ω , χ and ϕ) in correct Bragg position of the single crystal for a given reflection. Since this operation is repetitive for hundreds of reflections for a crystal, these instruments are highly automated. All over the world automation of neutron diffractometers had preceded that of single-crystal x-ray diffractometers. Neutron instruments were automated quite early on, in order to make the best use of the low neutron fluxes from nuclear reactors. Developments at BARC of these instruments also followed a similar path.

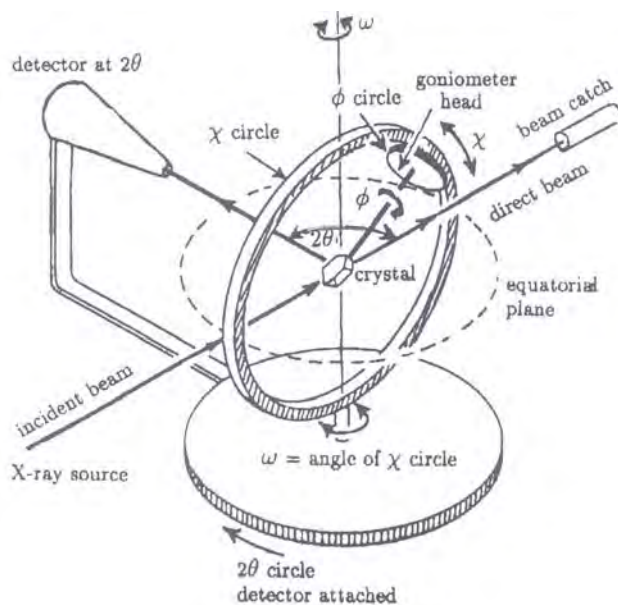


Fig. IV.2.1 A schematic of single crystal diffractometer

A typical requirement of the four-circle orienter is that point of intersection of all the axes must coincide. In practice, there will be some error. This is called the sphere of confusion. It is typically 50-100 micron for a neutron diffractometer and 10 micron or less for the X-ray one. Therefore by the current world standards, the precision required for fabrication of an x-ray diffractometer is an order of magnitude more than that of a neutron diffractometer.

IV.2.2 Neutron diffractometer development at BARC

The first such instrument was Semi-Automatic Neutron Diffractometer (SAND) that became operational during 1964. It was a two-dimensional instrument, capable of recording only the zonal data. However, it had provision to carry out hardware programming of up to twenty Bragg reflections at a time. The next development was a paper-tape controlled, fully automatic diffractometer (3DFAD), for recording three-dimensional data. A quarter-circle crystal orienter for this instrument was procured from abroad, but the rest of the instrument including the digital encoders was fabricated at BARC. This instrument became operational during 1967. A four-circle diffractometer, controlled by the TDC-312 computer (made by ECIL) was made during mid-seventies at BARC, with the software for data acquisition developed jointly by BARC and ECIL. Another four-circle diffractometer, with off-centered chi-circle, became operational at Dhruva reactor during early nineties, as a part of the National Facility for Neutron Beam Research (NFNBR), BARC. Keltron developed the instrument control system. Crystallographers at BARC again developed the data acquisition software. Recently, the aging Keltron system was replaced by a PC controlled system. All these developments met international standards of neutron diffractometry of those times.

IV.2.3 X-ray diffractometer development: Phase - I

Using the experience gained while developing the neutron diffractometers at BARC, the development of a four-circle single-crystal x-ray diffractometer was taken up during the late seventies. The instrument was fabricated in the Nuclear Physics Division workshop. The control system was based on the TDC-312 computer, made by ECIL. The x-ray generator and the detector were imported. Data from a few crystals were recorded, analyzed and published. The sphere of confusion was found to be about 50-100 microns, which, by the international standards prevailing at that time was not that bad. It was proposed to transfer the technology to ECIL, to make a more precise instrument. Before taking up this, ECIL wanted commitment that a sufficient number of user groups would buy the instruments produced. Since, this could not be assured, the technology transfer did not take place.

IV.2.4 Development of an X-ray generator

Because of the expertise in high voltage available at Variable Energy Cyclotron Centre (VEC) at Calcutta, X-ray generators were developed jointly by VEC and BARC in 1980. Half a dozen units were fabricated and given to various Divisions in BARC for testing. The X-ray tubes as well as the high voltage cables were imported. The specifications for voltage stability were as for the imported units. However these were not met. There were frequent failures in the units. Because the developers were located at Calcutta and the users at Bombay, the servicing was difficult to arrange. The technology transfer was not attempted. None of the units is operational now.

IV.2.5 X-ray diffractometer development: Phase - II

This was taken up for development as a part of a DST project. It was decided that two units would be fabricated. First unit was to be installed in BARC, and feedback from the first unit was to be used to improve the second

unit. This second unit was to be deployed in some other Organization, to be decided by DST. The 4-Circle Goniometer was fabricated with a sphere of confusion of 30 micron. The mechanical alignment was much better than the earlier Phase-I instrument. Positioning accuracy was 0.01 degree on ϕ -axis and 0.005 degree on other axes. $\chi - \phi$ perpendicularity was within 60 arc seconds. X-ray generator and detector were again procured from abroad. Control system hardware and software development was done in house. Peak search, and refinement of orientation matrix and cell constants as well as data collection within the specified limits of reciprocal space could be done correctly. First data were collected on a standard crystal (ammonium bi tartrate), and an R-factor of 3.5% was obtained, comparable to the published one. The data quality was good enough to solve the structure of 20-hydroxyecdysone by direct methods (Yadava et al, Natural Products Research 17 (2002) 103-108). Data were also collected on two more crystals. While refining these structures, it was noticed that the quality of data deteriorated as the experiment progressed. A close inspection of the instrument showed that there was a slight misalignment between the motor and the axis shaft of the phi-drive, which progressively increased as the experiment continued. A new diffractometer, incorporating this correction, and with symmetric mount of the chi-circle, is under fabrication. It is expected to be available for testing by the end of 2004.