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# ***Research and Training Equipment*.**

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# Glossary

AEB.............Atomic Energy Board, RSA

ASC.............Agricultural Science Council, RSA

ARIP............Academic Research Infrastructure Programme, USA

BEd .............Bachelor of Education

CALICO........Cape Libraries Consortium, RSA

CapeTech ....Cape Technikon, RSA

CEP.............Co-operative Equipment Project, RSA

CG...............Council for Geoscience, RSA

CHI ..............Computer Horizon Inc., RSA

CHSC...........Committee of Heads of Scientific Councils, RSA

CMC............Canadian Microelectronics Corporation

CPA.............Cape Provincial Administration, RSA

CUP ............Committee of University Principals

DACST.........Department of Arts, Culture, Science and Technology, RSA

DFG.............Deutsche Forshungsgemeinschaft, Germany

DNE ............Department of National Education, RSA

DoC.............Department of Commerce, USA

DoD.............Department of Defense, USA

DoE .............Department of Energy, USA

DTI ..............Department of Trade and Industry, RSA

ESATI...........Eastern Seaboard Association of Tertiary Institutions, RSA

FDA.............Food and Drugs Administration, USA

FRD.............Foundation for Research Development, RSA

FTE .............Full Time Equivalent

FY.................Financial Year

HartRAO ......Hartebeestpoort Radio Astronomy Observatory, RSA

HDTV ...........High Definition Television

HEIs ............Higher Education Institutions

HHS ............Department of Health and Human Services, USA

HMSO ..........Her Majesty's Stationery Office, UK

HSRC...........Human Sciences Research Council, RSA

IDF ..............Instrument Development Fund, UK

INFOLIT .......Information Literacy Development Project

MA................Master of Arts

MEd.............Master of Education

MINTEK .......Council of Mineral Technology, RSA

MRC............Medical Research Council, RSA

NAC ............National Accelerator Centre, RSA

NIH...............National Institutes of Health, USA

NIST............National Institute for Standards and Technology

NMR............Nuclear Magnetic Resonance

NRF.............National Research Foundation, RSA

NRTA ...........National Research and Technology Audit, RSA

NSB.............National Science Board, USA

NSF.............National Science Foundation, USA

OMB............Office of Management Budget, USA

PenTech ......Peninsula Technikon, RSA

R&D ............Research and Development

R&T.............Research and Training

RAU ............Rand Afrikaans University

SC................Science Council (sometimes referred to as Research Councils)

SIC ...............Standard Industrial Classification

RISK............Western Cape Science and Technology Project, RSA

S&T .............Science and Technology

SAAO...........South African Astronomical Observatory, RSA

SABS ...........South African Bureau of Standards, RSA

SESC ...........Science and Engineering Science council, UK

SME ............Small and Medium Enterprises

SPII .............Support Programme for Industrial Innovation, RSA

STW............Science and Technology Foundation, Netherlands

SUNI ...........Southern Universities Nuclear Institute

TFS .............Technikon Free State, RSA

THRIP ..........Technology and Human Resources for Industry Programme, RSA

TIPC............Tertiary Institutions Purchasing Consortium, RSA

UASC...........Upper Atmospheric Research Collaboratory

UCT.............University of Cape Town, RSA

UDW ...........University of Durban Westville, RSA

UFH.............University of Fort Hare, RSA

UGC ............University Grants Council, UK

UK................United Kingdom

UN................University of Natal, RSA

UNo.............University of the North

UNISA..........University of South Africa, RSA

UOFS...........University of Orange Free State, RSA

UP................University of Pretoria, RSA

UPUCH........University of Potchefstroom, RSA

US................United States

US................University of Stellenbosch, RSA

USA.............United States of America

USDA...........US Department of Agriculture, USA

UV................Ultraviolet

UW...............University of the Witwatersrand

UWC ............University of Western Cape, RSA

UZ ................University of Zululand, RSA

VRG .............Vice Rectors' Group

WCTIT..........Western Cape Tertiary Institutions Trust, RSA

# Contents

**GLOSSARY** .......... **i**

**CONTENTS** .......... **vi**

**LIST OF TABLES** .......... **viii**

**LIST OF FIGURES** .......... **ix**

**LIST OF BOXES** .......... **ix**

**EXECUTIVE SUMMARY** .......... **1**

**THE IMPORTANCE OF RESEARCH/TRAINING EQUIPMENT** .......... **9**

**OBJECTIVES, SCOPE AND APPROACH OF THE PROJECT** .......... **18**

**RESEARCH AND TRAINING EQUIPMENT IN SOUTH AFRICA** .......... **22**

Science councils (SCs) .......... 24

Universities .......... 32

Technikons, Museums and government departments .......... 40

**PUTTING EQUIPMENT ON THE NATIONAL AGENDA** .......... **43**

**IMPROVING THE UTILISATION OF AND INVESTMENT IN EQUIPMENT** .......... **49**

Market principles .......... 49

Benchmarking .......... 51

*Planning* .......... *52*

*Procurement* .......... *53*

Management of equipment through the life cycle .......... 53

Structural approaches .......... 54

Informational approaches .......... 58

Remote utilisation .......... 60

**OFF-THE-SHELF VERSUS CONSTRUCTED EQUIPMENT** .......... **64**

The Paul Instrument Fund .......... 70

Instrument Development Fund (IDF) .......... 71

INDUSTRIAL DEVELOPMENT WITHIN THE ACADEMIC RESEARCH INFRASTRUCTURE PROGRAMME (ARIP) ... 72

**DISCUSSION AND RECOMMENDATIONS ... 74**

*Planning ... 80*

*Procurement ... 80*

*Management of equipment through the life cycle ... 81*

**APPENDIX I ... 85**

QUESTIONNAIRE: SURVEY OF RESEARCH/TRAINING EQUIPMENT ... 85

**APPENDIX II ... 86**

USA LEGISLATION RELATED TO RESEARCH EQUIPMENT ... 86

**APPENIX III ... 89**

COPY OF THE PROPOSAL TO FORD FOUNDATION TO SUPPORT REGIONAL COOPERATION ... 89

**APPENDIX IV ... 95**

EASTERN SEABOARD ASSOCIATION OF TERTIARY INSTITUTIONS (ESATI) - BACKGROUND INFORMATION AND STATEMENT OF INTENT ... 95

# List of Tables

**TABLE 1:** INDUSTRIAL SECTORS EXPERIENCING THE HIGHEST AND LOWEST GROWTH IN SHIPMENTS, 1972–88 (1988 SHIPMENTS EXPRESSED AS A PER CENTAGE OF 1972 SHIPMENTS) (1982 $) ..................... 12

**TABLE 2:** EMERGING TECHNOLOGIES IDENTIFIED BY THE US DEPARTMENT OF COMMERCE ........................... 14

**TABLE 3:** AGE PROFILE OF EQUIPMENT IN SOUTH AFRICAN HEIS, SCS AND GOVERNMENT DEPARTMENTS... 23

**TABLE 4:** COUNTRY OF MANUFACTURE OF EQUIPMENT CURRENTLY AVAILABLE AT SOUTH AFRICAN SCS. ... 27

**TABLE 5:** REPLACEMENT VALUE PROFILE OF EQUIPMENT AT SOUTH AFRICAN SCS ........................................ 27

**TABLE 6:** AGE PROFILE OF EQUIPMENT AT SOUTH AFRICAN SCS ........................................................................ 28

**TABLE 7:** UTLISATION OF EQUIPMENT, BY ACTIVITY ................................................................................. 30

**TABLE 8:** NUMBER OF USERS OF THE EQUIPMENT AT SCS ........................................................................ 30

**TABLE 9:** UTILISATION OF EQUIPMENT AT SCS, BY DISCIPLINE ........................................................................ 31

**TABLE 10:** UTILISATION OF EQUIPMENT AT SCS, BY SOCIO-ECONOMIC OBJECTIVES ........................................ 31

**TABLE 11:** COUNTRY OF MANUFACTURE OF EQUIPMENT AT SOUTH AFRICAN UNIVERSITIES . ......................... 35

**TABLE 12:** REPLACEMENT VALUE PROFILE OF EQUIPMENT AT SOUTH AFRICAN UNIVERSITIES ..................... 35

**TABLE 13:** AGE PROFILE OF EQUIPMENT AT SOUTH AFRICAN UNIVERSITIES ..................................................... 36

**TABLE 14:** USAGE OF EQUIPMENT, BY ACTIVITY ........................................................................................ 38

**TABLE 15:** NUMBER OF USERS OF EQUIPMENT AT SOUTH AFRICAN UNIVERSITIES........................................... 38

**TABLE 16:** UTILISATION OF EQUIPMENT AT SOUTH AFRICAN UNIVERSITIES, BY DISCIPLINE ............................ 39

**TABLE 17:** UTILISATION OF EQUIPMENT AT SOUTH AFRICAN UNIVERSITIES, BY SOCIO-ECONOMIC OBJECTIVES ........................................................................................................................ 39

**TABLE 18:** COUNTRY OF MANUFACTURE OF EQUIPMENT CURRENTLY AVAILABLE AT SOUTH AFRICAN TECHNIKONS, MUSEUMS AND GOVERNMENT DEPARTMENTS ........................................................... 41

**TABLE 19:** REPLACEMENT VALUE PROFILE OF EQUIPMENT AT SOUTH AFRICAN MUSEUMS, TECHNIKONS AND GOVERNMENT DEPARTMENTS........................................................................................................ 42

**TABLE 20:** BASIC TECHNOLOGICAL TRAJECTORIES OF DIFFERENT TYPES OF INDUSTRIAL SECTORS............. 67

## List of figures

*FIGURE 1:* **DISTRIBUTION OF R&T EQUIPMENT IN SOUTH AFRICA** ........................................................................... 3

*FIGURE 2:* **EQUIPMENT LIFE-CYCLE** ....................................................................................................................... 7

*FIGURE 3:* **DISTRIBUTION OF R&T EQUIPMENT IN SOUTH AFRICA** ......................................................................... 23

*FIGURE 4:* **EQUIPMENT LIFE-CYCLE** ..................................................................................................................... 51

## List of boxes

*BOX 1:* **MAJOR EQUIPMENT AWARDS FOR BIOMEDICAL RESEARCH IN SOUTH AFRICA** .................................... 11

*BOX 2:* **INSTRUMENTAITON IN THE HEART OF NEW TECHNOLOGIES AND MONEY** ............................................. 13

*BOX 3:* **EXPENSIVE CAPITAL EQUIPMENT POSITION AT NATAL UNIVERSITY** ....................................................... 32

*BOX 4:* **RESEARCH EQUIPMENT - A STRATEGIC VIEW** ............................................................................................ 76

# Executive Summary

This investigation, which aims to collect, organise and analyse data related to training and research equipment in the country, is part of the National Research and Technology Audit (NRTA). The exercise has two main objectives: firstly, to collect data for inclusion in the NRTA database and, secondly, to cast light on policy and management issues related to research and training (R&T) equipment at a national level in South Africa.

We suggest that research and training equipment constitute a critical part of the national infrastructure for a number of reasons. Scientific instrumentation is of importance to research, economic growth and human resources development.

Modern, well-maintained equipment is a prerequisite for high quality research. Highly cited papers, Nobel prizes and lists of critical technologies and priorities internationally testify to that.

Equipment has considerable economic impact. It constitutes the most basic common component of the entire manufacturing sector. International studies indicate that advances in instrumentation play an increasingly central role in innovation and that the instrumentation-based sectors exhibit higher growth rates than low instrumentation-intensive fields.

The use of equipment in the educational sector is a key success factor in nurturing curiosity, developing skills for inquiry and providing the necessary experience for the needs of modern industry and commerce.

Furthermore, we argue that a number of factors make pluralistic, hands-off policies inappropriate for the field of R&T equipment infrastructure.

The main issues are:

? Administrators of organisations financed primarily by general institutional grants (which cover both teaching and research, for example) are usually unable to maintain a proper balance between spending on salaries and investing in equipment. This problem is particularly acute during periods of sinking or level funding.

? Trends towards the broader use of generic instrumentation (for example, NMR equipment) across different fields have resulted in considerable scope for the more efficient deployment of resources through common-use facilities or equipment sharing by bodies such as academic departments and faculties and science councils.

? Funding agencies do not always place the appropriate emphasis on equipment support. Short-term priorities based on quick results and political considerations almost always take precedence over meeting long-term infrastructural needs. Discipline-based committees make it difficult to establish and support equipment funding programmes that are not associated with particular research disciplines.

? The increasingly high cost of equipment makes institutional collaboration and government involvement the only feasible approach to the development and maintenance of the equipment infrastructure.

? The basic technological trajectories of scientific instrumentation companies differ considerably from those of other sectors, with the interface between academic institutions and instrumentation companies growing in importance. These particularities make government intervention of paramount importance.

Equipment is still handled on a pluralistic basis in South Africa, despite the fact that this is at odds with theoretical evidence and international practice. There are clearly adverse consequences.

The main findings of the investigation are:

? There are 2 168 items of equipment in the database with a total replacement value of R1.79 billion.

? Most of the equipment is to be found at the science councils (SCs), which declared that they own 966 pieces of equipment valued at R1.12 billion.

? Universities declared 884 items of equipment with a replacement value of R376 million.

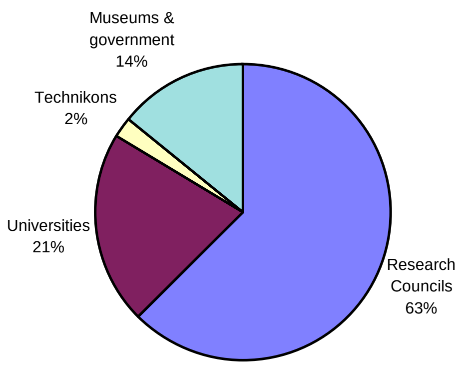
? Technikons are the third largest equipment-owning group. They declared that they have 202 items of equipment with a replacement value of R40 million.

? Museums and government departments declared 118 pieces of equipment with a value of R256 million.

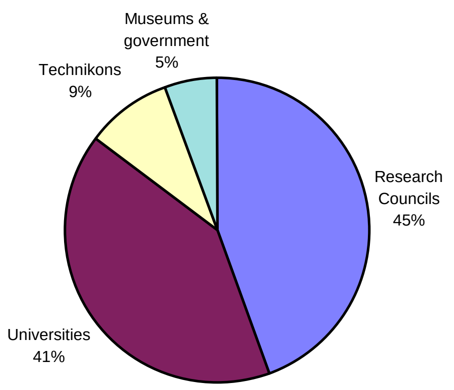
? Two pieces of equipment alone are valued at more than R100 million each. These are the National Accelerator Centre (NAC) with a declared replacement value of R500 million and the CSIR's medium-speed wind-tunnel with a replacement value of R125 million.

***Figure 1:*** Distribution of R&T Equipment in South Africa

**Number of items of equipment**




**Replacement value**



? The technical sophistication of the stock of equipment appears to be below international standards. The results indicate that only 290 items of equipment, with a replacement value of R174 million, can be characterised as state-of-the-art. They represent only 13 per cent of the stock of equipment in terms of number and 9.7 per cent in terms of value. In comparison, a recent investigation in the United Kingdom (UK) identified that nearly one-fifth of the total stock of instruments is considered to be state-of-the-art. Furthermore, the results of the British survey reveal that British researchers believe that research groups at leading universities in the UK are in most cases more constrained in terms of equipment than their counterparts in the United States (US) and continental Europe.

The lack of sophistication of the South African stock of equipment is further corroborated by its age profile, which indicates that only 31 per cent of the equipment was acquired in the last five years, compared with 40 per cent of research equipment abroad.

? The financial requirements for supporting the stock of equipment appear to be substantial. Survey respondents indicated that equipment valued at R512 million will have to be replaced in the next five years (until 2002). A further R224 million is required to upgrade the equipment infrastructure to meet the research and training needs of institutions. The latter amount increased to R429 million when respondents were asked to identify the two most important instruments on their wish list that they would buy if money were available.

? Equipment policy and management in the country appear to differ considerably from best international practice. Some institutions follow normal accounting practices in the depreciation of their equipment, others attempt to keep equipment budgets separate from budgets for other needs, while the regional cooperative initiatives provide incentives for the development of some form of equipment recording. None of the institutions surveyed was found to have a coherent approach to the planning, procurement and management of equipment throughout its life-cycle. More importantly, however, is that the institutions receive no guidance on the appropriate management of teaching and research equipment.

The sectors are all left to support their equipment needs on their own. South African universities receive only 11 per cent of their equipment needs from government support (science councils) while in the US and UK, the respective figures are in the region of 50 per cent.

On that basis, we make the following recommendations:

1. The Department of Arts, Culture, Science and Technology (DACST), within its mandate to coordinate the scientific and technological system, should establish an inter-departmental committee on 'Critical Scientific and Technological Infrastructures'.

   The mandate of the committee should be to investigate and make recommendations on policy and programmes affecting 'critical scientific and technological (S&T) infrastructures' such as research and training equipment, scientific and technological telecommunications, and research and development (R&D) management.

   The committee should consider, among others things, the viability of introducing:

   ? the funding of 'critical S&T infrastructures' as a separate line item in the governmental budget [Expenditure defrayed from the National Revenue Account]
   ? approaches that promote closer collaboration on aspects of critical S&T infrastructure among organisations reporting to different government departments (for instance, academic institutions, science councils and parastatals).

2. The National Research Foundation (NRF) – to be established – should institutionalise the support of research and training equipment by establishing an appropriate, dedicated directorate/division. The division should be funded by dedicated (earmarked) funds, by top-slicing the budget of the other directorates and by raising funds from local and international donors.

   The NRF should establish appropriate 'competitive grants'/funding mechanisms that promote :

   ? interaction between academia and industry for the development and construction of new or improved equipment

   ? the maintenance and augmentation of the R&T equipment infrastructure

   ? the development of the necessary infrastructure at institutions where it is lacking or deficient

   ? the development of a programme promoting the remote utilisation of equipment, which should be considered as an urgent priority in view of its possible impact across all other programmes

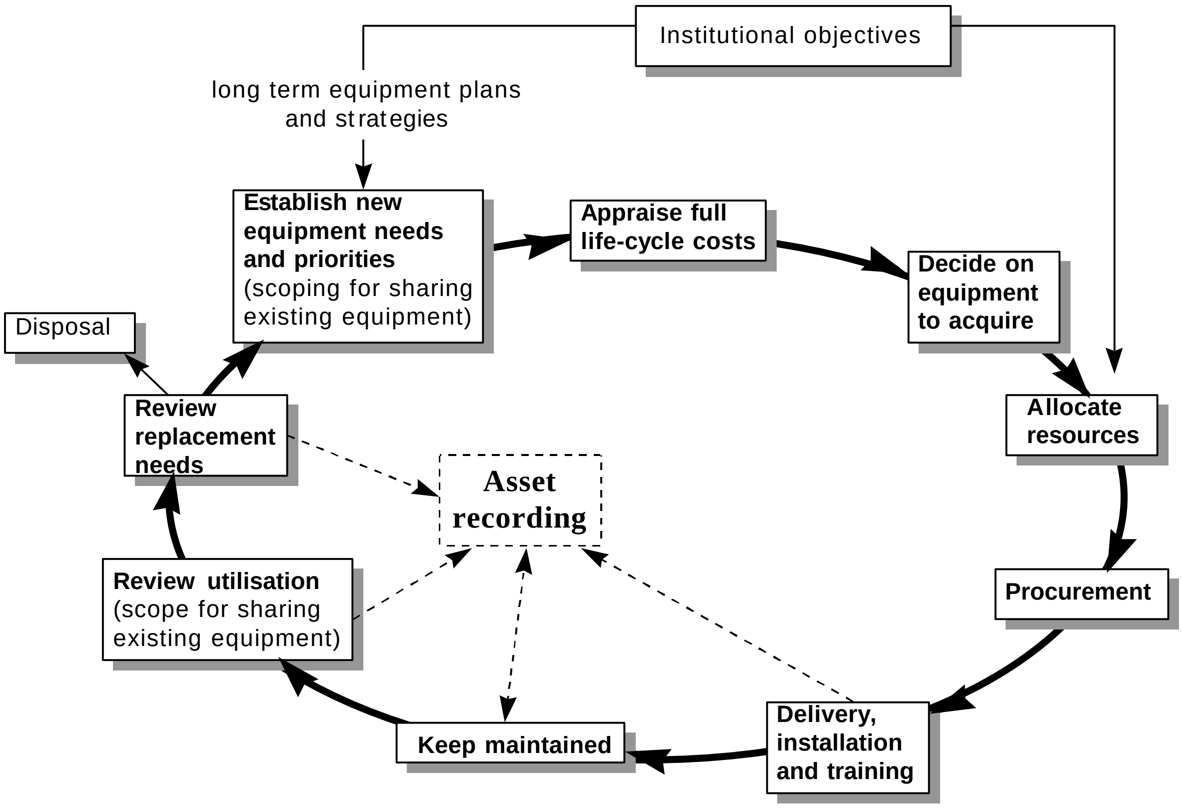
   It is suggested that separate programmes should be established to pursue the various objectives and should operate according to international norms in order to optimise effectiveness and efficiency.

3. The Department of Education's funding formula for academic institutions (which is currently under investigation) should make R&T equipment an explicit component of the formula. Furthermore, adequate funds should be earmarked for equipment for at least the next five years in order to facilitate the necessary replacement and upgrading of R&T equipment.

4. Best international practice should be adopted by all relevant South African organisation in their management of equipment and should also be used for benchmarking. (Fig. 2). Benchmarking is a tool for monitoring progress on an ongoing basis and assessing the South African situation in the light of constantly

improving best practice world-wide. It goes beyond competitive analysis by providing an understanding of the process and skills that contribute to superior performance management of equipment over its life-cycle. The Committee of Heads of Scientific Councils (CHSC), the Committee of University Principals (CUP) and the NRF could play pivotal roles in investigating best international practice and introducing to their institutions the concepts of management over the life-cycle of the equipment. Linking the introduction of the concepts to additional funding for equipment (from the NRF, for example) would serve to facilitate and speed up the implementation of the approach.

***Figure 2:*** Equipment life-cycle




A number of issues may have been excluded from the scope of this study and may merit further investigation. However, the results of this investigation could be complemented by:

? investigating the availability and condition of equipment (particularly in the business environment) that could be used for research and training but which is currently used for other purposes

? investigating the instrumentation industry in the country

? enlarging the NRTA database to include equipment in the major research-performing organisations in the business sector, especially the parastatals and business-funded research laboratories

? considering, as a future option for South Africa, that equipment surveys be conducted independently of surveys of facilities, as is the practice of the US National Science Foundation (NSF)

The structure of the report is as follows:

In Chapter 1, 'The importance of research/training equipment', the case is made that instrumentation forms a critical part of S&T infrastructure. In Chapter 2, 'Objectives, scope and approach of the project', we briefly provide the background to and framework of the investigation. In Chapter 3, 'Research and training equipment in South Africa', we highlight the main findings of the survey. Information is provided for three groups – science councils; universities; and technikons, museums and government departments as a single group. This level of aggregation has been chosen in order to assist in the development of a national policy and to avoid deviating from the issues of importance.

Chapter 4, 'Putting equipment on the national agenda', outlines and contrasts South African policy on R&T equipment with that of the US. The US has been chosen as a benchmarking country because of its pluralistic approach to research management, an approach that was used in South Africa until recently. In Chapter 5, 'Improving the utilisation of and investment in equipment' a number of international approaches are described, and in Chapter 6, 'Off-the-shelf versus constructed equipment', we raise the importance of developing supporting mechanisms to enhance the interface between academia and the instrumentation industry.

The report ends with a chapter entitled 'Discussion and recommendations'.

## The importance of research/training equipment

This investigation, which aims to collect, organise and analyse data related to training and research equipment in the country, is part of the National Research and Technology Audit (NRTA). The exercise has two main objectives: firstly, to collect data for inclusion in the NRTA database and, secondly, to cast light on policy and management issues related to research and training (R&T) equipment at a national level in South Africa.

Scientific instrumentation is important because of its contribution to research, economic growth and human resources development.[1]

Scientific instruments are the tools used to discover new knowledge. Throughout the history of science, revolutionary ideas would have faded and disappeared if they had not been supported by appropriate instrumentation. Without the telescope, Galileo could only have guessed at the nature of the solar system. Without the microscope, Van Leeuwenhoek could only have speculated on the nature of microbial life.

The role of instrumentation in research is pervasive. A study conducted for the NSF, by Computer Horizon Inc. (CHI) Research, entitled *Analysis of the Contribution of Scientific Instrumentation to Highly Cited Research*, investigated the role of instrumentation by examining highly cited research papers. The study found that "the fields of botany and organic chemistry were highly instrumentation dependent with nearly 100 per cent of the papers describing research in which instrumentation played a necessary role". In the fields of solid state physics and electrical engineering, the findings pointed to "more diversity in the role of instrumentation

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1 CHI. 1985. *Analysis of the Contribution of Scientific Instrumentation to Highly Cited Research*. As quoted in *Trends in the Instrument Intensity of Scientific Research at US Colleges and Universities*. Proposal to NSF by Abt Associates.

and in the actual instruments mentioned. In solid state physics, the reported research depended directly on necessary instrumentation in 55 per cent of the papers". The pervasive dependence on instrumentation across a great many scientific fields is exemplified in the study's finding that only 9 per cent of papers across the five fields examined were judged to require no instrumentation – with computers not regarded as instrumentation in some papers. This study strongly indicates that the scientific process is critically dependent on instrumentation.

The importance of instrumentation to the advancement of science is also highlighted by the number of Nobel prizes awarded for the development of novel instruments and new experimental techniques, such as the aperture synthesis radio-telescope, phase-contrast microscopy and nuclear magnetic resonance. Between 1901 and 1990, 15 Nobel prizes were awarded for the development of new instruments and a further eight for new experimental techniques. This means that more than a quarter of the awards were instrument related.

The need for instrumentation is not restricted to disciplines that are traditionally dependent on expensive instrumentation – big science and small instrumentation-intensive fields like analytical chemistry and engineering. Disciplines with historically low instrumentation needs (like archaeology and cognitive psychology) have become increasingly dependent on instrumentation. Biomolecular archaeology, dendrochronology research and resistivity surveying are some of the newly emerging disciplines and techniques with high instrumentation needs within archaeology, while player-based simulations provide new insights in economics, sociology, marketing and other social science disciplines.

International foundations recognise the importance of equipment, as Box 1 indicates.

Indeed, instrumentation appears to be a fundamental element in scientific research, with new horizons opening through the use of computers and the greater analytical capability that is possible through coupling two or more instrumental components.

Scientific instrumentation has considerable economic impact. Growth over the last 20 years has been fastest in high-technology sectors such as scientific instruments, as indicated by Table 1, which shows the US industrial sectors with the highest and lowest growth as reported by the US Department of Commerce. There is moreover the broader strategic consideration that a strong basic competence in generic instrumentation technologies will be a key asset in future attempts to capture the potential economic benefits arising from innovation in other manufacturing sectors.

**Box 1: *Major Equipment Awards for Biomedical Research in South Africa***

The Wellcome Trust introduced a scheme in 1996 to consider requests from South African biomedical researchers, working in academic institutions or science councils, for items of equipment costing in excess of R300 000.

This scheme was developed to address the perceived lack of such major items of equipment and the difficulties experienced by researchers in obtaining adequate funding from local sources.

All requests for equipment must come from individual scientists, and applications are judged on the strength of the case for the research project or projects for which the equipment will be used. Collaborative use is encouraged, both within and between institutions, and the Trust is prepared to consider applications in cases when a contribution to the cost has already been committed by local sources. All applications are judged by expert peer review, and funding recommendations are made by one of the Trust's specialist advisory committees.

This scheme is part of a Trust programme designed to build research capacity in the biomedical sciences in developing and restructuring countries. This programme has a budget of some £10m sterling for the current year. No specific allocation has been made to this particular equipment scheme, nor for any one country. It is the Trust's policy, in all its funding activities, to enable individual research workers to pursue their work to the highest standards possible and thereby to encourage the development of scientific excellence.

Thus far, four applications have been considered but only one award made. One of the unsuccessful applications has been re-submitted in a modified form and several other applications are in the pipeline.

For any award made, the Trust is always prepared to consider providing funds to cover the cost of the necessary equipment, as well as consumable expenses. Such awards generally cover the cost of smaller items of equipment.

***Personal communication***

***Table 1:*** Industrial sectors experiencing the highest and lowest growth in shipments, 1972–88 (1988 shipments expressed as a percentage of 1972 shipments) (1982 $)

| SIC | Top 10 sectors | Growth (%) | SIC | Bottom 10 sectors | Growth (%) |
|---|---|---|---|---|---|
| 3573 | Computing equipment* | 8823 | 3211 | Turbine generator sets | 17 |
| 3674 | Semiconductor devices* | 6072 | 2793 | Photo-engraving | 23 |
| 3832 | Optical devices/lenses | 940 | 2121 | Cigars | 35 |
| 3593 | X-ray apparatus | 537 | 2386 | Leather/lined clothing | 38 |
| 2795 | Lithographic services | 394 | 3743 | Railroad equipment | 42 |
| 2831 | Biological products | 387 | 2661 | Building paper/board mills | 42 |
| 3678 | Electronic connectors | 356 | 3333 | Primary zinc | 44 |
| 2833 | Medicinals & botanicals | 347 | 3552 | Textile machinery | 48 |
| 3842 | Surgical appliances | 337 | 3021 | Rubber/plastic foot/wear | 50 |
| 3841 | Surgical & medical instruments | 327 | 2517 | Wood TV/radio cabinet | 50 |

*Source:* DoC. 1990. *Emerging technologies: A Survey of Technical and Economic Opportunities*. Washington DC. US Department of Commerce.

* The growth rates for these industrial sectors have been adjusted for technical change as well as price change.

The importance of instrumentation is clearly apparent from the list of 12 emerging technologies identified by a US Department of Commerce study of future opportunities for R&D (Table 2). Several are core technologies in the scientific instrumentation sector (for instance, digital imaging technology, sensor technology and medical devices and diagnostics), while instrumentation is specified as a 'major technology element' in many others (for instance, X-ray lithography for advanced semiconductor device production).

The findings from a survey of 4 000 British innovations by Pavitt *et al.* [2] are also significant. They show that advances in instrumentation have played an increasingly central role in innovation by firms over the period 1945–83, principally in the chemicals, metals, mechanical engineering and electrical/electronics sectors. Moreover, figures on patents granted in the US indicate that the category 'professional and scientific instruments' has accounted for a growing proportion of the overall total, rising from 11 per cent in 1978 to 13.6 per cent in 1988.[3]

***Box 2: Instrumentation in the heart of new technologies and money***

By Michael Gianturco, *Forbes*, 7 April, 1997

Invest in a biotech company with one good drug and you have a single, risky bet. Invest in a company with a good method for finding drugs, and you have a potentially endless series of bets. A single Food & Drugs Administration [FDA] rejection does not sink the company.

Agouron Pharmaceutical in California, USA won FDA approval on March 14, for Viracept, a protease inhibitor that attacks the AIDS virus. Viracept seems designed to be a successful first product, but Agouron is not a one-product company. Its method of discovery is the intensive use of X-ray crystallography and computers to determine protein structure. The AIDS virus' protease, an enzyme that the virus requires to mature and reproduce, is a protein. By doping out the three-dimensional structure of the viral protease, Agouron was able to engineer a drug that would thwart that protein. Other drug companies can do X-ray crystallography, but Agouron has made it a centrepiece of its research effort. A research partner in Viracept is Japan Tobacco, which contributed more than $50 million to the drug's development.

AIDS isn't the only virus that can be attacked with enzyme inhibitors. Agouron's scientists have homed in on a protein that cold viruses need in order to reproduce. They have succeeded in formulating a drug that inhibits this protein. FDA approvals are difficult to forecast, but the cold drug should go into clinical trials in 1998 and might be marketed as early as 1999. It would initially be a prescription drug for patients with respiratory conditions, for whom a cold is a real hazard.

2 Pavitt K, Robson M and Towsend J. 1989. 'Technological Accumulation, Diversification and Organisations in UK Companies'. *Management Science,* **35**(1).

3 NSB. 1989. *Science and Engineering Indicators 1989*. National Science Board. Washington DC. USA.

| *Table 2:* Emerging Technologies Identified by the US Department of Commerce | |
|---|---|
| **Emerging technologies** | **Major technology elements** |
| **Materials** | |
| Advanced materials | Structural and functional ceramics, ceramic and metal matrix composites, int polymers, surface-modified materials, diamond thin films, membranes, biom |
| Superconductors | High-temperature ceramic conductors, advanced low-temperature conducto |
| **Electronics and information systems** | |
| Advanced semiconductor devices | Silicon, compound semiconductors (GaAs), ULSI, memory chips, X-ray litho |
| Digital imaging technology | High definition systems, HDTV, large displays, data compression, image pro |
| High-density data storage | High-density magnetic storage, magneto-optical storage |
| High-performance computing | Modular/transportable software, numerical simulation, neural networks |
| Opto-electronics | Integrated optical circuitry, optical fibres, optical computing, solid-state lasers |
| **Manufacturing systems** | |
| Artificial intelligence | Intelligent machines, intelligent processing of materials and chemicals, expe |
| Flexible computer-integrated manufacturing | CAD, CAE, CALS, CAM, CIM, FMS, PDES, integrated control architectures, |
| Sensor technology | Active/passive sensors, feedback and process control, non-destructive evalu monitoring and control |
| **Life sciences applications** | |
| Biotechnology | Bioprocessing, drug design, genetic engineering, bioelectronics |
| Medical devices and diagnostics | Cellular-level sensors, medical imaging, in-vitro and in-vivo analysis, targete |

Source:  DoC. 1990. *Emerging Technologies: A Survey of Technological and Economic Opportunities*. US Department o f Comı

As far as human resources development is concerned, scientific instrumentation is a key parameter. The NSF[4] states that "Science and engineering education at all levels involves hands-on experience. Developing the human potential in all segments of our society means nurturing curiosity and developing skills for inquiry. From grade school to graduate school, interest is awakened and learning is enhanced through experience with real instruments. Each participant in a learning community benefits from sharing experiences and data over computer networks such as the National Information Infrastructure – the 'information superhighway'."

In another point they write:

> *Scientific instruments can be catalysts for combining research and education. In many cases, the first chance that students get to actually do scientific research is during their undergraduate years. For most students, this research will take place in a library, but an increasing number of forward-looking colleges and universities are enlisting undergraduates into research teams traditionally limited to faculty, post-doctoral fellows, and graduate students. Meaningful research involvement adds depth and impact to the undergraduate experience, regardless of whether the student goes on to a career in science and engineering. Genuine research experience makes learning an active pursuit that combines instruction and inquiry. It helps create a citizenry that is scientifically and technologically literate and provides opportunities to advance to higher levels of scientific training. Research experiences can also validate an individual's curiosity and promote the habit of lifelong learning.*

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4 NSF. 1996. *Research Instrumentation – Enabling the Discovery Process*. National Science Foundation. Washington DC. USA.

Similarly, the National Audit Office[5] in the UK states:

> *Students need practical experience with up-to-date equipment so that they are qualified to meet the needs of industry and commerce. Without a sound base of teaching equipment institutions could fail to attract students and hence lose income from Funding Council grants and tuition fees.*

5 National Audit Office. 1996. *The Management of Teaching and Research Equipment in Scottish Higher Education Institutions*. Report by the Comptroller and Auditor General. HMSO. London.

## Objectives scope and approach of the project

The objectives of the survey of research and training equipment in South Africa are to create a related database and analyse the collected information in order to cast light upon the current state, stock and needs for equipment and associated policy and management issues.

The NRTA management invited members of the higher education sector (universities and technikons), science councils, government research establishments and major businesses to participate in the survey.

The criterion for inclusion was the availability of a piece of equipment used wholly or partially for research and/or training. It was recommended that a set of equipment items connected together and used as a working whole be regarded as a single piece of equipment. Free-standing computers were excluded, but computers dedicated to supporting other instruments were included.

Only equipment with a replacement value of more than R80 000 was included in the survey. This level was selected in order to make the collection of the data feasible in terms of cost. It was decided not to impose a ceiling value on the equipment included in the study.

The higher education institutions, science councils and other government research establishments were approached comprehensively (using a census approach), but it was decided that the survey of businesses would be conducted on a sampling basis by another consultant. The business sector survey covered only research equipment valued at R100 000 or more. Data on a total of 104 pieces of equipment were collected from 21 firms, which represents approximately five items of equipment per firm.

While the small number of firms providing information on the 104 items of equipment might not lend itself to rigorous analysis, the situation, nonetheless, invokes a number of questions. For example, is the low response rate indicative of an unwillingness by firms to disclose their equipment infrastructure? Alternatively, are the figures indicative of the existence in the business sector of only a small number of items of equipment valued at over R100 000? Equally, is the low response a reflection on the methodology used in collecting the information?

In short, methodological and other issues do not facilitate the drawing of conclusions concerning the total equipment-using sector, and we address issues of importance for the business sector in our recommendations section.

A questionnaire (Appendix I) was developed, piloted with a number of institutions, approved by the NRTA management and distributed to higher education institutions, science councils and government departments.

The questionnaire was divided into two parts. Part A was concerned with the *adequacy and need for research/training eq uipment*. Participants were asked to complete one questionnaire for each reporting unit (such as a university departments). The questions concerned the overall capability of the equipment in the department/unit for research and teaching; the availability of resources and expertise related to equipment; the types of equipment required for adequate performance by the department/unit, as well as the associated cost; and possible agreements with manufacturers/suppliers.

Part B was intended to enable the compilation of an *inventory of the available items of equipment,* and respondents were requested to complete one questionnaire for each piece of equipment or set of items of equipment connected together and used as a working whole. The questions were aimed to obtain information on:

? the identification and technical capabilities of the equipment

? the various facets of utilisation

? the means and sources of acquisition

- the age and anticipated remaining useful life of the equipment
- the availability of the equipment for use by external institutions

The questionnaires were sent to the identified institutions after informational visits by the NRTA management. Each institution was dealt with individually. Certain institutions requested that we approach their heads of departments/units directly, while others requested that we work through their administration. At some, the executive of the institution took responsibility for collecting the information data and sending it to us, while at others, the responsibility was delegated to a coordinator who dealt directly with the survey team. Some institutions asked us to provide them with the number of questionnaires they estimated they might need (for example, one for each head of department and one for each item of equipment), while others requested a single questionnaire which they duplicated and distributed accordingly. The University of Stellenbosch (US) sent us their data directly from a newly developed database.

Despite the variability of the approaches used for the distribution of the questionnaires, 2 700 were distributed centrally by the survey team.

A number of institutions were visited in order to improve response rates and gain first-hand experience of issues related to research equipment. The broad issues for discussion at such meetings included:

- positioning the survey as part of the NRTA
- ensuring the maximum response to the questionnaires and capturing meaningful information for the survey
- establishing the importance of research and training equipment in the hierarchy of strategic needs of the institution
- optimising national access to research and training equipment, including the role of government

The institutions visited were:

| Institutions | Participants |
|---|---|
| Agricultural Research Council (ARC) | Dr J Terblanche and the rest of the executive |
| Human Sciences Research Council (HSSC) | Dr J Beukes |
| Medical Research Council (MRC) | Dr JA Louw |
| Council for Geoscience (CG) | Dr C Frick |
| Foundation for Research Development (FRD) | Dr G von Gruenewaldt<br>Dr R Stobie<br>Professor J Sharpey-Schafer and six programme managers |
| Council for Mineral Technology (Mintek) | Dr MA Ford |
| CSIR | Dr A Patterson |
| Department of Trade and Industry (DTI) | Mr A Hirsch |
| Department of Health | Dr M Jeenah |
| Department of Arts, Culture, Science and Technology (DACST) | Dr R Adam |
| University Cape Town (UCT) | Cyril O'Connor and a number of deans and faculty members |
| University of Stellenbosch (US) | F Hahne and a number of deans and faculty members |
| University of the Western Cape (UWC) | Professor R Christie |
| Peninsula Technikon (PenTech) | Dr Fransman and all heads of departments |
| South African Museum | Dr M Cluver and Dr B Hulley |
| University of Natal (UN) | Professors S Drewes and Savage |
| Rhodes University, JLB Smith Institute of Ichthyology | Professor H Parolis and a number of staff members |
| University of Zululand (UZ) | Professor B Spoelstra |
| University of Durban-Westville (UDW) | Professor R Bharuthram |
| University of Fort Hare (UFH) | Professor J Brand |
| University of the Free State (UFS) | Mr WS Malherbe |
| National Museum - Bloemfontein | Drs DC Engelbrecht and Lynch |
| Technikon Free State (TFS) | Professor BJ Frey |
| Potchefstroom University (UPuch) | Professor A Viljoen and a number of deans and faculty members |
| University North (UNo) | Professor N Steyn |
| University of South Africa (UNISA) | Dr P Becker |
| University of Pretoria (UP) | Professor J van Zyl and a number of deans and faculty members |
| Pretoria Technikon | Dr P van Eldik and a number of deans and faculty members |
| Transvaal Museum | Dr N Rautenbach |
| University of the Witwatersrand (UW) | Professor F Sellschop |
| Rand Afrikaans University (RAU) | Professor P van Staden |
| Medical University of Southern Africa (MEDUNSA) | Mr C Berndt |

In this section we analyse of the major issues that emerged from the information collected.

A number of different levels of detail could be chosen for the analysis, and the various stakeholders will obviously have differing needs and perspectives.

*We have tried to focus on issues of national importance and on leverage points.*

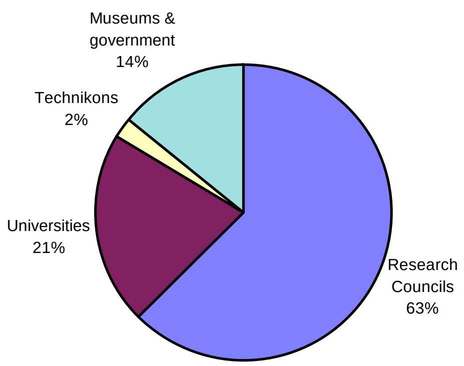
We describe briefly the broad picture emerging from the investigation and then outline in more detail the findings related to major groups – namely, science councils (SCs); universities; and technikons, museums and government departments as a single group.

The investigation identified 2 168 items of equipment with a total replacement value of R1 792 039 561.

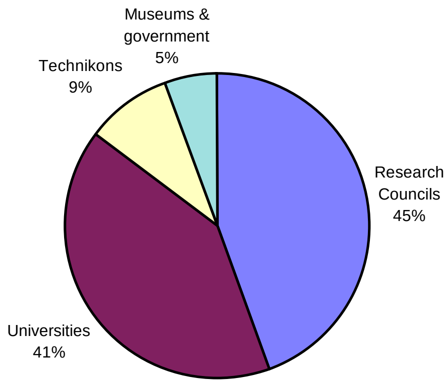
Most of the equipment was found at the SCs, which declared that they own 966 items of equipment valued at R1 120 276 435. Universities declared 884 items of equipment with a replacement value of R376 237 076. Technikons are the third major equipment-owning group. They declared that they have 202 items of equipment with a replacement value of R40 218 500. Museums and government departments declared that they own 118 pieces of equipment with a value of R256 million (Fig. 3).

***Figure 3:*** Distribution of R&T Equipment in South Africa

**Number of items of equipment**




**Replacement value**




Items of equipment regarded as state-of-the-art amounted to 290, with a replacement value of R174 million. This represents only 13.4 per cent, in terms of value, of the total stock of equipment.

Respondents declared that they need R224 million in order to acquire sufficient equipment for their units to fulfil their mission. However, their wish lists included equipment amounting to R429 million (even though each responding unit was limited to mentioning only two items of equipment).

The age profile of all the equipment in the database is outlined in Table 3.

***Table 3:*** Age profile of equipment in South African HEIs, SCs and government departments

| **Year of purchase** | **Number of items of equipment** | **Replacement value** (R million) |
|---|---|---|
| 1991–96 | 838 | 895.4 |
| 1986–90 | 432 | 322.1 |
| 1981–85 | 273 | 211.1 |
| 1976–80 | 175 | 166.2 |
| before 1975 | 183 | 115.8 |

The respondents indicated that equipment valued at R512 million will have to be replaced in the next five years (until 2002). This is a substantial amount for South African circumstances and presents a number of opportunities (for example, for procurement) and threats to the scientific infrastructure. The largest suppliers of equipment to South Africa are, in order of importance, the USA, Germany, England and Japan.

The current stock of equipment is utilised for an estimated 29.68 hours per week. The difference in average utilisation times between science councils (31.8 hours per week) and universities (27.7 hours per week) is not significant, even though we were expecting that the different *modus operandi* of the two types of institutions would affect the utilisation rates of their equipment.

***Science councils (SCs)***

The family of the science councils includes the following eight institutions:

?? Agricultural Research Council (ARC)

?? Council for Geoscience (CG)

?? CSIR

?? Foundation for Research Development (FRD)

?? Human Sciences Research Council (HSRC)

?? Medical Research Council (MRC)

?? Mintek (Council for Mineral Technology)

?? South African Bureau of Standards (SABS)

The FRD administers three national facilities – the National Accelerator Centre (NAC), the South African Astronomical Observatory (SAAO) and the Hartebeestpoort Radio-Astronomy Observatory (HartRAO). The SABS was not included in the investigation, as it does not undertake either research or training.

The SCs were among the best respondents in this survey, with their executives taking responsibility for the collection of data. Consequently, the data are considered to be comprehensive (100 per cent coverage). As a group, the SCs indicated that identification of training needs and appropriate training of staff are more important issues than equipment and that they manage their stock of equipment by depreciating it and reserving funds for replacement purposes. The identification of human resources as a higher priority than equipment is common among the other participants in the survey. Depreciation of equipment, however, is a practice that is not followed by the other sectors surveyed. None of the SCs indicated that they had an equipment policy manual covering procurement, acquisition and/or maintenance.

The majority of the SC respondents (76 per cent) ranked the overall capability of their equipment to fulfil their responsibilities as adequate or better. However, 24 per cent of the respondents suggested that the capability of their unit was less than adequate or poor. Six per cent indicated that the capability of their unit was excellent.

Similar responses were received concerning the availability of resources to operate and maintain the current equipment stock. Forty-three per cent of respondents suggested that the available resources were adequate, 33 per cent above adequate and 24 per cent less than adequate.

Concerning the rating of the expertise related to the utilisation of equipment, 97.5 per cent of the respondents thought that the available expertise was adequate or better. Twenty-six per cent rated the expertise in their units as 'excellent'. These were general responses across all sectors of the survey. The majority of respondents believed that the expertise related to the utilisation of the equipment was more than adequate. This assertion should be contrasted with our discussion in the chapters which follow that performers of research are critical to the development of new and improved equipment and in South Africa and that this is a neglected area.

The SCs declared collectively that they own 966 items of equipment with a replacement value of R1.12 billion.

Two pieces of equipment alone are valued at more than R100 million each. These are the NAC accelerator facility with a replacement value of R500 million and the CSIR's medium-speed wind-tunnel with a replacement value of R125 million.

The SCs declared that they need just under R48 million to acquire sufficient items of equipment to bring their units to the level of 'adequate' capability. However, the total value of the equipment they listed when to identify the two most-needed pieces of equipment for their units came to R216 million (less than 13 per cent was required for the replacement of existing items of equipment).

Eighty-eight per cent of the respondents needed equipment valued at less than R500 000 per item and 43 per cent needed equipment valued at less than R80 000 per item. However, only 13 per cent of the need, in terms of value, is for equipment valued at less than R80 000 per item. This finding is in accordance with international indications that equipment valued at less than the equivalent of R100 000 constitutes a small per centage, in terms of value, of the stock of equipment.

Approximately 12 per cent of the respondents mentioned that they had an agreement of some kind with manufacturers/suppliers.

Table 4 shows the countries that supply most of the equipment to SCs and the replacement value of such equipment. The facilities of the NAC and the wind-tunnel At the CSIR have been excluded as they are special cases. Both instruments, however, were developed in South Africa.

| *Table 4:* Country of manufacture of equipment currently available at South African SCs | | |
|---|---|---|
| **Country** | **Number of items of equipment** | **Replacement value** (R million) |
| USA | 282 | 111.4 |
| South Africa | 107 | 61.0 |
| Germany | 103 | 46.6 |
| UK | 101 | 81.4 |
| Switzerland | 50 | 32.2 |
| Japan | 47 | 29.5 |

Only 13 per cent, in terms of value, of the equipment was declared as having been manufactured in South Africa (excluding the NAC accelerator and CSIR wind-tunnel). The USA appears to be the top supplier, followed by the UK and Germany.

Table 5 shows the replacement value profile of the equipment.

| *Table 5:* Replacement value profile of equipment at South African SCs | |
|---|---|
| **Number of items of equipment** | **Value range per item** (R million) |
| 563 | <250 000 |
| 190 | 250 000–499 999 |
| 91 | 500 000–999 999 |
| 39 | 1 000 000–1 499 999 |
| 46 | 1 500 000–2 999 999 |
| 12 | 3 000 000–99 999 999 |
| 2 | 100 000 000–500 000 000 |

Sixty per cent of the equipment falls into the category valued at under R250 000 per item, and a further 20 per cent into the category valued at R250 000–R499 999.

Table 6 indicates the age profile of the equipment stock.

***Table 6:*** Age profile of equipment at South African SCs*

| **Year of purchase** | **Number of items of equipment** | **Replacement value** (R million) |
|---|---|---|
| 1991–96 | 377 | 667 |
| 1986–90 | 209 | 251 |
| 1981–85 | 118 | 87 |
| 1976–80 | 77 | 27 |
| before 1975 | 85 | 62 |

* The NAC and the CSIR wind-tunnel are included

Forty-three per cent of the equipment was bought during the last five years, 24 per cent is between five and 10 years old, and the remaining 33 per cent is more than 10 years old. If the NAC accelerator facility and the CSIR wind-tunnel are excluded, the share of the value of equipment that was purchased during the last five years is reduced to 31 per cent and the share of the equipment that is older than 10 years increased to 46 per cent. The per centage of equipment older than 10 years is exceedingly high by international standards. In Australia, the per centage of equipment in this category is 18 per cent, in the USA 22 per cent and in the UK 37 per cent.

The respondents were asked to indicate when the equipment will need to be replaced. Five hundred and twenty-four items of equipment valued at R323 million were identified as needing to be replaced in the next five years (before 2002). Another 266 pieces of equipment, valued at R125 million, will have to be replaced between 2002 and 2007. These replacement needs provide a number of opportunities, such as using for economies of scale in their procurement and developing indigenous industry, as we will discuss in the policy-related chapters.

The average operational time per week of equipment was declared to be 31.8 hours. However, 325 items of equipment, valued at R103 million, were used for less than 10 hours a week, and a further 181 items, valued at R280 million were used for between 10 and 20 hours a week.

Funds for the purchasing of almost all equipment are from own funds (in other words, not funds earmarked for equipment by an institution other than an SC). Only 10 pieces of equipment (or approximately 1 per cent in terms of number) were identified as having been purchased with some financial support from the private sector. Most of the equipment (73 per cent) was purchased new and had a replacement value of R437.5 million. Equipment constructed by the SCs was valued at R570.1 million and represented approximately 6 per cent of the items of equipment currently available at SCs. The high collective value of equipment constructed by the SCs is attributed to the disproportionate replacement cost of the NAC accelerator facilities, valued at R500 million. Equipment which was donated to the SCs (including both used and new equipment) represented approximately 4 per cent of the items of equipment. SCs bought approximately the same number of used items of equipment.

Of this equipment, 11 per cent were reported as being state-of-the-art, representing approximately 50 per cent of the replacement value of all the equipment at the SCs. Respondents reported that some 36.5 per cent of the equipment in the SCs (or 21.7 per cent in terms of value) was in good working order.

On the question of the adequacy of the equipment for research and teaching, 43.6 per cent of the equipment (or approximately 26 per cent in terms of value) was considered adequate for research, while 65 per cent (or approximately 90 per cent in terms of value) was considered adequate for teaching.

The respondents mentioned that 57.1 per cent of the operational time of the equipment was used for research, 37.5 per cent for training and 5.4 per cent for testing. There were substantial variations among institutions, however. The declared variations are indicated in Table 7.

| *Table 7:* Utilisation of equipment, by activity | |
|---|---|
| **Activity** | **Maximum and minimum (% time)** (institutional average) |
| Research | 84.9–32.6 |
| Teaching | 12.4–2.8 |
| Testing | 53.8–5.1 |

The number of researchers/students to have used the equipment in the last 12 months is indicated in Table 8.

| *Table 8:* Number of users of equipment at SCs | |
|---|---|
| **Type of user** | **Number** |
| Staff of the unit | 5 150 |
| Researchers from own institution (not own unit) | 1 822 |
| Researchers from another institutions | 1 647 |
| Students | 1 669 |

According to respondents, 36 per cent the equipment at SCs was dominated by particular programmes. The utilisation of equipment according to discipline is shown in Table 9.

| ***Table 9:*** Utilisation of equipment at SCs, by discipline | | |
|---|---|---|
| **Field** | **Number of items of equipment** | **%** |
| Engineering | 198 | 20.5 |
| Agriculture | 192 | 19.9 |
| Technology | 165 | 17.1 |
| Biological sciences | 105 | 10.8 |
| Earth & marine | 105 | 10.8 |
| Other | 202 | 20.9 |
| **TOTAL** | **966** | **100.0** |

The respondents declared that the equipment was used for various socio-economic objectives, as indicated in Table 10.

| ***Table 10:*** Utilisation of equipment at SCs, by socio-economic objectives | |
|---|---|
| **Socio-economic objective** | **%** |
| Economic development | 32.8 |
| Defence | 9.9 |
| Society | 15.1 |
| Environment | 10.1 |
| Advancement of knowledge | 32.1 |
| **TOTAL** | **100.0** |

*Universities*

All 21 South African universities were invited to participate in the survey. Eighteen responded to the invitation and submitted lists of equipment in their organisations. This represents an 86 per cent response rate.

The response rate related to equipment is more difficult to estimate. Comprehensive inventories of research equipment at the survey institutions would be required in order to calculate the response rate with some certainty. Such inventories, however, are not available.

The quality of the responses from the research-intensive universities tended to be very high. These universities, in general, appointed coordinators who took responsibility for the distribution and follow-up of the questionnaire and for organising meetings with the executive and members of staff. The University of Stellenbosch was the only institution of all those surveyed that submitted its response in digital format. Based on the quality of response of the research-intensive universities and the fact that the universities that did not respond are not significant users of research equipment, we estimate that the response rate for this sector is over 80 per cent in terms of the number of items of equipment and over 90 per cent in terms of value.

Like the science councils, universities identified the attraction and retention of staff as their highest priority. A number of universities mentioned that they did not have any infrastructure available for managing research or equipment, others indicated that they did not have a separate budget for equipment and that they manage the allocation of funds for expensive equipment centrally. No university made provision for the replacement of equipment, and the majority of institutions suggested that they were dependent on the science councils, particularly the FRD, for their equipment. The lack of funds for equipment was also a common characteristic (see Box 3) and the earmarking of funds for equipment was mentioned as desirable.

There was no lack of recognition of the importance of utilising the available stock of equipment more efficiently and effectively, and a number of efforts in this regard were mentioned, such as the Control Analytical Laboratory at Stellenbosch (an effort to manage equipment centrally even though the items are situated in decentralised locations), the establishment of the Strategic Fund at the University of Potchefstroom (which allocates funds for equipment, provided that 50 per cent of the cost is raised externally); and the efforts of various regional consortia/forums that we will discuss more extensively later on.

**Box 3:** ***Expensive capital equipment position at Natal University***

Present position

During 1995, researchers applied to the University Research Fund (URF) for capital equipment above R20,000 to a total value of $10 \times 10^6$

For items below R20,000 the figure was $0.9 \times 10^6$

Applications to the FRD for items below R200,000 amounted to $6.29 \times 10^6$

TOTAL R$17.19 \times 10^6$

Money allocated during 1995 was R$3.03 \times 10^6$

*Leaving a deficit of R$14.6 \times 10^6$*

FRD applications in 1996

Only the top six applications were forwarded to the FRD for equipment above R200,000. The sum involved was R$3.1 \times 10^6$, and R60,000 was granted.

**Communication with University authorities**

The majority of the university respondents (64 per cent) ranked the overall capability of their equipment to fulfil their responsibilities as adequate or better. However, approximately 36 per cent of the respondents suggested that the capability of their unit was less than adequate or poor. Just under 6 per cent indicated that their unit's capability was excellent.

The responses concerning the availability of resources to operate/maintain the current equipment stock reflected that 38 per cent of the equipment was less than adequate, 42 per cent adequate and 20 per cent more than adequate.

Concerning the rating of expertise related to the utilisation of equipment, 94.5 per cent of the respondents thought that the available expertise was adequate or better, while 32 per cent rated the expertise in their units as excellent.

The universities declared, collectively, that they own 884 items of equipment with a replacement value of R376.2 million.

They stated that they need just over R123 million to acquire sufficient items of equipment to bring their units to the level of 'adequate' capability. However, when they were asked to place on a wish list the two pieces of equipment that their unit most needed, the total amount came to R175 million (just over 19 per cent of which was required to replace existing equipment).

Eighty-eight per cent of the respondents needed equipment valued at less than R500 000 per item and 37.5 per cent equipment valued at less than R80 000 per item.

Approximately 10 per cent of the respondents mentioned that they have some type of agreement with manufacturers/suppliers.

Table 11 shows the countries that supply most equipment to the universities and the replacement value of such equipment.

| ***Table 11:*** Country of manufacture of equipment at South African universities | | |
|---|---|---|
| **Country** | **Number of items of equipment** | **Replacement value** (R million) |
| USA | 264 | 78.8 |
| UK | 76 | 70.2 |
| Germany | 72 | 35.0 |
| Japan | 52 | 29.7 |
| South Africa | 35 | 9.9 |
| Netherlands | 24 | 18.5 |

Only 2.7 per cent, in terms of value, of the equipment was declared as having been manufactured in South Africa. The USA appears to be the top supplier, followed by Germany and the UK.

Table 12 shows the replacement value profile of the equipment.

| ***Table 12:*** Replacement value profile of equipment at South African universities | |
|---|---|
| **Number of items of equipment** | **Value range per item** (R million) |
| 530 | <250 000 |
| 156 | 250 000 **to** 499 999 |
| 69 | 500 000 **to** 999 999 |
| 37 | 1 000 000 **to** 1 499 999 |
| 42 | 1 500 000 **to** 2 999 999 |
| 15 | 3 000 000 **to** 99 999 999 |
| 2 | 100 000 000 **to** 500 000 000 |

Sixty-two per cent of the equipment falls into the category valued at under R250 000 per item, and a further 18 per cent into the category valued at R250 000–R499 999.

Table 13 shows the age profile of the equipment stock.

***Table 13:*** Age profile of equipment at South African universities

| **Year of purchase** | **Number of items of equipment** | **Replacement value** (R million) |
|---|---|---|
| 1991–96 | 319 | 156 |
| 1986–90 | 165 | 53 |
| 1981–85 | 115 | 54 |
| 1976–80 | 85 | 46 |
| before 1975 | 76 | 35 |

Forty-two per cent of the items of equipment were bought during the last five years, approximately 22 per cent were between five and 10 years old, and the remaining 36 per cent were more than 10 years old. This profile indicates a relatively old stock of equipment. The respective figures for Australia, for example, are 62 per cent, 15 per cent and 18 per cent and for the USA, 53 per cent, 24 per cent and 22 per cent.

Respondents were asked to indicate when the equipment would need to be replaced. Three hundred and five items of equipment valued at R150 million were identified as needing to be replaced in the next five years (before 2002). Another 284 pieces, valued at R115 million, will have to be replaced between 2002 and 2007.

The average operational time per week of equipment was declared to be 27.7 hours. However, 362 items of equipment, valued at R99 million, were used for less than 10 hours a week and a further 153 items, valued at R44 million were used for between 10 and 20 hours a week.

As the utilisation of equipment at universities does not follow market principles, since the users are not charged, these utilisation rates should be regarded with concern.

The private sector contributed R26.6 million towards the purchase of equipment at universities (or 7 per cent of the total replacement value of equipment), which included contributing R7.6 million towards funding 33 items of equipment in their entirety. Science councils contributed R41.2 million towards the purchase of equipment at universities (or 11 per cent of the total replacement value), which included contributing R14.1 million towards funding 47 items in their entirety. The contribution of science councils was thus almost double that of the private sector.

Most of the equipment (86 per cent) was purchased new and had a replacement value of R281.7 million (74.7 per cent of the total value). Equipment constructed by the SCs was valued at R13.6 million and represented approximately 3.5 per cent of the items of equipment available at universities. Equipment that was donated to the universities (including both used and new equipment) represented approximately 4.1 per cent of the items of equipment. About 5.5 per cent of the pieces equipment that universities bought was not purchased new.

Twenty-five per cent of the equipment at universities was reported to be state-of-the-art, which represents approximately 45.5 per cent of the replacement value of the entire stock of university equipment. Respondents reported that about 75 per cent of the equipment at universities (or 54.5 per cent in terms of value) was in good working order.

On the question of the adequacy of the equipment for research and teaching, 37 per cent of the equipment (or approximately 36 per cent in terms of value) was considered adequate for research, while 68 per cent (or approximately 75.5 per cent in terms of value) was considered adequate for teaching.

The respondents mentioned that 56.4 per cent of the operational time of the equipment was used for research, 21.5 per cent for training and 6.8 per cent for testing. There were substantial variations among institutions, however. The declared variations are indicated in Table 14.

| ***Table 14:*** Usage of equipment, by activity | |
|---|---|
| **Activity** | **Maximum and minimum (% time)** (institutional average) |
| Research | 86.8– 33.3 |
| Teaching | 38.6–10 |
| Testing | 30.1–0.78 |

The number of researchers/students to have the equipment in the last 12 months is indicated in Table 15.

| ***Table 15:*** Number of users of equipment at South African universities | |
|---|---|
| **Type of user** | **Number** |
| Staff of the unit | 1 599 |
| Researchers from own institution (not own unit) | 2 956 |
| Researchers from other institutions | 5 427 |
| Students | 12 220 |

According to respondents, almost 30 per cent of the equipment at universities was dominated by particular programmes. The utilisation of equipment according to discipline is shown in Table 16.

| ***Table 16:*** Utilisation of equipment at South African universities, by discipline | | |
|---|---|---|
| **Field** | **Number of items of equipment** | **Per cent (%)** |
| Chemical sciences | 89 | 16.5 |
| Biological sciences | 152 | 19.5 |
| Medical & health sciences | 135 | 17.3 |
| Engineering | 64 | 8.2 |
| Earth and Marine | 58 | 7.4 |
| Physical sciences | 51 | 6.5 |
| Other | 335 | 24.6 |
| **TOTAL** | **884** | **100.0** |

The biological and medical sciences appear to dominate use of the stock of equipment (36.8 per cent). It is difficult to assess whether the reason is that these disciplines are more equipment-intensive or whether or whether the result is an indication of priorities in the academic environment.

The respondents declared that the equipment was used for various socio-economic objectives, as indicated in Table 17.

| ***Table 17:*** Utilisation of equipment at South African universities, by socio-economic objectives | |
|---|---|
| **Socio-economic objective** | **%** |
| Economic development | 7.46 |
| Defence | 0.45 |
| Society | 27.94 |
| Environment | 8.59 |
| Advancement of knowledge | 48.19 |

| | |
|---|---|
| **TOTAL** | **100.0** |

***Technikons, museums and government departments***

This category comprises 15 organisations, including technikons, museums and research-performing government departments (for example, the Department of Environmental Affairs and Tourism and the Department of Health). Six technikons and one research-performing institution attached to a government department did not respond to the survey. However, the research-intensive technikons (like the research-intensive universities) were among the respondents, and we consequently believe that the response rate is more than adequate.

Technikons declared 202 items of equipment with a replacement value of R40 million. Museums and government departments declared 118 pieces of equipment with a replacement value of R256 million. Collectively, the category of technikons, museums and government department was responsible for almost 15 per cent of all items of equipment in the database and 16.5 per cent of their declared replacement value.

However, R166 million of the replacement value of equipment in government departments can be accounted for by three research motor vessels. If these three vessels are not included, the group of technikons, museums and government departments is responsible for only 7.25 per cent, in terms of value, of the equipment in the database.

Respondents in this group declared that that they need just over R53 million to acquire sufficient items of equipment to bring their units to the level of 'adequate' capability. When they were asked to place on a wish list the items which their unit most needed, the total value of items listed R36.8 million. Technikons are a good example of the trend in this group. Technikon respondents declared that they need R43.8 million to purchase equipment to raise their capability to 'adequate'. R30 million of this was needed for the two most important items on each unit's wish list.

Table 18 shows the countries that supply most equipment to museums, technikons and government departments and the replacement value of such equipment.

***Table 18:*** Country of manufacture of equipment available at South African technikons, museums and government departments

| **Country** | **Number of items of equipment** | **Replacement value** (R million) |
|---|---|---|
| USA | 88 | 29.2 |
| South Africa | 41 | 67.3 |
| UK | 30 | 7.5 |
| Germany | 21 | 4.8 |
| Japan | 17 | 8.6 |
| Netherlands | 17 | 2.8 |

Almost 23 per cent, in terms of value, of the equipment was declared as having been manufactured in South Africa. The USA appears to be the top supplier, followed by the UK and Germany.

Table 19 shows the replacement value profile of the equipment.

***Table 19:*** Replacement value profile of equipment at South African museums, technikons and government departments

| **Number of items of equipment** | **Value range per item** (R million) |
|---|---|
| 166 | <250 000 |
| 54 | 250 000–499 999 |
| 26 | 500 000–999 999 |
| 3 | 1 000 000–1 499 999 |
| 7 | 1 500 000–2 999 999 |
| 6 | 3 000 000–99 999 999 |
| 0 | 100 000 000–500 000 000 |

## Putting equipment on the national agenda

Scientific equipment is a distributed responsibility in South Africa. Research performers – science councils and academic institutions – receive 'block' funds from government and they are then responsible for deciding how much (if any) to spend on equipment. Similarly, funding institutions (for example, the FRD) decide independently whether equipment will be one of their priorities, as well as the level and *modus operandi* of their support.

Universities are funded according to a formula which uses as endogenous variables the number of scientific articles published by staff and students and the magnitude of what are termed 'effective subsidy students'. Effective subsidy students are calculated on the basis of the average sum of full-time-equivalent (FTE) enrolments and credits for degree courses passed, weighted by factors of between 1 and 4 (1 for a bachelor and 4 for a PhD degree), and a distinction is made between human science and natural science students.

In summary, the formula is as follows:

$$F_G = K_1S_H + K_2S_N + K_3A_H + K_4A_N + K_5I_H + K_6I_N$$

where $F_G$ denotes the budget for educational and general programmes, $S_H$ denotes the projected effective subsidy students in the human sciences, $S_N$ denotes the projected effective subsidy students in the natural sciences, $A_H$ denotes the projected number of articles published in the human sciences, $A_N$ denotes the projected number of articles published in the natural sciences, $I_H$ denotes the increase in the projected effective subsidy students in the human sciences from the previous maximum, $I_N$ denotes the increase in the projected effective subsidy students in the natural sciences from the previous maximum, and $K_6$ denotes coefficients that are independent of university, expressed in current rand values for a particular year.

The difference between the S and I variables is that the former makes provision for the existing structure of the university, while the latter makes provision for the initial costs of fixed assets necessitated by an increase in student numbers. Instrumentation does not appear directly in the formula.

The institutions receive funds, as allocated by the funding formula, and decide how they will be spent.

This pluralistic approach to S&T policy provides the background for the neglect of instrumentation and facilities. There are a number of exacerbating factors:

? Administrators of organisations financed primarily by general institutional grants (which cover both teaching and research, for example) are usually unable to maintain a proper balance between spending on salaries and investing in equipment. This problem is particularly acute during periods of sinking or level funding.

? Funding agencies do not always place the appropriate emphasis on equipment support. Short-term priorities based on quick results and political considerations almost always take precedence over meeting long-term infrastructural needs. Discipline-based committees make it difficult to establish and support equipment funding programmes that are not associated with particular research disciplines.

? Trends towards the broader use of generic instrumentation (for example, NMR equipment) across different fields have resulted in considerable scope for the more efficient deployment of resources through common-use facilities or equipment sharing by bodies such as academic departments and faculties and science councils. Pluralism, conflicting vested interests and institutional rigidities, however, prevent the realisation of potential economies of scale and other related savings which could be achieved, for example, by restructuring technical support and workshop facilities for building, modifying and servicing equipment. Simultaneously, the apparent lack of coordination at policy level gives rise to the argument that the issue is less a lack funds than a lack of cooperation.

In South Africa, the efforts of the FRD (which supports equipment on a matching-funds basis,[6] manned by a manager on a part-time contract) and DACST (which earmarks once-off funding for equipment on an *ad hoc* basis) are indicative of the inadequacy of the country's pluralistic system to plan for and meet instrumentation needs.

Even new, legislated initiatives suffer from the shortcoming of past philosophies on the provision of research/teaching equipment. The recent National Research Foundation Bill, for example, states under Clause 4 'Functions, powers and duties of the Foundation' that the "functions of the Foundation shall be ... (f) to provide financial support for the acquisition or establishment of research facilities by research institutions". This statement is only enabling, however, and the imposition of a disciplinary divisional character for the envisaged National Research Foundation sows the seeds for instrumentation becoming a marginalised issue, dependent on the foresight of vice-presidents whose horizons are limited by a mandatory three-year term of office in the foundation. It is questionable why disciplinary interests were safeguarded in the new foundation, with infrastructural needs taking a back seat.

The Higher Education Bill similarly pays lip service to instrumentation, for example, by not identifying instrumentation as one of the areas for which earmarked funds for institutional redress can be used. Clause 4.28 of the bill states that "funds provided through this programme will be available to support improvements in the following areas: staff development, academic

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6 Matching funding internationally is usually tied to a particular project proposal, especially if there is an industrial partner, and rarely takes into consideration broader national or institutional circumstances. Such funding creates laboratories with a hotchpotch of equipment, each item acquired for a different reason. These laboratories are a far cry from the time-tested idea of a 'well-found laboratory' – one with a stock of advanced generic equipment that enables it to take on a wide variety of pioneering projects as well as collaboration with industry.

development, curriculum development, library holdings, student amenities, buildings and the development of institutional capacity". Equipment is not explicitly included in the list of priorities.

The deficiencies of the pluralistic system should be contrasted with systems where budget appropriations are approved on a line by line basis. Needs are identified comprehensively, funds are allocated for a particular priority and can be used for that purpose alone.

In the USA, which favours a pluralistic approach to the management of S&T, congressional action has mandated specific technology development programmes and obligations in federal agencies which did not initially support such efforts. Much of the programme development was based on what individual committees judged appropriate within the agencies over which they had authorisation or appropriation responsibilities.[7]

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[7] An NSF-initiated study identified the following federal government programmes within four agencies that support science and engineering instrumentation in academic institutions:

National Institutes of Health (NIH)

?? Shared instrumentation Grant Program in the Division of Research Resources

?? Minority Biomedical Research Support Supplemental Program in the Division of Research Resources

?? Shared Instrumentation Grant Program in the National Institute of General Medical Sciences

Department of Defense (DoD)

? University Research Instrumentation Program

Department of Energy (DoE)

? University Research Instrumentation Program

National Science Foundation (NSF)

? Chemical Instrumentation Program in the Division of Chemistry

? Biological Instrumentation Program in the Division of Molecular Biosciences and the Division of Physiology, Cellular, and Molecular Biology

? Instrumentation for Materials Research Program in the Division of Materials Research

? Engineering Research Equipment Program in the Division of Materials Research

? Computer Systems Design Program in the Division of Computer Research

? Earth Sciences Instrumentation and Facilities Program in the Division of Earth Sciences

The NSF has a number of programmes that support equipment (as we will discuss under a separate heading), but it is not the only body with such responsibility, and the issue is regularly on the political agenda. For example, in 1986, the White House Science Council proposed a comprehensive facilities programme, which would award $5 billion in grants over a 10-year period, with the stipulation that awards be matched one-to-one with non-federal funding. The report also recommended that R&D support include enlarged reimbursement of indirect costs for the use and depreciation of facilities, as well as expanding tax credits for facilities funding. Proposals were also made for smaller specialised facilities grants programmes in other agencies. In 1989, HR2581, a bill passed in the House would have given the Federal Aviation Administration authority to award funds to construct academic facilities. The National Advisory Committee on Semiconductors concluded, in a 1989 report, that the DoD, Department of Energy (DoE) and the NSF should increase academic facilities funding for research and teaching associated with silicon technology. The original version of the NHI authorisation bill for 1990 (which was passed in the Senate), bill S2857, authorised a new NIH programme for biomedical and behavioural research facilities, at $150 million. It was not included in the bill that was passed and became PL101-613, however. A similar provision is included in the Financial Year (FY) 1992 Senate authorisation bill for the NIH, S1532, but not HR2507, which was passed by the House. The US Department of Agriculture (USDA), in response to a congressional request, developed a proposal for a major new facility grants programme. It was entitled 'America's agriculture in the 21st century depends on current research investments'. The proposal was for an annual competitive facility grants programme of $100 million under the authority of the Research Facilities Act of 1963, as amended. (See also Appendix II.)

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- ? Astronomical Instrumentation and Development Program in the Division of Astronomical Sciences
- ? Oceanographic Technology Program in the Division of Ocean Sciences
- ? College Science Instrumentation Program in the Office of College Science Instrumentation

Similarly, several laws and regulations attempt to encourage industry–university cooperation and to ensure that equipment needs receive attention. Firms, for example, are permitted a larger than normal tax deduction for charitable contributions of equipment used in scientific research at academic institutions. According to the Equipment Donation and Discount Scheme, firms that donate equipment to universities and government laboratories are allowed to offset the full market value against future corporate taxation.

Transferring responsibility for equipment funding to the political level through earmarking has been questioned because the scientific peer-review process is bypassed, agency budget priorities are compromised (as agencies are obliged to fund particular priorities) and other important priorities are possibly be neglected. However, earmarking for long-term needs that cut across disciplinary and institutional boundaries (such as instrumentation) is an accepted, if not the most appropriate, funding option.

The research sector, like the health care, financial services and pollution control sectors, would malfunction under complete deregulation. What these sectors have in common is that they depart from the perfect market of economics textbooks. They may have elements of natural monopoly; lingering pockets of market power; positive or negative spill-overs not reflected in market pricing; or public policy goals, such as universal service or public health, that entail cross-subsidisation. All these sectors could benefit from a closer adherence to market principles. However, these contrived markets paradoxically require smart, discerning regulation.

The case of tradable pollution permits in the USA provide an example that may be useful for the management of research equipment. Tradable pollution permits have long been advocated by economists and finally enacted as part of the Clean Air Act of 1990 to control acid rain. Congress set a ceiling on the total national emission of sulphur dioxide and then created a market in entitlements to pollute. Polluting industries could either invest in new technologies or buy the certificates. The market set the price. The system has proved to be an ingenious incentive, but the market is altogether artificial. It required the regulatory determination of a safe level of sulphur dioxide emissions, as well as the regulatory creation of a new property right.

All over the world, the efficient deployment of resources is a major concern of administrative bodies that support equipment needs and a common concern of policymakers faced with the budgetary demands of scientists.

Various approaches are used internationally to overcome problems associated with the cost-effective utilisation of research equipment.

***Market principles***

Introducing market principles in the utilisation of research equipment is a tried and tested approach. Introducing usage charges and taking the depreciation of equipment into account are at the heart of the issue.

Only a small number of the institutions at which we conducted interviews mentioned that they impose usage charges, depreciate equipment and earmark funds for its replacement. Two institutions provided anecdotal evidence of cases in which the users of equipment had requested the administration to reverse budgetary allowances for the depreciation of equipment.

Abroad, market principles dominate the agenda. In the USA, the Office of Management Budget (OMB), in June 1991, proposed changes to Circular A-21, which governs indirect costs, to require universities to set aside a dedicated fund for facilities-related indirect-costs reimbursements to be used only for research buildings and equipment. This requirement received considerable criticism on the grounds that it would be costly and would interfere with management practices and that academic institutions regularly use more of their own funds to pay for the renewal and construction of facilities than they receive in indirect costs reimbursements. Therefore, in the final regulation, issued on 3 October 1991, OMB required the universities only to provide assurance that they would use such reimbursements for facilities. This requirement applies only to the 99 largest academic recipients of federal R&D funds as specified in the revised Circular A-21. HR 2282, passed by the House on 11 July, requires universities that receive NSF funds to use facilities-related reimbursements only for facilities. HR 2507, the NIH Revitalisation Amendments of 1992, which was passed in the House, requires HHS approval if academic institutions use facilities-related indirect-costs reimbursements for capital projects costing more than $3 million.

Similar approaches are used to safeguard investment in equipment. It has also been recommended that universities be required to develop 'plant asset protection formulas' to hold down costs, develop priorities of needs and manage existing facilities more effectively. It has been reported that these formulas could be used to establish the level of financial reserves to be set aside to ensure sufficient funding or debt financing for day-to-day facility maintenance and long-term investments in facility construction and renovation. The formulas would also determine sources of revenue for capitalising these reserves. Such formulas could be attached to legislative proposals for competitive grants for facilities, but such proposals might be controversial.

In a more recent effort, George Brown, a well-known supporter of science in the US Congress, is floating the 'investment budget', designed to increase investment in productive activities that spur long-term economic growth. It is structured to force decision-makers to distinguish between investments and consumption. The plan calls for changes in appropriations and budgeting rules, requiring that spending allocations be made across each appropriations subcommittee in investment and non-investment categories. Once allocated, funds may not be diverted across the firewall for other purposes.

The goal of the investment budget is to provide a higher degree of budgetary discipline at a time when Congress is attempting to balance the federal budget against revenue by 2002. For Brown, the challenge in attaining this goal is to sustain investments that produce economic growth. Otherwise, he observes, the US could face an economic downturn and an exacerbation of federal budget deficits.

The areas characterised as investments are R&D, transportation and public works, and education and training.

In South Africa, the current low and deficient standards hamper the effective build-up and maintenance of the research infrastructure.

***Benchmarking***

A more comprehensive approach has been suggested by the National Audit Office of the UK, which examined in more detail the issue of the management of equipment in the higher education sector following a benchmarking approach across the life-cycle of the equipment (Fig. 4)

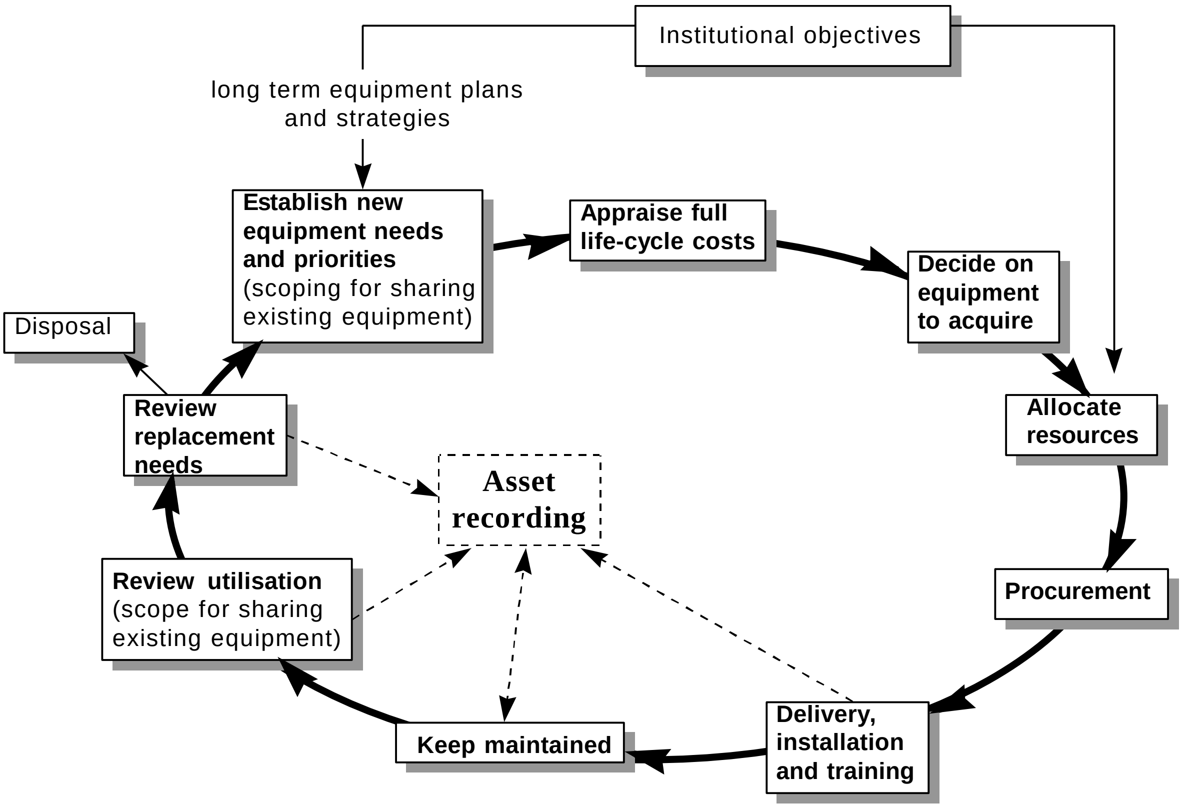


***Figure 4:*** Equipment life-cycle

Benchmarking is a tool for monitoring progress on an on-going basis and assessing the situation against continuously improving best practice worldwide. It goes beyond competitive analysis by providing an understanding of the process and skills that create superior performance.

The UK study had the following objectives:

? to examine the institutions' existing policies and practices on equipment

? to identify good equipment management practice

? to suggest ways in which better management of equipment might be promoted

The investigation identified three stages during which benchmarking against best practice is critical:

1. planning (in other words, resource allocation and equipment specification)

2. equipment procurement

3. management through the life cycle

The issues, suggested by the investigation as indicating best practice, are as follows:

**Planning**

? There should be a central focus on equipment, policies and practice throughout the life-cycle.

? There should be a process for ensuring that the proportion of the institution's budget allocated to equipment is sufficient and is allocated appropriately to meet equipment needs. This process would need to be effective in the event of the disappearance of the external sources for funding equipment.

? Decisions on the prioritisation of equipment provision should be informed by a longer-term perspective of the equipment needed, including the need to replace existing equipment.

- There should be a methodical approach to deciding on specific items of equipment to fund, taking account of the availability of equipment elsewhere in the institution.

**Procurement**

- There should be a proper market search leading to competitive tenders or quotations and a second round of negotiations.

- Action should be taken to secure value for money even when there is only one supplier.

- There should be an evaluation of which supplier provides the best value for money in terms of whole-life costs, taking account of all relevant downstream costs, particularly maintenance, consumables and the provision and cost of spares.

- Savings should be sought through combining purchases of common items or negotiating advantageous leasing deals.

- There should be appropriate application of professional purchasing skills, with the institution's purchasing coordinator being involved in all high value expenditure.

***Management of equipment through the life cycle***

- Formally appraise equipment use, soon after acquisition and periodically thereafter, to check that it is meeting its objectives and to identify spare capacity.

- Develop mechanisms to encourage the sharing of spare capacity and to ensure that equipment is not purchased by departments without an appraisal of the scope for sharing equipment with other departments.

- Cost in-house maintenance and encourage departments to use these costs in deciding on the maintenance strategy for each type of equipment.

- Consider whether in-house maintenance can be provided more cost-effectively by means of pooling arrangements.

- ? More actively consider the merits of taking out extended warranties and institutional maintenance arrangements.
- ? Establish standards and procedures for asset recording, including keeping records up-to-date and ensuring their completeness and accuracy.
- ? Consider using an internal audit to ensure that departmental records and procedures are up to standard.
- ? Introduce standardised systems for purchase and inventory recording.
- ? Use departmental asset records to check that equipment is secure.
- ? Consider arrangements for the investment appraisal of and, if necessary, funding for the replacement of equipment that is costly to maintain or to run.
- ? Establish policies for the disposal of equipment in some cases.

***Structural approaches***

Structural approaches attempt to influence investment in and utilisation of equipment through institutionalisation. Some of the most important efforts nationally and internationally are discussed:

1. *The Swedish Programme for Purchasing Expensive Scientific Equip ment*. This programme was established in 1981, following the recognition by government that universities had increasingly proved incapable of allocating sufficient funds for investment in research instrumentation and facilities from their general institutional grants. It was necessary therefore to adopt a new funding model, in which the science council system would be allocated a budget earmarked for new equipment. A single funding agency – the Council for Planning and Coordination of Research – was given responsibility for the programme. This enabled the various science councils in Sweden to adopt an interdisciplinary approach in determining overall priorities for spending on costly instrumentation and facilities. Similar benefits

resulted from the German Large Equipment Programme, administered by the Deutsche Forshungsgemeinschaft (DFG) on behalf of the Wissenschaftsrat (Science Council).

2. *The Korea Basic Science Centre*. This body is equipped with a wide range of high-performance instruments (such as protein sequencers), which are essential for scientific research, but which are beyond the financial means of most Korean universities. The centre is open to all academic researchers and the intention is to set up a number of branches at various regional universities. The centre could serve as a model that other newly industrialising nations might adopt as a cost effective means of meeting the equipment needs of scientists engaged in basic science.

3. *The Canadian Microelectronics Corporation (CMC)*. Using funds provided by the Natural Sciences and Engineering Research Council, the CMC administers an equipment loan programme for Canadian universities engaged in microelectronics research. Applications for equipment are assessed on a competitive basis by peer review, with decisions on purchasing policy made by an expert panel of industrialists and academics. The CMC is able to use its central buying power to obtain substantial discounts on the latest equipment, as well as cost-effective servicing and maintenance contracts. Most importantly, the companies involved benefit from being at the centre of a network of leading users of microelectronics instrumentation in Canada. This enables them to take advantage of innovative technical modifications to equipment or software. Consequently, the CMC also functions as a national clearing house for new ideas and developments.

4. *Tertiary Institutions Purchasing Consortium (TIPC)*. This effort in South Africa aims to provide benefits to its members (universities, technikons and one college) by providing a central purchasing agency. TIPC currently handles R130 million per year and it is estimated that it creates a benefit for its members of the order of R15–R20 million. The main items handled by TIPC are consumables, car rental, laboratory chemicals, stationery and, to a lesser extent, photocopiers and laser

printers. Factors which have been identified as preventing further expansion of the TIPC to instrumentation include lack of communication and differences in approach and in the timing of budgets.

5. *Attempts by universities and research institutes to restructure their technical and workshop facilities*. A number of universities locally and abroad recognise the importance of equipment for research and training and are attempting to address the issue of internal utilisation by introducing novel approaches.

   In South Africa, a number of efforts are in their initial stages. For example, the University of Stellenbosch (US) has established a Central Analytical Laboratory that is delocalised but centrally managed. The allocation of funds for equipment includes the cost of operator and running costs. The University of Pretoria (UP) is in the process of developing equipment-related strategies, including a technology strategy.

   Probably the most successful South African effort was the establishment and operation of the Southern Universities Nuclear Institute (SUNI), which was originally established to enable scientists and students at the universities of Stellenbosch (US) and Cape Town (UCT) to undertake fundamental research in nuclear physics and chemistry. The idea of a nuclear research institute in the south-western Cape was first publicly expressed in 1956. Wide support at the universities of Stellenbosch and Cape Town led to the formation of the Cape Nucleonic Society. When in 1958 the establishment of a Southern Nuclear Institute was incorporated into a national programme for nuclear research in South Africa, drawn up by Dr AJA Roux, a campaign was begun to enlist public support for the capital requirements of such a centre. Generous financial and moral support enabled the two universities to establish an independent organisation known as the Southern Universities Nuclear Institute, with the object of providing a joint facility for UCT and US.

The nuclear institute was formally created when its charter was signed on 29 March 1961. Its objects, as set out in its memorandum of association, were to provide, control, make available and operate facilities for research, development and education in all aspects of nuclear science, nuclear engineering and related fields, including applied radioactivity, radiobiology and radiochemistry, and to train technical, research and student personnel in all such fields. The institute was self-sufficient and operated as an independent, non-profit company in terms of the Company Act. The administration of the institute was thus the responsibility of its own small staff.

In terms of its charter, the institute was managed by a board of governors responsible for decisions relating to broad policy and finance. Appointed every two years, the board consisted of the vice-chancellor of UCT and the Rector of US (or their deputies), who alternately filled the office of chairman, three other persons appointed by each university and a representative from each of: the then Atomic Energy Board (AEB), the CSIR, the Cape Provincial Administration (CPA), local industry and local commerce.

Capital for the development of the institute was assured by grants from the AEB, the Department of Mines, the CSIR and central government, as well as donations from local industries and organisations.

SUNI's funding improved considerably when the Department of National Education (DNE) introduced a new system of financial support for expensive nuclear research at several South African universities. Subject to departmental approval of the budget for SUNI expenditure, it undertook to pay 85 per cent of the total current expenditure and required that UCT and US between them should cover the remainder from their own funds. The support of DNE through the 1970s was essential to the continued existence of SUNI and laid the foundations for the institute to flourish.

When, however, the special support by the DNE for nuclear research at universities was incorporated into a larger research subsidy to all universities, the main burden of financing SUNI was transferred to UCT and US themselves.

This amalgamation of budget was decisive to SUNI's being integrated into the CSIR's National Accelerator Centre in 1983. The integration was seen at the time as a rationalisation in view of the CSIR's role as a promoter and coordinator of the national S&T system.

Abroad, Carleton University in Ottawa has a useful model for providing most technical services on a centralised basis (traditionally, these have been the responsibility of individual, discipline-based departments), while at the same time improving and extending, rather than rationalising, the assistance given to researchers. Among other things, this has required a substantial improvement in the salaries and status of technicians to enable experienced staff to be recruited from industry (and the director of technical services is paid more than most professors). The costs involved are financed partly by allowing the central workshop to take on profitable, challenging contract work from high-technology companies. In addition, the wide-ranging skills of the technical staff make it possible for the university to reportedly accrue considerable savings, both through reduced payments for equipment service contracts and through the in-house construction of instrumentation that would have been purchased externally in the past. Consequently, unlike many other Canadian universities, Carleton is able to invest in the latest workshop equipment.

***Informational approaches***

Approaches to improve utilisation and access through information are the necessary first steps and prerequisites for any other efforts. Such approaches face less resistance in their implementation than other schemes, although their impact is less certain as it is based on voluntary participation and compliance.

- ? *The database on second-hand research equipment*, set up by the Technology Foundation (STW) in the Netherlands, is an example of an informational approach. The STWs facilitates the transfer of serviceable but redundant equipment between institutions by creating a market from which both 'buyers' and 'sellers' can benefit. It may be that, for example, that obsolete instrumentation in one field is still state-of-the-art in another, or that a technical college can use equipment that university researchers regard as outdated.

  Similarly, because the DFG handles the applications of German universities for federal government assistance for the purchase of research equipment (50 per cent of total costs), it has built up a comprehensive national database on available instrumentation and facilities. This is invaluable, not only in providing information to researchers on where they might access equipment in nearby institutions, but also in providing guidance in the negotiation of discounts and service contracts when purchasing new instruments. It is also useful as a means of monitoring trends in the costs and obsolescence of equipment over time.

? *South African Regional Co-operation Efforts*. The Western Cape Tertiary Institutions Trust (WCTIT) and the Eastern Seaboard Association of Tertiary Institutions (ESATI) are probably the most advanced of the cooperation measures among South African tertiary institutions.

WCTIT was established by the five tertiary institutions in the Western Cape that receive financial support from the Ford Foundation. It exists for the purpose of raising and handling funds for projects collectively operated by two or more (preferably all) of the participating institutions.

A number of projects are part of the collaborative effort (see Appendix III). One of them is the Co-operative Equipment Project (CEP), which has as its aim the rationalisation of expensive laboratory equipment by promoting the sharing of such facilities by academics and students of the participating organisations. At the time of our interviews, a steering committee had been established for this purpose and a proposal was being drafted for submission to the WCTIT trustees.

ESATI was initiated by the universities of Durban-Westville, Natal and Zululand in an effort to identify areas of possible cooperation, negotiate in good faith over these areas and act promptly on all decisions agreed upon. Equipment is one of ESATI's areas of concern. (Appendix IV).

The University of Natal (UN) aims to expand its database to include all regional equipment.

***Remote utilisation***

The effect and impact of the telecommunications revolution and of related technologies is an issue that was often the focus of attention during our interviews on research and training equipment. Most of the participants recognised that the utilisation of equipment would be affected dramatically by the new technologies and that people's view of science would change radically. However, they had difficulty in predicting the timing and consequences of the forthcoming changes. The example of astronomers who will receive all necessary data from computers without the need for a physical visit to a telescope was mentioned.

At an international level, the concept of remote utilisation is seen as part of a broader effort to facilitate distant collaborative research. Such long-distance systems will be among the mechanisms that will remove the barriers that have tended to confine cutting-edge research to scientists from elite institutions.

The concept of collaborative research by wire is not new. For example, upper atmospheric physicists from six US universities have been able to make observations of the interaction between the solar wind and the atmosphere over Greenland, courtesy of the Upper Atmospheric Research Collaboratory (UASC) based at the University of Michigan in Ann Arbor since 1993. The system links the researchers with a US-funded radar in Greenland that constantly monitors the upper atmosphere. In recent years, DoE researchers have demonstrated the ability to operate complex experimental devices, such as the Tokamak Fusion Test Reactor at Princeton University, from afar. Likewise, video-conferencing has existed for years. But all these technologies are cumbersome to use, even for trained scientists, and their operation can be as much of an experiment at times as the R&D researchers are trying to pursue with these tools.

A conference on this issue held at Ernest O. Lawrence Berkeley National Laboratory during February 1997 concluded that:

> *Multiple solutions will be required to address different levels of needs – ranging from collaboration that can take place using Netscape-like software platforms to systems that support more-data-intensive, higher-bandwidth activities.*

The DoE, led by the Office of Computational and Technology Research has budgeted US$11 million for research on the topic during 1998. Officials report that they expect that the results of their research could have huge impacts in the laboratory and in business.

Two pilot programmes are being used as vehicles to develop 'collaborative' capabilities based on virtual research environments. A number of consortia have been established to investigate aspects of remote collaboration. Sandia National Laboratories is working with Los Alamos, Berkeley and Livermore national laboratories, Cummins Diesel and Caterpillar on the Diesel Combustion Collaboratory.

The goal is to enable researchers at different locations to simultaneously share data and manipulate virtual combustion environments "We want to be able to walk into the flame front from a few thousand miles away," says Stewart Loken, director of the Information and Computing Science Division at Berkeley Laboratory.

The US government's Pacific North-west National Laboratory in Richland, Washington, has developed an environmental and molecular sciences collaboratory that enables people to operate two nuclear magnetic resonance spectrometers and other instruments at the laboratory.

Another effort is aimed at making it possible for institutional and university researchers to access different types of electron microscopes at Argonne, Berkeley and Oak Ridge national laboratories and at the University of Illinois. Called the Materials Micro Characterisation Collaboratory, the effort in its latter stages will link DoE's High Flux Isotope Reactor at Oak Ridge, the Advanced Photon Source at Argonne and the Advanced Light Source at Berkeley Laboratory.

In another activity, DoE researchers at Oak Ridge, Berkeley, and Pacific Northwest National Laboratory are developing an electronic scientific notebook that will be capable of recording the notes of all researchers at various locations who are working on a given project. This system will be deployed in the diesel collaboration pilot project.

Related programmes to create shared electronic work environments also are being developed by the Defense Advanced Research Projects Agency. Programmes in video steering, common integrated planning boards and other information technologies are being coordinated with DoE's collaboratory initiative. The effort is to create the feeling that the researchers 'are there'. The ability to control instruments remotely plays only a small part. Other measures include establishing video-conferencing and audio-conferencing links between remote users and the central laboratory, an electronic 'white-board' that collaborators can use to draw diagrams to accompany their comments, a chat system for exchanging text messages, an electronic notebook that records data from experiments, and software tools for writing documents as a team.

Support for the efforts is fuelled not only by the benefits that will accrue for the scientific and technological enterprise but also because of its impact on industry. A collaborative environment can drastically change the way business is conducted in the manufacturing sector, particularly in the extended supply chain. When companies have the necessary tools at hand, the extended supply chain, which is dominated by small business, will be able to provide cost-effective solutions and products for local and international markets.

The major infrastructural hurdle to widespread use of remote collaboration appears to be that the NET cannot provide enough bandwidth for data transmission capacity.

The issue of remote utilisation is of particular importance for South Africa because of its geographical size, the magnitude of the redress that the nation is currently undertaking and the importance that government places on Small and Medium Enterprises (SMEs).

## Off-the-shelf versus constructed equipment

The second half of the 1980s saw a change in philosophy on the support of research/training equipment. Programmes supporting procurement of off-the-shelf equipment were alleged to promote conservative science and to equip laboratories with instruments that were not on the 'cutting edge'. A study in the UK[8] found that a higher proportion of academic equipment constructed in-house was assessed as state-of-the-art than that purchased from manufacturers.

Scientific equipment has been identified as important, not only for research and training, but also in the economic sector, justifying government intervention. The change of philosophy arose from the recognition that the innovation process in scientific instruments has characteristics that are not often encountered in other sectors.

Firstly, there is evidence that 'users', who are usually researchers, play a more dominant role than 'producers' (scientific instrumentation companies) than in almost any other technology sectors. For example, Von Hippel[9] found in a detailed study of innovation in four major families of scientific instrumentation (gas chromatography, nuclear magnetic resonance spectrometry, ultraviolet spectrophotometry and transmission electron microscopy) that users accounted for: 100 per cent of 'first-of-type' innovations ($n$ = 4); 82 per cent of 'major improvement' innovations ($n$ = 44); and 70 per cent of 'minor improvement' innovations ($n$ = 63).

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8 Georgiou, L, Halfpenny, P; and Hinder, S. 1989. *Survey of Academic Research Equipment in the United Kingdom*. Advisory Board for the Science councils. London. UK.

9 Von Hippel, E. 1988. *The Sources of Innovation*. Oxford University Press. New York. USA.

Overall, 77 per cent of the innovations examined (*n* = 111) were 'user developed' (in other words, 'users' undertook all aspects of innovation up to and including construction, testing and use of the initial prototype), while manufacturers were responsible for only 23 per cent.

Secondly, a high proportion of innovative users are located within academic and government laboratories. In Von Hippel's study, 72 per cent of user-developed major improvement innovations (*n* = 36) were found to have been made by universities or research institutes, while private manufacturing firms were responsible for only 11 per cent. The explanation lies partly in the fact that radical advances in instrumentation are often closely associated with breakthroughs in science.

Thirdly, the basic technological trajectories of scientific instrumentation companies usually differ in certain important respects from those in other sectors. Pavitt *et al.* [10] have developed a useful typology dividing firms into four categories – science-based, scale-intensive, information-intensive and specialised supplier – on the basis of their analysis of 4 000 UK innovations (Table 20). Scientific instrumentation companies are classified as specialised suppliers in this scheme (along with producers of machinery, speciality chemicals and software) and obtain their technology primarily from large-scale users and small-firm design.

In contrast, science-based electronics or chemicals firms rely on in-house R&D laboratories. The technological trajectory of specialised suppliers is to improve the reliability and performance of producer goods, and the strategic problems facing their R&D management are matching technological opportunities with user needs, absorbing user experience, and finding stable or new product niches. In turn, innovations made by specialised suppliers

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10 Pavitt, K; Robson, M; and Townsend, J. 1989. Technological Accumulation, Diversification and Organisation in UK Companies. *Management Science* **35(1):** 81–99.

represent a significant source of new technology for scale-intensive and information-intensive companies.

***Table 20:*** Basic technological trajectories of different types of industrial sectors

| **Type of sector** | **Sources of technology** | **Trajectory** | **Typical core product groups of firms** | **Strategi** |
|---|---|---|---|---|
| Science-based | - R&D laboratory | - Synergetic new products<br>- Applications engineering | - Electronics<br>- Chemicals | - Complen<br>- Integrati<br>- Patient |
| Scale-intensive | - Design<br>- Production engineering<br>- Specialised suppliers | - Efficient and complex production<br>- Product design | - Basic materials<br>- Durable consumer goods | - Balance among a vertical c profit cer |
| Information-intensive | - Software/systems department<br>- Specialised suppliers | - Efficient (and complex) information processing<br>- Related products | - Financial services<br>- Retailing | - 'Fusion '<br>- Diffusion<br>- Exploitin<br>- Patient n |
| Specialised suppliers | - Small-firm design<br>- Large-scale users | - Improved specialised producer goods (reliability and performance) | - Machinery<br>- Instruments<br>- Speciality chemicals<br>- Software | - Matching<br>- Absorbir<br>- Finding |

| |
|---|
| *Source:* ibid 8 |

As Pavitt *et al.* recognise, individual firms can follow more than one technological trajectory, and large instrumentation companies, such as Bruker and Oxford Instruments, are undoubtedly becoming increasingly science-based. This is evident, for instance, in the way Oxford Instruments has integrated advances in several rapidly changing technologies to build its new compact X-ray synchrotron source (the first of which is being supplied to IBM at a cost of some £20 million). Nevertheless, most instruments companies still fit into the category of specialist suppliers in that they are small or medium-sized enterprises relying in large part on user-developed innovations to improve or extend their normally highly specialised product ranges.

These findings indicate that there is greater scope for government involvement in encouraging the commercial exploitation of promising developments in scientific instrumentation than in most other industrial sectors and also that simplistic 'umbrella' based funding programmes are unlikely to effect the desirable results. According to John Irvine,[11] "fashionable pre-competitive strategic research programmes are rarely attractive to specialised suppliers since they generally require collaboration with potential competitors and thus are unlikely to provide a mechanism for gaining access to the unique technologies which their future commercial success will be based".

In view of the special characteristics of scientific equipment, funding agencies internationally have begun to re-orient their equipment-support policies with a view to increasing support for self-built instrumentation. The Instrument Development Fund established by the Science and Engineering Research Council (SESC) in the UK in 1989 and the Academic Research Infrastructure Programme established by the NSF in the USA in 1992 are such examples.

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[11] Prime Minister's Science Council. 1990. *Capturing Innovation in Australian Manufacturing Industry*. Proceedings of the Third Meeting of the PMSC. Department of Prime Minister and Cabinet. Canberra. Australia.

Both programmes can be seen as contemporary versions of the similar but much smaller Paul Instrument Fund, and we briefly describe it before turning to its modern counterparts.

### *The Paul Instrument Fund*

The Paul Instrument Fund was established in 1947 to finance "the design, construction and maintenance of novel, unusual or much improved types of instruments" required in pure or applied physical science fields, especially when significant investment in experimental apparatus is necessary.[12]

The fund is administered by a committee on which the Royal Society, the Institute of Physics and the Institution of Electrical Engineers are represented. This constitution encourages the submission of proposals for collaborative work by researchers spanning various natural science and engineering disciplines.

Grants awarded in the early 1990s include funding for the construction of micro-machined optical wave-guide sensors, a far UV Fourier transform spectrometer and a depth and planar imaging scanning laser microscope.

One of the successes mentioned by the Royal Society[13] resulted from a grant to Cambridge University in the mid-1970s which funded the development of an ion-probe analytical instrument incorporating the first optical system for producing a sub-micron ion beam. This led to the P7 dual-beam ion-electron microscope now being manufactured by Kratos Analytical.

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12 Royal Society. 1985. *Paul Instrument Fund*. (Mimeo). The Royal Society. London. UK.

13 Ibid 10.

***Instrument Development Fund (IDF)***

The IDF was established by the Science Board of the British SESC in 1989. It provides support for:

> *the development of novel and innovative instruments and associated software which will play a key future role in scientific research. Such developments may have commercial potential, but they would not yet be considered 'near' market. The potential uses are likely to be multidisciplinary*. [14]

The programme was created by 'top slicing' the allocations available to disciplinary sub-committees and allocating the funds to a discipline-independent Instrument Development Panel.

It was argued that the establishment of the Instrument Development Panel was necessary as budgetary constraints on the discipline-based sub-committees responsible for awarding grants made it difficult to support projects costing significantly more than the average of £50 000. In addition, instrumentation-oriented projects did not easily fit into the three-year timeframe of research grants.

More importantly, however, the new structure addressed the fundamental problem that such projects often rely heavily on research inputs from specific physical or technical science specialities, although the subsequent use made of the instrumentation developed is generally multidisciplinary. In the past, there was consequently an inherent tendency for sub-committees to favour proposals in core disciplinary areas rather than provide what was often regarded as further support for the already well-funded field of physics.

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[14] SESC. 1990. *SESC Awards Grants for New Instrument Development*. (Mimeo). Science and Engineering Science council. Swindon. UK.

Grants range from £100 000–£600 000, and examples of projects funded are the development of translational spectroscopy as a spectroscopic technique and the development of a microprobe source for imaging radio-carbon tracer distribution in biological tissue.

***Industrial Development within the Academic Research Infrastructure Programme (ARIP)***

The NSF in the USA allocates approximately 10 per cent of its research and education funds to the development and acquisition of instrumentation. In the 1993 fiscal year, the NSF investment in this regard totalled nearly $220 million.

NSF has developed three different funding mechanisms. Small requests of up to $20,000 are typically funded as part of a research project award. More expensive items ranging in value between $20 000 and $100 000 are funded through dedicated instrumentation programmes within each disciplinary area. The most expensive instrumentation, costing between $200 000 and $4 million, is funded through ARIP, which encompasses all research-related activities that the NSF supports.

ARIP supports the instrumentation needs of researchers and educators. The effort was developed to help the research community acquire, through purchase or development, major state-of-the-art instrumentation. 'Major' instruments, as defined by the programme, fall within the $200 000–$4 million range. The NSF promotes institutional commitment to these projects in the form of cost-sharing. Most host institutions match the NSF's investment in instrumentation on a dollar-for-dollar basis. The programme encourages proposals from all types of institutions of higher education, independent non-profit research institutions, research museums and consortia of such organisations.

In reviewing ARIP instrumentation proposals, the NSF seeks to support projects with the highest level of technical excellence and the greatest potential for enhancing and expanding research and training opportunities. NSF staff also consider the degree to which the proposed instrument will address research areas of strategic importance to the nation, its potential for shared use and the geographic distribution of ARIP funds. The commitment of the host institution and other partners to operating and maintaining the instrument is a consideration in the approval of proposals. ARIP targets a minimum of 10 per cent of its funds to increasing the capabilities of colleges and universities with high minority enrolment as well as non-PhD-granting institutions.

In order to maximise instrumentation development opportunities, the NSF has designed ARIP to encourage partnerships that lead to new commercial products. Specifically, ARIP solicits joint proposals from academic institutions and private industry aimed at designing, developing and testing new instruments that can potentially be marketed and sold to other scientists. By taking this initiative, the NSF seeks to stimulate development of the next generation of scientific instruments and, in the process, helps create new companies, new products, and new high-quality jobs.

Recently funded projects include:

? the development of microwave and millimetre wave instrumentation for atmospheric science research at the University of Massachusetts, Amherst

? the development of an advanced neutron stress instrument at the University of Missouri, Columbia

? the development of a D-region measurement capability for the SRI frequency – agile radar (ESU 92-16) at SRI International and others.

# Discussion and Recommendations

### *Towards a National Policy for S&T Equipment*

The NRTA is a landmark exercise in the national effort to develop an informed and rational S&T policy. The investigation of research and training equipment aimed to create an informational database and to cast light on associated policy and management issues on a national level.

We have argued that modern, well-maintained equipment is a prerequisite for high quality research; that instrumentation has considerable economic impact, as a strong basic competence in generic instrumentation technologies is a key asset in the effort to capture economic benefits from innovation across the total spectrum of the manufacturing sector; that the technological trajectories of scientific instrumentation companies differ considerably from those in other sectors in the economy, indicating that there is great scope for government involvement in encouraging the development of the sector; and that scientific instruments in the educational field nurture curiosity, develop skills for inquiry and strengthen practical experience with up-to-date equipment so that students are qualified to meet the needs of the industry and commerce.

Furthermore, we suggest that instrumentation policies are not amenable to pluralistic approaches in S&T. The reasons include:

? Administrators of organisations financed primarily by general institutional grants (which cover both teaching and research, for example) are usually unable to maintain a proper balance between spending on salaries and investing in equipment. This problem is particularly acute during periods of sinking or level funding, as has been the situation in South Africa over the last decade.

- Funding agencies do not always place the appropriate emphasis on equipment support. Short-term priorities based on quick results and political considerations almost always take precedence over meeting long-term infrastructural needs. Discipline-based committees make it difficult to establish and support equipment funding programmes that are not associated with particular research disciplines.

- Trends towards the broader use of generic instrumentation (for example, NMR equipment) across different fields have resulted in considerable scope for the more efficient deployment of resources through common-use facilities or equipment sharing by bodies such as academic departments and faculties and science councils. However, vertical structures, vested interests and institutional rigidities prevent the exploitation of the available economies of scale.

- As equipment becomes exorbitantly expensive, governments are the only players with the capacity to act as catalysts for the development and maintenance of the equipment infrastructure. Government's economic and regulatory power can serve functions such as stimulating collaboration and rationalising utilisation and innovation.

- The basic technological trajectories of scientific instrumentation companies differ considerably from those of other sectors, with the interface between academic institutions and instrumentation companies growing in importance. These particularities make government intervention of paramount importance.

Despite the overwhelming international evidence on the importance of instrumentation and the inadequacy of a pluralistic system to address failures in the equipment infrastructure, both policy-makers and individual users of equipment in South Africa do not appear to assign a high priority to the issue.

The institutions visited were overwhelmed in dealing with their human resources deficiencies and consequently assigned a low priority to all other needs, including issues of equipment. More importantly, however, policy-makers appear to ignore infrastructural issues.

Forthcoming legislation, for example, chooses to ignore or deliberately not directly address infrastructural issues on the nature of equipment. The White Paper on Higher Education mentions equipment only circumstantially and in aggregation with other needs, and the National Research Foundation Bill does not give the new Foundation 'responsibility' for protecting and developing this infrastructural need. It should be mentioned that the NRF is enabled by the bill to support equipment needs, but this is not an entrenched responsibility in the same way as the NRF's disciplinary interests are.

The importance of the issue becomes even more evident when it is taken into account that survey respondents indicated that equipment valued at R512 million will have to be replaced within the next five years (up to 2002), that R224 million is required to upgrade the infrastructure so that equipment will not hamper the research and training needs of the institutions and that the national research wish list includes equipment expansion and upgrading to the value of R377 million.

**_Box 4_: Research Equipment – A Strategic View**

**Adi Paterson, Vice President, CSIR**
12 February 1997

The capital infrastructure of research institutions should be strategically managed.

Research equipment planning should be consciously linked to the current and planned research and teaching activities of the institution. In general, a moving five-year plan for research equipment should be derived from the strategic planning based on research staff and student populations, teaching and research requirements and funding models. Where affordability is a key factor, consortia and the alignment of research interests across a broader range of institutions should be planned.

Modern research equipment has a much shorter effective life-time than equivalent equipment purchased five or ten years ago. Improvements in performance and utility have accelerated with the increased integration of software for control, simulation and interpretation of results. Computer hardware and software also represent a major associated cost and present a particular challenge for long-term planning. These realities make huge demands in terms of equipment maintenance and computer, research infrastructure and technical support. Students frequently encounter more sophisticated equipment after entering employment than while they are being educated or undertaking research. The acquisition of equipment by research institutions should therefore not be based solely on direct cost considerations but on a full life-cycle costing of the support costs (maintenance, licences and upgrades) and operational costs (direct staff cost for operating the equipment, consumables and set-up). Only when such costs are accounted for is it possible to determine the financial risk of acquisition against the benefits that will accrue to the institution acquiring the equipment.

Proper asset planning also takes account of the type of utilisation that equipment will support. Suppliers have very different product strategies: some essentially make the equipment a highly efficient black box'– suitable for certain types of training and volume research use – while others allow highly variable specialist usage which supports cutting-edge research or, indeed, further development of the equipment itself. Trying to make a single piece of equipment do too much in these differing environments can lead to all users' becoming the victims of sub-optimal performance.

The financial policies of research institutions differ widely. Usually in educational contexts the charge-for-use of equipment is only costed on a marginal basis. In most science councils, charges for equipment use include depreciation charges. This results in a substantially improved ability to fund future capital but *de facto* increases the cost to users. Strong consideration should always be given to including at least a partial depreciation charge for all capital equipment usage in all research and educational institutions. In science and engineering teaching environments, the higher subsidies for certain types of student could be used to fund such charges and develop a much improved (and internally controlled) base for capital programmes for research equipment. Indeed, the higher subsidies paid for engineering students should be recognised to have, in part, this underlying purpose.

Modern research equipment often has a high acquisition cost but the utilisation costs can dwarf these initial expenses. One of the greatest hidden costs' of research equipment is the carrying cost when it is not utilised either, for instance, though loss of skilled or interested staff or through the lack of active planning of research and teaching programmes based on effective utilisation of the equipment. Regular assessments of utilisation, state of repair, supporting skills and maintainability of the equipment need to be undertaken. Often large equipment that is frequently or never used represents a lost opportunity to take a new and strategic view of the research, teaching and long-term equipment planning of research institutions. Charging a small nominal rent for research space may be sufficient to correct this tendency.

As global competition increases, research institutions that responsibly plan for their equipment needs over the long term and become less dependent on external bidding processes will differentiate themselves from institutions with ageing equipment and tactical, rather than strategic, acquisition programmes. Such planning is less complex than it at first appears, and most research staff welcome the discipline, if it is associated with greater long-term security for the institution. Such approaches are also congruent with current science and technology policy developments locally and globally and permit the institutions and their staff to participate in larger research consortia and thereby access new funding streams efficiently.

The importance of the issue becomes even more evident when it is taken into account that survey respondents indicated:

?? that equipment valued at R512 million will have to be replaced within the next five years (up to 2002),

?? that R224 million is required to upgrade the infrastructure so that equipment will not hamper the research and training needs of the institutions

?? and that the national research wish list includes equipment expansion and upgrading to the value of R377 million.

Two issues of importance for policy arise from this finding. Firstly the deficiencies in the provision of research equipment cannot be rectified without the injection of additional funding and intelligent future approaches. The term "additional" is used in this instance to mean not only funds outside the S&T envelope. Different approaches may be required for the different components of the system (for example, for science councils *vis-à-vis* academic institutions); although a coordinated effort between, for instance, DACST and the Department of Education may be preferable, at least for the next five years (as we expand on in our recommendations section). A coordinated effort of this nature will also be compatible with the second issue of importance, which is improved management of the provision of equipment.

The size and timing of the need for replacing and upgrading the equipment infrastructure presents a number of opportunities: promoting/developing local instrumentation manufacturing capabilities; achieving economies of scale through centralised purchasing and bargaining; encouraging collaboration and rationalising are some of the issues that should be considered.

While all the issues are interrelated, the current 'one-fits-all' approach should be avoided. Local funding programmes tend to have multiple objectives and limited resources. The multiplicity of objectives is obviously introduced in order to satisfy the various constituencies of both funders and users and to introduce flexibility to the programme. However, funding programmes are policy instruments, and their ability to achieve their policy objectives is considerably impaired when they aim to achieve more than one objective. It could be argued that the Technology and Human Resources for Industry Programme (THRIP) (which strives to bring industry and academia together) and the Support Programme for Innovation (SPII), (which funds research in industry) already cover the specialised needs of the instrumentation industry, but it should be expected that their impact in the field will be limited. International experience indicates that more than one means (for example, a funding programme) should be used to achieve a particular objective and not *vice versa*.

The approaches used internationally, as outlined, are instructive in this regard. In the USA, for example, the NSF has a number of separate equipment programmes for various purposes, such as different disciplines, equipment of different values and for the development of new equipment. Furthermore, industry is given incentives to donate equipment to universities and government laboratories. The Equipment Donation and Discount Scheme allows firms that donate equipment to identified institutions to offset the full market value against future corporate taxation.

More instructive, however, may be the fact that it is customary abroad for most of the funds for equipment to come from a centralised authority rather than to be left to the initiative of individual institutions. In the UK, the University Grants Council (UGC) provides 46 per cent of the equipment funding at universities. Similarly, in the USA, federal agencies provide more than 55 per cent of the funds for equipment, despite the decentralised nature of the country's science system.

At the level of the management of equipment, the situation in South Africa appears to be a far cry from international best practice. Institutions at best follow normal accounting practices in the depreciation of their equipment, attempt to keep equipment budgets separate from budgets for other needs and maintain some form of equipment database. Institutions, which operate in this way are isolated cases, however, and do not reflect the broader South African situation.

A number of survey participants recognise the need for a more methodical approach, and some embryonic efforts are under way to promote cooperation. The regional cooperative initiatives among the various academic institutions (for example, the WCTIT) and the requirements by the FRD for common proposals (or at least for support from other institutions for equipment funding proposals from any one institution) lay the foundations for collaboration.

We were unable to identify any institution, which manages its equipment by taking into account its entire life cycle. More important, perhaps, is the fact that no guidance is available to institutions on the appropriate management of teaching and research equipment on the basis of the whole life cycle. International best practice currently makes the following recommendations for the various stages of the equipment life cycle:

**Planning**

? There should be a central focus on equipment, policies and practice throughout the life-cycle.

? There should be a process for ensuring that the proportion of the institution's budget allocated to equipment is sufficient and is allocated appropriately to meet equipment needs. This process would need to be effective in the event of the disappearance of the external sources for funding equipment.

? Decisions on the prioritisation of equipment provision should be informed by a longer-term perspective of the equipment needed, including the need to replace existing equipment.

? There should be a methodical approach to deciding on specific items of equipment to fund, taking account of the availability of equipment elsewhere in the institution.

**Procurement**

? There should be a proper market search leading to competitive tenders or quotations and a second round of negotiations.

? Action should be taken to secure value for money even when there is only one supplier.

- ? There should be an evaluation of which supplier provides the best value for money in terms of whole-life costs, taking account of all relevant downstream costs, particularly maintenance, consumables and the provision and cost of spares.
- ? Savings should be sought through combining purchases of common items or negotiating advantageous leasing deals.
- ? There should be appropriate application of professional purchasing skills, with the institution's purchasing coordinator being involved in all high value expenditure.

**Management of equipment through the life cycle**

- ? Formally appraise equipment use, soon after acquisition and periodically thereafter, to check that it is meeting its objectives and to identify spare capacity.
- ? Develop mechanisms to encourage the sharing of spare capacity and to ensure that equipment is not purchased by departments without an appraisal of the scope for sharing equipment with other departments.
- ? Cost in-house maintenance and encourage departments to use these costs in deciding on the maintenance strategy for each type of equipment.
- ? Consider whether in-house maintenance can be provided more cost-effectively by means of pooling arrangements.
- ? More actively consider the merits of taking out extended warranties and institutional maintenance arrangements.
- ? Establish standards and procedures for asset recording, including keeping records up-to-date and ensuring their completeness and accuracy.
- ? Consider using an internal audit to ensure that departmental records and procedures are up to standard.

? Introduce standardised systems for purchase and inventory recording.

? Use departmental asset records to check that equipment is secure.

? Consider arrangements for the investment appraisal of and, if necessary, funding for the replacement of equipment that is costly to maintain or to run.

? Establish policies for the disposal of equipment in some cases.

On that basis, we make the following recommendations:

1. The Department of Arts, Culture, Science and Technology (DACST), within its mandate to coordinate the scientific and technological system, should establish an inter-departmental committee on 'Critical Scientific and Technological Infrastructures'.

   The mandate of the committee should be to investigate and make recommendations on policy and programmes affecting 'critical scientific and technological (S&T) infrastructures', such as research and training equipment, scientific and technological telecommunications, and research and development (R&D) management.

   The committee should consider, among others things, the viability of introducing:

   ? the funding of 'critical S&T infrastructures' as a separate line item in the governmental budget [Expenditure defrayed from the National Revenue Account]

   ? approaches that promote closer collaboration on aspects of critical S&T infrastructure among organisations reporting to different government departments (for instance, academic institutions, science councils and parastatals).

2. The National Research Foundation (NRF) – to be established – should institutionalise the support of research and training equipment by establishing an

appropriate, dedicated directorate/division. The division should be funded by dedicated (earmarked) funds, by top-slicing the budget of the other directorates and by raising funds from local and international donors.

The NRF should establish appropriate 'competitive grants'/funding mechanisms that promote :

? interaction between academia and industry for the development and construction of new or improved equipment

? the maintenance and augmentation of the R&T equipment infrastructure

? the development of the necessary infrastructure at institutions where it is lacking or deficient

? the development of a programme promoting the remote utilisation of equipment, which should be considered as an urgent priority in view of its possible impact across all other programmes

Different programmes should be established for different objectives.

3. The Department of Education's funding formula for academic institutions (which are currently under investigation) should make R&T equipment an explicit component of the formula. Furthermore, adequate funds should be earmarked for equipment for at least the next five years in order to facilitate the necessary replacement and upgrading of R&T equipment.

4. Best international practice should be adopted by all relevant South African organisations in their management of equipment and should also be used for benchmarking. (Fig. 2). Benchmarking is a tool for monitoring progress on an ongoing basis and assessing the South African situation in the light of constantly improving best practice world-wide. It goes beyond competitive analysis by providing an understanding of the process and skills that contribute to superior performance management of equipment over its life-cycle. The Committee of Heads

of Scientific Councils (CHSC), the Committee of University Principals (CUP) and the NRF could play pivotal roles in investigating best international practice and introducing to their institutions the concepts of management over the life-cycle of the equipment. Linking the introduction of the concepts to additional funding for equipment (from the NRF, for example) would serve to facilitate and speed up the implementation of the approach.

A number of issues may have been excluded from the scope of this study and may merit further investigation. However, the results of this investigation could be complemented by:

? investigating the availability and condition of equipment (particularly in the business environment) that could be used for research and training but which is currently used for other purposes

? investigating the instrumentation industry in the country

? enlarging the NRTA database to include equipment in the major research-performing organisations in the business sector, especially the parastatals and business-funded research laboratories

? considering, as a future option for South Africa, that equipment surveys be conducted independently of surveys of facilities, as is the practice of the US National Science Foundation (NSF)

# Appendix I

***Questionnaire: Survey of Research/Training Equipment***

***USA legislation related to research equipment***

**HR 111 (Edwards)**

Amends Title 38, United States Code, to authorise the Secretary of Veterans' Affairs and the Secretary of Defense to carry out a joint programme to make grants for the establishment of research centres at qualifying medical schools. Introduced on 3 January 1991; referred to the Committee on Armed Services. Passed by the House as amended on 27 February 1991. Referred to Senate Committee on Veterans' Affairs on 5 March 1991.

**HR 150 (Matsui)**

Non-profit Organisations Tax-Exempt Bond Reform Act of 1991. Amends the Internal Revenue Code to provide for the tax treatment of bonds of certain non-profit educational institutions in a manner similar to governmental bonds. Introduced on 3January 1991; referred to the Committee on Ways and Means.

**HR 714 (Barnard)**

Biomedical and Behavioral Facilities Construction Act of 1990. Amends the Public Health Service Act to authorise competitive matching grants for the renovation or construction of biomedical and behavioural research facilities. Establishes the Technical Review Board on Biomedical and Behavioral Research Facilities. Introduced on 30 January 1991; referred to the Committee on Energy and Commerce and the Subcommittee on Health and the Environment.

**HR 1557 (Downey)/S 359 (Boren)**

Amends the Internal Revenue Code of 1986 to provide that charitable contributions of appreciated property will not be treated as an item of tax preference. HR 1557 introduced on 21

March 1991; referred to Committee on Ways and Means. S 359 introduced on 15 February 1991; referred to the Committee on Finance.

**HR 3544 (Whitten)**

Emergency Job Creation Appropriations Act of 1992. Appropriates $200 million to construct or rehabilitate higher education academic and research facilities as authorised by Title VII of the Higher Education Act, with funds to be awarded on a competitive basis. Introduced on 10 October 1991; referred to the Committee on Appropriations.

**HR 3553 (Ford)**

Higher Education Amendments of 1992 Title VII, "Construction, Reconstruction and Renovation of Academic Facilities", permits awards for research facilities; requires matching and peer review (instead of formula grants); authorises appropriations for all facilities grants at $50 million for FY1993 and for each of four succeeding years; consolidates loans for undergraduate and graduate schools, permits loans for research facilities; authorises appropriations for all types of loans at $100 million for FY1993 and each of four succeeding years. Introduced on 1 October 1991; referred to the Committee on Education and Labor, reported, amended Rept. No. 102-447, 27 February 1992; passed by the House as amended on 26 March 1992.

**HR 4315/S 2265 (Fawell/Brown)**

Spending Priority Reform Act of 1992. Rescinds unauthorised appropriations for FY1992 for 642 projects, totalling $1.5 billion, including earmarks for academic facilities. Introduced on 26 February 1992; referred to the Committee on Appropriations.

**S 150 (Moynihan)**

Higher Education Tax-Exempt Bond Reform Act of 1991. Amends the Internal Revenue Code to provide for the tax treatment of bonds of certain non-profit educational institutions in a manner similar to governmental bonds. Introduced on 14 January 1991; referred to the Committee on Finance. Hearings held on 12 June 1991.

**S 222 (Gramm)**

Authorises the Secretary of Veterans' Affairs to make competitive grants to qualifying medical schools for the establishment of research centres in selected, specified research areas. Introduced on 16 January 1991; referred to the Committee on Veterans' Affairs.

**S 1150 (Pell)**

Higher Education Amendments of 1992. Sec. 711, "Higher Education Facilities Act of 1992", provides awards for academic facilities to state higher education agencies on the basis of population and number of students served; requires dollar-for-dollar matching by the state or institution; subtracts from the state allotment federal facilities awards made non-competitively; authorises $400 million in appropriations for FY1993 and each of the succeeding six fiscal years; provides assistance in the form of loans for graduate and undergraduate institutions; authorises appropriations of $30 million for FY1993 and such sums as necessary for each of succeeding six fiscal years. Introduced on 23 May 1991. Referred to the Committee on Labor and Human Resources. Reported on 12 November 1991 (S. Rept. 102-204). Passed by Senate as amended on 23 February 1992. House substituted and passed language of HR 3553 amended, Mar 26, 1992. House conferees appointed on 26 March 1992; Senate conferees appointed on 8 April 1992.

**S 1523 (Kennedy)**

NIH Re-authorisation Act of 1991. Authorises $150 million for a new biomedical/behavioural academic-facilities competitive-grant matching programme. Introduced on 22 July 1991; referred to the Committee on Labor and Human Resources.

**S 2137 (Kennedy)**

Emergency Anti-Recession Act of 1992. Appropriates an additional $60 million to the NSF for the facilities programme. Introduced on 21 January 1992; referred to the Committee on Appropriations.

*Copy of the proposal to the Ford Foundation to support regional cooperation*

## Project proposal to the Ford Foundation – Infrastructural support for regional cooperation amongst tertiary institutions in the Western Cape

Professor Wieland Gevers
Chair: Western Cape Tertiary Institutions Trust

12 February 1996

### 1. Summary

Significant cooperation already exists among the five tertiary institutions in the Western Cape. In addition to modest levels of collaborative teaching and research, there are a number of large joint projects. These report to the Vice-Rectors' Group (VRG) established in 1991. A tax-exempt educational trust, the Western Cape Tertiary Institutions Trust (WCTIT) has been created to raise and manage funds for projects reporting to the VRG. This proposal to the For Foundation is a request for funding support over a critical two-year period:

a) to promote further infrastructural and academic cooperation among the five institutions in a capacity-building way

b) to provide infrastructural support to the VRG and WCTIT

c) to coordinate and develop income-generating activities for the WCTIT

### 2. Background

The Western Cape is home to three universities and two technikons, serving over 60 000 students drawn from all over Africa. Although these institutions are in close geographical proximity, for much of their history they operated largely separately from one other, divided by language, by function, and by attitude.

In recent years, however, important developments have taken place in cooperative arrangements among the five institutions, collectively and in various combinations. Such arrangements may conveniently be classified into the two main categories of (i) projects and fund-raising through formal cooperative channels and (ii) academic initiatives among the various partners.

### A. **The VRG and WCTIT**

In 1991 an informal VRG was set up among UCT, US, UWC and PenTech. At the time of its foundation, the VRG sought funding support in the areas of library cooperation, inter-institutional training programmes, academic development and information systems. When a grant was received from the Ford Foundation for a cooperative library, an educational trust, the WCTIT, was formed. It exists solely for the purpose of raising and managing funds for projects collectively operated by two or more (preferably all) of the participating institutions.

At present, the following projects report to the VRG, typically through a project steering committee chaired by a vice-rector-in-liaison:

i) **Cape Libraries Consortium (CALICO)**: This is an ambitious project aimed at the creation of a single library system to serve the five institutions. Planning around the delivery of the system and the adoption of the appropriate technology for a shared automated system is at an advanced stage. The Andrew W Mellon Foundation awarded a grant to CALICO for 1996, which will enable it to appoint a project director for this growing project.

ii) **Information Literacy Development Project (INFOLIT)**: A component of the CALICO project, INFOLIT, is generously funded by the Readers Digest Association. It aims over a five year period to upgrade the skills of the most disadvantaged students and integrate information literacy into academic programmes over a five year period.

iii) **Western Cape Science and Technology Project (RISK)**: The core of the project is to apply modern computing technology as to enhance the tertiary education of scientists and engineers. To this end, IBM RW/6000 workstations have been placed in suitable locations at each of the five institutions, making significant computing power available to senior undergraduate and postgraduate students.

iv) **Development of a shared School of Public Health**: The governing councils of all five institutions have approved in principle the creation of a School of Public Health – a farsighted attempt to pool and expand existing resources in the rapidly developing field of public and community health education.

v) **Science and Technology Exploratorium**: This project comprises the tertiary educational component of the planned Gateway Discovery Centre being developed for Cape Town and its environs.

vi) **Scientific and Industrial Leadership Initiative**: Funded by the Gatsby Charitable Foundation, this recently adopted project provides support for a range of educational initiatives in mathematics, the natural sciences and technology aimed at increasing the participation in South African business leadership of black South Africans who are technologically literate.

vii) **Copyright**: Planned for 1996, this project entails the establishment of a cooperative clearing house for copyright and publishing liaison, modelled on the experience of the University of the Witwatersrand.

### B. Academic Initiatives among Institutions

While the focus of the VRG and WCTIT has been on specific projects, regional cooperation is also developing at the level of academic programmes. These include cooperation across two or three university campuses, as well as between universities and technikons. Most have been developed at the faculty or departmental level. While this is not an exhaustive list, examples include:

- the Western Cape Chemical Engineering Joint Working Group, with combined research and teaching dimensions (UCT, US, PenTech and Cape Technikon (CapeTech))
- the LLM programmes devised and offered jointly by three law faculties (UCT, US and UWC)
- joint honours and course work MA in political studies (UCT, US and UWC)
- the ORTSTEP programme to enhance student understanding of S&T (UWC and PenTech).
- a working group of representative of three education faculties which aims at cooperation on BEd and MEd taught courses (UCT, US and UWC).

## 3. Consolidating and developing regional cooperation

This proposal takes as axiomatic that regional cooperation and/or coordination in tertiary education is desirable in contemporary South Africa. Increased pressure on access and budgetary constraints together constitute a strong argument in favour of regional ventures, which can lead to exciting and innovative projects and programmes, avoidance of unnecessary duplication and greater articulation between the various types of higher education institution.

In order to consolidate existing instances of regional cooperation (as described in 2A and 2B above), promote new initiatives, provide some measure of infrastructural support to them and systematically raise funds for them, it is proposed to set up an office of tertiary regional initiatives in cooperation and education.

The WCTIT office will be located in Rondebosch in a suite next to the office of the Desmond Tutu Educational Trust, as approved by the VRG. It will employ two people: (i) a part-time executive director and (ii) a secretary. The executive director will report to the VRG and WCTIT, and his primary responsibilities will be to play an active role in supporting and managing fund-raising activities on behalf of the WCTIT. He will necessarily work closely with officers responsible for fund-raising and development at each of the participating tertiary institutions. He will also be responsible for developing and sustaining strategic planning initiatives on closer regional cooperation in the Western Cape tertiary education sector. The secretary will provide support to the executive director, the VRG and the WCTIT.

The funding support sought for the WCTIT office includes:

a. the salaries of the executive director and secretary for two years, after which the office should be self-sustaining (either through its own income-generating efforts or through salary subvention by the five participating institutions)

b. the costs of running the office (including rent, telephone, telefax, photocopier, word-processor; furniture and filing cabinets and stationery)

4. the budget of WCTIT for the period 1996–1997

(Draft funding proposal prepared by Professor Colin Bundy, UWC. Draft budget prepared by Dr Jim Leatt, executive consultant to WCTIT.)

## Appendix IV

***Eastern Seaboard Association of Tertiary Institutions (ESATI) - Background information and statement of intent***

ESATI was initiated late in 1992 by UDW, UN and UZ.

These institutions recognised that the existing system of tertiary education, like other educational sectors, was in need of fundamental restructuring. The envisaged restructuring entails addressing:

?? fragmentation at all levels

?? racial and gender inequalities

?? inequitable resource allocations

?? duplication of services

?? wastage and inefficiency

?? poor articulation and transfer possibilities between institutions

?? severe constraints on access into the system

?? undemocratic governance

?? inadequate processes and structures within which to develop institutional objectives and choices

?? outdated curricula and syllabi

?? poor coordination of human resources requirements with national or regional development agendas

Within a framework of such problems, the universities committed themselves to the process of identifying areas of possible cooperation, negotiating in good faith around these areas and acting promptly on all decisions agreed upon jointly. With regard to the latter, the institutions acknowledged that the project would pose a variety of complex challenges to certain preferred views about the appropriate relationship between the regional and the national, as well as about the status and limits of institutional autonomy within a regional dispensation. Despite this, the shared view was that the benefits of cooperation far outweigh whatever disadvantages may exist.

The Ford Foundation was approached and agreed to assist with initial funding for the project. A board of management was established consisting of five representatives from each of the three universities. In mid-1993, Professor Mervyn Shear was appointed as regional coordinator. Since August 1995, Professor Shear has been chair of the board, and Professor John Butler-Adam has become executive director of the association. There is also a secretariat comprising the project manager and the office manager, as well as working or steering groups for each project, with members drawn from the member institutions.

A start has been made to collating regional educational data of use to the project, and questionnaires have been circulated to all departments at the three institutions, calling for information on current cooperation as well as possible future areas of cooperation. In addition, a number of national meetings have been held with various educationalists and organisations in an attempt to establish the national extent of tertiary cooperation – both current and potential.

Late in 1993, the association entered into discussions with UNISA, Technikon Natal, Mangosuthu Technikon and the ML Sultan Technikon on to how best they might participate in the project. At the ESATI board meeting in November 1993, it was agreed that all four institutions should have full and equal status in the project.

Five key strategic areas have been identified by the board:

?? Access

?? Distance education/part-time studies

?? Services (libraries, audio visual, buying offices and computer services)

?? Educational development

?? Articulation

Each area is to evolve into a strategic initiative and workshops, meetings and seminars are to take place early in the year to launch these areas.

**Statement of intent**

As participating institutions in a process of regional cooperation, we recognise that the existing system of higher education, like other education sectors in South Africa, is in need of fundamental restructuring. While some value may have developed within the system, it is characterised, to a greater or lesser extent, by inequity and incoherence. These include:

?? fragmentation at all levels;

?? racial and gender inequalities;

?? inequitable resource allocations;

?? duplication of services which leads to wastage and inefficiency;

?? poor articulation and transfer possibilities between institutions;

?? severe constraints on access into the system;

?? undemocratic governance;

?? outdated curricula and syllabi; and

?? poor coordination with human resource requirements and national or regional development agendas.

Concrete regional and national strategies will have to be developed in order to address the above legacies of the apartheid system and to build an equitable and efficient system which can guarantee quality education. Such educational strategies will have to serve equally the needs of both human resource requirements as well as of democracy in this country. The role of specific institutions within the tertiary sector will have to be understood within the context of such regional and national needs and strategies.

While being conscious of the dynamics of national systematic restructuring on the one hand and of creative institutional initiatives on the other, we believe that it is of vital importance to begin a process of cooperation among institutions of higher education in the Natal region.

Such regional initiatives could form the basis of a more coordinated and well-functioning national system.

We acknowledge that the need for cooperation among participating institutions of tertiary education in the region is driven by a number of inter-related educational, political and economic factors. The basis for cooperation cannot be reduced solely to a narrow conception of economic rationalisation but must be underpinned by a commitment to, at least, some of the following values and concerns:

?? the creation of a strong, comprehensive and well-articulated tertiary sector in the region that could turn out graduates of quality who would be able to respond to the needs of a society in transition;

?? the facilitation of redress and equity in connection with issues of institutional inequality, limitations on access, academic development programmes, etc.;

?? the involvement of relevant communities and constituencies in the shaping of a new educational system;

?? the better use of existing resources and available finances through rationalisation and the elimination of duplication and wastefulness;

?? the facilitation of a coherent education and training approach to the specific human resource and development need of the region within the framework of a national strategy;

?? the development of joint ventures as well as areas of specialisation within a regional framework;

?? a cooperative rather than a competitive approach to the provision of educational and other services; and

?? interaction and cooperation with other national and regional initiatives concerned with educational and economic reconstruction and development.

Despite our differing histories and experiences, we as participating institutions commit ourselves to a process of regional cooperation that will allow for both bilateral as well as multi-lateral interaction. We agree that the process will be inclusive of internal institutional constituencies as well as major external stakeholders in higher education in the region. We further agree to the requirement that our institutional planning will consciously address the removal of institutional and other barriers of cooperation, the facilitation of cooperation where none exists and the deepening and enhancement of all existing cooperation.

We acknowledge that the process will include short, medium and long term changes to existing policies, and operate at different levels of cooperation ranging from the sharing of resources like computers and libraries to the creation of a new system of tertiary level governance for the region. We, therefore, commit ourselves to the process of identifying areas of possible cooperation, negotiating in good faith around these areas and acting promptly on all decisions agreed upon jointly. In this regard, we acknowledge that the project of regional cooperation will pose a variety of complex challenges to our preferred views about the appropriate relationship between the regional and the national as well as about the status and limits of institutional autonomy within a regional dispensation. We are, however, of the view that such issues must continue to be debated within the regional institutional cooperation forum itself and that the benefits of cooperation far outweigh whatever disadvantages may exist.

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