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INTERNAL REPORT

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and
United Nations Educational Scientific and Cultural Organization

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS



# PHYSICS AND DEVELOPMENT

No. 9

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# FOREWORD

The ICTP Physics and Development Programme resulted from the recognition that the scientific, economic and social progress of the developing nations is strongly interrelated and from the recognition that physical and mathematical sciences play an exceedingly important role in providing satisfactory solutions to problems of development in general.

Within the framework of this Programme, renowned experts are usually invited to give lectures on science and technology, economics and planning, with particular reference to the needs of developing countries. The purpose is to improve the awareness of scientists visiting the Centre, of the current technical, economic and social aspects of development, thereby assisting them in better utilizing their talent in the development programmes of their countries.



H.R. Dalafi

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**SCIENCE AND TECHNOLOGY TRANSFER TO THE THIRD WORLD**


**Address by Professor Abdus Salam**

**Director, International Centre for Theoretical Physics**

**President, Third World Academy of Sciences**


**30th Anniversary of the**

**International Atomic Energy Agency**

**21-25 September 1987, Vienna, Austria**

*"In the conditions of modern life, the rule is absolute: the race which does not value trained intelligence is doomed ... To-day we maintain ourselves, tomorrow science will have moved over yet one more step and there will be no appeal from the judgement which will be pronounced ... on the uneducated."*

*Alfred North Whitehead*

Mr. President, Director General, Distinguished Delegates, Ladies and Gentlemen,

1. I am honoured to be asked to address you to-day on the occasion of the Agency's 30th Anniversary. Being here in these circumstances brings to mind the events leading to the founding of the International Centre for Theoretical Physics, and I am particularly conscious of the debt which is owed by the physicists of the Third World to the foresight and courageous action taken by the Agency and its Board of Governors during 1964 in setting up the International Centre for Theoretical Physics at Trieste. The concept was then novel (though it is now being adopted more and more) and it took a great deal of time and effort to convince the skeptics of its utility.

I am confident that events have more than justified the action, however, and I believe that the Centre has become an instrument for Science and High Technology Transfer in which each of its parent organizations - the Agency and UNESCO - as well as the Italian Government, can take pride.



The title assigned to me for my talk was "Nuclear Science and Technology Transfer to the Third World". I believe it would be wiser if I interpreted it more widely, and spoke to you from the standpoint of a physicist who is concerned about the larger question of the transfer of science in general, to the poorer countries of the world.

With your permission, therefore, Mr. President, I intend to present my remarks on three topics: 1) The International Centre for Theoretical Physics *as a modality for Science Transfer;* 2) The hang-ups of the developing countries in relation to Science for development and the Ivory Tower isolation of the scientist in most parts of the world; and finally, 3) How the North can help in the tasks of development through Science.

## A. ICTP - A MODALITY FOR SCIENCE TRANSFER

2. First, a few remarks on the Centre. As a house of scientific research and high-level training it is unique within the United Nations family, and has had, over twenty three years, visits numbering some 30,000 (3,800 during 1986 alone) of physicists and mathematicians from 100 countries, with more than one-half of the visitors coming from the developing countries*. It has established firm links with the world physics community, at both the individual and the institute level. Perhaps the aspects about which I am most

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* The utilisation ratio of the Centre for those from the developing countries is over 70%.

happy is the scientific reputation it enjoys and the fact that Third World physicists, in the same way as all other physicists, truly regard the Centre as their own*.

The Centre has several inter-related modalities of operation. These include the Associateship Scheme, under which some 350 high-level scientists from developing countries are appointed for periods of six years, during which they may make a total of three visits of up to three months, with the Centre paying their travel and per diem. This Scheme has been the backbone of the Centre's efforts to overcome the brain-drain from developing countries.

Complementary to this is the Federated Institute Scheme, linking the Centre with more than 250 institutes in the Third World, and which makes

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* If I may be permitted to be parochial, in the context of funds to be devoted to research in each discipline of Science, it is good to remind ourselves that Physics is an incredibly rich discipline: it not only provides us with the basic understanding of the Laws of Nature, it also is the basis of most of modern high technology. Thus physics is the "science of wealth creation" par excellence. The situation may well change in the 21st century, but this is certainly true, as of today. This is even in contrast to chemistry and biology which together provide the "survival basis" of food production and pharmaceutical expertise. Physics takes over at the next level of sophistication. If a nation wants to become wealthy, it must acquire a high degree of expertise in physics, both pure and applied. Let us take high temperature superconductivity, as an example. Apparently, any nation may join in this potentially rich and, fortunately, still open quest if it can afford just thirty thousand dollars for equipment and payment for the physicists.



provision for several hundred visits each year by individual scientists from these institutes, the costs of which are shared.

Some three dozen training activities are now held each year - ranging from courses of up to more than two months to shorter courses, seminars and workshops at the frontier of all sub-disciplines of Physics. These activities - where those from developing countries are supported by the Centre - are augmented by a number of scientific meetings each year. In addition, there is the continuing presence of some 100 or more scientists for varying periods of up to a year, or more, who come in order to carry out research in their own fields.

Two other programmes were instituted recently. The first is a scheme of extended visits averaging about nine months to a number of Italian experimental laboratories by selected Third World scientists. Under this scheme some 100 physicists each year are able to take part in high-level experimental research in various disciplines of physics. This compensates to some extent for the lack of experimental facilities at the Centre itself and is supported to the extent of 1.3 million dollars by the Italian Government*.

The second is a special programme of support extended to scientific activities in different Third World countries (symposia, seminars, workshops and training and research carried out particularly at centres in Asia, Africa and Latin America, which follow the same pattern and traditions which we have built up at Trieste). During 1986 and 1987, this programme made 159 grants, amounting to 2.8 million dollars.

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* Direzione Generale per la Cooperazione allo Sviluppo.

During 1986, the Centre was able to distribute 50,000 books and journals to 500 institutions in 96 developing countries. In addition, twenty laboratories, notably including CERN at Geneva and the Seibersdorf Laboratory of the Agency in Vienna, have contributed equipment worth 1.8 millon dollars to institutes in the developing countries, through the Centre. These equipment and book donation activities are incidental to the major activity of Training and Research.

Finally Mr. President, it is, of course, impossible to speak of the Centre and not mention the extremely generous support of the Italian Government and of the City of Trieste. A large number of the world's physicists now look upon the Trieste area as a second home.

When the history of Physics Research in the last three decades of the century is written up, I am sure the Centre will figure prominently in it.

## B. SCIENCE AND THE THIRD WORLD

3. I shall now turn to the factors affecting Science Transfer and certain of the Third World's hang-ups in dealing with Science.

From the experience of the 30,000 visits I have just mentioned of high-level physicists and mathematicians from some 100 countries, we at Trieste can perceive just five - at most six - Third World countries which have built up large enough communites to be of critical size and which do value Physics. These countries are Argentina, Brazil and Mexico in Latin America and China, India and South Korea in Asia, Egypt and Nigeria in Africa. Barring these, the Third World, despite its growing realisation that science and technology are the sustenance, and its major hope for economic



betterment, has taken to it as a marginal activity. This is, unfortunately, also true of the aid-giving agencies of the wealthier countries and also of the agencies of the United Nations.

4. **The Science Gap**

The Third World as a whole is slowly - too slowly - waking up to the realisation that Science and Technology are what distinguish the South from the North. On Science and Technology depend the standards of living of a nation. The widening gap in Economics and in Influence between the nations of the South and the North is basically the Science gap.

To see this growing gap in Sciences, just turn over the pages of a multidisciplinary science journal - like "Nature". Not more than 2% of the papers originate in the South. This, unfortunately, is a reflection of the sub-critical size of the Third World's scientific enterprise. Another, more important, indicator is the annual spending on Research and Development, and I shall comment on this in a moment.

We should be aware that Science Transfer is effected by and to communities of scientists. ***Such communities need building up to a critical size in their infrastructure and human resources (through a meaningful training effort).*** This building up calls for wise science policies with three cardinal ingredients - ***(i) long-term commitment as well as active deployment of scientists in the tasks of development, (ii) generous patronage, (iii) self-governance of the scientific community, including freer international contacts.*** Of these three ingredients, the last refers to the manner in which we in the Third World, run our scientific enterprise. The first two depend upon State action (outside the Science communities) and I wish to make a plea to those in authority to help us redress the situation.

5. **Science Funding: A Wise Investment**

The North is spending of the order of 2-2.5% of its GNP on Science and Technology, whereas the South spends less than 0.2% of its GNP. The important remark is that the corresponding figures for Defence, Education and Health *do not show the same order of magnitude difference*. They are, 5.6% versus 5.6% for Defence; 5.2% versus 3.8% for Education and 4.8% versus 1.5% for Health for North and South, respectively (Tables I and II).



TABLE I

Defence, Education and Health Expenditure in US$ (1983)
(as % of GNP)

| | POPULATION x (1,000) | GNP MILLION (US$) | GNP CAPITA (US$) | DEFENCE (%) | EDUCATION (%) | HEALTH (%) |
|---|---|---|---|---|---|---|
| Industrialized | 1,116,969 | 10,518,183 | 9,415 | 5.6 | 5.2 | 4.8 |
| Developing Countries | 3,574,133 | 2,569,796 | 720 | 5.6 | 3.8 | 1.5 |
| Africa* | 455,608 | 355,804 | 616 | 4.1 | 3.9 | 1.2 |
| Middle East** | 141,875 | 384,099 | 2,556 | 17.1 | 5.9 | 2.5 |
| South Asia | 971,915 | 247,830 | 255 | 3.4 | 3 | 0.8 |
| Far East*** | 1,490,582 | 1,899,284 | 462 | 5.9 | 3.2 | 1.2 |
| Latin America + Caribbean | 385,168 | 790,726 | 1,867 | 1.4 | 3.6 | 1.3 |

Based on "World Military & Social Expenditures" (published 1986)

*Less South Africa
** Less Israel
*** Less Japan

TABLE II

| COUNTRY | POPULATION (Millions) | GNP PER CAPITA (US$) 1984 | EDUCATION* TOTAL PUBLIC EXPENDITURE (% of GNP) | SCIENTISTS/ENGINEERS IN R&D (PER MILLION INHABITANTS) | EXPENDITURE ON R&D** (% of GNP) |
|---|---|---|---|---|---|
| France | 55.17 (1985) | 9,760 | 5.8 (1983) | 1,363 (1980) | 1.8 (1980) |
| Fed. Rep. of Germany | 61.02 (1985) | 11,130 | 4.5 (1983) | 2,084 (1983) | 2.5 (1985) |
| Japan | 120.75 (1985) | 10,630 | 5.7 (1983) | 4,436 (1984) | 2.6 (1983) |
| Netherlands | 14.48 (1985) | 9,520 | 7.7 (1983) | 2,126 (1983) | 2.0 (1983) |
| U.K. | 56.49 (1984) | 8,570 | 5.3 (1983) | 1,545 (1980) | 2.3 (1980) |

*At Tertiary level.

**Based on Unesco statistics 1986.



In the North, patronage of Science is given in three critical areas: Research in Basic Sciences, Research in Applied Sciences; and Research and Development in Technology. The ratio of funds spent on these three areas is of the order of 1 : 1 : 2.

In respect of patronage, let me first set down some of the norms followed by the industrialised countries. As a general rule, some 2 - 2.5% of GNP is made available for Research and Development in most of the industrialised countries in <u>three broad areas</u>. These include:

i) <u>Research in Basic Sciences</u> in the Universities or in Research Centres, plus support for <u>International Science</u>, plus <u>Training for Research</u>. These are the sorts of functions familiarly carried out by National Science Foundations or by Academies of Sciences.

ii) <u>Research in Applied Sciences</u>, carried out, generally, under the auspices of "Applied Research Councils". This includes research and application of scientific methodology in areas of <u>health, agriculture, energy, environment, climate and exploration and utilisation of natural resources</u>. What is emphasised more in any given country depends on a nations's priorities.

iii) <u>Research and Development in Technology</u> (including R & D funded by private industrial sources). Such research, in general, includes areas of coarse and fine chemicals (including petro-chemicals), engineering technology (including defence), transport, telecommunications, as well as science-based, newer high technologies (microelectronics and biotechnology).

So far as absolute expenditures are concerned, rather than use percentages of GNP, I shall use as a convenient and easily remembered unit, a country's educational expenditure. Typically, the funds spent on Basic Sciences Research amount to some 4-10% of a nation's educational budget while roughly the same amount is spent on Applied Science Research, and twice as much on Research and Development related to Technology and High Technology.

Following the industrialised countries, *let us adopt for the Third World countries, the lower figure of 4% of the educational expenditures as a desirable minimum, to be spent on Basic Sciences, (including Research, Training for Research and also including International Science).* The corresponding desirable figures for each Third World country are set out in Table III.

Surprisingly, even these modest funds (equal to 4% of the Third World's current educational expenditure) would reach the colossal figure of $3.5 billion dollars*. No reliable figures are available for present expenditures, but I do not believe we, of the Third World, as a whole, spend anywhere near 3.5 billion dollars on Basic Sciences (including for Training for Research and for International Science). For Applied Sciences, one may consider a further

* Of this total of 3.5 billion dollars, 43 countries of Africa would account for 463 million dollars, 26 countries of Asia for 1.9 billion dollars, the four countries of Oceania and Indonesia for 136 million dollars, 13 countries of the Caribbean for 298 million dollars while the 11 Latin American countries would account for 740 million dollars (Table III).



figure of 4% of the educational budget as a desirable minimum - bringing up the desirable total for Sciences - Pure and Applied - to around seven billion dollars for the South as a whole.

We should make no mistake about it. *No Science is possible without a nation spending an inescapable minimum of funds on it.*

## TABLE III

### DESIRABLE EXPENDITURE FOR RESEARCH AND TRAINING FOR RESEARCH IN BASIC SCIENCES IN THE THIRD WORLD

The attached figures for GNP and Educational expenditure in Third World countries are taken from the "World Military and Social Expenditure" publication (1986 edition). These figures are based on 1983 data, and are quoted in 1983 US dollars.

The desirable expenditure for Basic Sciences research and training for research (as well as for international science) for each developing country is worked out on the basis of the expenditure in industrialised countries where this amounts to an average of 4-10% of the education budget. For Third World countries, the figures suggested are at the lower end - 4% of the educational budget of each country. This should be regarded as the <u>minimum</u> amount each Third World country should spend on Research in Basic Sciences and Training for Research, including expenditures on International Science.



### Africa

| Country | Population (1,000) | GNP (in million US$) | GNP/capita (in US$) | Education expenditure (in million US$) | Education (% of GNP) | Suggested expenditure for Basic Sciences research including expenditure for international Science and training for research - 4% of education expenditure (in million US$) | Participation in ICTP Activities: # of Visits 1970-86 | # of Associates 1987 | # of Federation Agreements 1987 | # of Visits to Italian Laboratories | # of External Activities |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Algeria | 20,744 | 47,713 | 2,300 | 2,195 | 4.6% | 87.8 | 132 | 4 | 2 | 4 | |
| Angola | 7,558 | 6,906 | 914 | 343 | 5.0% | 13.7 | 3 | | | | |
| Benin | 3,778 | 1,109 | 294 | 56 | 5.0% | 2.2 | 34 | 3 | 1 | | |
| Botswana | 1,000 | 919 | 919 | 80 | 8.7% | 3.2 | 3 | 1 | | | |
| Burkina Faso | 6,569 | 1,192 | 181 | 38 | 3.2% | 1.5 | 13 | 1 | | | |
| Burundi | 4,416 | 1,046 | 237 | 36 | 3.4% | 1.4 | 19 | 2 | 1 | | 1 |
| Cameroon | 9,219 | 7,789 | 845 | 277 | 3.6% | 11.1 | 32 | | 1 | | |
| Central African Rep. | 2,520 | 682 | 271 | 26 | 3.8% | 1.0 | 3 | | | | |
| Chad | 4,935 | 600 | 122 | 15 | 2.5% | 0.6 | | | | | |
| Congo | 1,694 | 2,158 | 1,274 | 130 | 6.0% | 5.2 | 12 | | 1 | | |
| Côte d'Ivoire | 9,314 | 6,603 | 709 | 343 | 5.2% | 13.7 | 18 | | 1 | | 4 |
| Egypt | 46,427 | 31,205 | 672 | 1,289 | 4.1% | 51.6 | 802 | 17 | 24 | 6 | 4 |
| Ethiopia | 41,308 | 4,844 | 117 | 199 | 4.1% | 8.0 | 37 | 2 | 2 | 1 | 1 |

From: *Military and Social Expenditures 1986.*

# Africa

| Country | Population (1,000) | GNP (in million US$) | GNP/ capita (in US$) | Education expenditure (in million US$) | Education (% of GNP) | Suggested expenditure for Basic Sciences research including expenditure for international Science and training for research - 4% of education expenditure (in million US$) | Participation in ICTP Activities: # of Visits 1970-86 | # of Associates 1987 | # of Federation Agreements 1987 | # of Visits to Italian Laboratories | # of External Activities |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gabon | 921 | 3,417 | 3,710 | 157 | 4.6% | 6.3 | 4 | | 1 | | |
| Gambia | 700 | 202 | 289 | 10 | 5.0% | 0.4 | 2 | | | | |
| Ghana | 11,939 | 4,275 | 358 | 64 | 1.5% | 2.6 | 176 | 4 | 2 | 7 | 2 |
| Guinea | 5,057 | 1,721 | 340 | 55 | 3.2% | 2.2 | 22 | | 3 | 2 | |
| Kenya | 18,586 | 6,446 | 347 | 312 | 4.8% | 12.5 | 84 | 2 | | | 1 |
| Lesotho | 1,438 | 672 | 467 | 26 | 3.9% | 1.0 | 11 | 1 | | | 1 |
| Liberia | 2,091 | 986 | 472 | 54 | 5.5% | 2.2 | 8 | | 2 | | 1 |
| Libya | 3,486 | 6,446 | 1,849 | 312 | 4.8% | 12.5 | 103 | 5 | 3 | 1 | |
| Madagascar | 9,398 | 2,945 | 313 | 96 | 3.3% | 3.8 | 39 | 1 | 1 | 1 | |
| Malawi | 6,612 | 1,388 | 210 | 35 | 2.5% | 1.4 | 10 | | | | 1 |
| Mali | 7,404 | 1,128 | 152 | 50 | 4.4% | 2.0 | 41 | 2 | 1 | 3 | |
| Mauritania | 1,591 | 775 | 487 | 34 | 4.4% | 1.4 | 9 | | 1 | | |
| Mauritius | 993 | 1,148 | 1,156 | 49 | 4.3% | 2.0 | 14 | | | | |



# Africa

| Country | Population (1,000) | GNP (in million US$) | GNP/ capita (in US$) | Education expenditure (in million US$) | Education (% of GNP) | Suggested expenditure for Basic Sciences research including expenditure for international Science and training for research - 4% of education expenditure (in million US$) | Participation in ICTP Activities: # of Visits 1970-86 | # of Associates 1987 | # of Federation Agreements 1987 | # of Visits to Italian Laboratories | # of External Activities |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Morocco | 22,055 | 15,751 | 714 | 1,165 | 7.4% | 46.6 | 123 | 5 | 6 | | |
| Namibia | 1,049 | 1,819 | 1,734 | 35 | 1.9% | 1.4 | | | | | |
| Niger | 6,080 | 1,481 | 244 | 55 | 3.7% | 2.2 | 8 | | | | |
| Nigeria | 97,726 | 71,684 | 734 | 1,592 | 2.2% | 63.7 | 394 | 16 | 15 | 20 | 7 |
| Rwanda | 5,805 | 1,486 | 256 | 46 | 3.1% | 1.8 | 19 | | 1 | 3 | 1 |
| Senegal | 6,335 | 2,702 | 427 | 127 | 4.7% | 5.1 | 51 | 3 | 1 | | |
| Sierra Leone | 3,687 | 1,178 | 320 | 37 | 3.1% | 1.5 | 61 | 2 | 1 | 2 | 1 |
| Somalia | 7,153 | 1,750 | 245 | 25 | 1.4% | 1.0 | 8 | | | 2 | |
| Sudan | 20,993 | 8,249 | 393 | 379 | 4.6% | 15.2 | 208 | 4 | 2 | 1 | 3 |
| Swaziland | 632 | 613 | 970 | 36 | 5.9% | 1.4 | 6 | 1 | | | |
| Tanzania | 20,356 | 4,896 | 241 | 285 | 5.8% | 11.4 | 75 | 3 | | | 1 |
| Togo | 2,842 | 782 | 275 | 46 | 5.9% | 1.8 | 27 | 1 | | | |
| Tunisia | 6,935 | 8,913 | 1,285 | 394 | 4.4% | 15.8 | 70 | 1 | 4 | | |

## Africa

| Country | Population (1,000) | GNP (in million US$) | GNP/ capita (in US$) | Education expenditure (in million US$) | Education (% of GNP) | Suggested expenditure for Basic Sciences research including expenditure for International Science and training for research - 4% of education expenditure (in million US$) | Participation in ICTP Activities: # of Visits 1970-86 | # of Associates 1987 | # of Federation Agreements 1987 | # of Visits to Italian Laboratories | # of External Activities |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Uganda | 13,827 | 4,292 | 310 | 55 | 1.3% | 2.2 | 38 | 1 | | | |
| Zaire | 28,966 | 5,044 | 174 | 298 | 5.9% | 11.9 | 36 | 2 | 1 | 1 | |
| Zambia | 6,395 | 3,587 | 561 | 206 | 5.7% | 8.2 | 22 | 1 | 1 | 3 | |
| Zimbabwe | 8,138 | 6,052 | 744 | 519 | 8.6% | 20.8 | 11 | 1 | | | 1 |
| Totals for 43 countries: | 488,672 | 284,594 | 28,630 | 11,581 | | 463.2 | 2,788 | 86 | 79 | 57 | 30 |



## Asia

| Country | Population (1,000) | GNP (in million US$) | GNP/ capita (in US$) | Education expenditure (in million US$) | Education (% of GNP) | Suggested expenditure for Basic Sciences research including expenditure for International Science and training for research - 4% of education expenditure (in million US$) | Participation in ICTP Activities: # of Visits 1970-86 | # of Associates 1987 | # of Federation Agreements 1987 | # of Visits to Italian Laboratories | # of External Activities |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bahrain | 394 | 4,098 | 10,401 | 127 | 3.1% | 5.1 | 3 | 1 | | | |
| Bangladesh | 95,935 | 12,395 | 129 | 241 | 1.9% | 9.6 | 246 | 13 | 3 | 4 | 5 |
| Burma | 35,480 | 6,464 | 182 | 131 | 2.0% | 5.2 | 6 | | | | |
| China | 1,019,666 | 305,676 | 300 | 8,471 | 2.8% | 338.8 | 557 | 18 | 34 | 63 | 12 |
| India | 735,596 | 192,912 | 262 | 6,173 | 3.2% | 246.9 | 1,572 | 42 | 17 | 56 | 17 |
| Iran | 42,490 | 75,760 | 1,783 | 5,791 | 7.6% | 231.6 | 222 | 9 | 14 | 8 | 2 |
| Iraq | 14,509 | 27,000 | 1,861 | 880 | 3.3% | 35.2 | 114 | 2 | 2 | 2 | |
| Jordan | 2,494 | 4,216 | 1,690 | 254 | 6.0% | 10.2 | 114 | 5 | 4 | 3 | 2 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| Korea, North | 19,185 | 21,500 | 1,121 | 750 | 3.5% | 30.0 | 2 | | | | |
| Korea, South | 41,366 | 81,800 | 1,977 | 4,120 | 5.0% | 164.8 | 125 | 4 | 2 | 4 | |
| Kuwait | 1,565 | 27,464 | 17,549 | 1,133 | 4.1% | 45.3 | 99 | 1 | 2 | | |
| Lebanon | 2,624 * | 3,413 ** | 1,301 | | | | 107 | 3 | 2 | | |
| Malaysia | 14,775 | 27,714 | 1,876 | 2,078 | 7.5% | 83.1 | 142 | 12 | 2 | | 6 |
| Mongolia | 1,812 * | 1,703 *** | 940 | | | | 1 | | 1 | | |
| Nepal | 16,169 | 2,478 | 153 | 69 | 2.8% | 2.8 | 85 | 3 | 1 | | |
| Oman | 1,131 | 7,050 | 6,233 | 283 | 4.0% | 11.3 | | | | | |
| Pakistan | 94,140 | 34,914 | 371 | 718 | 2.1% | 28.7 | 487 | 18 | 7 | 9 | 6 |
| Philippines | 54,252 | 39,262 | 724 | 785 | 2.0% | 31.4 | 88 | 4 | 1 | 2 | 3 |

* *World Bank Atlas, 1985.*

** *UNESCO Statistical Digest, 1986.*

*** *The Statesman's Yearbook, 1986-87*



## Asia

| Country | Population (1,000) | GNP (in million US$) | GNP/ capita (in US$) | Education expenditure (in million US$) | Education (% of GNP) | Suggested expenditure for Basic Sciences research including expenditure for International Science and training for research - 4% of education expenditure (in million US$) | Participation in ICTP Activities: # of Visits 1970-86 | # of Associates 1987 | # of Federation Agreements 1987 | # of Visits to Italian Laboratories | # of External Activities |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Qatar | 267 | 5,946 | 22,270 | 295 | 5.0% | 11.8 | 14 | 1 | 1 | | |
| Saudi Arabia | 10,443 | 127,331 | 12,193 | 9,071 | 7.1% | 362.8 | 63 | 5 | 2 | | |
| Singapore | 2,502 | 16,645 | 6,653 | 849 | 5.1% | 34.0 | 44 | 2 | | | 1 |
| Sri Lanka | 15,735 | 5,131 | 326 | 156 | 3.0% | 6.2 | 164 | 9 | | 2 | 2 |
| Syria | 9,787 | 16,392 | 1,675 | 995 | 6.1% | 39.8 | 86 | 2 | 5 | 3 | 1 |
| Thailand | 49,705 | 40,271 | 810 | 1,581 | 3.9% | 63.2 | 148 | 1 | 6 | 2 | 2 |
| Turkey | 48,392 | 58,574 | 1,210 | 1,954 | 3.3% | 78.2 | 450 | 11 | 16 | 9 | 3 |
| United Arab Emirates | 1,206 | 26,664 | 22,109 | 522 | 2.0% | 20.9 | 1 | | | | |
| Vietnam | 58,538 * | 5,853 *** | 100 | | | | 27 | 2 | 1 | | |
| West Bank | 767 *** | | | | | | 7 | 1 | 2 | | 1 |

* *World Bank Atlas, 1985.*

*** *The Statesman's Yearbook, 1986-87.*

## Asia

| Country | Population (1,000) | GNP (in million US$) | GNP/ capita (in US$) | Education expenditure (in million US$) | Education (% of GNP) | Suggested expenditure for Basic Sciences research including expenditure for international Science and training for research - 4% of education expenditure (in million US$) | Participation in ICTP Activities: # of Visits 1970-86 | # of Associates 1987 | # of Federation Agreements 1987 | # of Visits to Italian Laboratories | # of External Activities |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Yemen, Arab Rep. | 5,830 | 4,171 | 715 | 311 | 7.5% | 12.4 | 38 | 1 | 1 | | 1 |
| Yemen, Dem Rep. | 2,085 | 1,019 | 489 | 74 | 7.3% | 3.0 | 3 | | 1 | | |
| Totals for 30 countries: | 2,398,840 | 1,183,816 | 117,404 | 47,812 | | 1912.5 | 5015 | 170 | 127 | 167 | 64 |



## Indonesia and Oceania

| Country | Population (1,000) | GNP (in million US$) | GNP/ capita (in US$) | Education expenditure (in million US$) | Education (% of GNP) | Suggested expenditure for Basic Sciences research including expenditure for international Science and training for research - 4% of education expenditure (in million US$) | Participation in ICTP Activities: # of Visits 1970-86 | # of Associates 1987 | # of Federation Agreements 1987 | # of Visits to Italian Laboratories | # of External Activities |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Brunei | 214 | 4,267 | 19,939 | 77 | 1.8% | 3.1 | | | | | |
| Fiji | 672 | 1,200 | 1,786 | 77 | 6.4% | 3.1 | 1 | 1 | | | |
| Indonesia | 165,787 | 88,633 | 535 | 3,069 | 3.5% | 122.8 | 143 | 4 | | 1 | |
| Papua New Guinea | 3,191 | 2,433 | 762 | 184 | 7.6% | 7.4 | 10 | | | | |
| Totals for 4 countries: | 169,864 | 96,533 | 23,022 | 3,407 | | 136.3 | 154 | 5 | 0 | 1 | 0 |

## North and Central America

| Country | Population (1,000) | GNP (in million US$) | GNP/ capita (in US$) | Education expenditure (in million US$) | Education (% of GNP) | Suggested expenditure for Basic Sciences research including expenditure for international Science and training for research - 4% of education expenditure (in million US$) | Participation in ICTP Activities: # of Visits 1970-86 | # of Associates 1987 | # of Federation Agreements 1987 | # of Visits to Italian Laboratories | # of External Activities |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Barbados | 250 | 1,008 | 4,032 | 57 | 5.7% | 2.3 | 2 | | | | |
| Costa Rica | 2,948 | 2,539 | 861 | 145 | 5.7% | 5.8 | 33 | 3 | | 1 | |
| Cuba | 9,890 | 18,320 | 1,852 | 1,154 | 6.3% | 46.2 | 22 | 3 | 2 | 4 | 2 |
| Dominican Rep. | 6,282 | 6,929 | 1,103 | 157 | 2.3% | 6.3 | 6 | | | | 1 |
| El Salvador | 4,779 | 3,554 | 744 | 135 | 3.8% | 5.4 | 6 | | | | |
| Guatemala | 7,861 | 8,795 | 1,119 | 161 | 1.8% | 6.4 | 3 | | | | |
| Haiti | 5,548 | 1,562 | 282 | 18 | 1.2% | 0.7 | | | | | |
| Honduras | 4,205 | 2,756 | 655 | 119 | 4.3% | 4.8 | 10 | | 1 | 1 | |
| Jamaica | 2,223 | 3,000 | 1,350 | 226 | 7.5% | 9.0 | 9 | | 1 | | 1 |
| Mexico | 75,702 | 163,074 | 2,154 | 4,527 | 2.8% | 181.1 | 237 | 3 | 5 | 4 | 9 |
| Nicaragua | 3,305 | 2,633 | 797 | 121 | 4.6% | 4.8 | 1 | | | | |
| Panama | 2,809 | 4,137 | 1,473 | 220 | 5.3% | 8.8 | 4 | | | | |
| Puerto Rico | 3,295 * | | | | | | 13 | 2 | 1 | | 1 |

* *World Bank Atlas, 1985.*



## North and Central America

| Country | Population (1,000) | GNP (in million US$) | GNP/ capita (in US$) | Education expenditure (in million US$) | Education (% of GNP) | Suggested expenditure for Basic Sciences research including expenditure for international Science and training for research - 4% of education expenditure (in million US$) | Participation in ICTP Activities: # of Visits 1970-86 | # of Associates 1987 | # of Federation Agreements 1987 | # of Visits to Italian Laboratories | # of External Activities |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Trinidad/ Tobago | 1,149 | 7,851 | 6,833 | 422 | 5.4% | 16.9 | 5 | | 1 | | |
| otals for 4 countries: | 130,246 | 226,158 | 23,254 | 7,462 | | 298.5 | 351 | 11 | 11 | 10 | 14 |

## South America

| Country | Population (1,000) | GNP (in million US$) | GNP/ capita (in US$) | Education expenditure (in million US$) | Education (% of GNP) | Suggested expenditure for Basic Sciences research including expenditure for international Science and training for research - 4% of education expenditure (in million US$) | Participation in ICTP Activities: # of Visits 1970-86 | # of Associates 1987 | # of Federation Agreements 1987 | # of Visits to Italian Laboratories | # of External Activities |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Argentina | 29,745 | 60,397 | 2,030 | 1,538 | 2.5% | 61.5 | 384 | 11 | 3 | 15 | 9 |
| Bolivia | 5,833 | 3,512 | 602 | 107 | 3.0% | 4.3 | 33 | | | 2 | |
| Brazil | 132,908 | 270,000 | 2,031 | 7,790 | 2.9% | 311.6 | 491 | 14 | 3 | 11 | 9 |
| Chile | 11,595 | 22,261 | 1,920 | 1,115 | 5.0% | 44.6 | 108 | 4 | 1 | | 4 |
| Colombia | 28,153 | 38,808 | 1,378 | 1,142 | 2.9% | 45.7 | 142 | 5 | | 3 | 10 |
| Ecuador | 8,857 | 11,680 | 1,319 | 430 | 3.7% | 17.2 | 11 | | 1 | | |
| Guyana | 765 | 453 | 592 | 40 | 8.8% | 1.6 | 9 | | 1 | | |
| Paraguay | 3,734 | 4,200 | 1,125 | 73 | 1.7% | 2.9 | 1 | | | | |
| Peru | 18,707 | 19,900 | 1,064 | 782 | 3.9% | 31.3 | 118 | 6 | | 4 | 10 |
| Uruguay | 2,916 | 7,336 | 2,516 | 157 | 2.1% | 6.3 | 10 | | | | |
| Venezuela | 16,394 | 66,021 | 4,027 | 5,334 | 8.1% | 213.4 | 117 | 1 | | 1 | 1 |
| Totals for 11 countries: | 259,607 | 504,568 | 18,605 | 18,508 | | 740.3 | 1,424 | 41 | 9 | 36 | 43 |

| Country | Population (1,000) | GNP (in million US$) | GNP/ capita (in US$) | Education expenditure (in million US$) | Suggested expenditure for Basic Sciences research including expenditure for international Science and training for research - 4% of education expenditure (in million US$) | Participation in ICTP Activities: # of Visits 1970-86 | # of Associates 1987 | # of Federation Agreements 1987 | # of Visits to Italian Laboratories | # of External Activities |
|---|---|---|---|---|---|---|---|---|---|---|
| Totals for 102 countries: | 3,447,229 | 2,295,669 | 208,574 | 88,770 | 3550.8 | 9,732 | 313 | 226 | 271 | 151 |

6. <u>The Real Obstacles to Progress</u>

So much for the expenditure patterns involved. What is really wrong with Science and Science-Based technology in the Third World to-day?

There are basically three things wrong: (a) A lack of meaningful commitment towards Science, either pure or applied; (b) The manner in which we run our scientific enterprise; and (c) A lack of commitment towards acquiring self-reliance in Technology in most Third World countries. I shall take these three points briefly in turn.

a) <u>Lack of Meaningful Commitment Towards Science, Either Pure or Applied</u>

Barring a few countries, there have been few declared commitments from our rulers and our States, to acquiring and enhancing scientific knowledge among us. Whose fault it is - the rulers' or of the leaders of the scientific community - I do not know. But, by and large, there has been scant realisation that Science can be applied to development as, for example, there was in Japan at the time of the Meiji Restoration around 1870, when the Emperor took five oaths as part of Japan's new constitution. One of these oaths was that: "Knowledge will be sought and acquired from any source with all means at our disposal, for the greatness of Imperial Japan". How many of our rulers in the Third World have made a similar pledge as part of our constitutions?

b) <u>The Manner in Which the Enterprise of Science is Run</u>

Science depends for its advancement on towering individuals. An active enterprise of science must be run by working scientists themselves and not by bureaucrats or by those scientists who may have been active once, but have since ossified. When the late Amos de Shalit (then Director of the Weizmann



Institute) was asked in a UN Committee, what was the Israeli policy for science, his reply was: "We have a very simple policy for growth of science. An active scientist is always right and the younger he is, the more right he is.". Unfortunately, in most of our science organizations this is far from the accepted norm.

c) <u>No Commitment to Self-Reliance in Technology</u>

In technology, by and large, few of our Governments have made it a national goal to strive for self-reliance. And we have paid little heed to the scientific base of technology, i.e. to the truism that <u>*science transfer must always accompany technology transfer*</u>, if technology transfer is to take. Thus, while some of our governments and industrial enterprises may claim that they are encouraging the transfer of technology, often all that this means is the importation of designs, machines, technical personnel and sometimes even processed raw materials.

Clearly this must change if the South is to regenerate Science and Science-based Technology. I say "regenerate", as in an earlier era some few-hundred years ago, it was the South that led the North in developing the knowledge and expertise of the day, a fact which many appear to have forgotten - even those from the South.

7. <u>The Transfer of Science in the South</u>

I shall not speak to-day about classical Engineering Technologies. Nor shall I speak of "Technology-transfer", not because this is not important - quite the contrary - but simply because policy makers, prestigious commissions (even the Brandt Commission), as well as aid-givers, speak uniformly and solely of problems of "technology-transfer" to the developing countries as if that were all that is involved. It is hard to believe, but true, that the word "science" does not figure in the Brandt Commission report.

Very few within the developing world appear to stress that ***the science of to-day is the technology of tomorrow*** and that when we speak of science it must be broad-based in order to be effective for applications. I would even go so far as to say that if one were being Machiavellian, one might discern sinister motives among those who try to sell to us the idea of "technology-transfer" - and particularly of High Technology Transfer - without the accompanying Science Transfer. There is nothing which has hurt us in the third world more than the slogan in the wealthier countries of "Relevant Science". Regretfully, this slogan was parroted in the Third World countries unthinkingly to justify stifling the growth of all science.

But why does the South persist in neglecting Science in the first place? First and foremost, there is the question of national ambition. Let me say it unambiguously. We have no science communities geared to development because we do not want such communities. As a rule, we suffer from a lack of ambition towards acquiring science, a feeling of inferiority towards it, bordering sometimes even on hostility.

Very few among us, either in the South or in the North, appreciate that the acquiring of Science and Science-based Technology is not hard. In eloquent phrases C.P. Snow in his famous "The Two Cultures" lecture made the point that Science and Technology are the branches of human experience "that people can learn with predictable results. For a long time, the West misjudged this very badly. After all, a good many Englishmen have been skilled in mechanical crafts for half-a-dozen generations. Somehow we've made



ourselves believe that the whole of technology was a more or less incommunicable art."

In Snow's words: "... There is no evidence that any country or race is better than any other in scientific teachability: there is a good deal of evidence that all are much alike. Tradition and technical background seem to count for surprisingly little.

"There is no getting away from it. It is ... possible to carry out the scientific revolution in India, Africa, South-East Asia, Latin America, the Middle East, within fifty years. There is no excuse for Western man not to know this."

## C. SCIENTISTS AND DEVELOPMENT

### 8. The Southern Perspective

Symptomatic of the lack of appreciation of Science and Technology throughout most of the Third World, is the near total absence in most countries of even the few highly trained individuals a country might possess in the development activities of the country. For example, very few countries use any scientists at all for looking after the energy problem, or for their electronics industry, two areas in which the lack of any deep understanding of the basic principles, as well as of the technologies involved, could have the gravest consequences. One looks in vain, however, at the higher levels of government - even at the higher levels of advisory groups - for scientific competence in most developing countries.

The reasons for this are, of course, historical. The result has been that the scientist in most countries of the world - assuming that he even exists - has simply retreated to his Ivory Tower, from which little contribution from him towards development is asked for, or ever received. This is a waste. It is a criminal misuse of a highly skilled, human resource, which, if given the proper orientation and support, could make a very positive contribution to development.

9. I personally miss in the developing countries themselves, *a possessive attitude towards Sciences, an attitude which considers science as being an integral part of our lives.* May I suggest that the time has come when our courts of State should once again be adorned with Scientists. I am reminded of King Arthur of legendary fame; at his Court there was a Court Magician; his name was Merlin. Merlin was responsible for using magic for forging steel for swords and to provide magical medicinal potions. We, the scientists, are the Merlins of to-day. We can perform feats of magic undreamt of by Merlins of yesteryears. We can indeed transform society. But in our Third World countries, the Merlins have no place in the courts of State. Should they not be invited back? Some will say - and perhaps rightly - that the Merlins in developing countries are amateurs, they do not know their applied craft. They choose to live in their own ivory towers, and our Southern societies are thereby forced to import the real Merlins from the North. This may be true, but why is this? *Could this emasculation have come about through the fact that our own Merlins are so few in numbers, and even these few have never been invited to make a contribution to development in their own countries.* Not even by their colleagues - the professional economists - who in this metaphor



are the High Priests of Development. *Only experience can teach the Merlin-Scientist the craft of developmental problem-solving, even if he knows his science.* This vicious cycle of lack of mutual trust must be broken, I hope before the year 2000.

## D. THE ROLE OF THE NORTH

10. Having spoken about the lack of appreciation of Science in the Third World, I would now like to add a few words in relation to the industrialised countries. First and foremost, it is to these countries, and the international institutions mainly supported by them, to which the nations of the South must turn for help. They have indeed been generous in many ways, but, regretfully, not so much in Science*.

11. The tasks which could be undertaken are well known, e.g. the building up of literacy, the building up of infrastructure for science teaching as well as for scientific research, the need for building up of libraries as well as of laboratories and, above all, of building up indigenous scientific communities.

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* Could this be because, to a certain extent, the scientist is not a valued person even in his own environment in several countries of the North? In one respected view put forth in the New Scientist of 30 July 1987, Dr. Barbara Hall - who had done pioneering research in physiology and medical research - lamented that "The undeniable fact is that scientists in my country (in the North) have no professional status and no prospects of a satisfying and continuous career. Despite benefits brought by science to almost every aspect of our lives, we scientists are shown little or no respect by society or the government, which seem to know very little about science and have no wish to learn more.".

In carrying out these tasks and given the world as it is today, we need to combine the best of bilateral help with the multinational approaches. One proposal which may be considered in this context is that of specialisation. Could, for example, a consortium of Universities in the US and UK be helped by their Governments and encouraged to take care of University Science in all those developing countries which desire this? Could one envisage the USSR taking care of primary, secondary and vocational education? Could the Netherlands and Belgium look after the building up of libraries and laboratories? Could Germany and Japan look after technical education at all levels? Could Scandinavia look after the scientific aspects of ecology? Could Switzerland and Austria (with their well-known pharmaceutical expertise) look after medical education? Could Italy with its experience of setting up International Centres in Physics and Biotechnology, look after the creation of similar institutions in all disciplines of science in concert with developing countries? Could the US, Canada, Australia and New Zealand look after education for agriculture and education for prospecting? Could France and Spain, apart from offering their own expertise, translate these actions for the French and Spanish speaking developing countries if desired by them?

In this, one must not forget that (even though not sufficiently affluent to contribute materially) Argentina, Brazil, China, Egypt, India, Pakistan, Nigeria, Yugoslavia and many others could make highly valued intellectual inputs to these specialized efforts.

This is merely an illustration of what a possible division of the relevant tasks could be. Eventually, of course, these suggestions would have to be tailored and modified when detailed projects are elaborated.



What I have in mind is something patterned along the lines of the success which India achieved in the decade of the sixties when it created four Indian Institutes of Technology. The one in Kanpur was created by a US consortium of universities which helped to raise and furnish it, besides supplying the higher cadres of teaching staff for a number of years. The one in Delhi was helped by a consortium of British universities; the one in Bombay by the USSR and the one in Madras by the Federal Republic of Germany. Each nation helped to build up the institute under Indian auspices, contributed staff and left behind a tradition in teaching and research which has continued even after the original contracts have expired. There was a healthy rivalry between the donor nations vying with each other; this guaranteed the excellence and standards of quality. What I envisage in the proposal above is something like this, supervised by the United Nations Agencies, except that it is to be carried out on a much wider canvas. One would hope that by the year 2000, if the plans are drawn up now, many of the objectives I have mentioned could be achieved.

12. Nine hundred years ago, a great physician of Islam, Al Asuli, living in Bokhara, wrote a medical pharmacopaea which he divided into two parts: "Diseases of the Rich" and "Diseases of the Poor". If Al Asuli were alive and writing today about the afflictions wrought upon itself by mankind, I am sure he would divide his pharmacopaea into the same two parts. One part of his book would speak of the affliction of possible Nuclear Annihilation inflicted on humanity by its richer half. The second part of his book would speak of the affliction which poor humanity suffers from - underdevelopment, undernourishment and famine. He would add that both these diseases spring

from a common cause - excess of Science and Technology for the case of the rich, and a lack of Science and Technology for the case of the poor. He might also add that the persistence of the second affliction of mankind - underdevelopment - was the harder to understand, considering that the remedies for it are readily available in that the world has enough resources, technical, scientific, and material, to eradicate poverty, disease and early death for the whole of mankind, if it wishes to do so. It has only to eschew deployment of these resources towards aggravating the first affliction.

I am sure that peace, and particularly nuclear peace, will come soon. Mankind has truly awoken to the nuclear danger and big powers have seen the futility of arming themselves beyond the calls of any reasonable measures of security.

Nuclear peace will mean that mankind will be able to save at least 100 billion dollars per annum - one tenth of one trillion dollars which are the current global military expenditures. Of this 100 billion dollars, I pray and hope that the world's statemanship deploys at least one tenth - around 10 billion dollars - to help the developing countries. Of these 10 billion dollars, at least five billion dollars should be globally spent on Science and scientific education for the developing world. Such outlays would bring about a revolution. I hope that this does happen. I pray fervently that mankind does turn to real peace and that the funds saved will not be spent on simply reducing taxes for the rich. *In this we need, and deserve, the active support of our scientific bretheren in the Northern scientific communities.*



I am sure we will receive this support if we start by helping ourselves. Let me end quoting from the Holy Quran:

*The Lord changeth not what is with a people*
*until the people change what is in themselves.*

# International Cooperation in Science and Technology.

## Its Significance for Developing Countries.

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One way of looking at the world is to see it divided into North and South. The North consists of a minority of relatively affluent nations which are industrialized, have efficient educational systems and in which the problem of hunger has been solved for the vast majority of the population. The greater part of mankind is living in the South and is afflicted with overpopulation, poverty, hunger, economic and political instability, and a lack of educational facilities. This North-South dichotomy is co-existent with a perilous East-West conflict and with an economic crisis of world-wide dimensions. The old scourge of war has not been overcome by mankind. Wars are being waged all the time, more than 100 of them have taken place since the end of World War II, all of them in the South.

The nations of the South have old cultures which had been in relative equilibrium with their environment for centuries. This equilibrium has been destroyed by their contact with the civilization of the North which itself has not yet found equilibrium with its environment. Signs of this loss of equilibrium are overpopulation in the South and the pollution and destruction of nature in the North. Here we see side- and after-effects of the progress of medicine and technology which conquered diseases, increased agricultural and industrial production and thereby enhanced the standard of living enormously, mostly in the North.

Modern technology enabled the nations of the North to exploit the resources of the earth not only in their own region but world-wide. The nations of the South are justly asking to share in the wealth created by modern technology and by the resources which this technology makes accessible. But they do not want to be given these fruits as a charity. They are entitled to be self-reliant. This means, however, that they have to adopt modern science and technology. It is also in the interest of the North that the economic gap between North and South is not widening further. With modern means of communication, any catastrophe in the South will have repercussions in the North.

We sometimes hear politicians from the developing countries say that efforts must be made to produce a "New International Scientific and Technological Order" (NISTO). This recalls the "New International Economic Order" (NIEO) which has played a large part in the North-South dialogue of recent years. The NIEO is intended to provide a fairer distribution of the world's economic and industrial resources and thus increase the prosperity of the developing nations and reduce their dependence upon the industrialized countries. In fact, the NISTO is generally considered as a component and often a precondition of the NIEO. We find, for instance, that at present about 97 % of the cost of scientific and technical research is borne by the industrialized nations and only 3 % or so by the developing countries and - not without justification even though ignoring other historical factors - this situation is connected with the pronounced economic and technical superiority of the industrialized nations. It is impressive to note that politicians from developing countries firmly believe in progress based on science and technology at a time when this belief is being shaken in many circles in the industrialized nations. The purpose of the NISTO is to enable the developing nations to make progress in the scientific and technological sectors and reduce their disparity with the industrialized countries.

Of course, this immediately raises many questions: Who is to pay for it? Who is to organize it? Where are we to find the instructors? Which research and technology should be promoted as a matter of urgency? Should the developing nations concentrate initially upon applied research or do they also need basic research? If so, how much? Are there technologies which are better suited to conditions in the developing countries than the current ones which have been produced by the industrialized nations?

If the developing nations are to make progress, we shall have to ask: In which direction? What are the goals of development?

These and other questions were also raised in Vienna in August 1979 at two closely linked international events:

1. The United Nations Conference on Science and Technology for Development (UNCSTD).

2. An international colloquium on "Science, Technology and Development: needs, challenges and limitations" to which individual invitations were issued by the United Nations Advisory Committee on the Application of Science and Technology to Development (ACAST).

An analysis of the national papers prepared by the countries of the Third World for UNCSTD showed the following four goals for the application of science and technology in the development process:

- Autarky
- Fulfillment of basic needs
- Catching up with the developed countries
- Social pacification.

As main obstacles to development were identified: lack of educated manpower and of educational facilities, external and internal



brain-drain, inadequate administration, lack of communication, and of popularization of science and technology.

There is very little mention in the national papers of the role of cultural identity. The Japanese example seems to show, however, that the maintenance of cultural, authentic identity is related to the success of the development process. Therefore, this aspect should not be neglected. Much too often, scientific development is just seen as a means to the end of technological development, and technological development as a means to the end of industrial development. The importance of cultural identity is often overlooked.

We shall devote a separate lecture to the questions of cultural identity. At this point let me only ask: Is there anything scientists can do for reaching these goals, and for overcoming those obstacles? I think, the following can be said in this context:

1. Science administers a large portion of the knowledge of humanity, and much knowledge is needed for finding ways out of the present impasses.

2. Scientists are used to dealing with complicated issues, to sorting and analyzing facts, drawing conclusions, and revising them if new facts make revisions necessary. In many cases, they will be able, in interdisciplinary and international cooperation, to work out options for political decisions, giving the costs or risks, and the benefits, for each option. It will then be up to the public and to the elected decision-makers to decide which benefits are so desirable that they are worth the costs, and which risks are considered acceptable.

3. Scientists can afford to think in terms of decades, to tackle long-range issues, because, usually, they do not depend on re-election. Politicians often understand the arguments just as well as scientists do. But more often than not they believe that they cannot afford to follow the path of reason because that, they think, would make them lose the next elections. So it is up to the scientists to inform the public of the long-range consequences of our present policies.

4. **Scientists are familiar with international cooperation. Many scientific problems can only be solved in this manner. This is something they have in common with the great political problems of our time.**

The maintenance and expansion of international scientific and cultural cooperation is certainly in the self-interest of scientific and cultural workers. Cooperation creates ideas by exchange of views, it facilitates comparison of results, it stimulates criticism, it allows joint ventures and the realization of projects which would be beyond the scope of any one group or nation. But apart from this self-interest, scientific and cultural cooperation has many beneficial effects: It contributes towards an equilibrium of standards and forces, thereby reducing psychological and political tensions. This is particularly important in North-South and East-West relations. Moreover, many problems of developing countries can only be solved in international cooperation. Furthermore, international cooperation in science strengthens the influence of the international scientific community. This in itself is desirable because of the level-headedness and respect for facts that can be found within this community. International cooperation also opens up new channels of communication between different political systems. The Pugwash Conferences are a convincing example. Sometimes, scientific and cultural contacts have been used as a first step in the re-establishment of relations between hostile states.

But cooperation in science and technology is only possible if the partners are suitably equipped so that a give-and-take, possibly in both directions, can take place. To this end, UNCSTD formulated a great number of recommendations aimed at

1. strengthening the scientific and technological capacities of developing countries;

2. restructuring the existing pattern of international scientific and technological relations;



3. strengthening the role of the United Nations in the field of science and technology, and the provision of increased financial resources.

Among these recommendations, the following may be found:

- The government of each developing country should formulate an effective national policy for science and technology which involves carrying out certain essential responsibilities like planning, budgeting, coordination, management, stimulation, promotion, and execution of scientific and technological activities relevant to defined development objectives.

- Science and technology components should be included in national development plans or strategies as basic instruments for achieving the different objectives and goals.

- Effective steps and measures should be taken for strengthening the scientific and technological capacities by way of establishing institutions and bodies to ensure compatibility and coordination of the activities of different components of the science and technology system.

- Appropriate institutions for a national system of science and technology should be set up.

- Each developing country should formulate a policy on transfer and acquisition of technology as an integral part of its national policy for scientific and technological development.

- National scientific and technological information systems should be devised as an integral part of overall national development.

- Policies for human resources development should be formulated.

- Efforts should be made to ensure that adequate financial resources are made available for the effective implementation of science and technology policies.

- A set of measures for enhancing the cooperation among developing countries in fields of science and technology should be prepared.

At the international level, the Vienna Programme of Action (VPA) recommended:

- Direct linkages should be established between the research and development systems of developed and developing countries through cooperative arrangements.

- Cooperation between scientific and technological associations of developing and developed countries should be encouraged.

With regard to the practical problems which should be tackled by this international cooperation, the ACAST Colloquium gave detailed recommendations. Here are some examples:

Agriculture
Unless the target of a 4 % annual increase in food production is soon attained, the world's food problems may reach unmanageable proportions. Research and development in the following fields are urgently required: relative protein and energy requirements in diet; influence of specific agricultural technologies and production systems, including food control and distribution; biological nitrogen fixation; genetic engineering; photosynthesis; multiple crops; provision of higher quality protein and more vitamins; fisheries; prevention of post harvest losses; recycling of agricultural waste; soil and water management and protection of farmland against erosion, water-logging and desertification.

Health
In this sector, the link between malnutrition and susceptibility to disease must be studied. The causes of infantile diarrhoea, one of the main causes of mortality in children, should be prevented. Preventive and community medicine and primary health care should be developed.



Natural resources
Water shortage will become acute with the increasing population, industrialization and improvement of the standard of living. Development of inexpensive desalination plants is one solution. Explorations should be expanded, both on land and at sea, to determine total available resources and to permit planned exploitation. Marine science and technology require international cooperation.

Transport
Transport policy and planning in developing nations should take account of population growth and movements, urban and rural development, agriculture, food production, health service, education, communications, energy use, and investment capabilities. Manufacture of standardized parts in order to facilitate vehicle maintenance should be initiated to set the stage for the assembly and production of essential transport vehicles and equipment.

Communications
By employing satellites, radio and micro-processors, modern technology can incorporate remote areas into the communication system. For this purpose the infrastructure must be developed in coordination with other forms of communication. The various options must be carefully explored with due consideration to the social and cultural aspects, cost effectiveness, the available capital and the local capabilities.

Industrialization
The capital goods industry should form an important part of the developing countries' technological plans. The enormous technical developments in the industrialized nations and the growing problems in the developing countries, such as unemployment, low productivity and unequal job distribution, require policy responses and action.

Human settlements
New technological efforts in this sector should be integrated in the overall planning process and be aimed at the low-income strata of the population.

**Environment**

Programmes for problem-oriented studies of ecosystems - especially tropical and subtropical forests, arid regions, mountain regions and coastal areas - require longer-term commitments. Scientific efforts should be strengthened in the following fields:

a) The identification of social and environmental "outer limits";
b) The role of certain ecosystems in the hydrological cycle and in their uptake and release of carbon-dioxide;
c) The impact of the use of chemicals and energy on ecosystems;
d) The effect of changes in the natural vegetation cover;
e) The study of ecosystems for their economic use;
f) Agro-forestry activities.

Energy

The development process will impose greater demands upon the energy resources. All forms of those resources must be developed.

Population

The conditions under which changes in fertility occur must be identified more precisely. Nor is much known about the consequences of internal migrations and the most suitable means of control for achieving social objectives.

Information systems

Information is indispensable to development. It calls for dissemination of scientific and technological information to policy-makers, industrialists, farmers and the general public. Decisive progress in informatics, telecommunication and similar technologies can help to overcome the obstacles to the flow of information which are found particularly in the developing countries.

The recommendations of the ACAST Colloquium and of the VPA start from the basic assumption that, in principle, the resources and technical potential for remedying underdevelopment and increasing the prosperity of mankind already exist. The preamble of the VPA mentions as a precondition for achieving this aim the developing nations' own control over their resources and the equitable distribution and creation of the world's scientific and technological capabilities. The provision of concrete and



action-oriented recommendations and the adoption of the corresponding decisions on the use of science and technology for the development of all countries are considered integral components of the efforts to achieve the New International Economic Order. The present international relations in the scientific and technological field must undergo fundamental changes so that the developing countries have much better access to the technology they require, including advanced technology.

When we look at the present situation in developing countries as compared to that 10 or 20 years ago, we must admit that some progress has indeed been made in some areas and in some places. Not every dollar and every effort spent for development has been wasted. Some institutions and some factories that have been built in the Third World in recent years are working satisfactorily or even well. But overall and generally speaking, the situation in many countries of the Third World is far from satisfactory. The gap between the industrialized and the developing countries has increased in terms of GNP/head. Apparently, there are many obstacles to any attempts at closing this gap.

In order to find out about the nature of these obstacles we have conducted two surveys: one among German scientists who cooperate with institutions of the Third World, the other among scientists and administrators in developing countries. The latter survey was carried out by Prof. Subas C. Pati, the director of the Science Policy Research and Analysis Group of Berhampur University, India, while he spent a sabbatical year at our Research Unit in Munich. A few hundred letters were written asking about the experience in North-South cooperation. The replies were evaluated.

It is interesting to compare the replies from the industrialized world, in this case from Germany, with those from developing countries. One might have expected that there would be a certain tendency to stress the shortcomings on the other side. This is usually so when politicians and diplomats discuss problems of development. Among scientists, however, this seems to be different. There is a great amount of self-criticism on both sides, and many fruitful suggestions.

Among the obstacles identified by German scientists involved in cooperation with Third World institutions were the following:

- scarcity of skilled personnel in many developing countries, particularly at the intermediate levels of technicians, mechanics, engineers, administrators; lack of educational facilities; external and internal brain-drain; insufficient popularization of science and technology.

- a lack of perspective and long-range planning both in the developing and industrialized countries which are often content to conclude bilateral agreements on isolated projects with no relation to the existing infrastructure and to the educational aspects. Students from developing countries are often trained in industrialized countries in professions for which there are no opportunities in their countries of origin.

- inadequate evaluation of the success of development projects.

- a lack of positions in industrialized countries for professionals who would be willing to work for a decade or so in the Third World and then return home.

- a lack of technology transfer within a developing country.

- a lack of communication between institutions in developing countries and 'contractors' in industrialized countries, a lack of mutual trust and understanding, a lack of the spirit of joint mission.

- a lack of consideration for ecological and social consequences of projects.

- quite generally, inadequate administration, lack of coordination, and lack of funds.

A number of measures were proposed to counteract the well-known difficulties with which scientific institutions in developing countries have to cope. Among them were the following:

Difficulty: Scientific isolation

Measures:

1. University and institutional partnerships should be established. They are most fruitful if the institution in the industrialized country makes available full-time personnel for operations under the partnership.

2. Cooperation should be long-range. Tasks should not be assigned to integrated units from industrialized countries, but all teams should include members from the developing countries.

3. Corresponding university degrees should be mutually recognized.

4. Scientists from developing countries derive the greatest benefit from spending time at scientific institutions in industrialized countries if they have already some experience, and well-defined questions, before they go there.

5. Results from scientific cooperation should be published in a language understood in the developing countries concerned. The results should be accessible to scientists in the developing country.

6. Counterparts from the developing country should be involved in all aspects of joint enterprises so that the work can be continued after the departure of the experts from the industrialized country.

7. Since some developing countries already produce excellent technologies, the exchange of technologies among the developing countries should be encouraged.

Difficulty: Lack of infrastructure

Measures:

1. Care should be taken that not only scientists but also engineers, machinists, technicians and administrators be trained in sufficient numbers.

2. Type and localization of industries to be created should be carefully chosen on the basis of a general concept.

3. Existing socio-economic structures should be taken into account.

4. Technical and financial assistance should be well coordinated.

Difficulty: Lack of understanding in the industrialized countries of the conditions in the developing countries.

Measures:

Employment in developing countries requires special training covering the cultural, geographic, climatic and other particulars in the country concerned. Universities in industrialized countries should introduce special courses taking into account the requirements of developing countries.

Difficulty: Differences between the conditions in developing countries and in industrial countries.

Measures:

1. Scientific and technical personnel should be trained on the spot in order to ascertain that the existing conditions are taken into account.

2. Training programmes and lectures offered by industrialized countries should be relevant to conditions in the developing countries.



Difficulty: Shortage of instructors

Measures:

Instructors from industrialized countries, specially trained for this purpose, should be contracted to spend a number of years in developing countries. Shorter periods are not sufficient for making a lasting impact. In order to counteract fears of losing contact with home countries, home positions should be reserved for the period spent abroad.

Difficulty: Lack of motivation for scientific work

Measures:

1. Instructors from industrialized countries should not induce students to study subjects of no interest to them. Subjects taught should be relevant to tasks in the developing countries.

2. Remunerations for work in research should be such that successful scientists are not motivated to look for alternative jobs.

Difficulty: Brain Drain

Measures:

1. Train students in their home countries whenever possible. Training in industrialized countries often results in qualifications not needed in the home country, and in unrealistic expectations on the part of the student. Both effects tend to reduce the motivation of the students to return home.

2. Enable students to learn how to solve practical problems as they occur in their home countries.

**Difficulty**: Lack of mutual trust

Measures:

1. Mutual trust into the personal and institutional partner must be established by delegating persons of high qualification and motivation.

2. The partners in scientific collaborations from the developing countries must participate fully in the fruits of the joint scientific work.

Letters from scientists and administrators in developing countries express the overall mood of the letter-writers with respect to the application of science and technology to development. Unfortunately, many of them show a sense of frustration. There are, however, valuable suggestions as to what could be done in order to improve the situation. I just mention here, as an example, the proposal "to identify active groups of scientists in the developing countries and provide adequate support to their well defined research programmes", rather than spread the available support equally and thinly to well defined and ill-defined programmes. This would, of course, require a functioning evaluation mechanism.

Among the main difficulties mentioned in the letters are:

- the lack of political will to apply science and technology for development,
- the lack of financial resources,
- the lack of skilled personnel,
- the lack of a consistent science and technology policy,
- the lack of consciousness, within the public, of the significance of science and technology,
- the difficulty to obtain information on new developments in science and technology,
- the political instability in many developing countries,
- the lack of awareness in industrialized countries of the special conditions in those developing countries with which they intend to cooperate.



As far as the suggestions for tackling these difficulties are concerned, it is interesting to note that there is no marked difference between the suggestions made in this survey by experts from developing countries, and the measures recommended by representatives of universities and research institutions in the Federal Republic of Germany. The latter, however, seemed on the average to be somewhat more detailed and project-oriented. This may be due to the different nature of that survey. It could also be due to the European habit of dissecting and analyzing, in contrast to the traditions in many non-European regions where the stress is more on integration and compromise than on identification of contradictions and imperfections.

Of course, many questions remain open, as was to be expected. It would be good to know, e.g., the relations between the various obstacles. What are the reasons for the lack of political will towards the application of science and technology? Has the lack of financial resources or the shortage of manpower anything to do with it? Does the lack of an appropriate science and technology policy create a shortage of manpower? Or vice versa? Is this a vicious circle? What would be the best way to break it?

Answers to these questions can only be obtained from practical experience. This experience is gained step by step, as the establishment of science and technology in developing countries and the cooperation between developing and industrialized countries progresses slowly in many fields of science and technology.

Many detailed recommendations are contained in the report written by Prof. Pati.

Close cooperation between developing and industrialized nations is certainly needed for the design of long-range goals for societal development, separately for various types of industrialized and developing countries, but in such a way that these goals are not incompatible with each other. Such goals could be:

- satisfying the basic needs of the developing countries. This should be done not just by applying the standards of industrialized countries but by respecting the cultural identity and individuality of each developing country.

- elaborating an overall concept for a sparing treatment of the resources of the earth.

- solving the debt problem of developing countries in such a way that the necessary sacrifices are shared justly by the industrialized countries.

- drafting of an international, cooperative programme in science, economy and industrial technology for handling problems of world-wide ecology (deforestation, overgrazing, energy conversion, climate, waste disposal, etc.)

- whenever applicable: Studies, and spreading of information, on systematic connections between policy measures (including the introduction of new technologies) and side-effects on nature and society.

Thus it is not only for the negative goal of avoiding dangers that the spirit of cooperation is required. Science and technology offer great chances in this state of transition. The recommendations mentioned above give examples. Close cooperation and thoughtful coordination are needed if these chances are to be seized for the benefit of humanity.



## Cultural Identity and Scientific-Technological Development.

### Questions, Theses, Antitheses

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Yesterday we have mentioned several obstacles which often prevent a successful application of science and technology for the benefit of developing countries. One of the main obstacles seems to be that the cultural identity of the countries concerned is not properly taken into account when the transfer of science-based technologies from the U.S.A. or Europe to Africa, Asia or Latin America is attempted. We all know examples of development projects set up artificially in an environment into which they do not fit and under the conditions of which they do not function as they should. What is the reason? What is cultural identity?

The social psychologist Ernst Boesch, who specializes in development planning, has expressed the problem as follows, in a book which our study group has produced recently[1]:

"The question is to what extent science can help development in a culture different from the one where it originated. ... 'Culture' can be defined in a very simple, yet still correct form as the ways in which a group or groups of people live together. Science, on its side, can be defined as the ways in which people enlarge and organize their knowledge in a consistent way. The definitions suggest at least the possibility of antagonism between the two terms. The definition of culture implies the need for stability: people cannot live together unless they can in some essential ways trust each other; or, trust means the possibility to anticipate one's partners' ways of acting and reacting. Regularity thus is a precondition for anticipation, and therefore one finds in all cultures a tendency to reject unpredictable change. However, there are, too, endogenous processes inciting to change, but which are only to a smaller extent due to a wish for increasing knowledge.

Science, on the other hand, seems to strive for change. Expanding knowledge implies a constant need to reorganize existing information in the light of new one. A distrust of one's knowledge appears to be basic for the scientist, and he therefore welcomes innovation as much as he immediately starts to look beyond it. Science, therefore, will be likely to get into conflict with culture - even its own. This description, however, is somewhat idealized, because science is an institution for which acquiring and organizing knowledge is only one of several functions. In its social context, science represents a means for livelihood, for gaining and ascertaining status and power, for forming castes with their specific bonds of loyalty. In other words, it is a subculture which, in some ways, is not less adverse to change than other cultural groups. Thus, the reality of science may deviate quite severely from its ideal definition. Rigidities as to methodology, theory, or to social privileges are too frequent for constituting mere accidents.

The antagonisms between science and culture, therefore, appear to be threefold. First, the changes in knowledge brought about by science may antagonize conservative tendencies in the non-scientific parts of the community - witness the controversies between 'evolutionists' and 'creationists' in the United States; second, the social privileges and powers claimed by scientists may lead to conflicts of interests - witness the monopolizations by doctors, lawyers, pharmacists, or architects, to mention only some obvious examples;



third, scientific innovations which - for reasons whatsoever - have been welcomed by the community may yield undesired consequences for at least some groups - witness atomic power, DDT, antibiotics or even contraceptive medication; such consequences may be direct or indirect, short-range or long-range, but, once they are recognized, will strain relations between scientists and their culture.

Science, to a greater or lesser extent, has developed in most cultures, but in its modern technological form it mainly is a product of Europe and North America, and is closely linked to other features of Western culture: first, more obviously, to its technological orientation which ... (is) related to a certain number of special historical conditions. ... Whatever those ecological and historical conditions, scientific development also has a second cultural root which may be less obvious but is closely related to our basic attitude towards life: Western cultures do not consider nature as "their brother" or "their mother" but as their opponent. Western man ... strove to subjugate nature. Exploiting natural resources to the point of exhausting them - from minerals to animals - became frequent, once technology permitted it; but this tendency to subjugate nature expresses itself also in the insatiable drive to dissect, analyse, to penetrate the secrets of matter and life, and to conquer nature wherever it is felt to be an obstacle or to offer an opportunity. All this, obviously, has allowed many victories over adverse conditions, as well as discoveries which benefit mankind. As yet, however, nobody has assessed the price we paid for it."

So far Ernst Boesch. Science may be characterized by its dissecting methods of analysis for studying the laws of nature, and for conquering and employing the forces of nature. To some extent, of course, Man was always forced to study, conquer and employ the forces of Nature. If he had not done so, he would not have survived. This was already true in the early periods of his existence on this planet. Nature had not endowed him with great strength, with powerful claws and teeth or with the capability to run very fast. Man had to use his brain which enabled him to develop curiosity, to learn, to invent, to communicate, and finally to understand the laws of nature to an extent which made it possible to use the forces of nature for the purposes of man. By introducing agriculture, by cutting down forests, by building cities, canals and dams, by setting up industries, by polluting air and water, Man has changed the face of the earth, at first very slowly, then faster and faster. He is now changing it extremely fast. In the beginning, the resources of nature seemed inexhaustible, and the idea that Man should limit his activities out of concern for his environment, though raised from time to time, seemed far-fetched. The benefits which Man derived from his curiosity- and necessity-based activities far outweighed, one could be sure, any detrimental effects.

When modern science was born and industries developed which were based on scientific discoveries in fields like thermodynamics, electricity, pharmacy, radio waves, aerodynamics, electronics, this attitude continued to prevail, and it is still the general position of most scientists and engineers and of the great majority of the populations, not only in industrialized countries but also in the Third World. Nevertheless, the dark consequences of scientific progress - such as the invention and design of weapons of mass destruction, the pollution of the environment, the misuse of drugs, the control of the minds by the new media, and the disquieting prospects of gene manipulation - have become too obvious to be overlooked. This has led to a spreading conviction that there must be a change of attitude: no longer can it be permitted that anything which becomes possible in science may also be done without further justification. Of course, there have always been limits to science set by law or by institutions, such as the Hippocratic Oath, or by other rules of ethics. But these limits concerned the behaviour of individual scientists or physicians. In our days the question is being discussed increasingly whether there should be limits to science as such. There are influential voices which express the opinion that the ultimatee goal of science should be the well-being of society, not the search for truth. Indeed, it is sometimes claimed that there cannot be a disinterested search for truth because some people will always benefit from the results, and others will suffer because of them. Therefore, it is said, science needs supervision in order to guarantee that only "good" things are found or invented and "bad" consequences avoided. Sometimes a "new



science" is called for, and the terms "alternative science", "non-destructive science" or "partisan science" are used in this context.

Although some of these arguments show a misunderstanding of the role of science, they point to a real grievance which needs correction: The number of human beings on this planet has become so great, and the methods of science and technology have become so powerful that the side-effects of human activities on nature, on the human environment and on human health can no longer be neglected. Out of old habits, out of greed, and out of sheer poverty, as the case may be, this neglect, however, still takes place. From now on, these by-products and side-effects will have to be taken into account. For doing that we shall again need the scientific method. But in order to avoid frustration and failures, it will be of vital importance to understand better the problems of cultural identity, of the relations between science and culture, and of the obstacles standing in the way of harmonious cooperation between countries of different historical, cultural and social background.

In our Study Group of the Federation of German Scientists (Vereinigung Deutscher Wissenschaftler, VDW) we have begun to investigate these topics in 1980. In order to be specific, it was decided to focus attention on two particular cultural spheres: that of Islam, and that of Africa south of the Sahara. With the assistance of experts on and scholars from these regions, the Study Group met six times reviewing the literature, preparing working papers, and discussing various aspects of the problems in question. Then we held three conferences and produced two books[1 2].

Let me quote some of the results. First, I should like to add a remark with regard to the goals of development . I have already mentioned yesterday the four goals which the governments of developing countries gave in their national papers submitted to the UNCSTD (Vienna 1979): Autarky, fulfillment of basic needs, catching up with developed countries, social pacification. But members of government were often educated in industrialized countries. Traditional cultures may have different values and different goals.

There are, e.g., cultures in Asia which consider it as a high value to be poor. Their highest religious goal is to be happy and content in poverty. People know they will be reborn anyhow. For them it would not be self-evident that to fight poverty should be the goal of development. In any case, and for many reasons, particularly because of the scarcity of resources, it cannot be the goal of development just to imitate the civilization we now see in the North. With its waste of resources, its pollution of the environment, its social and economic problems it cannot be recommended for unreflected imitation, in spite of the affluence it has produced in the North for about half a billion people. If that wealth were to be shared by more than ten times as many people, with two cars per family and all that, if that were the goal, the world would become a very unpleasant place to live in. The growing slum-cities around the metropolies of the Third World indicate what life would be like for billions if that were the (unattainable) goal. The South cannot follow the same path the North has gone. It took the European nations about a century, and enormous sacrifices, to industrialize. Moreover, they had much better starting conditions. They had cities, sophisticated craftsmen, leading scientists, and a stable population, when industrialization started. The population only increased significantly when industrialization gained momentum. In the Third World of today, the population is increasing faster than the GNP.

The gap is widening. But it is not only the gap between North and South, but also a gap between the rich and the poor within each developing country which creates problems for many Third World nations. The understandable desire not to have to wait an indefinite time for the fruits of development has led to the import of the products of northern technology, more often than not on a credit basis, and with the result of a tremendous indebtedness. (The debts of developing countries amount to about 1,000 billion US $.) Moreover, it has led to a dependence on the creditors, technologically and financially as well as politically. To make things worse, the capital goods imported were sometimes not well adapted to the economic and cultural traditions of the region concerned, did not fit well, from a systems point of view, into a coordinated development strategy, if such a stategy existed at all.



Therefore, the investments sometimes did not lead to the benefits they were meant to produce. Furthermore, valuable resources were, and still are, squandered on excessive purchases of armaments.

If the Western countries are no model to be followed by the Third World, what about the example of the USSR? The industrialization of the Soviet Union certainly followed a different pattern from that of Europe and the United States. But the USSR had vast resources and, particularly under Stalin, made vast sacrifices. A dictatorship cut the country off from the outside world and enforced industrialization with an enormous toll of human lives and no regard at all for personal freedom. Few countries of the Third World will be able or willing to follow that example. Even China with its huge resources seems to have decided to follow a different pattern.

So there is no established model of development which would fit the conditions of today's Third World countries and which could be recommended to them as such.

The Japanese example seems to show, however, that the maintenance of cultural identity and authenticity is related to the success of the developmental process. The importance of cultural identity (which can be a pluralistic identity) is often overlooked. People must have the feeling that they themselves understand what is happening, that they themselves are in control and in harmony with their beliefs and traditions, and that what is happening is for their benefit.

Mentioning "pluralistic identities": Cultural identity is not monodimensional, not monovalent. In most cases, several identities are recognizable in the same place and at the same time: national, ethnic, denominational, tribal and other identities. They are given by mentalities, norms, and attitudes. Pluralism is the cultural identity of modern Europe.

Maintaining cultural identity is important for self-respect. Only self-confident people who are quietly sure of their own value can be tolerant and appreciative with regard to values different from their own, and with regard to cultural achievements of others. People who are not self-confident are insecure and unhappy. Inferiority complexes breed hatred. Goethe said to Eckermann that chauvinism, national hatred, is strongest and most violent on the lowest levels of cultures. It disappears, he said, at the highest cultural levels. We must make sure that as many people as possible consider themselves to be at one of the highest cultural levels.

Is there a relationship between "political culture" and economic development? The evidence is that pluralism, observation of individual human rights, democracy, only flourish in a minority of states which, on the average, have reached the highest economic affluence. In most developing countries democracy has no very strong roots, many even have dictatorships, and the stress is on "collective" human rights. This is similar in socialist countries, and it is also true for the past of Western Europe. Absolutism and mercantilism ruled here not so very long ago. Is it really true that states have to become affluent first and democratic later, or is the affluence a consequence of democracy? Reality is probably more complex than these simplistic alternatives. It seems that there is some truth in both these sequences: It is easier to establish, and maintain, democracy under conditions of wealth, but wealth is no guarantee. It is easier to become wealthy under democratic conditions but democracy is no guarantee.

What does this mean with respect to the adoption of modern science and technolgy? Modern science has first developed in Europe. But there is nothing in science which says that the absorption of European civilization is a prerequisite for the introduction and use of modern science. Indeed, it seems that modern science could, in principle, be used and adapted by many different cultures. We now know that there is no rigid relation between science and philosophy. This has been pointed out by Alfred Gierer. He writes under the title MODERN SCIENCE IS CONSISTENT WITH CULTURAL PLURALISM [3] :

"The relationship between science and culture is a controversial subject, particularly with reference to developing countries. Some observers claim that modern science is the foundation of a fairly uniform civilization, determined by technology and industrialization, which eventually overcomes 'non-modern' cultural traditions. This view is tacitly assumed by a considerable part of



the scientific community. There are others who look on science as a vehicle importing life styles and mental attitudes from industrialized into developing countries, thus perpetuating a pattern of dependency. This view has many supporters in the social sciences, the humanities, and in the literary circles of both developing and developed countries. According to a third view, a modest assessment of the meaning of science and its thoughtful application is consistent with a continuous development of unique cultures. Though arguments can be put forward in favor of all of these views, the third one, being underrated in the public discussion, deserves particular attention.

Modern technology and industry are still intuitively associated to the naively materialistic mechanics of the last century which suggest unrestricted determinism and universal applicability. Progress in the basic sciences (mathematics, physics and biology) has since led to a more modest understanding of the meaning of science. Intrinsic limitations have been found whenever the basis of science is reflected by its own methods. This is essentially the root of indeterminacy in quantum physics, of undecidability in mathematical logics, and of unpredictability in the theory of chaos. Similar self-limitations seem to emerge with respect to the interpretation of evolution. There is no question about the fact of evolution, but the dilemma of 'chance versus necessity' has no unambigious solution. Problems arising from intrinsic limitations of the scientific method also occur when considering the relationship of mental to physical states of the human brain. While the scope of science has expanded tremendously, it has become increasingly clear that its metatheoretical understanding is open to different interpretations. Therefore, scientific rationality is consistent with many different - though of course not all - philosophies, religious and cultural attitudes. There is not 'the' philosophy, life style or culture of the scientific age.

This does not imply, of course, that the influence of science and technology leaves cultures unaffected, nor that it cannot cause the decay of a particular culture; however, decay is just one of several possibilities for the results of interaction, others being branching, merging and adaptation of cultures. Since it is highly desirable to maintain cultural identity and diversity as an element in the quality of life, as a stimulus to dynamic development and as a source of self-respect and self-confidence, the style of science and science education should be consistent with cultural values and cultural diversification."

We notice from this: Modern science is compatible with many cultures, religions and philosophies. It would be wrong to destroy living, traditional roots for the sake of introducing modern civilization as we Europeans or Americans know it. People should not be forced to give up their traditions and to forgo possible contentedness in the present time for an uncertain future. We should allow time for a slow change and let people follow their interests. Then they will be strongly motivated to do useful work, within the limits given by outside conditions. This way, the existing traditional knowledge in ethno-medicine, ethno-psychiatry, ethno-botanics etc. will be used, not destroyed. A policy along these lines would also help to mitigate the harsh contrast which exists in many countries between the "modern" sector in the cities and the "traditional" sector in the rural areas. Strengthening the traditional sector would preserve its self-respect and prosperity. The values of old cultures could be preserved if conscious efforts were made to adapt the application of science and technology to those values. Ignorance of the cultural background, or negligence on the part of the industrialized countries, but frequently also on the part of the governments of the developing countries themselves, are often the cause for the failure of joint development projects.

When planning joint projects in research or industrial application, one should be aware of these historical roots and should choose projects which fit into that background. This can only be done on a case-by-case basis, not in a general way. For the case of Islam our workshop showed that the promotion of science and technology in Muslim countries is more likely to succeed if it is done within the framework of Islam. Islam is so deeply rooted in the emotions and in the life of a great part of Muslim youth, of Muslim students, that nothing can easily be done which looks like a deviation from Islam. People want to revitalize Islam, perhaps not only for religious reasons but also for reasons of self-respect after the age of



colonialism. What does this mean for the promotion of science? The Koran encourages the seeking of knowledge. It forbids the seeking of knowledge only if it is done for its own sake. The justification for the gaining of knowledge is its application for the benefit of society under the laws of Islam. The great philosopher and scholar Ibn Khaldun who taught in Tunis and Cairo in the 14th and 15th century and who classified all sciences said that the results of scientific research should only be accepted as far as they did not contradict the Holy Scriptures. If science and the Holy Scriptures came to different results, then the latter were right. Ibn Khaldun was a rational thinker. At a time when Arabic science was much superior to European science he foresaw, some people claim, where science without God would lead. Therefore, he gave priority to Faith. He did not choose the course later chosen by Galileo, a course which led to the Atomic Bomb.

It is interesting to note that nowadays again there is some discussion going on in Muslim countries about the qualities of "Islamic science". Is this another variety of "alternative science"? Ziauddin Sardar, in an article in Nature (Vol. 282, 22 November 1979) distinguishes four definitions of science in the Islamic sense:

1) Science as such is universal, neutral and value-free. The Islamic scientist, however, will use it for the benefit of his people and will try to make it accessible to his brothers by, e.g., teaching in Arabic.

2) Science is neutral, but it has been entrusted to scientists by God. Knowledge is a gift of God. It depends on its application whether science is Islamic or un-Islamic.

3) Science is not neutral but fraught with ideology. Modern science is based on the ideology of the West and promotes the ideology of the West with its particular growth and development and with its placement of man - instead of God - in the centre.

4) The axioms of Islamic science are different from those of Western science. Revelation is the supreme authority. Science is subservient to the goals of society. The goals of an Islamic

Society are to increase brotherhood, reduce consumption and increase spiritual awareness.

The definitions 2 and 3 of Islamic science as quoted above are reminiscent of the arguments of some proponents of "alternative science" and of the "green movement" in Europe.

Our workshop on Black Africa confirmed the view that each region of the Third World is different, that one must not generalize. Whereas the Islam workshop showed that the pure sources of the Koran - if liberated from later scholastic additions - are no obstacle to modern science and technology, our African colleagues did not think that their own old tribal traditions would be compatible with temporary scientific thought. A new beginning has to be made. But the tribal traditions are important for the maintenance of moral values, family bonds and human dignity. In order not to destroy these before new African values are established, science and technology must be incorporated very carefully. Values must be restructured so that a stable and progressive society is produced. That was the view of a leading African scientist at our workshop. It means, as other Africans pointed out, that Europeans and Americans, in their technical assistance to Africa, should not orient themselves merely according to economic considerations. Cultural and educational requirements are just as important. Africans must get into a position in which they can set their own goals for development and make their own rational decisions. Africa is different from Europe or the United States or the USSR. Even the meaning of "human rights" is different, as one African professor pointed out, when people suffer from a lack of food, clothing, shelter, and education. Some people have even coined the term "human rights imperialism" (Theodore von Laue). It describes the attitude of Western democracies which transplant their own ideas about human rights unthinkingly to other countries in spite of the fact that these other countries have a different social structure and are in a different phase of development.

Is it possible to summarize the results of our study on the relationship between cultural identity and the development of science and technology? Perhaps the summary is best given in a



dialectic way, i.e. by a number of theses and antitheses. Reality could then be described by a synthesis of these theses and antitheses:

- Modern science and technology are compatible with a diversity of cultures (on the one hand); modern science and technology create their own culture which we see in Europe and which is now spreading all over the world (on the other hand).

- Science and technology create rationality, and this rationality will help developing countries to solve the formidable problems with which they are faced (on the one hand); despair about these problems and about the increasing gap between developing and industrialized countries will lead to irrationalism which will lash back into the industrialized countries (on the other hand).

- Different cultures may produce different ways of looking at nature, i.e. different "sciences", just as they produce different sets of values and different human rights (on the one hand); there is only one successful and correct science which is independent of culture just as basic human rights are independent of culture (on the other hand). Of course, this comparison of the universality of science with the universality of human rights is debatable in itself.

- The ideal of "cultural identity" has been invented by the old colonial powers in order to keep the developing countries in their technical dependence; or it has been invented by the elites of the developing countries in order to block social transformation; the developing countries should direct their attention to transformation, not to preservation of cultural identity (on the one hand); the preservation and the development of cultural identity is a necessary element of self-reliance (on the other hand).

There is also a number of open questions which I do not dare yet to cast into the form of theses and antitheses:

Is the rejection of political and ideological pluralism shown by Islam - particularly by its Schiitic form -, the trust in authority, compatible with the principles of science (knowledge is never closed, is always subject to revision)?

What are the main determinants of scientific-technological development: Religion? It is sometimes suggested that the fact that man is put above nature in Christianity has something to do with the progress of modern science and technology in the Christian West. Economic development? General literacy and culture? Political conditions? Or self-confidence alone?

The progress of science and technology, in particular in the areas of traffic and communication, has made this world small. It has brought very different cultures, value systems and political systems into close contact. So we often witness a collision of old traditions with new ways of thinking. An arms race with weapons of mass destruction, and overpopulation and hunger in many parts of the world are confounding the problem. Mankind is in a state of transition. Old equilibria have been destroyed, a new state of equilibrium under the conditions created by science and technology and by a change of cultural consciousness has not yet been reached. If catastrophic events are to be avoided before this equilibrium has established itself, those menacing problems have to be tackled systematically and in a spirit of international and intercultural cooperation. Interconnections and causal relations have to be considered because the developments in armaments and in economics, in politics and in mass psychology, in food production and in environmental pollution - to mention only a few - are not independent. They are part of one system. Actions in one area without due consideration of these interconnections can do more harm than good. People are governed by psychic and mental processes. It is important to understand these processes. The realities of cultural traditions and cultural identities certainly play a special role in these mental conditions and psychic processes.

It belongs to the role and responsibility of science in society to contribute towards the creation of an atmosphere of peaceful cooperation not only by elucidating scientifically the origins of



the existing mistrust, hatred, and strife, and the possibilities for overcoming them, but also by using the international channels of communication available to scientists because of the character of their work. I think that ICTP and a few - too few - institutions like it make a very valuable and important contribution toward this goal.

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# NEW TECHNOLOGIES AND THE THIRD WORLD:

## Issues, Impacts and Policies

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I am honoured to be given this opportunity to give two lectures on "New Technologies and the Third World". I am particularly grateful to Professor Abdus Salam for having invited me to do so. I think Trieste and the Centre (ICTP) is an appropriate place for this opportunity since it was here that the Third World Academy of Sciences - an excellent initiative of Professor Salam - was born. This Academy and the Centre, in my view, may have a catalytic role to play in the future, to assist the developing countries in facing up to the new technological challenge posed by new technologies such as microelectronics, biotechnologies and new materials.

I shall divide the two lectures into the following parts: Today, I shall present to you some thoughts on the issues, potential and actual implications and policies towards new technologies.



Tomorrow, I shall present to you the scope, limitations and potentials of what has been labelled "technology blending" - that is, applications of new technologies particularly to traditional sectors in the Third World countries with a view to alleviate poverty and raise standards of living of the majority of the populations.

As a starting point, it is useful to consider how and why new technologies are distinct from the conventional ones which continue to be used in most of the Third World today. The new information technologies are often considered revolutionary and are compared to the Industrial Revolution in terms of the radical and all-pervading influence they are likely to exercise on growth, employment, income distribution, patterns of work organisation, educational systems and even the whole social and economic fabric of society.

Secondly, these new frontier technologies are leading to a growing interdependence between the North and South by spurring worldwide competition and globalisation of production. Another important feature of these technologies, (unlike the earlier traditional and conventional technologies) is that they are almost virtually produced only in the advanced countries. To add to this, within the advanced countries, a few big conglomerates and corporations (e.g. the case of photovoltaic production in the United States by the big oil companies) control the production of new technologies. Thus, the developing countries are faced with a single source of supply of frontier technologies. Their disadvantages in bargaining for technology acquisition are magnified when we realise that the suppliers hold a monopolistic position in many fields. Even in the case of non-proprietary technology, university research establishments are increasingly entering into joint ventures with private firms (in biotechnology for example) and patent their discoveries in order to recover high sunk research costs. It is estimated that during 1982 licensing of one patent in biotechnology raised for the University of California over US$1.5 million in licensing fees.[1]

Another characteristic of significant potential interest to the developing countries is that frontier technologies like microelectronics are becoming increasingly miniaturised and simplified in applications and require simple maintenance. They are also becoming cheaper with their falling prices. These characteristics of flexibility contrast with



those of complexity, rigidity and large scales of production with which the conventional technologies have been characterised.

## I. ISSUES

These characteristic features of new technologies (which are by no means exhaustive) raise a number of difficult issues and problems which the Third World countries will have to face. The most important of these issues are:

(i) new rules of international technology transfer;
(ii) new dimensions to technological dependence;
(iii) problems of domestic production of new technologies versus imports;
(iv) scope and limitations of small-scale decentralised production.

Since the new technologies can have both beneficial as well as harmful effects (depending on how they are utilised), a debate has polarised into proponents and antagonists of their suitability for the Third World. This debate is somewhat reminiscent of the earlier controversy that surrounded "appropriate technologies" which were considered by some people to be promoted by the North to keep South perpetually dependent on it. In the new debate, one group would like the Third World to actively participate in evaluating the positive and negative implications of new technologies, and even to participate in their development. The opposing school of thought is more alarmist and finds that the new technologies are too sophisticated and costly for the Third World, particularly for the least developed countries, and their utilisation will entail massive unemployment and further worsening of income inequalities. Their utilisation would imply further technological dependence on the advanced countries and would be harmful to the building up of their national technological capacities.

While the above dangers are real, it is clear that no developing country can ignore the new technological developments which are bound to influence the Third World in one way or another. However, before we examine the specific issues, it is important to recognise that the Third World is very heterogenous. Currently it is only a small group of the more advanced developing countries (the NICs) which account for some of the global R and D expenditures which are concentrated heavily in the advanced countries. They are also the ones with the mininum of human capital, physical infrastructure and national capabilities to participate in the



development of microelectronics components for example. They are also the ones with a real choice between increasing the use of new technologies through local production and/or imports. For the least developed countries, there is no such choice. Increased applications of new technologies would essentially depend on imports from advanced countries - in the foreseeable future these countries will remain consumers but not producers of new technology. Thus their dependence on other more advanced developing or advanced countries is likely to increase.

There are also restrictions on the transfers of new technology to developing countries which would adversely affect the latter. For instance, it has been noted that the advanced countries like the United States are imposing increasing restrictions on the exports of computers, computer systems and information technology. Recently, a coordinating committee for multilateral export control (COCOM) has been set up jointly by several advanced countries to supervise policies in respect of such exports.[2]

It is not clear whether transfer of new technology from the more advanced of the developing countries (e.g. Brazil, India and the Republic of

Korea) will be less restrictive than those from the industrialised countries. The recent phenomenon of leading exporters of manufactures from the NICs setting up subsidiaries and organising subcontracting and licensing arrangements with other less advanced developing countries, suggests that there may be somewhat healthier technology transfers among developing countries.[3] These initiatives seem to be a reaction to the erosion of labour-cost advantage of these countries by the microelectronics-based innovations. But the extent to which the NICs at present possess new technologies ready for transfer is rather limited. On the other hand, NICs may have a potential comparative advantage in the export of software (as against hardware) a relatively labour-intensive activity in which some NICs with abundant qualified manpower, may develop an advantage with relative ease. This seems to be the case in India which has made a beginning in the exports of software programmes to other developing countries.

The question of national self-reliance and capacity-building endogenously versus imports of new technologies by the developing countries is a tricky one. Will the widespread import and use of new technologies in the Third World inhibit or facilitate endogenous capacity? There cannot be a clear-cut



answer to this question. One thing is clear however; some local production of new technologies within developing countries has the advantage of local learning effects and employment generation which would be foregone if these countries relied exclusively on imports of new technologies from abroad. This being said however, in the process of national technology development, even NICs like India, Brazil and the Republic of Korea could not do without some imports of raw materials and components from abroad.

Related to this question of national capacity-building is the scope for some NICs to be able to leap frog by using new frontier technologies. Late comers do not necessarily have to go through the stages experienced by the pioneers - today's advanced countries. For example, NICs could move away from manual methods directly to flexible manufacturing systems without having to first introduce fixed automation.

Several arguments have been presented in support of leap frogging. First, competition in the international technology market for microelectronics is so keen that prices are falling rapidly - this should make the technology much more easily accessible to the developing countries. Secondly, in view of the rapidly changing character of new technology, it is difficult to appropriate its benefits through patents (true mainly of microelectronics) - this factor should in principle make possible an easier diffusion of new technology. Thirdly, one of the most significant characteristics of new microelectronics technology is noted to be their capital-saving as well as labour-saving nature. That is to say, these are gaining in both capital and labour productivity, thus making this technology superior. To capital-scarce developing countries, the use of microelectronics should in principle be advantageous. But in practice, it is important to remember that if one takes account of the electronic infrastructure (e.g. transport and telecommunications networks) needed for the successful applications of microelectronics, this technology turns out to be quite capital-intensive.

The above argument in support of leap frogging is based on the existence of organisational capacity, technical and cognitive skills, infrastructure and minimum treashold of technological capabilities, which are often lacking in many developing countries. It is for this reason that the diffusion of new technologies is at present very limited.



Although costs of many new technologies are going down, they are still quite high relative to the per capita incomes and foreign exchange availability in most developing countries. Furthermore, the experience in the use of microcomputers in education shows that in principle they can be beneficial by (i) raising efficiency of the traditional educational system, and (ii) permitting training outside the school system. But in practice their potential cannot be exploited for lack of adequate software programmes.

Finally, is the scope for small-scale and decentralised production enhanced by the use of new microelectronics-based innovations? In principle, the characteristics of miniaturisation and flexibility of the new technology should offer greater product differentiation and easier production in small batches in response to frequent demand fluctuations. This should also mean that developing countries can adapt a basic technology to suit to their local socioeconomic requirements. In practice, experience on this is limited so far. I shall have more to say on this subject in my second lecture tomorrow.

## II. IMPACTS

Having examined some general issues, let us now turn to some experience with actual impact of new technologies on developing countries. We shall consider these impacts at three levels: (i) employment, (ii) income distribution and (iii) international comparative advantage and export prospects.

### 1. Employment

The impact of new technology on employment is one of the most controversial subjects today even in the advanced countries, not to speak of the Third World. The empirical evidence to-date relates mainly to industrialised countries, and is quite conflicting depending on the level of aggregation and the coverage of activities considered.[4] One can caricature the debate into three divergent views. First are the optimists who assume that any loss in direct employment will be offset by the indirect employment generated. This is essentially a long-term view. In fact, although the first spurts of automation in the 1960s generated considerable resistance, employment increases occurred subsequently because of world economic expansion, market growth and the emergence of new industries.

Second is a group of "neutralists" who believe that the impact of new technology on employment is unlikely to be significant in the near future since the spread of new technology is much slower than expected, partly because of prolonged recession, slow investments, serious skill shortages and other bottlenecks.

Pessimists - the third group - are alarmist about the employment situation particularly because of the capital-intensity of new technology.

Evidence of the actual employment impact in developing countries is very scanty however. But my organisation, the ILO, has done some research, the preliminary results of which are worth mentioning.

In a study on the impact of robotisation on employment in the Brazilian automobile industry,[5] it was noted that from 1,140 to 1,900 jobs of general-purpose machine tool operators had been displaced by 190 NC-machine tools installed while about 600 new jobs were created in programming and servicing. These labour displacement estimates are based on the assumption that NC-machine tools substituted for 3 to 5 conventional general-purpose machines. The negative employment impact was small because of the limited diffusion of the new technology.

A study on the Republic of Korea[6] based on secondary data and a field survey of 40 users of microelectronics equipment concluded that employment expanded despite the use of factory and office automation. This was due mainly to the growth of demand in business. Another reason for the absence of any adverse employment effect was the relative newness of factory automation and new office technology. To quote the Korean study "Office automation users also experienced an increase in overall employment, but at slower rates than during the 1970s. Banks, insurance companies and investment firms reported significant cuts in manpower related to routine operations such as window service and customer file management."

In India, the computerisation of banking industry has been the subject of some debate and analysis. A committee appointed by the Reserve Bank of India in July 1983 recommended a five-year programme of computerisation of banking. It is assumed that the implementation of this programme would expand employment by about 40-50, through the local manufacture of microprocessors and ledger processing



machines in India. The computerisation might also entail a job loss to the tune of about 40 per cent.[7] Whether this magnitude of job loss would actually take place depends on the speed with which computerisation is adopted.

So far we have examined in these cases, only <u>direct</u> employment effects of actual applications of microelectronics-based innovations. There are however more <u>indirect</u> ways in which the developing countries (especially primary producers) are likely to suffer from employment losses. The new technologies (materials) and biotechnological developments are increasingly leading to "dematerialisation" of production and to the replacement of traditional raw materials by new synthetic ones. Minerals and metals, for example, are facing increasing competition from a wide range of new materials like plastics, ceramics, composite materials, powdered metals and alloys, and silicon and optical fibres. The use of fibre optics in new telecommunication lines is likely to have adverse effects on export markets of such copper producting countries as Chile and Zambia. The resulting loss of foreign exchange earnings would indirectly reduce employment by slowing down economic growth of these economies.

Another example could be that of high fructose corn syrup (HFCS) replacing sugar. It has been noted that "from 1980 to 1985 world production (of HFCS) grew at an estimated 18.6 per cent per annum to nearly 6 million tonnes on a dry basis ...".[8] This expansion may also adversely affect markets for the sugar-producing developing countries, although as of now, no clear trend is discernible. An UNCTAD report notes that "prospects for further growth of HFCS consumption and its substitution for sugar are more limited than in the recent past ...". One of the reasons for this conclusion is that at present the price of HFCS is higher than the price of sugar, but this situation may not continue in the future.

In general, in the Third World so far, the employment impact of new technology seems to have been marginal, mainly owing to the slow diffusion of these technologies. All one can say therefore is that with the acceleration of the diffusion process, there may be greater employment losses than in the past.

## Qualitative effects

More than the effect on the quantity of employment, the new technologies are likely to affect



the skill structures and occupational composition of the labour force. Other qualitative changes like part-time employment, shorter working hours and quality of working life, are also likely to occur. In respect of skill consumption of the labour force, in general, it would seem that craft skills will be increasingly replaced by higher-level professional skills. There is some controversy however about such effects. Some people believe that the new technologies will generally reduce skill requirements which would facilitate the task of developing countries. An ILO study by Hoffman and Rush on garments industry for instance shows that the impact of microelectronics-based innovations has considerable impact on deskilling and training costs. In the case of garments, in certain operations it led to a saving of several months of training, and thus of training costs. The skill-saving effect of these innovations needs to be interpreted carefully. Although NC-machine operators for example, require much less experience than those working on conventional machines, much higher skill and knowledge are required of programmers, supervisors and maintenance staff. More research on this subject is needed before any general conclusions can be drawn. The ILO Training Department is in the process of undertaking some of this research.

## 2. Income distribution

As with employment, with respect to the distribution of benefits resulting from new technology applications, we are operating with fragmented and incomplete information. Our ignorance arises from the fact that the impact of new technologies on income distribution has so far not received sufficient attention either in the advanced or in the developing countries.

An ILO study has attempted to examine the impact of microelectronics on the personal or size distribution of incomes by looking at the following five sets of outcomes, viz. (i) distribution between producers and consumers, (ii) between consumers, (iii) between producers and workers (as well as between those workers who are unemployed or underemployed), (iv) between producers, and (v) between the domestic economy and foreign producers operating within the domestic economy.[9] It concludes that the effects of microelectronics on income distribution are likely to be quite different from those of the Green Revolution. This is shown in Table 1, which illustrates that microelectronics is likely to be much more producer-biased than the Green Revolution; the bias is likely to be weighted in favour of large producers who enjoy a comparative advantage in large-scale production and exports.



Table 1

The nature of producer gains from technological change

| | Microelectronics | Green Revolution |
|---|---|---|
| Producers versus consumers | Producers tend to benefit from relatively elastic product demands (especially in the initial phases of the adoption cycle and especially in export markets) | Producers suffer from the highly inelastic demand for wage-goods |
| Producers versus workers | Producers benefit from the absence of capital-saving bias in the new technologies | More or less neutral technological change (Binswanger, 1980) |
| Producers versus producers | Permanent biases favouring large producers as well as transitory biases arising from the adoption cycle | Only transitory biases in favour of large producers resulting from lags in the adoption cycle |

Source: Jeffrey James: The employment and income distributional impact of microelectronics: a propsective analysis for the Third World, ILO/WEP Research Working Paper Series, WEP 2-22/WP. 153, Geneva, Sept. 1985.

In the case of the Green Revolution, the gains to consumers accrued mainly to the poorest whereas in the case of microelectronics, according to the above-mentioned study, these gains are likely to accrue mainly to the rich consumers in developing countries who can more easily afford the products incorporating microelectronics (e.g. watches and clocks, and passenger cars). The demand for these types of goods seems to be elastic whereas that for wage goods (in the case of the Green Revolution) was highly price and income-inelastic.

The above hypothesis needs to be tested empirically. While at a macro level it may be valid, in individual cases the situation may be quite different. For example, the use of microelectronics-related innovations can raise productivity and reduce production costs of very small enterprises; they further tend to improve competitiveness of these enterprises vis-à-vis large-scale enterprises. To the extent this occurs, the poor consumers are also likely to benefit from cheaper and better-quality products (e.g. garments and textiles where use of new technologies had reduced costs and improved quality). In a survey by the Policy Studies Institute (PSI) of the United Kingdom industrial establishments using



microelectronics, 47 per cent of the product users and 54 per cent of the process users, reported lower production costs as an important benefit from the use of new technology.[10]

Let us take an example of photovoltaics technology. Based on case studies on PV power and drawing on an impressive fund of research in that field, Bhatia concludes that one of the important contributions that PV can make is to reduce enormous differences in rural/urban inequality. In principle, this can be achieved because the PV technology can reach remote rural areas without requiring large infrastructure and distribution systems. Income gaps can also be narrowed since PV technology for irrigation can easily reach small and marginal farmers who can maintain it cheaply. In practice, however, actual distribution of benefits of PV technology among large numbers of people, will depend crucially upon the existence of appropriate institutions and government policies which ensure that monopolistic control of the new technology by the rich does not take place. For example, Bhatia noted that in the village of Achheja (UP), PV street-lighting was not universal: it was biased towards the higher income households, with particular concentration around the house of the village headman. This monopoly of the use of new technology by the powerful and rich groups is reminiscent of the experience of the Green Revolution which generally benefited the larger farmers more than the small farmers. But this was not the fault of the new technology per se, but instead, of the institutions and policies which ensured greater access to the richer and the more privileged. Appropriate incentives (perhaps by different income groups and end users) and decentralisation of PV technology can overcome some of the problems of organisation and social inequity noted above.

When new technology is introduced and controlled by large multinationals who have partial monopsonistic positions with respect to hiring, it is far from clear that significant benefits accruing to increased productivity will trickle down to workers in the traditional sectors. Cloning of palm oil trees in Malaysia and Costa Rica could fit this pattern as also might the microbial leaching of copper and other metals in Andean countries (although here government-owned firms would also be involved).

So far we have considered inequalities within the developing countries. There is however an international dimension to the problem. Inequalities



between countries may be caused by factors beyond the control of developing countries. In this context, Cole and Bessant have made a bold attempt to work out employment and income distribution effects of new information technologies for three main groups of countries, viz. high-income industrial economies, the middle-income developing economies, and low-income developing economies.[11] Although the authors do not specify, they use a global model of social accounting matrix to determine the distributional impact on the basis of certain assumptions about changes in relative factor prices, and propensities to consume, etc. The authors' general conclusions is that the distributional effects of information technology are complex and likely to be unevenly distributed between different sectors, workers, and countries. Across countries income gaps are likely to widen because introduction of new technology raises productivity most in advanced countries.

## 3. International comparative advantage

The impact of new microelectronics technology on the comparative cost advantage of developing countries (especially those producing textiles, clothing and footwear) has been the subject of some debate. It has been assumed for some time now that the developing countries would lose their comparative advantage due to low labour costs, since the use of microelectronics in the North tends to relocate industry back there. An ILO study on garments industry suggested that this might be the case. However, there is little clearcut evidence in favour or against this view. At present, the effect on current level and pattern of garments trade is minimal because of the limited use of automation in the assembly stages of production. But this situation is likely to change in the long run, when diffusion of the new technology is likely to be more widespread.

Jacobson's analysis of CNC-machine tool producers in Argentina, Taiwan (China) and the Republic of Korea, suggests that the dominant role of Japan as CNC equipment supplier would considerably lower the market for conventional machine tools. The above three producers according to him, would find it difficult to switch to CNC-machine production in the short run.[12]

On the other hand, there may also be a possibility of an indirect positive effect on developing-country production and exports. New areas of international division of labour may be opened up



for the benefit of developing countries as a result of the advance in product cycles. For example, it has been reported that the Japanese machine-tool manufacturers now subcontract the production of conventional machine tools to the Republic of Korea and Taiwan, province of China, and concentrate themselves on the more advanced end of the technological spectrum.

In general, the large-sized NICs like India, Brazil and Mexico, may be in a better position to maintain their position in the export markets in the face of increasing competition, than would the other less developed developing countries. In the absence of a solid industrial base, the latter countries are at a handicap in carving out market niches especially in conditions of growing protectionism in the North.

## III. POLICIES

In the Third World countries (and in the advanced ones for that matter), the role of government intervention is important for minimising the adverse effects and maximising the benefits of new technologies: it is equally important for building up of infrastructure and domestic technology capabilities.

We shall now examine the policies of two major developing countries - Brazil and India - towards new technologies (mainly microelectronics-based innovations: there seem at present no consistent policies towards new biotechnologies with the exception of setting up of new national biotechnology centres).

1. Brazil[13]

In the 1960s, the production and development of electronic semi-conductor components (SCC) and electronic data processing equipment (EDPE) were largely in the hands of the subsidiaries of multinational enterprises (MNEs). These enterprises produced mainly for the domestic Brazilian market rather than for exports (as is generally the case in other developing countries).

In the 1970s, the Brazilian government policies were therefore intended to (i) increase local control of foreign firms operations, (ii) protection of domestic production against foreign competition. Subsequently, in 1980, the Government used policy



instruments - (i) fiscal incentives and (ii) linking imports of components to exports of finished products - for encouraging exports of electronic products.

The Brazilian Government has promoted the growth of local suppliers of components of EDPE to the subsidiaries of MNEs, through the policy of market reservation. Protection of the market for local producers implies market segmentation under which some product lines (the simple ones) are reserved for the local producers in which participation of foreign firms and subsidiaries is not allowed. In addition, the government imposed import controls on EDP components and products. In principle, the government policy allowed for joint ventures with foreign firms, but the latter were to transfer technology to local producers. Thus five Brazilian-owned firms were allowed to produce microcomputers with licensed technology.

Import controls and local production under protection has resulted in the high cost and relatively low quality of the domestic products vis-à-vis imported ones.

A national information policy law (which covers electronics and all other related services) was formulated in 1984. The objective of the law is to ensure national control on information technology development. The State will refrain from participating in production in those areas which the private sector is able and competent to cover.

A special fund for information technology and automation has been established to give financial support to national firms engaged in the development of hardware and software. As local technology development and capacity building are the major objectives, financial assistance is conditional upon the firms guaranteeing that investments will be made in technology generation.

The Information Law and Policy will be administered by the National Council of Informatics and Automation (CONIN) attached to the Office of the President.

The Brazilian policy described above seems to concentrate most heavily on the control of imports and fiscal incentives, and appears to be silent on other equally important aspects like credit policy and R & D.



2. India[14]

In the case of India, the government policy towards new technology may be traced back to the 1970s when a major decision to develop rapidly the electronics industry was taken and a new Department of Electronics was created. The policy towards electronics reflected the more general principles underlying the national industrial policy - reservation of markets exclusively for small-scale sector, control of imports, direct participation by the Government in manufacturing, and geographical dispersion of industry. One of the interesting features of the electronics policy was the use of a criterion of employment impact (along with local availability and importance of the hardware) in examining the request for import licenses for computers. Another was a policy decision to ensure indigenous manufacture of computers and microcomputers consistent with the national goal of self-reliance.

It has been noted that the electronics policy did not result in expanding production to match the demand. The failures are attributed to rigidity and bureaucratic red tape in the issue of licenses, restrictions on the import of technology even when indigenous technology was not available, fragmentation of production capacity among too many small producers, which led to high production costs, preference for public undertakings in terms of markets and imports leaving little scope for private-sector growth, and failure of R & D laboratories to interact with industry, etc.

Recognition of the above failures has perhaps led to the formulation of a new electronics and computer policy in March 1985 and November 1986. The new policy on electronics attempts to reduce unnecessary import controls and encourages joint ventures under which foreign companies, with equity participation of up to 40 per cent will be allowed to manufacture electronics components in India. Technology imports are liberalised in order to help develop appropriate electronics industry. The Government keeps the option open for centralised purchase of technology only when the individual products produced by liberally-imported technology were "costly in comparison with international prices" because one of the objectives of the new policy is to make equipment available at near international prices.

The new computerisation policy is broadly guided by three main objectives:



(i) to increase local component of computer manufacture;

(ii) to facilitate acquisition of computers through liberalisation of imports and domestic manufacture; and

(iii) to facilitate and promote selective and appropriate computer applications for development purposes.

In the case of <u>manufacture</u>, the CPU or mainframe and super minicomputers are reserved for the public sector for a period of two years, whereas micro/minicomputers and personal computers can be produced by wholly owned Indian companies, or by joint foreign and Indian-owned ones.

The restrictions on capacity of the private sector up to total production value of Rs.2 crores per year is now abolished. This means that capacity can be expanded freely to match the growing demand.

In respect of <u>import policy</u>, the following new measures are significant:

(i) imports of computers are liberalised in order to provide, <u>inter alia</u>, competition to domestic manufacturers;

(ii) procedures for the import of raw materials and components by the manufacturers are simplified; and

(iii) customs duties on the import of finished products, components and raw materials, are considerably reduced - from 80 per cent to five per cent in the case of components and peripherals; and from 100 per cent to 60 per cent for software in object code in any media.

A special emphasis is placed on <u>exports</u> of software programmes.

In respect of <u>R & D</u>, the Indian Government has continued to promote broad-based research and manufacturing programmes. For instance, ECIL's programmes on TCD 312, 316, 332 computer systems have been financially supported. Other companies with R & D programmes for computers include Tata Consultancy Services, Hinditron Computer Systems, and Consultants, Digital Systems International.

To summarise, the new computer and electronics policies in India have involved shifts from over-protection to limited competition, from a ceiling on manufacturing capacity to a floor, from



physical controls (in the form of import bans or capacity constraints) to fiscal control and incentives.

It is too early to examine the effects of new Indian policy. But some scholars have speculated on the implications of the new policy in the light of a limited experience to date. One feeling is that despite some liberalisation towards imports and foreign ownership, the Government policy remains somewhat ambiguous. There is furthermore, continued control and regulation of foreign enterprises that may not encourage many joint ventures in the near future. Thirdly, it is felt that removal of capacity fragmentation may not necessarily build greater technological capacity. To quote Khan of the National Institute of Science, Technology and Development Studies:

> "The high rates of protection in India yield high profit margins in the early stages of import substitution and attract an excessive number of firms, and push down the average size of firm. Once set up, small firms manipulate policies to ensure their survival. Thus it is unlikely that the new policy will bring about greater technological depth or capacity."[15]

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The above descriptions of policies refer to countries which are at a somewhat advanced stage of development in respect of infrastructure, research institutions and sophistication of industrial production structures. Even here, however, the policy formulation for new technologies is a recent phenomenon of the 1980s. Major coverage of the policies extends to computers and telecommunications and much less to other new technologies like biotechnologies and genetic engineering. In this latter case, the technology in many cases is still at the laboratory stage (the genie is not out of the bottle yet!). All that the developing countries like NICs seem to be doing is to set up new institutions (R & D laboratories and national biotechnology boards) to deal with the subject and new training programmes at the universities to prepare biotechnologists and scientists.

A national policy frame and in some cases, even the awareness about the potentials and harmful effects of new technologies, are not visible in many developing countries which are not so well endowed with research facilities and scientific manpower as the NICs. Nevertheless, even though these countries may not at present have national capability to develop new technologies, as potential users, they



are bound to be affected by these new technologies. Most of the new technologies are so pervasive that they make developing and advanced countries increasingly more interdependent. Even when the developing countries may not use new technologies, actions taken in the advanced countries, to use new technologies (e.g. optical fibres replacing copper or sucrose replacing sugar) have adverse effects on primary-producing countries through decline in their export earnings.

Similarly, use of microelectronics-based innovations like CAD/CAM in garment and footwear manufactures in advanced countries may bring about gloomy prospects for the exports of these products from the developing countries.

Even within the group of NICs, different policy approaches have been adopted, depending on their economic motivations, political ideologies, and locational considerations. For example, countries like Brazil and India have largely followed import-substitution types of policies under which high priority was given to "infant-industry" type protection to domestic producers engaged in new technology generation. On the other hand, in South-East Asia, countries like Singapore and the

Republic of Korea have adopted a more open-door policy to the development of microelectronics. In Singapore, growth of microelectronics has been structured around a strong consumer electronics base, together with linkages from off-shore electronic component assembly or manufacture, mostly through foreign subsidiaries of multinational enterprises. Similarly, in the Republic of Korea, nationally-owned companies like Samsung, Hyndai and Gold Star (Lucky) have been successful in competing in international markets in microelectronics-based products through joint ventures and licensing arrangements with foreign manufacturers.

In practice, the precise approach and course of action followed would depend on the type of overall development strategy that a country follows. For example, the first option noted above is likely to be adopted more easily in planned and mixed types of economies with a strong public sector. The second option is likely to be favoured more by market-oriented and liberal economies.

Whatever the policy options adopted, in the field of new technology development, most developing countries face a real dilemma. Since most of the new technologies are developed in the advanced countries,



developing countries do not have the wherewithal to develop efficiently all components of the technology hardware. The choice between local use versus local manufacture is not very simple since the development of national technology capabilities and local learning make some local production imperative for the developing countries. In the short run, the increased local use of new technologies may encourage the imports of new technology components from abroad which may in turn discourage local production and confine it to assembling and retailing. On the one hand, greater use may require liberalisation of imports whereas increased local manufacture may require protection from foreign competition. It is this dilemma which seems to explain the ambivalence in the past in the Indian policy towards computers and electronics.[16]

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# BLENDING OF NEW AND TRADITIONAL TECHNOLOGIES IN DEVELOPING COUNTRIES

## Concept, Potential and Limitations

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The theme "technology blending" refers to a special component of the applications of new technology to the Third World. In a national policy for technology choice and development in a developing country, three elements may broadly be observed, namely:

(i) preservation and improvement of traditional technologies through the introduction of more suitable technologies, quality control and marketing techniques;

(ii) selective use of newly emerging technologies in fields in which they are most suited; this would imply a decision about their import or domestic production; and

(iii) applying newly emerging technologies to traditional activities to promote modernisation.

We shall first consider the concept which is not free from some controversy.



## I. THE CONCEPT

This last aspect can refer to any blending of technologies of different vintages. In this sense, blending, or "retrofitting", as it has been called in the more technical literature, has always occurred in the historical experience with technical progress. Thus it is not a very new concept. But in the context of today's developing countries, the term "technology blending" is being used with a special focus and connotation given to it by the United Nations Advisory Committee on Science and Technology for Development (ACSTD), a few years ago.

Dr. Swaminathan, the first chairman of ACSTD, also a Fellow of the Third World Academy of Sciences, once stated: "Science and technology are important components of the wall dividing poverty and prosperity".[1] This statement provides the genesis of the concept of technology blending which can in fact be considered a reaction against concentration in the past of the benefits of science and technology among very small segments of society. Technology blending implies that the new technologies offer a rare opportunity to the Third World countries to improve the quality of life of the bulk of the rural and urban populations by reducing drudgery and raising incomes. Thus, blending should ideally meet three tests:

(i) traditional and conventional technologies are improved, not displaced;

(ii) a large majority of the rural and urban poor benefit; and

(iii)

the technological gaps between modern and traditional sectors in developing countries are reduced.

The concept of technology blending, like that of earlier concept of appropriate technology can be best defined in terms of some important characteristics. However, before we do this, it is useful to ask whether the concept is any different from that of intermediate or appropriate technology. We believe that these concepts are different - first, because technology blending as we have just defined, refers to radical innovations whereas intermediate technology was confined to only incremental innovations. But apart from this, there are other differences.

New technologies like microelectronics are being increasingly miniaturised and simplified in application and maintenance. These characteristics of flexibility are in contrast to those of large



scales of operation, complexity and rigidity by which most of the conventional technologies are characterised. One may argue that the characteristics of simplicity and miniaturisation are common elements between the concepts of intermediate technology and technology blending. While this is true, the fact remains that in contrast to the experience with intermediate or appropriate technology, the frontier technologies are being developed and applied at uncharacteristically rapid rates. They are also potentially capable of causing widespread and significant alterations in the prevailing social and economic landscape.[2]

The application of new technologies to traditional activities will typically involve capital costs far exceeding those envisaged by the proponents of intermediate or appropriate technology. Furthermore, while intermediate technology can in the foreseeable future be developed with local knowledge/technology/materials, with few exceptions, blending must rely on the importation of new technologies from advanced countries. Furthermore, the application of new technologies to traditional activities, say in rural areas, is also likely to raise the dependence of these areas on urban industrial networks in the same way as did the Green

Revolution. The HYV technology made the rural producers dependent on the urban industrial sector to purchase fertilisers, machinery and fuel and "to sort out, decode and evaluate the scientific and economic messages that reach them from bureaucracies, banks and experimental stations".[3] This factor is also likely to distinguish technology blending from intermediate technology. The latter is generally based on local self-reliance which tends to be eroded with the application of new technologies.

However, there is one sense in which a parallel may exist between the concepts of intermediate technology and technology blending. In a continuum of technological change, blending represents an intermediate stage between the conventional and the newly emerging technologies just as intermediate technology was conceived as a stage in between traditional and modern conventional innovations. Whether technology blending also represents a transitional stage, is however an open question which needs to be answered empirically.

We now consider some of the key characteristics of technology blending and examine scope of its diffusion in the Third World.



Characteristics

Technology blending may be characterised by the following features:

(1) Miniaturisation - The new technologies like microelectronics are highly miniaturised which is likely to make small-scale production more efficient. Promotion of a larger number of smaller and decentralised enterprises can be defended on the grounds that they prevent concentration of incomes and power in a few hands. One can argue that with the use of NC and CNC machines, the disadvantages of handicrafts production (e.g. low output, productivity and quality) can be overcome. CNC can for instance, ensure product quality in two ways. First, the technology can be programmed to diagnose faults in the control system and the machine. Secondly, often the new technology can remove the causes of defective production altogether.

(2) Resource augmentation - Application of new technologies to traditional activities should be resource-augmenting when applied to natural resources (e.g. land). For example, the case of satellite technologies shows how available water resources can be better matched with the timing

of rice culture decisions, e.g. in West Africa. Similarly, remote-sensing data make it possible to increase the supply of water through more appropriate sites for boreholes and wells. In the traditional economic literature too much emphasis on two-sector models using only capital and labour has neglected the role of natural resource augmentation which new technologies can facilitate.

(3) Systems dependence - New technologies like microelectronics are systems dependent, that is, like the Green Revolution, they are dependent on a wide range of complementary inputs and infrastructure. For example, for its effective utilisation, the new "micro" technology depends on a network of communications, and costly auxiliaries such as sensors, software, peripherals, etc. The application of this technology to traditional sectors may therefore require provision of these supporting facilities on a centralised basis.

(4) Participation - In the case of new technology applications by traditional small-scale producers, participation of these beneficiaries (especially in the case of "bio-revolution") would be essential to ensure positive attitudes



towards adoption of new technologies. Moreover, the local populations are likely to possess empirical knowledge of environmental conditions and the socioeconomic and cultural characteristics of the community in which new technology is to be adopted. Thus local participation may become particularly important in the case of technology blending.

## Dynamics of technology blending

The purpose of blending a new technology with the traditional one, as noted above, is to increase the latter's efficiency by transforming its character - raising its factor productivity, output, etc. Two situations may arise in principle. First, the new technique may be so dominant that it simply replaces (or completely transforms) the traditional technique. Such replacements might entail a biotechnologically-produced sweetener that affects the demand for sugarcane or the installation of a modern food-processing plant which substitutes for food preparation formerly performed in households or small enterprises. These are examples of what has been called "technological disintegration".[4] Sophisticated technologies can however be applied in ways that do not achieve technological disintegration. Indeed, much of the rationale for technology blending is based on supplying a more benign alternative to technological displacement. However, blending may not prevent some obsolescence of traditional technologies. While discussing Schumpeterian concept of "creative destruction", Strassmann maintained that qualitative changes resulting from new innovations seldom involve more than the partial destruction of an older industry.[5] Historical experience shows that the process of replacement of old technologies is quite slow.

In most circumstances initial versions of technical innovations undergo a series of modifications which add to productivity; expand the number of applications; and accommodate local inputs, markets and environmental conditions. In addition to adjusting to existing conditions in traditional sectors, newly infused technologies should be sufficiently technologically malleable to respond to changing product demands, to the appearance of new complementary technologies, or to alterations in the availability of inputs.

The degree of technology blending can change with time as the proportions of traditional and new components are altered. Indeed, if we consider an entire traditional sector composed of a variety of economic activities, several trajectories can be envisaged. The first may be "straightforward modernisation" whereby more and more activities are completely replaced by the most advanced technology. The second may be the use of technological blends that employ larger proportions of emerging technologies as the technological frontier progresses and the absorption capacity of traditional sector grows. An additional possibility is that new technologies may be adapted (made more miniaturised, rugged, easier to maintain and less complicated, etc.) to be more compatible with conditions in traditional sectors. In the real world, these three adjustments will take place concurrently as individual sub-sectors follow different technological paths.

## Technology diffusion

One would need to examine the determinants, both supply and demand, of the diffusion of "blended technology" in the developing countries. On the demand side, arguments noted above would suggest that severe competition among producers and falling prices should favour the process of diffusion. But in addition to price factor, incomes of small producers in traditional sectors also determine their access to new technologies. If the cash outlays required for access to these technologies are large relative to scarce resources of the potential end users, the innovation is unlikely to be adopted (unless it is subsidised). In many developing countries, the relatively low wage costs may make the new technologies uneconomical at the prevailing factor prices. For example, it has been noted that the decline in the wages of draughtsmen (which were artificially high earlier on) made the use of computer-aided design (CAD) by the firms unjustifiable on the basis of labour cost savings alone.[6]

On the supply side, the process of diffusion is likely to hinge on the existence of supporting infrastructure, requisite skills, capabilities in design and engineering and information about new technologies.

Diffusion and acceptability of new technologies and products also has to do with factors of risk and uncertainty. Rapid technological change involves accelerated obsolescence and an expectation of rapidly declining costs and prices. All this may tend to postpone the decisions by entrepreneurs to adopt new technologies now under conditions of uncertainty and unfamiliarity. To quote Rosenberg, "practical businessmen tend to remember what social scientists often forget: that the very rapidity of the overall pace of technological improvement may make a postponed adoption decision privately (and perhaps even socially) optimal".[7]

Thus far, empirical information on the adoption rates for new technologies (especially microelectronics-based ones which are diffusing more rapidly) in the Third World is extremely hard to find. This is even more so in the case of their applications to traditional activities. In preparing a volume on "Blending of new and traditional technologies" (Dublin, Tycooly, 1984) we sent a questionnaire to over 250 individuals and organisations in the Third World countries. Although the response rate was not too low, most of the information that we received related to traditional and appropriate technologies, involving no use of new frontier technologies. It is also important to note that data on the diffusion of "high" technology microelectronics innovations in the agricultural sector are hard to find even for the advanced countries not to speak of the developing countries where the agricultural sectors are far more significant and account for the bulk of traditional economic activities. Also diffusion pattern across sectors is quite uneven. Therefore, generalisations become extremely difficult if not impossible.

In a recent study for the ILO on microelectronics, Raphael Kaplinsky shows that in the sphere of telecommunications alone, the rates of adoption in the developing cuntries seem to be as rapid as those in the advanced countries. He attributes this unusual situation to three factors.[8] First, telecommunications are generally backward in the developing countries which means that they do not have to scrap much of the old infrastructure. Second, a sudden appearance of electronics technology has reduced costs of installations particularly in rural areas (microwave and satellite technology is much cheaper than the older cabling system). Third, the use of this new electronics technology is not skill-intensive, maintenance is also cheaper than that of the older electro-mechanical systems.

Thus, Kaplinsky concludes:

"... it is difficult to conclude, outside of six first tier NICs (Brazil, Hong Kong, the Republic of Korea, Mexico, Singapore, and Taiwan, China) that the developing countries have moved quickly to take advantage of the potential offered by the introduction of the new technology."[9]

We believe that blending cases need to be promoted in future, on a selective basis. Even if a blending case is not very feasible <u>initially</u> (on the basis of simple cost-benefit criteria) it may still be desirable to pursue it because:

(1) the learning-by-doing in the process of operation of the blended technology will more than compensate for the initial costs;

(2) social resistance will break down over time due to better knowledge and understanding through continuous experimentation;

(3) the degree of risk will be lower after the technology has been demonstrated to function effectively.

## II. <u>SOME EMPIRICAL EVIDENCE</u>[10]

In our present state of knowledge, empirical data on the LDC experience with new technology applications is generally hard to find.

Nevertheless, there are some examples from the ILO work to date which I would like to describe very briefly.

## 1. Small-scale use of microelectronics

In the manufacturing sector, there is some indication that small enterprises in Brazil, Hong Kong, Singapore, etc. are beginning to use NC, CNC and CAD/CAM with a view to improve quality, precision and productivity. In the case of Brazil, in the mechanical industry in the State of Sao Paulo, 19 firms adopted these technologies. Their experience suggests that there was no net employment loss, since additional demand for labour resulted from work reorganisation and training.

The case of Hong Kong textile and garment industries using CAD/CAM is a little more peculiar, since in this area, scarcity of land makes it easier to have separate factories rather than big ones. Furthermore, competition for the export of garments in the international market further imposes the use of new technology.

The experience of Singapore in the use of robots and CNC machines shows that motivating factors were



the high wage costs and scarcity of spray painters. Furthermore, government's policy for rapid productivity growth through automation, has also encouraged the use of new technologies.

A second example of small-scale use of microelectronics is that of the electronic load controller - a sophisticated electronic device which reduces the feasible scale of hydroelectric power generation. Relatively small streams can now be used as sources of power for dispersed locations. These controllers are being used in villages in Colombia for powering saw mill operations, in Sri Lanka for drying of tea, and in Thailand as general power source for lighting villages. Thailand has started local assembly and further R & D on technology.

The use of microelectronics can be in both production proper and in managerial and accounting functions. Although there is no clearcut empirical evidence we believe that in most developing countries more effective use of this new technology would be in management and accounting for two reasons. First, computer applications in management are likely to be less labour-displacing. Secondly, applications in management may require fewer skills than those in direct production which involves handling of hardware.

One interesting feature of the above examples is that invariably the firms adopting high technology are subsidiaries of multinational enterprises producing either for local markets or for exports. This is to be expected since foreign firms have a comparative advantage in respect of sources of information and access to advanced technology.

The real test of benefits of new technology diffusion would be seen in the domestic firms using the technology to their advantage. The experience of load-controllers suggests that they are used primarily by local users.

The effective utilisation of the new technology by small production units is likely to be enhanced if the producers are organised in the cluster-type workshops or co-operative production modes. This indeed has been the experience of the Prato textile industry near Florence in Italy.

## 2. Laser technology use in Egypt and Saudi Arabia

Experimental trials on the use of lasers for levelling of land as against conventional levelling have been done in Saudi Arabia and Egypt which show that laser levelling has several advantages. It



ensures a higher degree of precision, is 50 per cent cheaper than conventional levelling, and requires less skilled labour. Conventional methods of levelling require high skilled operators to achieve the precision required. Another benefit of the new technology is in the saving of water use and thus reduction of variable costs incurred (e.g. cost of pumping ground water including energy costs, repair and maintenance and irrigation labour).

The disadvantage on which data could not be obtained would be in terms of possible loss of employment in making a switch to new technology. Laser levelling would displace labour used in plenty in conventional manual methods of land levelling.

## 3. Telecommunications for rural development

The new telecommunications technology - satellites, small earth stations, portable telephones, mobile radios, teletext and videotex - are all important for contributing to rural development of the Third World. Of course, one may wonder why the new technology, which is much more costly, should be appropriate for poor developing countries? One answer to this question is that the new technology enables leapfrogging and the modular systems of the new microelectronics-based innovations enable a gradual building of a network from a range of basic modules.

Applications of new telecommunications technology can be wide ranging. For example, in agriculture satellites used for provision of meteorological data, weather forecasts and disaster warnings, data on cropping patterns and agricultural innovations. This is shown in Table 1. In India, satellites are used for broadcasting to rural areas. Similarly, new technology can be used for improving rural education through tele-conferencing systems. In the health sector, in the South Pacific experimental satellite network has been used to summon medical teams to fight cholera and to coordinate emergency assistance after typhoons.



Table 1

Applications of telecommunications

| Sector/Applications | Examples |
| --- | --- |
| 1. Agriculture and rural development | |
| Provision of meteorological data, weather forecasts, warnings about disasters; data on cropping patterns and agricultural innovations; rural producers can schedule market deliveries to cut spoilage and gain higher market prices. | In the Cook Islands, agricultural officers use a two-way radio network to tell the shipping agents how much fresh fruit is ready to be picked up from each island. Use of satellite in India for broadcasting to rural areas Use of telephones in Sri Lanka by small farmers to obtain crop prices from Colombo. It is estimated that now they can get 80 to 90% (rather than 50 to 60% as before) of the Colombo price for their products. |
| 2. Education | |
| Distance teaching through satellites, computer-based conferencing systems; quality and diversity of rural education can be improved by offering courses previously available only in the urban areas. | Use by the University of South Pacific (Fiji) of ATS-1 satellite for teleconferencing (network has terminals in all South Pacific countries and operates for an average of 23 hours per week, and has receiving and transmitting facilities as well as audio-cassette recorders for taping educational programmes); use of satellites for distance learning in the Caribbean (seven countries are at present participating with headquarters of the network at the University of West Indies in Jamaica). |

3. Health

| | |
|---|---|
| Use of two-way radios and telephones for monitoring delivery of drugs, supply of advice and diagnoses of health problems and ailments, and in general sharing urban facilities with rural areas. | South Pacific uses the experimental PEACESAT satellite network to summon medical teams to fight cholera and to co-ordinate emergency assistance after typhoons; in Guyana, rural health workers "medex", communicate with Georgetown through two-way radio to obtain medicines. |

4. Manufacturing industry

| | |
|---|---|
| Use of telecommunications for reduction of inventory costs, transport costs, and savings in management time, and for attracting industries to rural areas and smaller towns. | In Kenya, benefits for several enterprises through improved communications far outweighed the costs. |

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Sources: Based on data contained in ITU: The missing link - Report of the Independent Commission for Worldwide Telecommunications Development, Geneva, 1984; and W. Pierce and N. Jéquier: "Telecommunications for development, ITU, Geneva, 1983, and H.E. Hudson: Telecommunications for rural development", in Development, (CIDA, Ottawa), Spring-Summer, 1986.



## 4. Use of photovoltaics for rural development

As a power source photovoltaics is quite useful for remote rural areas where extension of the supply grids to transmit electricity is generally high. Applications can range from water pumping to village water supply, household and street lighting, supplying power for refrigerators for rural health clinics, for rural telecommunications, power supply for rural radio and television sets, etc.

Let us take the case of PV-powered pump irrigation, for which a comparative cost-analysis with alternative power sources has been undertaken in Northern India. Comparative evaluation covered costs (capital and operating) of irrigating one hectare and 0.4 hectare land, through grid electricity, diesel, biogas/diesel, producer gas and diesel, solar thermal, PV systems and windmills. Three cropping patterns were considered. Table 2 shows that at 1983 costs, and for the user conditions considered, PV water pumping compared favourably with windmills and solar thermal systems for all the three cropping patterns. With an anticipated increase in the efficiency and decline in costs of solar cells, PV water pumping would become the most economical.

Table II

Present Values of Sum of Capital and Operating Costs of Alternative Technologies for Irrigation Pumping in Ghazipur (in 1983 $)*

| Technologies | | Farm size: 1 ha Head: 5 m Crop rotation I | II | III | Farm size: 0.4 ha Head: 5 m Crop rotation I | II | III |
|---|---|---|---|---|---|---|---|
| Electricity | | 2,130 | 1,570 | 2,250 | 1,550 | 1,500 | 1,600 |
| Diesel oil | | 1,830 | 1,330 | 2,260 | 1,280 | 1,080 | 1,450 |
| Biogas + diesel | | 1,810 | 1,500 | 1,920 | 1,480 | 1,420 | 1,530 |
| Producer gas + diesel | | 2,310 | 2,070 | 2,530 | 2,040 | 1,940 | 2,120 |
| Solar photovoltaics | (A) | 5,000 | 5,000 | 14,050 | 2,110 | 2,110 | 5,730 |
| | (B) | 3,740 | 3,740 | 10,430 | 1,610 | 1,610 | 4,280 |
| | (C) | 2,030 | 2,030 | 5,490 | 920 | 920 | 2,310 |
| | (D) | 1,550 | 1,550 | 4,100 | 730 | 930 | 1,750 |
| Solar thermal | (E) | 5,820 | 5,380 | 16,230 | 2,550 | 2,360 | 6,690 |
| | (F) | 3,030 | 2,790 | 8,230 | 1,450 | 1,350 | 3,520 |
| Windmills | (G) | 4,960 | 5,420 | 10,840 | 1,980 | 2,170 | 4,340 |
| | (H) | 6,060 | 6,620 | 13,260 | 2,420 | 2,650 | 5,300 |



* The figures in this table have been rounded up the nearest ten for easy comparison. Rows (A) through (H) include different assumptions as noted below.

(A): Current costs ($11.75/Wp); current efficiencies (3.4 per cent overall instantaneous).
(B): Current costs ($11.75/Wp); future efficiencies (4.6 per cent overall instantaneous).
(C): Future costs ($4.5/Wp); current efficiencies (3.4 per cent overall instantaneous).
(D): Future costs ($4.5/Wp); future efficiencies (4.6 per cent overall instantaneous).
(E): $\$286/m^2$ for the whole system and 0.5 per cent daily average efficiency.
(F): $\$286/m^2$ for the whole system and 1.0 per cent daily average efficiency.
(G): Appropriate technology (Ghazipur-Allahabad multivane type with a piston pump).
(H): Hybrid technology (NAL sail type with a centrifugal pump).

Source: R. Bhatia, "Energy alternatives for irrigation pumping: an economic analysis for Northern India", in R. Bhatia and A. Pereira (eds.), Socioeconomic aspects of renewable energy technologies, (Praeger on behalf of the ILO, forthcoming).

In the case of photovoltaic lighting, we may give the example of rural Fiji where PV lighting kits provide 4.5 hours of lighting per night in areas averaging six hours of bright sunshine per day. Comparison with provision of light through a diesel generator showed that the photovoltaic system was technically and financially viable. A preliminary survey also found that the consumers liked PV-lighting.

In general, the effectiveness of the PV-technology will depend on how rapidly the costs go down. At the current costs, three groups of applications may be noted. The first group where PV-technology is viable even at current costs and present conditions, that is, low power applications, e.g. lighting, powering of radio, TV sets and refrigerators for rural health clinics. The second group refers to those low-power applications where alternatives to PV systems seem, at present prices, to be more cost effective, e.g. water pumping and grain milling. PV technology here is <u>generally</u> viable only when other alternatives are not available at particular remote locations. The third group of applications refers to requirements of high power e.g. daily energy requirements of about 25kW per hour, for which PV technology is uneconomic. For



these applications, efficiency will have to increase and costs decline enormously to make PV technology cost effective.

## III. <u>LIMITATIONS IN NEW TECHNOLOGIES APPLICATIONS TO TRADITIONAL SECTORS</u>

As we have noticed, the diffusion of new technologies to the Third World in general is at present isolated and limited. Also in the past, the government authorities have made very little effort to explore scope for <u>selective</u> applications in traditional sectors. A number of factors seem to hinder greater technology diffusion and applications. First, blending of new and traditional technologies is difficult because the knowledge in the Third World about the traditional sectors and technologies (which have been in existence for centuries) is very poor. Furthermore, knowledge about which of these technologies lend themselves easily to technical improvements and which do not, is also very limited. In some cases, there may be a real danger that the applications of new technologies will displace local modes of production and techniques which may not be socially desirable for the developing countries.

Secondly, one of the characteristics of the use of new technologies in the advanced countries is the product quality improvements it makes possible. Of course, better-quality products (especially if they are also more durable) are also useful for the poor in the Third World countries. However, it is not as simple as that. For one thing, the consumer preferences of the poor may be such that they do not opt for "high-income characteristics" of the products which are more appropriate for the advanced countries. Even if they did, with low purchasing power, they may have no access to these products. A study of technology choice in the textile industry of Ivory Coast concluded that to a large extent, the choice of technology was determined by international standards for a given product, e.g. denim and polyester shirts, but lower standard was acceptable in the cases of locally traded goods.[11]

Thirdly, in spite of the isolated case studies done to date, it is not very clear whether the high total capital costs (notwithstanding their capital-saving nature) would not limit their diffusion to small-sized firms in developing countries. The utilisation of new technology in small farms and firms may involve cash outlays which are too large for these producers to afford. To some



extent this demand constraint can be overcome through government intervention (in areas where new technologies are deemed to be profitable) via subsidies.

Fourthly, at prevailing relative factor prices in developing countries (with few exceptions like Singapore and the Republic of Korea, where wages are rapidly rising), the new technology applications may not be a more economical alternative to the existing conventional technologies. Nevertheless, blending enables not only a wider choice among alternatives but also it leads to new activities, products and end uses. In this latter sense, the use of microelectronics, for example, in health and education sectors could improve the delivery of services at lower costs. But at present, diffusion of new technologies in these sectors is extremely limited.

Fifthly, some of the new technology applications may be both labour-saving and employment-destroying if the compensatory indirect employment generation was negligible. This may be the case of laser use in levelling of land and other construction which generally tends to be labour-intensive in the developing countries. This is a social cost which needs to be offset against benefits in terms of higher productivity, quality, etc.

Finally, the potential benefits and possible harmful effects of new technologies are not generally known or understood by the policy makers or producers in developing countries.

## IV. SOME LESSONS AND CONCLUSIONS

The existing literature on the experience of new technology applications in LDCs is quite thin, and is concentrated mainly on a few NICs in East Asia and Latin America. Even the experience that is available does not give a clear indication of the economic and social feasibility of using new technologies in given country situations. Among other things, economic feasibility and cost effectiveness of new technologies in traditional settings would depend on the costs of acquiring, utilising and maintaining new technologies. The case studies done so far are not very conclusive about their cost effectiveness. Experiences available represent a heterogeneous array of activities at different stages of development and utilisation.



Table 3
Socioeconomic assessments

| Variables / Technology | Economic | Social | Political | Other |
|---|---|---|---|---|
| 1. Microelectronics<br>2. New biotechnologies<br>3. New materials<br>4. New energy technologies | Scale, product, skills, capital, energy and other inputs | Employment, behaviour modes, work organisation, length of working hours, occupational safety, etc. | Income-distributional implications | Consumer acceptance, risk factor, infrastructure requirements, etc. |

Ideally, socioeconomic assessments should be undertaken, whenever feasible, of new technologies as applied to traditional sectors, compared to any available alternatives. These assessments could as a minimum, be undertaken in the light of economic, social, political and cultural variables, as indicated in Table 3.

Of course, comparative assessments of new and conventional technologies may not always be possible. These assessments would be relevant only where alternative options are comparable, e.g. in the cases of PV-power generation and laser land-levelling. When high technology is applied to new end uses, organisational, institutional and political factors may be more important than the purely economic ones, but knowledge about the costs of introducing them, and potential benefits that they may bring about, would still be very important for the Third World.

This is a field in which the Centre, and the Third World Academy of Sciences may have a catalytic role to play. Assessments as well as documentation of experiences in new technology applications to traditional activities could be sponsored by these two institutions. The results could be disseminated



through the Third World Science Journal which the Academy intends to establish. Sensitisation of policy makers to the potentials and pitfalls of new technologies, and alerting them about possible future developments, are equally important. Although some beginning has been made by the UN in New York here (in the ATAS Bulletin and Network) a lot more needs to be done. The Academy could also encourage existing Third World regional groupings, e.g. ASEAN and SAARC in Asia, and Andean Pact in Latin America, for example, to document actual experiences on the application of new technologies.

Another lesson that we can draw from limited experience of new technology applications is the importance of government intervention. Government can play a role in at least four areas. First, a state may either acquire the new technology and make it available to users on a shared basis, or take the lead in encouraging other arrangements, e.g. co-operatives and sub-contracting which would help overcome risks involved in new unknown technology.

Secondly, governments could promote appropriate training programmes. Thirdly, governments can promote research, development and experimental trials which are necessary to adopt new technologies to local requirements in the developing countries.

The most important role for the government is to provide an appropriate policy framework within which some technology blending projects could also flourish within the private sector. To take a specific example of India, photovoltaic applications to irrigation are unlikely to take place unless existing policies are changed. The prices for energy sources like electricity and diesel oil are administered by the government. Provision of electricity is subsidised. So is the investment in biogas plants. But this is not true of investments in photovoltaic pumping sets and windmills.

There may thus be a case for temporary protection of some applications that are <u>socially</u> desirable.

The governments also have a role in providing the infrastructure required. As we noted earlier, the new technologies are quite systems dependent and infrastructure-intensive. Collective or centralised provision of infrastructure and other services might be necessary even for promoting decentralised small-scale production.

Now, regarding the distributional implications of applying new technologies in the traditional sectors, they can be double-edged. In principle, these



applications should spread the benefits more widely among different socioeconomic groups. For example, take the case of PV technology - it can reach remote rural areas without requiring large infrastructure and distrubution systems. In the case of PV applications to rural irrigation, they can easily reach small and marginal farmers thus enabling a reduction in rural-urban income inequalities.

In practice, however, whether the benefits of PV technology are shared by a large number of people will depend very much on the existence of appropriate institutions and government policies to ensure that monopolistic control of the new technology by the rich does not occur. The actual experience of PV street lighting in the villages of Uttar Pradesh in North India warns against the dangers of aggravated inequity resulting from new technology applications. It has been noted that the use of new technology was controlled by the village headman and the richer groups in the village. This control of the new technology by the rich is reminiscent of the Green Revolution experience which generally benefited the larger farmers than the small farmers.

In the final analysis, political commitment at the highest level, to support the use of new technology mainly for poverty alleviation and fulfilment of basic needs would be essential. Without this, the new technology applications may make the rich richer and keep the poor in perpetual poverty.

To conclude the potential of new technologies for broad-based socioeconomic development in the Third World is as yet poorly explored. Greater research efforts and dissemination of research results are therefore needed.

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HISTORY OF GEOMAGNETIC OBSERVATION
IN THE WORLD

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It has been noticed since the 18th century that a magnet hung by a thread shows a slight deflection regularly or irregularly during the course of a day. Professor Celsius (known for his temperature scale) and his student Hiorter, in Stockholm, first noticed a sudden deflection of magnetic direction simultaneously with the appearance of a bright aurora.

The continuous observation of the geomagnetic field variation started at several places in Europe, America and India, in the middle of the 19th century, soon after the method for photographic registration was invented.

In the later half of the 19th century, a number of European countries were engaged in the expedition to the arctic region. In 1875 Carl Weyprebt (Austrian lieutenant; he himself had an experience for the arctic expedition) proposed that the priority for future arctic expeditions must be given to the coordinated observation of geophysical phenomena at a number of stations simultaneously by expedition teams from various countries, in order to contribute to our knowledge of natural phenomena, rather than competing for new geographical findings. His idea was widely accepted by the academies of various countries, and after negotiations among the countries in Europe, it was finally agreed to designate the interval from August 1882 to August 1883 as the "International Polar Year" for the period of concentrated observations by expedition teams in the arctic area. This was the beginning of the international cooperation in geophysics. The observation items at that time were only "Meteorology, Geomagnetism and Aurora". It was agreed at that time that a similar large-scale international cooperation be repeated after 50 years.

From August 1932 to August 1933, the Second International Polar Year observations were carried out with more stations (see Table 1) and the additional observation item of the ionosphere and/or radiowave propagation (because the ionosphere was experimentally found in 1925). The world financial crisis came just during the preparation period for the Second International Polar Year, due to which almost all countries had to cut



down some part their original plans of expeditions and/or intensified observations within their territories.

A World Magnetic Archive was established in the Meteorological Institute in Copenhagen during the Second International Polar Year, to which all the copies of magnetogrammes were sent from individual magnetic observatories all over the world. This was the pioneering action for world data utilization, which is now being done with the aid of World Data Centres for geophysical data. In Japan, in 1951, we bought a complete set of microfilms from this Archive and I could enjoy the analysis of magnetogrammes taken at several tens of stations to study the morphology of geomagnetic field variations over the world.

World War II was, of course, a great disaster also for geophysical observations. A great number of observations were destroyed, and the recommissioning was difficult even several years after the end of the war.

April 5, 1950, is a memorial day for the world geophysical community, because the idea of an International Geophysical Year was borne on this day. It was in the home of Professor J.A. Van Allen (who discovered later the famous radiation belt encircling the earth) in the suburb of Washington, D.C., when he invited some leading geophysicists (including Sydney Chapman from the United Kingdom, who worked later as the President of CSAGI, which was responsible for promoting IGY enterprise) to a dinner at his home. On that evening, Dr. Lloyd V. Berkner (one of the pioneers in ionospheric research; he became later the President of the International Council of Scientific Unions) proposed to hold the Third International Polar Year during 1957-58, i.e. 25 years after the Second I.P.Y. of 1932-33, without waiting until 1982-83. His idea was supported by all the guests, and his proposal was soon conveyed to ICSU after receiving support from all relevant Scientific Unions such as IUGG (Geodesy and Geophysics), URSI (Radio Science), IAU (Astronomy) and IUPAP (Pure and Applied Physics). In the meantime, the proposal was further expanded to include new observation items (not only those for the study of the earth's atmosphere and the environmental space but also those for the earth's interior and the hydrosphere) and to recommend worldwide intensified observations without restricting emphasis on the polar region only, and a new name "International Geophysical Year" (abbreviated to IGY) was introduced to replace the "Third Polar Year".

IGY was really a new era for international geophysical cooperation. It contributed to establishing not only a world network of geophysical observations regardless of nationality, ideology or race, but also the data accumulation and exchange for wide utilization by the world community of scientists. The success of IGY is the background for today's advanced study of various projects in geophysics, including space research.

In 1980 ICSU (International Council of Scientific Unions) adopted a resolution at its General Assembly, which recommended all member countries to celebrate in 1982-83 the anniversaries for international geophysical cooperation (100 years from the First International Polar Year, 50 years after the Second International Polar Year, and 25 years since the International Geophysical Year) in their own countries in their own way.

In Japan a ceremony was held on 15 March, 1983, at the Science Council of Japan, to celebrate the 100$^{th}$ year since the start of geomagnetic variation observation in Japan. On the occasion of this ceremony a commemorative medal was issued, and the golden medals were presented to those senior people who worked for the Second Polar Year observations, whereas the silver ones to the leaders of IGY observations. The Japanese community of geophysists wishes to present these medals also to the magnetic observations in various countries which participated in the Polar Years and IGY. Whenever I had the chance to visit these observatories (or their parent institutions), I presented the medals to them in order to appreciate their contributions to the development of geomagnetism through their long-term observations.

In this Spring College on Geomagnetism and Aeronomy we have a number of participants from magnetic observatories (or institutions responsible for magnetic observations in their countries). On this occasion I would like to request them to receive the medals (golden ones for the Second Polar Year observatories, and silver ones to IGY observatories) and take them back to their observatories with the appreciation to them from the Japanese community of geomagnetists. I am personally especially grateful to the Second Polar Year observatories because I was able to write my D.Sc Thesis in 1953 through the analysis of their data to study the world morphology of magnetic storms.



TABLE 1

| | First International Polar Year | Second International Polar Year | International Geophysical Year |
|---|---|---|---|
| Designated Period | August 1882 - August 1883 | August 1932 - August 1933 | July 1957 - December 1958 |
| Number of Participating Countries | 11 | 44 | 66 |
| Number of stations for observations | 12 in arctic region<br>30 in middle-low latitudes cooperative stations | 100 over the world | ~ 4.000 stations for all disciplines of observations |
| Observation Items | Meteorology<br>Geomagnetism<br>Aurora | Meteorology<br>Geomagnetism<br>Aurora<br>Ionosphere | Meteorology<br>Geomagnetism<br>Aurora and Airglow<br>Ionosphere<br>Solar Activity<br>Cosmic Rays<br>Nuclear Radiation<br>Oceanography<br>Glaciology<br>Latitudes and Longitudes<br>Seismology<br>Gravity<br>Rockets and Satellites |

# The participation of developing countries in space research

**Juan G. Roederer**

**The Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82) identified crucial problems and made recommendations on strategies for developing countries to bridge the gap with advanced nations in the area of space technology. This article addresses some issues which, although implicit in the UNISPACE Report, are not discussed in detail therein. The role of space science and related scientific research is particularly emphasized. Close attention is paid to the role of human factors, such as the motivation to conduct research, the motivation to engage in international cooperation, and the motivation to utilize and exploit space. Possible opportunities for space research for developing countries, as well as relevant issues concerning management of space, are briefly discussed.**

*Keywords:* space research; space technology; Third World

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The Second (1982) UN Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82) identified crucial problems and made recommendations on strategies for developing countries to bridge the gap with advanced countries in the area of space technology. In this article some general aspects of particular relevance will be addressed which, although implicit in the UNISPACE Report,[1] are not discussed exhaustively therein. Space science, space technology and space applications will be treated as inseparable components of one and the same endeavour. Close attention will be paid to the 'boundary conditions' within which the development of space research and applications is to take place, both in advanced nations and in the developing countries – especially the human factors.

For the purpose of this article, let us define the concept of 'space' as that portion of our outer environment, above the aerodynamically navigable atmosphere, which can be directly and *in situ* probed and measured by humans or human-made devices. Note that we do not consider meteorology and astronomy as pertaining to space research, although they are now being studied from space; on the other hand, important aspects of what we have defined as 'space' can also be studied from ground and from earth-bound platforms such as aircraft and balloons.

The use of space and space technology is becoming routine. Yet space retains some distinguishing features that must be taken into account in the development of policies for the management of space.

First, near-earth space does not recognize national boundaries, nor can national boundaries be meaningfully defined in space (although some equatorial countries consider the geostationary orbit a *sui generis* region that should fall outside the regulations of outer space).

Second, in all countries, the ultimate beneficiaries of space applications are people unfamiliar with space technology *per se*; so are most of the decision makers in government who set the policies and appropriate the necessary funds. This puts the intermediaries between decision makers and beneficiaries – the space experts – in a special position: they must develop the user market.

Third, space exerts a degree of fascination on the lay person, stimulating instincts that developed in the distant past of human

[1]Report of the Second UN Conference on the Exploration and Peaceful Uses of Outer Space, UN Doc A/CONF 101/10, August 1982.



evolution, relating to territorial conquest and the mystique of the universe. This degree of fascination can be, and has been, an important motivator in the development of space science and technology, but it also has, on occasion, led to precipitous and unbalanced commitments.

Fourth, long before the space age began, military uses of space were a crucial driving force in the development of space hardware and space systems and many research endeavours were promoted mainly because of their military relevance.

## Basic space research and research policies

Why does a country want to carry out space research? Can a country afford to undertake space research? The answer depends very much on the particular group of people to which these questions are addressed. The existence of quite distinct classes of participants is important to take into account in the development of space policies.[2]

*Pure scientists* carry out space research mainly in response to an innate drive to explore and expand human knowledge. As a result of the process of human evolution regulated by the ability to control, predict and exploit the environment, deeply seated in our brain are genetically preprogrammed instructions to explore, to search and to predict – a behavioural instinct that goes far beyond simple animal curiosity. This drive comes out in its purest form in the pursuit of basic science, and 'pure' space research is now one of its clearest manifestations.

*Socially responsible scientists* have the necessary vision to realize how space research can lead to a better understanding of the environment and how space research can impact on the future of society through the stimulation of technological development based on scientific demands. Most importantly, these scientists will clearly comprehend the role that space research can play as an advanced training ground for higher education in science and technology.

*Political-activist scientists* realize the high degree of fascination that space research can exert on the lay public, a fascination that can be exploited politically or ideologically. They realize that advanced space research places a nation in a position of advantage that goes far beyond mere scientific results and scientific knowledge acquired in such research.

*Applied scientists and engineers* consider space research as an essential element for the development of communications and defence systems, and for the development of space platforms for such uses as in meteorology, geology, oceanography, astronomy, zero-g biology and metallurgy, and solar energy conversion.

*Politicians* view space research in relation to the development and consolidation of their own power base. This necessarily pushes them towards giving almost exclusive consideration to the short-term benefits of space research, especially in the areas of technological applications such as remote sensing, communications and defence. This group usually has little understanding and patience for basic space research.

Three establishments intervene in any major national research enterprise: the political, the technological and the scientific. A national space research policy is a country's scheme to allow these three components to interact with each other concerning the management of space research, with a maximum benefit to the achievement of their own, often quite disjunct, goals. Space research policies vary from

[2]J. G. Roederer, 'Space research policies in advanced and developing countries', in *Advances in Space Research*, Vol 2, Pergamon Press, Oxford, 1983.

country to country and from political system to political system, but there is one invariant, central feature common to all: the question of funding. Indeed, space research is expensive, space research cannot be carried out in small pieces in isolation, and space research does not render quick benefits.

The most advanced nations cope with this by long-term infusions of financial support through space agencies and/or by setting up joint programmes through appropriate multinational agencies. In this context it is relevant to note that in advanced countries basic research is carried out in relative detachment from economic, social and political issues. Scientific knowledge and scientific discoveries are considered to be the seeds, the catalysts, upon which applied research and technology are being built – usually by a different community. In this process, a natural equilibrium is established between scientific activity and technological needs, in which scientific research is guided or influenced by the complex and relatively long-time-scale process of governmental funding. Research topics are chosen according to what we may broadly call their 'relevance', as the result of setting certain priorities at the national level. A national space research policy defines such priorities, hence defines the relevance *per se* of different space research topics.

In developing countries the situation is far more complex. Several factors may represent 'boundary conditions' into which space research (and other scientific research) policies must fit. For instance, one factor may be the existence of natural resources of vital importance to the advanced nations, a fact which creates commercial interests and dependencies, related economic and political tensions, and an adverse climate for the local development of research and higher education. Another factor may be an exploding population, increasing the local basic subsistence demands for food, shelter, energy, transportation and related technologies that have little chance to benefit from space research on a short-term basis. A third factor could be big socio-economic changes with related instabilities that have an impact on research and, particularly, higher education. A fourth is the existence of a widening technological gap with the advanced nations.

For many decades it was believed that the potentialities of modern science offer the only way to shorten the time it takes to bridge the gap between the economically and socially underdeveloped countries and the advanced nations. Yet it is clear that this gap has continued to widen with stubborn persistence, due to the fact that science and technology for economic development cannot be bought in the market and imported; they need to be developed locally through a long and painful process. During its first incipient phase, scientific research in a developing country should have as its principal and perhaps only goal that of allowing the participating nuclei of scientists to achieve a 'critical mass'. Here we define critical mass as the set of minimum conditions necessary to allow a research group to remain relatively stable and active during short-term economic and political changes, upheavals or interferences. In the achievement of a critical mass, what counts is not the particular choice of research topics, but the fact that research is being done, the fact that the group of scientists in question has information of, and interacts with, research groups in other countries, and the fact that the research group is transferring scientific knowledge to others in its own country. Space research is one appropriate venue for certain research groups to achieve a critical mass – regardless of the





question of whether that research will lead to immediate applications of specific interest to the country in question.

Turning to applied research, in the most advanced industrialized countries the goals of applied research are directly linked to the economic interests of particular enterprises, private or governmental, and applied research plans are subordinated to those objectives. In such countries large-scale technological research is done mainly in industrial or governmental laboratories. In developing countries the situation is different. In the first place, industry is often in the hands of foreign firms which normally do not have the necessary incentive to develop local technologies. Local companies, on the other hand, usually do not have enough resources to invest in applied research. This is the reason why in regard to technological research in less developed countries, the universities must play a central role, a role almost without counterpart for the universities in advanced countries. Space research is one appropriate venue to train people in ways to find solutions to specific technological problems.

Finally, another incentive to organize indigenous space research programmes in developing countries is related to what the late space scientist Dr Vikram Sarabhai forcefully called for at the First (1968) United Nations Conference on the Exploration and Peaceful Uses of Outer Space: to turn into an asset the disadvantage of having little base to build on. That is, to identify those problems in space research to which a given developing country can make unique contributions because of its geographical location, because of some specific locally developed expertise or because of special links to some advanced country.

## Opportunities for space research

Let us be more specific by suggesting a few examples of research that could be particularly relevant for developing countries.

There is a solid tradition of biological and medical research in many developing countries. Through bilateral or multilateral programmes with countries which conduct manned spaceflight programmes, biomedical research – for instance on the integration of human and animal sensory functions in micro and macro gravity – could be carried out, as well as a myriad of other studies on animals and plants in which the effects of gravity and near-absolute vacuum are principal targets. The US Space Shuttle and the Soviet Intercosmos missions offer opportunities for direct involvement in such space experiments.

Research on digital remote sensing image-processing, pattern recognition and interpretation is still at a very early stage of study and needs increased participation of experts in artificial intelligence, information theory and neuropsychology – the latter to help shift the human–machine interface towards the machine. This interdisciplinary mix can be found in many developing countries, where the results of such research applied locally to remote sensing would render immediate benefits in the effort to provide the immense primary basic information needed on land cover and land use, hydrology, geology and natural resources.

Improvement of remote sensing techniques depends on extensive ground-truth experiments, calibration measurements and transfer function determinations. Such experiments are labour-intensive and could be organized on a massive scale through cooperative efforts in many developing countries. This would also apply to research in meteorology and large-scale atmospheric modelling. Joint programmes with large computer centres in advanced countries could put the necessary computer hardware at the disposal of such studies.

Several developing countries straddle the magnetic equator. Many low-latitude ionospheric effects are the subject of intensive study in which several low-latitude countries are already participating. Intensification of this research is warranted; a particular autonomous contribution would be coordinated, systematic wide-scale sounding rocket studies of ionospheric phenomena. Such a programme will benefit directly the development of local telecommunications technology.

Several developing countries are involved in vigorous research programmes in Antarctica. Upper atmospheric and near-Earth space studies in Antarctica need a concerted, coordinated effort to determine important global North–South asymmetries of the phenomena controlling the earth's magnetosphere. Remote sensing of the Antarctic ice sheet and Southern Ocean sea ice will be a most important objective of Antarctic research in the next decade. Also, comparative studies from high altitude and space of atmospheric aerosols and pollution over the two polar caps is of crucial importance for global climate research.

Concerning opportunities for international cooperation, several initiatives for large programmes are in a planning stage by bodies affiliated with the International Council of Scientific Unions. A major proposal has been made for an international effort at the end of the 1980s to study global change – the International Geosphere-Biosphere Program[3] – of magnitude equal to or greater than the International Geophysical Year. These all could lead to significant opportunities for participation in coordinated space research for developing countries.

Many of the above mentioned studies would have to be conducted at universities. Space research thus would effectively contribute to the development of university research, an activity essential to the function of the university as a centre where new knowledge is created, and where the know-how on how to create such new knowledge is taught to the students. One cannot emphasize enough the need for strong and intimate relationships between the universities and research laboratories, the decision makers in government and the users of space technology in industry and government.

Finally, the development of local space research programmes, however modest, can serve admirably to develop societal awareness of the role of science in general for the benefit of humankind. We must cultivate and nurture the fascination with space that captures and stimulates the imagination of all people and use this as an effective bridge towards achieving public understanding of the benefits of research, even that kind of basic research which does not bring immediate returns but which, as history has demonstrated, is bound to shape the long-term future of society. That kind of research, in the case of space science, will provide the locally trained manpower that is so absolutely essential for a developing country to enter into cooperative association with satellite-launching countries as a respected partner with self-determination and initiative.

[3] T.F. Malone and J.G. Roederer, eds, *Global Change*, Cambridge University Press, Cambridge, 1985.

## Uses of space technology

The Report of the 1982 UNISPACE Conference presents a detailed



analysis of space applications and space technology, especially in relation to their contribution to developing countries and to the participation of developing countries in such endeavours. Therefore, it is not necessary to go into any technical detail here. The subjects or projects of importance are even more obvious than those cited above for space research: for example, the use of remote sensing satellites; meteorological satellites; and satellites for telecommunications, education and navigation.

A recurring theme in the UNISPACE 82 Report is how these endeavours, if properly planned and managed, could help countries in the development of trained manpower and an indigenous research and technology infrastructure. To accomplish this task, it is more important to set up cooperations *among* developing countries than it is for individual countries to link up independently with some advanced country in cooperative endeavours. This is in analogy with the question of technology transfer to developing countries: what is needed is not a transfer of technology *per se*, but a transfer of the knowledge of how to create local technologies. In this, one should recognize the existence of a whole spectrum of levels of development, and organize through a series of bilateral agreements a serial transfer of technology and know-how from one level to the next, rather than directly from the top to each one of the lower levels through parallel, independent channels. The same should apply to cooperative space endeavours: the 'continuous' transformation and local adaptation of scientific and technological know-how would be more beneficial to the cooperating partners, than the building of individual and mutually independent bridges to span the often profound gaps with the most advanced countries.

## Issues in space management

The 1982 Conference identified a number of critical issues that require concomitant consideration of scientific, technological and political factors at the international level. Some of these issues and related problems such as the deployment of weapons in space, the clean-up of space, the environmental impact of rocket propellants, and the colonization of celestial bodies, can only be treated and solved by the so-called space powers.

Specific to the participation of developing countries in the management of space are the following issues.

*The development of indigenous scientific, technological and managerial expertise.* For the transfer of knowledge the same criteria should apply as to the transfer of technology. Recognizing the existence of a whole spectrum of levels of advancement among developing countries, technical and post-doctoral training missions, fellowships and graduate studies abroad should be organized on a serial basis through cooperative agreements *among* developing countries at different stages of scientific and technological advancement. This will be more profitable than the more traditional mode of sending trainees to the most advanced centres – from whence they return with a lot of knowledge but with little know-how on how to apply that knowledge in their native environments.

*Geostationary orbit management.* This is a difficult and pressing issue that will have to address many questions, including the return to alternate ground-based means to relieve the 'spacecraft pressure' on the orbit, the clustering of spacecraft with homologous functions, and the scientific–technical problems of highly focused radiowave beaming.

*The question of 'space privacy'.* That is, both in terms of the information acquired by an overflying satellite as well as the information beamed downward by a spacecraft.

*Space data and information policies.* We refer here not only to the most important question of utilization of data available in the public, commercial, multinational or international domains, but to the multifaceted issues involved at all levels from data acquisition to storage and archiving, as well as the issues related to the dissemination of information on who is doing what, where and when.[4] As a result of the 'data explosion', the need to retain ever-increasing amounts of data poses several major problems. One is given by the physical limits of storage and the decision-making processes on what to discard, what to retain, and for how long; others are related to data retrieval mechanisms. An international data policy is necessary in order to assure the availability, in adequate format and quality and at a rate commensurate with need, of information on the physical environment. Such a data policy must address the following questions by regulating, setting guidelines, or promoting, as applicable:

- What data should be deposited in regional and international data repositories?
- What information on data infrastructure, such as formats, the measuring devices, software, assumptions, possible error sources, data catalogues, etc, should be stored with the data?
- Who decides on data formating, data elimination, data compression and data manipulation in general?
- Who will check on data reliability and quality, and according to what criteria will this be done?
- How will the scientific value or the market value of data be determined?
- Should users control or influence the organization and operation of data repositories and, if so, how?
- Should repositories be 'passive' archives, or should they also provide facilities for individual and cooperative computer-interactive data analyses?

*The interaction between satellite-launching countries and partners from developing countries.* By and large, up to now most such cooperative programmes in space were based on the 'acceptance of offered opportunities'. Ideally, however, cooperative programmes should involve all participants on an equal footing, from the incipient phase of planning onwards – not necessarily in the total mission, but in the cooperative project or experiment in question. To achieve such an ideal mode of cooperation, the participants in the developing country must *demonstrate* to the satellite-launching country that the latter will genuinely benefit from such cooperation far beyond a possible political or economic advantage, or beyond the reception of a service function. The best way to demonstrate this is to take vigorous steps in the development of an autonomous scientific and technological base.

[4] J. G. Roederer, 'Considerations in the development of a national geophysical data policy', *EOS*, Vol 62, 1981, p 569.





# INMARSAT: a satellite safety net for seafarers

*The International Maritime Satellite Organization's (INMARSAT) success in operating the world's maritime satellite communications system has led to moves for it to expand its activities into other related areas. A vital role for INMARSAT in the Future Global Maritime Distress and Safety System has already been acknowledged and moves are currently being made to alter the organization's Convention to enable it to provide a range of aeronautical services.*

According to its Convention, INMARSAT's purpose is 'to make provision for the space segment necessary for improving maritime communications, thereby assisting in improving distress and safety of life at sea communications, efficiency and management of ships, maritime public correspondence services and radiodetermination capabilities'. The Convention also says that INMARSAT shall act exclusively for peaceful purposes, that ships of all nations may use the space segment, and that it is open for membership by all states.

By an agreement with the UK, INMARSAT's headquarters were established in London. Forty-one countries have now acceded to the INMARSAT Convention. These member countries have, in turn, designated Signatories, typically national telecommunications carriers, to sign the INMARSAT Operating Agreement. The Signatories finance the system by making capital contributions, or loans, in proportion to their respective investment shares, which are allocated on a percentage basis to correspond to the usage of the system by each country. The Signatories with the largest investment shares come from the USA (30.7%), the UK (14.6%), Norway (11.6%), Japan (7%) and the USSR (6.9%).

According to the Operating Agreement, INMARSAT should be a not-for-profit organization operating 'on a sound economic and financial basis, having regard to accepted commercial principles'. Surplus revenue, beyond that required to pay a reasonable return on capital to its investor Signatories, is to be recycled to stabilize or lower user charges. By the end of its first two years of operation, INMARSAT was already providing a return on investment to its Signatories, much earlier than originally forecast.

## Organization

INMARSAT has a three-tier organizational structure:

*The Assembly of Parties* meets once every two years to review the activities and objectives of INMARSAT and to make recommendations to the Council. All member states are represented and have one vote each.

*The Council of Signatories* is like a corporate board of directors; it is INMARSAT's policy making body. It consists of at least 22 Signatories: 18 with the largest investment shares and four others elected by the Assembly on the principle of a just geographical representation and with due regard for the interests of developing countries. The Council meets at least three times a year and each Signatory has a voting power equal to its investment share.

*The Directorate* carries out the day-to-day activities of the Organization. The Director General is INMARSAT's chief executive officer.

## The INMARSAT system

The maritime satellite system has three major components: the satellite capacity leased by the organization, the coast earth stations and the ship earth stations (see Figure 1).

The nerve centre of the system is the Operations Control Centre (OCC) at INMARSAT's headquarters. The OCC is connected directly by leased lines to the satellite control centres of the organizations from which satellite capacity is leased, by its own ship earth stations to the Atlantic and Indian Ocean satellites, and to all coast earth stations around the world. Operating 24 hours a day, it coordinates a wide range of activities. Should a serious problem arise with an oper-

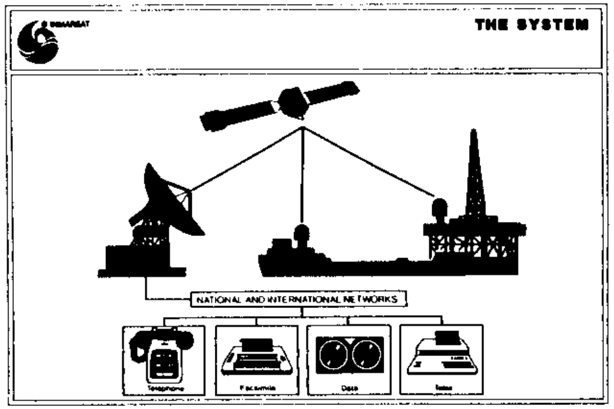


**Figure 1.** The INMARSAT system components.

## A PHYSICAL MODEL FOR IMAGINATION AND CREATIVITY

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**"L'ordre est le plaisir de la raison, mais le désordre est la délice de l'imagination." Paul Claudel**

The function of the brain is only poorly understood in terms of its basic chemistry and physics. This paper describes a physical model for imagination and creativity which does not depend critically on the detailed function of the brain. Part of the model has been suggested by Paul Claudel as indicated by the quote above. I will propose methods to evaluate some portions of the model.

The imagination of homo sapiens was as important for the evolution of modern society as was their intellect. In the article "The Biological Basis of Imagination" by R.W. Gerard which first appeared in The Scientific Monthly in June 1946 the author says imagination is a component of intelligence. I doubt that there is a connection between these two important brain functions. Imagination should not be confused with intelligence, an equally important human characteristic. Humanity is doubly blessed if both characteristics occur in the same individual.

It is rare that a creative solution occurs to you when you are struggling with a problem. The solution is more apt to come at a later time when you are not thinking about the problem. Often the solution occurs in a dream or upon awakening in the night.

Some individuals have used special techniques to enhance their creativity. It is said that Edison would study a problem intensely and then seek the solution while relaxing in an easy chair, trying to keep himself in a state of being half awake and half asleep. In order to avoid falling into a sound sleep, he held a heavy weight in each hand. If he fell asleep his muscles would relax causing the weights to clatter to the floor and wake him up. Newton, according to tradition, had one of his best ideas under an apple tree. In the book "SURELY YOU'RE JOKING, MR. FEYNMAN" by Prof. Richard Feynman, the author relates that he often solved a problem while walking in the dark.

In the introduction to the book The Scientific Imagination: case studies by Gerald Holton, the author states: *"Considering the progress made in the sciences themselves over the past three centuries, it is remarkable how little consensus has developed on how the scientific imagination functions."* Later in the book the author gives the example of Fermi's discovery of moderated neutrons. The incident is described by S.C. Chandrasekhar in Collected Papers of Enrico Fermi (Chicago, University of Chicago Press, 1978). Fermi had planned to insert a lead



filter in the neutron beam *"...when finally, with some reluctance, I was going to put it in its place, I said to myself: "No, I do not want this piece of lead here, what I want is a piece of parafin." It was just like that with no advance waarning, no conscious, prior, reasoning. I immediately took some odd pieces of parafin .... and placed it where the piece of lead was to have been."*

There is often confusion in the meaning of the words imagination and creativity. Sometimes the words are used together. A dictionary definition of imagination is *"a mental faculty of forming images of objects not present; a creative faculty of the mind"*. I prefer to define it by example. I consider our dreams - whether with the eyes opened or closed - and our fantasies as good examples of imagination. For purposes of this article I exclude the use of imagination "to reconstruct in our mind a previous image", which is a function of the memory.

I consider creativity to be the direct result of imagination. Creativity is a useful new idea that is spontaneously produced from our imagination.. This new idea may have been thought of many times before by other individuals. Reinventing the wheel can still be a creative thought.

Early philosophers realized the importance of imagination. Imagination, reasoning and memory were listed by Aristotle as the three internal senses of the brain. Bacon accepted the same philosophy and suggested that imagination is useful for science as well as in connection with rhetoric, poetry and the arts.

We can not pinpoint when man first acquired a good imagination. Evidence from archeology suggests that early hominids had little imagination. Until the appearance of homo sapiens about 50,000 years ago, the most creative invention of man appears to be the stone axe. This useful tool existed for tens of thousands of generations with little improvement. Stone axes found around the world from different stone age cultures are strikingly similar.

A significant mutation must have occured in the brain with the coming of homo sapiens which led to a greater intellect and a greater imagination. This greater imagination in turn led to creativity. Only with homo sapiens did man invent language, art and religion along with the technology that led to the iron age, the bronze age, the industrial revolution and finally to our present highly technical society. To me the most significant inventions were speech and writing, followed many centuries later by the invention of printing. These inventions each permitted the transmission of knowledge to other humans.

The basic source of imagination according to my model is the random electrical activity (noise) in the brain. This noise is of the same general type that produces static on your radio and "snow" on your television screen. To understand how this noise may produce imagingation you must understand a bit about the operation of the brain. There is strong evidence that the brain works by means of electrical pulses that "turn on" switches, called synapses. There are estimated to be $10^{14}$ synapses in the brain interconnecting more than $10^{10}$ neurones or electrical nerve cells. To turn on a synapse the electrical pulse must be above some minimal (threshold) level that is probably different for each of us. I propose that in imaginative individuals the threshold level for the synapses is lower than in unimaginative people.

There is a great deal of random electrical activity in the brain as there is in any electronic circuit. It seems likely that occasionally one of these noise pulses will pass through a synapse and connect two parts of the brain together. The resulting connection is much like a random connection between two telephones. Like most wrong numbers the result is generally not useful. In that sense the random electrical connection in the brain is analogous to the random chemical change of the DNA that leads to a mutation. Most mutations like most products of our imagination lead to useless or even negative results.

During normal waking activities nerve signals from our senses dominate brain function. Under relaxed conditions the brain noise will have an opportunity to connect various parts of the brain together in a more or less random way. Although most of these random connections result in nonsense, occasionally the new connection makes sense and results in a creative idea. This filtering action may be taking place in our subconscious without our being aware of it. This may explain why on occasion a composer wakes up and finds that much of a musical score is ready to be written down.

Man has succeeded in speeding up evolution of new plant types by irradiating the seeds to produce many more mutations than occur naturally. Perhaps we can speed up our creativity by using techniques to increase our imagination.

I believe that imagination and fantasy have played a large role in the evolution of science. Einstein said that his greatest gift was his fantasies. He also said that imagination is more important than knowledge. I would disagree with that assessment. Our most imaginative people are locked up in mental institutions.

In the article by Gerard On the biological basis of imagination, the author asks rhetorically "*What gives one man a vivid imagination but a poor memory, another an encyclopedic memory but dull imagination. And when that answer is at hand science will indeed have established the biological basis of imagination.*" I suggest that a possible explanation is that brain noise works in favor of a good imagination and against a good memory. I do not believe that there is "a biological basis of imagination". I consider "biology" a word to hide our lack of understanding of the basic physics and chemistry of living things.

It is generally acknowledged that some people are more imaginative than others. It is also a common supposition that imaginative people do not have good memories and conversely, that people with good memories have little imagination. I know of no scientific evidence to support these statements but I suspect there is some truth to them. I have spent a good deal of my professional life associated with the medical profession. Nearly all physicians I know have excellent memories. They had to have one in order to memorize all the facts



needed to get through medical school. I recall only a few physicians who I thought had good imagination. From societies' view point this situation is probably desireable. Who wants to go to an imaginative physician with a poor memory?

If my model of imagination is correct we might be able to find physiological evidence to support the model by measuring the thresholds of neurones in the brain of imaginative individuals and comparing the results to individuals with with little or no imagination.

The function of the brain must depend in some way on the local chemistry, thus our imagination and our memory may depend to some extent on our diet. A common folk lore in many countries in the world is that eating fish is good for the brain. It may have some truth to it. .Fish contain more potassium than meat. Potassium is an important element in function of the nerves. Perhaps it is time we study the idea. There is evidence that the diet of the pregnant mother affects the mental ability of the child.

Many people feel that children are more imaginative than adults. Since childrren have about the same number of neurones in the brain in a smaller volume, it is possible that their synapses have lower thresholds than adult brains.

If my proposed model has any validity we must consider ways to evaluate it. Physicists and electronic engineers have much familiarity with electrical noise. It is well known that electrical noise increases with the temperature. A common electronic technique to reduce noise is to lower the temperature of the detector. I don't think that this is the origin of the term to have a "cool head". My model would suggest that a person with a fever should be more imaginative than normal. When the fever becomes too high the patient has convulsions which may indicate that noise is over riding normal sensory signals.

An example of an important idea that occured during a fever is related in The Discoverers by D.J. Boorstin, Random House 1983 (pp473-474).] Albert Wallace conceived the idea of "survival of the fittest" during a malarial fever attach in January1858. He related that "*...I waited anxiously for the temination of my fit so that I might make notes for a paper on the subject.*" Wallace sent his paper a few days later to Darwin and asked him to submit it for publication. Darwin had independently conceived the same idea, for which he is well remembered. Both papers were published simultaneously. Darwin went on to write a book on the subject which called attention to the idea.

An interesting computer analogy to increasing brain noise with a fever is the "Simulated Annealing" computer technique used to solve the complex "traveling salesman" problem. (See S. Kirkpatrick, C.D. Gelatt & M.P. Vecchi-Optimization by Simulated Annealing, SCIENCE 220, 671-680 (May 1983)). The technique involves "raising the temperature" and then permitting the computer to remove energy slowly. This process is repeated a number of times until a good solution is obtained. At the conclusion of the article the authors state

*"Simulation of the process of arriving at an optimal design by annealing under control of a schedule is an example of evolutionary process modeled accurately by purely stochastic means. In fact, it may be a better model of selection processes in nature than is iterative improvement. Also, it provides an intriguing instance of "artificial intelligence" in which the computer has arrived almost uninstructed at a solution that might have been thought to require the intervention of human intelligence."*

It might be possible to arrange a study of imagination as a function of body temperature. I do not think it is practical as the subjects would be aware of the experiment and might introduce artifacts into the results.

There is a more controllable method to increase the brain noise. Randomly pulsed magnetic fields can be applied to part or all of the brain to increase the internal brain noise. Magnetic fields are not consciously detected by the brain and so the subject should be unaware whether the brain noise level has increased or not. The selection of the test periods for adding magnetic "noise" can be controlled by the computer on a random basis and recorded in the computer memory. The computer can indicate the experimental conditions by letters. This will permit the study to be done in a double blind manner, where neither the subject nor the experimenter is aware of the experimental conditions until the experiment is completed.

It will be difficult, if not impossible, to get people to agree on a method of evaluating imagination. I suggest that we begin with the measurement of a simple parameter, such as the ability to work mathematical problems or the ability to remember random letter sequences.

A measurable parameter that might be affected by increased brain noise is the threshold of vision. The minimum light that the eye can detect is limited by noise in the eye-brain system. The threshold of vision can be measured under laboratory conditions. Visual acuity under low light level conditions is another vision test that might be affected by the brain noise. It is not obvious that noise in one part of the brain will be the same as that in another part. It is reasonable to assume that some people may have imagination in one component of the brain and not in another part.

In THE CREATIVE PROCESS edited by B. Ghiselin among about twenty articles about creativity, all except one are novelists, composers, artists or poets. This suggests that scientists are not very creative. I believe scientists are as imaginative as artists and writers but their "creativity" is hampered by the requirement that their ideas must be tested against the facts of nature.

I have been contemplating the physical origin of imagination and creativity for over 15 years. My progress has been slow. Perhaps you will have suggestions to increase my imagination to come up with a more creative explanation for these important brain functions.



A. Rostagni

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The title I have chosen for my talk refers not only to the obvious, but rather unimportant fact that, being firmly settled in my eighties, I have no escape from considering myself an old man, but, more significantly, to the fact that at my start in Physics most of the teaching was inspired by the physics of the 19th century. Most of the fundamental discoveries of the two decades from 1895 to 1915 had been too revolutionary in order to be considered as part of the settled knowledge, at least as far as introductory teaching was concerned.

My first approach to physical sciences goes back to 1918, when I entered the "Liceo Classico " in Turin. The actual start was with a course on Chemistry, where we had our first opportunity to hear about chemical elements, atoms, molecules, and chemical reactions. It was all done on a very elementary and purely descriptive basis, dealing with valencies, and acid or alcaline behaviour, without any hint to the electronic structure of atoms, and its intervention in chemical binding. As a compensation for this deficiency we were shown a lot of amusing experiments on matter transformations by reactions.

Physics in the proper sense was taught in the second and third years of the Liceo, starting with mechanics and ending with electricity. The teacher was the same as for chemistry, and he was, I am glad to say, an excellent teacher, notwithstanding his not being so up-to-date. He had studied at the University of Pisa in the past century, and had clear ideas on classical physics. In his teaching he insisted on definitions, fundamental laws and experimental facts, leaving aside any at the time advanced theoretical interpretation. As well as in chemistry he entertained us with many demonstration experiments.

I think he was the proper teacher for such a school as the "Liceo Classico", where the main fraction of the students were not supposed to learn, or simply to hear, any more about physics after leaving that school. But the basic ideas he gave us were good also for scientifically-minded students. It was actually through that course that I felt attracted by physics.

Certainly, when I decided to choose this way for my life, I had not a definite idea of whether I was going to devote myself to scientific research, or to some kind of technical work. Or, to be more explicit, my ideas about scientific research were too vague at the time to give support to a choice.

The situation I found at the University of Turin, when I entered it in view of graduating in physics, was not particularly exciting. We had the standard two-year course on general physics, which was developed on a rather mathematical basis; one more course on physics, in the third year, treated of some more advanced subjects, including, as far as I can remember, elements of the Bohr-Sommerfeld theory of atoms. The other courses of lectures in the four-year curriculum were on mathematics, chemistry, mineralogy; and some laboratory courses with routine experiments.

I spent the fourth year working at an experiment for my graduation thesis, and then I became an Assistant at the Istituto di Fisica: which, as I had soon to realize, lacked a proper atmosphere of research.

Left to myself, I succeeded in doing some work on classical optics, geophysics, and finally on oscillating properties of ionized gases. Opportunities of discussing with anybody what I was doing, or planning to do, were rather limited. The students in physics were also very few, and mainly of a middle level.

As far as I could know, the situation in Turin was not very different from that of most Italian Universities.

However, a change was going to start in Rome. The Professor there was a middle aged very intelligent man, Orso Mario Corbino. Born in Sicily, one of the many children of a baker in Augusta, he had done some good work in Palermo, before being called to Rome, where he also reached an important political position. In the early twenties he met young Enrico Fermi, who was returning home after graduating in Physics in Pisa, as a student of the Scuola Normale Superiore. Corbino realized very soon with whom he had to do, and decided to help him to develop his outstanding qualities. Fermi went with a fellowship to Göttingen and then to Leyden to work with Born and with Ehrenfest. The next year he started teaching in Florence. But then Corbino succeeded in making available a Chair of Theoretical Physics in Rome, the first one in Italy, to which Fermi was appointed. Corbino had conceived the plan to start a School of Physics, guided by Fermi. He was intelligent enough not to worry about the presence of a colleague whom he valued much better than himself.

Here I will stop a while and analyse the peculiar situation which seems to me to have characterized Physics in Italy through the centuries. First of all one point has to be agreed upon: physics as a science, as we mean it now, had its start in Italy, with Galileo Galilei, at the end of the sixteenth century. This statement is not mine. I got it from J.C. Poggendorf, a German Physicist, perhaps the most renowned historian of physics in the past century. He states: "if a single man may have a claim to the honour of being considered as the founder of a science so wide and ramified as physics, there is no doubt that this honour belongs to Galilei".

Here I am pleased to recall that the official start of this building of ICTP has taken place in the 4th centenary of Galileo's birth (1964), this fact being recorded in the foundation stone.

I will not spend much time trying to analyse the beginning of scientific knowledge in mankind. It seems reasonable to suppose that, following the development of their thinking capability, human beings must have tried to recognize and somehow give themselves an explanation of the phenomena exhibited by Nature around them. I think that such attempts, materialized through man's imagination, are reflected in myths and religions. But, apart from that, inspired by practical needs, several thousand years ago, definite branches of scientific knowledge, like mathematics, astronomy, mechanics, began to develop in different Countries of the Far and Middle East, and perhaps elsewhere.

The main impact in the development of European culture came through the Greek culture, with some important additions from the Arabian culture during the Middle Ages. The Greek culture had shown an impressive development through many centuries, with outstanding achievements both in arts and science. Only in natural sciences the Greek were not so successful, because they mostly did not discover the proper method. Proceeding as they were doing with success in philosophy, they pretended to tackle fundamental problems such as the laws of motion, the constitution of matter, the form of the Universe, moving from general principles which they accepted as self-evident. In their investigation of natural phenomena speculation overweighed by far the direct observation of facts, not to say of experiments, which were unknown to them. This completely wrong way was followed in particular by the great philosopher Aristotle, whose theories on physics and natural sciences exerted the deepest influence on european culture through the Middle Ages.

Only one man, Archimedes from Syracuse, a Greek settlement in Sicily, in the third century B.C. applied the right method, investigating experimentally definite mechanical problems, and so was able to obtain some important results which are still known after his name. In the general revival of the Greek culture which took place with the Renaissance, Archimede's work came to light again: Galileo was influenced by it.

The blowing up of the new physics with Galileo can be considered as the final product of the Renaissance, the grand cultural movement which had its start in Italy through a renewed interest for classical culture, latin and greek; and developed through the 15th and 16th centuries, giving rise to a wonderful flourishing of arts, but also to an active revival of scientific interests. From Italy the movement spread over the rest of Europe, particularly through the students of the different Countries who were learning at the renowned italian Universities. It may be recalled that N. Copernicus studied mathematics and astronomy in Bologna and later in Padua, and W. Harvey, the discoverer of blood circulation, studied in Padua, while Galileo was lecturing there.

But in the last decades of the 17th century the center of gravity of physics research, which had remained in Italy as long as Galileo and his pupils had been in activity, moved to the north, particularly to England and Holland, and never came back. On previous occasions I happened to remark that after Galileo Italy had only two other truly outstanding physicists: Volta, at the end of the 18th century, and Fermi in our times. To them A. Avogadro may be added, a contemporary of Volta, who discovered the law named after him, whose fundamental importance was not recognized by the scientific world for half a century after its publication. In between there have been a few pretty good physicists, who never originated a school.

I think I cannot venture to suggest an explanation for such an anomaly. I will only mention some facts which may have exerted a negative influence on the study of physics in Italy. First, I will indicate the action of the Roman Church which, after having been for some time favourable to the development of science, became suspicious about the effects that new ideas might have on the religious faith. So, for instance, it rejected Copernicus's theory of the planetary system, and prosecuted Galileo for having taken a public position in favour of it.

The discovery by Galileo of satellites turning around Jupiter like the Moon around the Earth, made it very difficult to maintain to the Earth a privileged position as the center of the Universe, which the Church preferred to accept. Through the Ancient Ages there had already been scientists who had found that, by placing in the Sun the origin of the reference system, the kinematics of planets resulted much simpler. But this had not received much of attention, and all through the Middle Ages the firm belief prevailed that, the World having been created for man, the Earth had to be at the center of the Universe, as it was correctly represented by the Ptolemaic astronomical system.

The reviving interest for natural sciences through the 16th and 17th centuries had been marked by the appearance of learned societies, or Academies, having as their special aim the investigation of Nature. In 1603 Prince Federico Cesi, aged 18, founded in Rome the "Accademia dei Lincei", devoted to natural sciences, having as members Galilei with other leading scientists in Europe. By the untimely death of F. Cesi in 1630 the Accademia was practically dissolved. There were attempts through the centuries, also by some Popes, to have it revived under their control, until it could eventually start a regular existence as a free national Academy, following the unification of Italy with Rome as capital in 1870.

In 1657 in Florence a group of learned people, including Galileo's pupils, made up a society, which they named "Accademia del Cimento", with the sponsorship of Prince Leopoldo de' Medici, and the purpose of making investigations in physics. They succeeded in doing several good experimental works, during ten years. But in 1667 the Accademia del Cimento had to be closed by request of the Pope.

In this same decade the "Royal Society" was founded in London (1662) and the "Académie des Sciences" in Paris (1666), which have both had since then a glorious regular existence. By this a typical contrast is evidenced between the situation in Italy and Northern Europe.

Another fact which may have negatively influenced scientific activity was the decline of the political and economical power of the States fractioning Italy during the 17th century. Most of the country fell at last under Spanish domination, while, at the same time, England, France and Holland were growing into strong national States. It was the time when Boyle and Newton in England, Huygens in Holland made their discoveries. Through Newton's work, classical mechanics was given a definite basis, and so was the dynamics of the planetary system. The mathematical instruments for handling physical problems started to develop from the infinitesimal calculus, invented by Newton and independently by G.G. Leibnitz. A contrast remained between the theories of Newton and Huygens about the nature of light.

During the 18th century new problems came into consideration: a better definition of concepts concerning heat and related methods of measurements. A renewed interest was devoted to electrical and magnetic phenomena. Chemical research was largely cultivated and recorded notable successes, preparing the discoveries of the fundamental laws of mass conservation by Lavoisier, of definite and multiple proportions by Dalton, and finally of Avogadro's law: an ensemble which put on a firm experimental basis the notions of atom and molecule, imagined without any support of facts by Greek philosophers thousands of years before.

The experiments of Young and Fresnel put finally out of question the wave nature of light propagation.

But then a discovery by A. Volta (1800) opened quite a new field of investigation: that of electric currents, which led soon to the discovery of electromagnetism, and of electrochemistry, with their many-sided implications: the great names of Oersted, Ampère, Faraday, Maxwell made their appearance on the wide stage of physics. As a consequence of Maxwell's theory of the electromagnetic field, the light found its explanation as electric waves.

Another fundamental progress which took place toward the middle of the 19th century was the final interpretation of heat and the discovery of energy conservation. New fields of physics, like kinetic theory of gases, statistical mechanics and thermodynamics developed rapidly. Here I should mention, besides Maxwell, Carnot, Joule, Clausius, W. Thomson (Lord Kelvin), Boltzmann.



Toward the end of the century, a number of Physicists cultivated the opinion that physics in its whole was settled, no great discoveries were any more to be expected; and the most important thing to do was to refine the measurements of the fundamental and the material constants, perfectioning technical methods. This attitude was diffusedly accepted in Italy: and that is possibly one of the reasons why also in this last period, when the political situation was settled into a regular national state, independent of the Church, Italy did not show any really outstanding physicist. No significant part was taken in the great discoveries which followed rapidly, from the last decade of the 19th century to the start of the first world war.

Among the professors of physics the one who emerged in this period was A. Righi in Bologna, who did good experimental work in many different fields, but no true basic discoveries. In particular, he succeeded in reproducing with electric waves all experiments characterizing the propagation of light, so perfecting Hertz's discovery. It was looking at his experiments that Marconi conceived the idea of employing electric waves for transmitting signals through the space.

Now let me go back to my personal recollections. When Fermi started teaching in Rome he soon had as students Amaldi, Segrè, Maiorana ..... and as a colleague F. Rasetti, who had become his friend studying in Pisa. Rasetti was a very skilful experimenter and had done fine work in spectroscopy. After graduation Amaldi went to work on $X$ ray diffraction with P. Debye in Leipzig, and Segrè on molecular rays with O. Stern in Hamburg.

Meanwhile E. Persico, who as a boy had been a school friend of Fermi and then had become an Assistant of Corbino, went to teach theoretical Physics in Florence, and had soon a fine group of students: B. Rossi, G. Bernardini, G. Occhialini, G. Racah, D. Bocciarelli, who started working on cosmic rays.

The atmosphere in Florence was somehow similar to the one in Rome. As well as Corbino, the Head of the Department Antonio Garbasso was an open-minded man, who had done some good work in physics and then become involved in politics. But, although he did not participate in, nor give direct inspiration to the scientific work, he was ready to encourage and find support for it. So B. Rossi obtained a fellowship for Germany and spent a year working with Bothe.

Meanwhile Persico went to Turin to a new Chair of theoretical physics. It took some time before we became friends: he was a rather reserved man and in physics he was mainly interested in fundamental problems; so he did not particularly appreciate the work I was doing then on oscillations in ionized gases. By and by we started talking about the possibility of doing work on nuclear physics, as they were preparing to do in Rome.

But then, quite unexpectedly, toward the end of 1932 I was offered a fellowship for Germany, to work with H. Kallmann, who had just discovered the so-called "neutral rays" (Neutralstrahlen) obtained from a beam of positive rays by charge exchange in their own gas, under resonance conditions. As it happened, it was not the best time for me, from a private point of view, for going abroad. I had married during the summer. My wife was an Assistant at the Istituto di Fisica as well as I was. So we could not think of leaving for several months together. But we thought that the opportunity to go and work in an important center of research (it was the "Kaiser Wilhelm Institut für Physikalische Chemie" in Berlin) was too important to be thrown away. So at the beginning of January 1933 I left for Berlin, leaving my wife doing hers as well as part of my teaching work.

But it soon turned out that also from another point of view the choice of the time could not have been worse. In less than a month, end of January, Hitler became Reichskanzler, and very soon started giving out his new laws, particularly those against the Jews. The director of the K.W.I. was the famous chemist, Nobel-prize winner F. Haber, who had played a crucial role in Germany's resistance through the first World War, thanks to his processes for synthetizing ammonia from atmospheric nitrogen. But he was a Jew, and had to be removed from his place. It happened that almost all other scientists working at different levels in the Institute, including Kallmann, were not arians, according to the Nazi's definition, and so they had to prepare to leave, and look for a place where to go. It is a matter of course that they were going to show very little interest in my work.

Nevertheless, having from the first days designed an apparatus, following some suggestions by Kallmann, and had it built very soon in the excellent



workshop of the Institute, I could start my work. I had no previous experience on high vacuum, so I could not help doing some mistake, under the ironic looks of my German colleagues. But my ability improved rather soon, and I could go ahead with my work practically alone. The mere fact of seeing what others had done and becoming aware that I could do the same and sometimes better, gave me great confidence. Upon my arrival Kallmann had been rather worried when I had told him that I could spend at most seven or eight months in Berlin. He had remarked that the main paper they had published on that subject, with his collaborators, had required two years work. So I felt very happy when,having worked very hard, before the end of June I reached two interesting conclusions:

1. – a comparison of the coefficients of electron liberation from metal surfaces by ion and atom collisions at low energy: approaching definite limiting values depending on the ionization potentials for ions, while the coefficients for the atoms tend to zero as their kinetic energy approaches zero;

2. – a considerable refinement of Kallmann and coll's data on charge exchange cross-sections as a function of kinetic energy, resulting from improvements in the experimental setting.

In September the laboratory had to be closed by governmental decree. So I managed to buy some pieces of equipment, which helped me to start further experiments. Apart from improving further the investigation of charge exchange, I made experiments on scattering and ionization by collision of ions and atoms, always trying to go down to the lowest possible energies.

While I was progressing with this work, I began to think of building a small accelerator for nuclear research. Having obtained a contribution for a short stay in the Cavendish Laboratory in Cambridge, during the summer vacation in 1934, I first visited the Joliots in Paris, and then went to work in Cambridge with M.L. Oliphant, where I succeeded in assembling and testing an accelerator at a few hundred kV, from pieces which had been used for different purposes. Both from F. Joliot and from Oliphant I got encouragement for my project.

But in the next year I became professor in Messina, and my plans had to be changed completely. First I had to organize a Laboratory where no research had ever been done before, buying and building instruments and pieces of equipment, with very limited financial means and technical (not to say scientific) collaboration. I decided that the best thing to do was to go on working first in the field I knew better. What I had done in comparison with the previous investigators in the field was to improve substantially the precision of the measurements, and to extend them to lower kinetic energies. My aim was to go down to values comparable with chemical interaction energies, and possibly investigate elementary reactions. Being aware of the difficulty to reach such values through the charge exchange technique, I realized that the way to it was offered by molecular beams of thermal origin. So I obtained to spend the summer 1938 in N.Y. in Rabi's laboratory at Columbia University, learning a lot of the most advanced and ingenious technical refinements in the field.

I felt quite sure that work on that line could be done in Messina, not requiring large means, but personal skill and some technical support, which I had by then secured, developing a small workshop with a young very intelligent technician. I also began to have some students.

But in that same summer Mussolini's government, having definitely submitted himself to Hitler, started promulgating laws against the Jews, in particular dismissing them from the Universities. So B. Rossi and E.Segrè, who had respectively become professors in Padua and Palermo, had to leave and look for a place abroad.

By the end of 1938 I was called to Padua, where I found a large, newly-built laboratory, practically devoid of scientific collaborators. It had a good mechanical workshop and an accelerator at 1 MeV under construction. The second World War broke out in the following year, and practically put a stop to any important initiative. The worst came with the German occupation in 1943. I had then as the best collaborator N. Dallaporta. Toward the end of 1945 some young people who had graduated during the war started coming back to the laboratory, and we discussed what to do. Neutral or molecular rays did not appear a suitable field for such a group of people, lacking experimental practice, and also supposed to grow in number rather fast. The accelerator required still, in order to be completed, financial means and technical support, which were not expected to be available for years. So we



decided to start with cosmic rays, which required limited means and offered a lot of open problems. Experiments were initiated with counters, and then with nuclear emulsion and cloud chambers. The number of scientific collaborators and their enthusiasm grew rapidly, in spite of the very scarce financial means. Something similar was happening in Rome and Milan, which had not undergone such a long interruption through the war. In 1951 the CNR founded the INFN, with four divisions in Mi, Pd, Rome and To, endowed with reasonable financial means, and the possibility of appointing scientific and technical collaborators. To the four main divisions some subdivisions could soon be adjoined in Bo, Ts, Pi, Ge, where some people had started working in collaboration with the main divisions.

An opportunity for a success at an international level was offered to us by a proposal of C.F. Powell from Bristol to participate in a large collaboration for investigating strange particles, recently discovered in cosmic rays, by exposing nuclear emulsions on balloons in the stratosphere. Milan, Padua and Rome had with Bristol a leading part in the collaboration. In three subsequent expeditions through the years 1952–4, involving some 30 balloon flights, the main type of strange particles were recognized and their properties determined with a reasonable precision: just in time before the large american accelerators made such experiments with cosmic rays obsolete.

As I mentioned before, the INFN developed very rapidly, by and by including in an active collaboration the laboratories of many italian Universities. Two more initiatives to be mentioned were the decision to build a common laboratory with an electrosynchrotron in Frascati, and the decision to participate in the european collaboration at CERN. Collaborations were also established with laboratories in USA.

This development was practically completed through the 50ies, while the reconstruction of the whole Country from the ruins of the war, and a very fast industrial expansion (the so-called "miracolo economico") was taking place.

The INFN had started with all his activities concentrated on cosmic rays and high energy physics. Toward the middle fifties we thought we had reached sufficient forces to tackle some new field. So in Padua Careri, coming from Rome, started work on low temperatures, with a small group. In Catania work on low energy nuclear physice began, which had been neglected in Italy for years. Plasma physics was started in Frascati, and in Padua. Optics was cultivated successfully in Florence, Pisa and Pavia.

Beside the enthusiasm over the recovered political freedom, I think that a second important factor in this, which I am inclined to consider an extraordinary development of activities in physics, was the fact that they were concentrated in the Universities, which gave rise to a positive mutual interaction between teaching and research work. The INFN, a typical interuniversity institution, organized courses for graduate students, wherefrom to select the best of those wishing to start research work. What I used to say, that no school of physics had ever existed in Italy, is no longer true. After the small brilliant school initiated by Fermi in Rome in the 20ies, there are now many schools, involving most Universities, or we might say, considering the very close collaboration between different Universities operated by the INFN and similar organizations, like the GNSM, the GIFCO, connecting the groups working in the same field, that there is now a very large school flourishing all over Italy.

On this basis it seems that we might be, not only satisfied with the results we have obtained, but rather optimistic about the future. Unfortunately the present situation of the University is far from supporting such a view. The organization of the University has been upset by absurd laws introduced one after another since the late sixties, mostly as a consequence of requests of students and personnel at different levels. The number of full and associate professors has grown beyond any reasonable limit, while it is now almost impossible to appoint new people for research and teaching. So many brilliant young people are lost for the University and for research. It is to be hoped that something will change in this respect, but the experience of the political course in the last decades does not justify any optimistic expectation.

# Nuclear Power, Distributive Justice and Intertemporal Equity

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The amount of energy used in the whole world is about 7500 million tonnes of oil equivalent. Of this about 4% is generated by nuclear power. Present installed nuclear capacity is about 250 GW [1]. Public reaction to the Gorleben repository and Wackersdorf reprocessing plant in West Germany shows that no single aspect of nuclear power has excited continuous public concern as much as radioactive waste management. To what extent can waste management be taken into consideration in the future of nuclear power? Should capacity expand? Should reprocessing and breeder technology be introduced? In this paper, I argue that radioactive waste management at the moment is an unsolved problem and will remain so in the foreseeable future. Going ahead with nuclear power generation is a purely political decision. Many aspects of it cannot even be justified economically, let alone morally or scientifically.

Our sense of justice makes us suspicious about purely allocative economic efficiency -- whatever the rhetoric or esoteric mathematics applied by some economists to 'prove' the virtue of pure competition. We intuitively know what is just and what is unjust. We cannot support slavery or the domination of one race by another even if it could improve the economic situation. This results from our belief in liberty. The philosopher John Rawls [2] puts it as the first principle of justice that *everyone has the right to as much liberty as is consistent with a like liberty for all.* Reason for curtailing liberty must be derived from liberty preserving considerations. This principle means that countries or generations endowed with a high share of resources -- natural, technological or financial -- are not free to use the resources in a short sighted manner. This would jeopardize other countries and later generations and curtail their liberty.



Development in the Third World needs energy, most of which must come from fossil fuel. If carbon dioxide generated from burning fossil fuel is going to cause the "green house effect" then it would be only reasonable that the industrialized countries must use energy more efficiently and less pollutingly, so that enough room is left in the global commons for the poor countries to burn their share of fuel. If the industrialized countries go on polluting (in the technical sense) the atmosphere, then the liberty of poor countries (and later generations) will be curtailed because they will not be free to choose a comparatively less expensive ( at least in the financial sense) energy source. Capital costs [3] per kW of capacity for coal fired units vary from £581-1660, for oil fired units from £519-1484 and nuclear power units from £988-3452. Estimation about running costs are speculative.

The foreign debt of France, which generates 37.5 GW of nuclear electricity, is among the four highest in the world: USA, Mexico, Brazil and France. Some twenty percent of French foreign debt, about $20 billion, has been borrowed by Electricité de France to finance its nuclear programme. Nuclear poor Italy (1.3 GW nuclear electricity) has this year overtaken the United Kingdom (10 GW) in per capita income. West Germany (16.5 GW) has by far the highest per capita income among these four European countries with similar population.

West German politicians, industrialists and financiers have decided to build the Wackersdorf reprocessing plant. Waste generation remains the same in fuel cycles with reprocessing, whether or not part of a breeding cycle. So the project cannot be justified in terms of waste management argument. There is even no economic justification.

In the early seventies the oracles declared that the uranium supply would soon be exhausted. The price of uranium consequently soared to $40/lb. High price soon brought additional suppliers to the market. Now the price is about $20/lb and there is abundant uranium. The reprocessing technology will supply the equivalent uranium at $350/lb.

Purely allocative efficiency would approve the transfer of radioactive waste to poor countries, if the poor countries were paid for it. Industrialized countries would rid themselves of the dangerous waste and the poor countries would be better off economically. But let us recall the reason for concern in the rich countries. Their concern about radioactive waste management results from a sense of responsibility about future generations. They are concerned about distributive justice and not about allocative efficiency. We cannot solve the problem just by transferring the waste to a poor country. One generation or one country should not put other generations or other countries in a situation with a risk that is not acceptable to itself. So, as a first principle we can demand that the radioactive waste must remain in the country which generated it. Distributive equity must be the principal criterion for the disposal of radioactive waste.

Governments, international agencies and nuclear power planners rely heavily on physicists, chemists, engineers and mathematicians to develop waste disposal options. Geologists were first consulted only during the late seventies when they immediately pointed out that the geological assumptions made in the modelling of the transport of radioactive waste through the geosphere into the biosphere had little foundation in actual geological data, theory or experience.

A one-dimensional transport of a radionuclide through a uniformly porous geological medium can be modeled with the following equation [4]:

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial x}\frac{\alpha u}{R}\frac{\partial C}{\partial x} - \frac{u}{R}\frac{\partial C}{\partial x} - \lambda C + q \qquad (1)$$

where

C = concentration of radionuclide in the transporting water ($kg/m^3$)

u = ground water velocity (m/s)

$\alpha$ = longitudinal dispersion length (m)

R = retardation factor, which accounts for material absorbed in the rock

$\lambda$ = decay constant of the radionuclide (1/s)

q = some source of C ($kg / m^3 s$)

Eq. (1) can be solved analytically under suitable boundary conditions. If, for example, we assume a delta source at x=t=o, the solution is [5]:

$$C(x,t) = \frac{q_0 e^{\lambda t}}{2\sqrt{\pi \alpha v t}} \exp\left[ - \frac{(x-vt)^2}{4\alpha v t} \right] \qquad (2)$$

Of course, the model can be made very complicated, but no new insight is gained by employing complicated equations except that super-computers are needed for their numerical solution and that the politicians and civil servants, mostly non-numerate, are impressed by computer print-outs and complicated flow-charts.

Let us apply eq. (2) to the West German radioactive waste. Let me mention that I do not try to be correct up to the seventh decimal place, as is done in many repository safety assessments. I am, however, sure that the numbers given below are correct up to a factor of two.

West Germans have an installed generating capacity of about 16.5 GW [1]. If no new reactors are connected to the grid (6 units with a capacity of 6.5 GW are under construction), and if, as envisaged by the German Social Democrats, the reactors are phased out by the year 2000, we can assume that about 400 GWyr of electricity would by then be generated by nuclear reactors in West Germany.

The radioactive waste generated would contain about 80 tons of $U^{238}$ and 1 ton of $I^{129}$. There would, of course, be other radionuclides, I have chosen these two, because of their long half-lives. Half-life of $U^{238}$ being 4.5 billion and that of $I^{129}$, 16 million years. 80 tons of $U^{238}$ correspond to an activity of one trillion Bq and 1 ton of $I^{129}$ to six trillion Bq. These are very large numbers, if we consider that:

1) They cannot be dispersed in many locations. According to the Physikalisch-Technische-Bundesanstalt [6] only three sites are being considered for radioactive waste disposal -- Asse, Gorleben and Konrad and which in their turn are rather near to each other.

2) 1 Bq/l in drinking water is considered unfit for human consumption.



Eq. (2) has a maximum at x=vt,

$$C_{max}\ (x,t) = \frac{q_o}{2\sqrt{\pi\alpha x}}\ e^{\lambda t} \qquad (3)$$

Let us assume that the transport in the geosphere is being carried out along an effective (i.e., the effect of porosity is included) surface area of ten thousand square meter, in a geological medium with the following characteristics:

u = 0.1 m/yr

R = 1

$\alpha$ = 100 m

x = 10 km (length of the geosphere)

So that $q_o(I^{129}) = 6.\ 10^{12}/10^4$ Bq/m$^2$

and

$t = 10^4/0.1 = 10^5$ yrs

Correspondingly $C_{max}(10^4 m, 10^5 yr) \cong \frac{6.10^8}{2\sqrt{3.14\times100\times10000}} Bq/m^3$

$= 169$ Bq/l

So even after one hundred thousand years the ground water will remain contaminated by two orders of magnitude over the safety limit. This is not to say that someone will drink this water directly. But it does indicate that the time scale, during which there would be a safety problem, is large. Of course, the nuclear planners would say that the problem is much more complicated, e.g. the radioactivity might be diluted in the geosphere by other ground water streams and that the assumption of delta source is unrealistic. But correction of two orders of magnitude needs more than sleight-of-hand.

The nuclear planners might even argue that the retardation factor R is high. But R is determined by a variety of processes collectively referred to as "sorption", which can cause radionuclides to move more slowly than the water which carries them. These include irreversible precipitation as well as ion exchange and surface adsorption, diffusion etc. Nobody can actually measure the retardation factor for a geological medium. So that one easy way to make repositories safe is to make R very high. In the example given above R = 1,000 will make a safe repository. The same will be achieved by introducing diluting streams in the geosphere. The ultimate argument is of course: there will be no release from the repository, even in the geosphere, if the waste is placed in a salt dome.

Can one really take the models seriously which declare repositories to be safe for millions of years? Such statements would be without any scientific foundation. The great economist J.A. Schumpeter [7] warned the economic modellers, "Analysis, whether economic or other, never yields



more than a statement about tendencies present in an observable pattern. And these never tell us what *will* happen to the pattern but only what *would* happen if they continued to act as they have been acting in the time interval covered by our observation and if no other factors intruded".

Deterministic equations are just a help to predict the behaviour of very stable systems. Poincare [8] already pointed out nearly a hundred years ago that the information content of a system is in general insufficient to predict the state of the system at later times. (In this connection, any review paper on "chaos" may also be consulted.)

But models are made in which it is "shown" that the repositories will remain safe for millions of years. And if we consider history's lesson in this respect: The Pharaohs were not interested in such small time-scales as tens of millions of years. Their bodies were supposed to be reposed for eternity. What was the basis of their assumption that their graves would remain undisturbed for eternity? Cyril Aldred [9] writes:

> Egypt provided a physical *milieu* in which this balance could be easily secured, for its natural conditions are almost changeless. It escapes the earthquakes that devastate from time to time the Aegean world. It has climate but no weather. Each day the sun rises in glory, traverses the havens unobscured, and sets in splendour. Each year the Nile rises with predictable regularity and rejuvenates the tired land: only the volume of its inundation remains uncertain. Until the Late Period, the desert margins protected the Egyptians from those wayward floods of invaders that have altered radically the

history and fates of other ancient peoples. The infiltration of new races with new ideas was gradual enough to ensure that the native culture would be irrigated, not swamped, by such contacts. This environment fostered the Egyptian instinct to maintain a *status quo*. The dry sand have preserved much of the ancient past as a dominant present. Perhaps it is not wholly fortuitous that Egypt should be the traditional land of mummification.

But we do know that the world is not static. The differential equations that are employed in the repository safety analysis assume a static view of the world like the ancient Egyptians. Poor Pharaohs! For many of them, the eternity was less than a few hundred years. "Now they appear to have been systematically pillaged probably with the connivance of the officials in charge so that out of some thirty kings' tombs only the deposit of Tut-ankh-amun remained largely intact, probably because as a heretic, his name had been expunged from the necropolis records [9]"

At times burials proved too expensive and so were not carried out - a potential problem also for radioactive waste. At times preparations for burials were disrupted by war and domestic strife - a potential problem for radioactive waste.

The problems of the ancient Egyptians and the latter day radioactive waste mummifiers are not so very different: Prevent human intrusion and intrusion by moisture. The Egyptians relied on the divinity of the kings, curses, hidden tomb in the desert and tombs in special areas guarded by patrols. None of them worked. Humans intruded.



Do we really mean to guard the nuclear tombs for ten million years? No! The decision is political that nuclear power will be generated. The politicians, industrialists and financiers should admit it. There is not even economic, let alone moral or scientific justification for using nuclear power.

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