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Note by the Secretary-General

Addendum

Dialogue paper by the scientific and technological communities*

Role and contributions of the scientific and technological community to sustainable development**

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* Prepared by the International Council for Science (ICSU) and the World Federation of Engineering Organizations (WFEO), invited by the secretariat of the World Summit on Sustainable Development as the organizing partners of the dialogue segment for the scientific and technological communities. The paper has been prepared in consultation with scientific organizations worldwide facilitated by ICSU and WFEO. The views and opinions expressed do not necessarily represent those of the United Nations.

** The International Council for Science (ICSU) and the World Federation of Engineering Organizations (WFEO), as "co-organizing partners" for the scientific and technological community (chap. 31 of Agenda 21) in the preparatory process for the World Summit on Sustainable Development, prepared the present paper in collaboration with the Third World Academy of Sciences (TWAS), the Inter-Academy Panel (IAP) and the International Social Science Council (ISSC). All five organizations consulted their membership to reflect a wide range of views and ideas from those practising the natural, social and engineering sciences worldwide. The paper does not represent, however, an official position or statement of these organizations. Moreover, preparation of the paper has been coordinated with the United Nations Educational, Scientific and Cultural Organization (UNESCO), which acts as task manager for chapter 35 (science for sustainable development). All five non-governmental organizations will continue to cooperate to ensure the active participation of the major group "Scientific and technological community" in the Summit process together with other scientific, engineering and technological organizations and individual scientists and engineers from all parts of the world.

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Executive summary

One of the major lessons learned since the 1992 United Nations Conference on Environment and Development is that the transition towards sustainable development is inconceivable without science, engineering and technology. This is why promoting the goals of sustainability, addressing immediate human and social needs while preserving the earth's fragile life support systems, has emerged as an increasing priority for the international scientific and technological community.

Progress has been made towards meeting the challenges posed by sustainability but more needs to be done. Factors related to sustainability, such as global warming, biodiversity loss, population growth, consumption patterns and megacity expansion, pose problems that have outstripped the capacities of the scientific and technological community and society to forge effective and comprehensive responses. At the same time, the rapid pace of economic globalization along with the explosion in information technologies has radically altered the research environment in which scientists and engineers operate. The scientific and technological community and society are committed to devising a new set of strategies to meet the challenges that lie ahead. Building on chapter 31 of Agenda 21, the scientific and technological community proposes that these strategies be based on the following principles.

A new contract: addressing social equity, poverty reduction and other societal needs must be integral to scientific, engineering and technological endeavours

The scientific and technological community has enormous potential to contribute to sustainable development. In order to effectively utilize this potential, the scientific and technological community must increasingly direct its research agendas towards issues that address basic human and societal needs. As stated at the United Nations Educational, Scientific and Cultural Organization (UNESCO)/ International Council for Science (ICSU) World Conference on Science in 1999, the scientific community must be constantly aware of and take responsibility for the potential impacts that research may have on society. In turn, society has a responsibility to provide adequate funding, up-to-date research facilities, and appropriate career structures, as well as opportunities to inform and participate in the decision-making process. Such an effort requires a new contract between science and society in which ethical dimensions play a central and guiding role.

Reorient and invest: science and engineering must give higher priority to identifying solutions for pressing environmental and developmental challenges with enhanced support by society and government

Economists have consistently reported that investments in science and technology are among the highest-yielding investments that a nation can make. Yet investments in science and technology have in many ways been inadequate, especially in developing countries, where funding for research and development is often less than 0.5 per cent of annual gross domestic product (GDP). In order to address existing and future social and environmental challenges, nations must not only substantially increase their investments in science and technology but also come to view such efforts as fundamental aspects of their overall economic and social development strategies. Investment in science and technology must focus increasingly on activities that cut across disciplines, and the diversity of geographical regions and cultures, and examine the intricate relationship between nature and society.

Build and maintain: scientific and technological capacity, as an elaboration of knowledge and new tools, must be built up and maintained in all countries, but especially in countries that currently lack a minimum critical mass of scientific and technological capacity

It is not possible for science and technology to effectively contribute to sustainable development if countries do not have basic scientific capacity. The sustained and enduring investments that Northern countries have made in building their educational and science and technological capacity largely explain their economic success. Experiences in China, Brazil, India, Singapore and the Republic of Korea over the past decades indicate that a nation's willingness to systematically invest in science and technology can yield substantial dividends. However, national investment needs to be accompanied by responsible and mutually beneficial international partnerships. Experience shows that international scientific cooperation through efforts such as the creation of institutional networks, scientific exchanges and mobility, and the establishment of scientific centres of excellence among nations with weak scientific infrastructures, are excellent strategies for building scientific capacities. At the same time, coordinated measures must be taken to counter the negative effects of "brain drain" upon countries that are working to develop their own scientists and scientific capabilities. Science for sustainable development must be global in its reach, yet local and regional in its implementation. The responsibility for building and maintaining this capacity lies squarely on the shoulders of national Governments but requires significantly enhanced collaboration and partnerships with the global development assistance community and the scientific and technological community.

Innovate and sustain: development and sharing of new and existing technologies must be encouraged and directed towards sustainable production and consumption patterns with due emphasis on local, culturally appropriate and low-cost technologies

Science for sustainable development will fall short of its ultimate societal goals unless it is directly linked to innovation so as to achieve more sustainable production and consumption patterns. This requires greater investments in cutting-edge technologies that will reduce energy and natural resource requirements in both production and consumption processes. It will also require greater recognition of the value of indigenous knowledge, as well as the need to adapt existing technologies to meet local requirements. The social and behavioural sciences provide new insights and guidance to help facilitate the transition to more sustainable consumption patterns, especially in developed countries. Success will depend largely on the ability to forge new trusting relationships between the public and private sectors when devising policies and programmes that link science and technology.

Engage and involve: responsible engagement of the scientific and technological community in the decision-making process is indispensable for effective governance aimed at sustainable development

The scientific and technological community has a responsibility to inform and participate in decision-making processes in order to increase the impact of science in policy discussions and decisions. In an international arena increasingly defined by knowledge, in a global economy depending more and more on science and technology for its success, and in a world challenged by environmental and social problems that spill across political and cultural boundaries, scientists and engineers have an obligation to become more involved in sustainable development policy issues and processes. The products of scientific endeavours, such as integrated assessments, should be designed and disseminated in such a way as to contribute directly to decision-making processes. At the same time, it must be openly recognized and accepted that the accumulation of scientific knowledge is an iterative process; science and technology cannot have all the answers and uncertainty and risk are often inherent in the use of scientific knowledge. Moreover, the scientific and technological community has a major role to play, especially through its representative academies and professional organizations in promoting the public understanding of science, science education and literacy at all levels.

Introduction

1. The present paper reviews progress achieved and identifies priorities for implementation by the scientific and technological community related to chapter 31 of Agenda 21[1] entitled "Scientific and technological community". The role of science and engineering is also addressed in other chapters of Agenda 21, in particular chapter 34 ("Transfer of environmentally sound technology, cooperation and capacity-building") and chapter 35 ("Science for sustainable development"). Moreover, implementation of the different sectoral and cross-sectoral chapters of Agenda 21 (for example, on freshwater and health) must be based on sound knowledge[2] and the introduction of environmentally sound technology. This paper, however, focuses on the two priority issues in chapter 31: improving communication and cooperation among the scientific and technological community, decision makers and the public, as well as promoting codes of practice and guidelines.

2. These themes raise many challenges for the scientific and technological community. Our responses over the past decade have been proactive and significant in many areas, generating new initiatives, programmes and institutions related to sustainable development. However, as a community striving for increased integration, transparency and partnerships, we recognize that we have just begun the journey and that our actions to date have been clearly inadequate and too fragmented to effectively meet the challenges. Science, engineering and technology[3] are instrumental to advancing human civilization and improving the quality of life. The improper and insufficient application of knowledge has also led to growing threats to the earth's life support systems and has not enabled us to meet the basic needs of much of the world's population.

3. Ten years after Rio, it is difficult to report on progress on chapter 31 without serious reflection on the major events and challenges that have occurred during this period. Two major transformations are evident in our world. On the one hand, major global and regional changes in climate and the "health" of the biosphere have had serious implications for the sustainability of ecosystems and livelihoods, and, on the other, the simultaneous market-driven processes of globalization of people, ideas and goods have opened up both new challenges and opportunities.

4. Promoting the goals of a transition to sustainability, that is to say, meeting human needs while preserving the life support systems of the earth, has become a major challenge for the scientific and technological community. A significant response to this challenge has emerged from various global and regional programmes of environmental research, assessments and capacity-building mainly sponsored by the international organizations that make up the scientific and technological community, including the world's scientific academies and professional bodies and independent networks of scholars, scientists and engineers. This has been supported by relevant United Nations system organizations and by an informal network of national research funding agencies, called the International Group of Funding Agencies for Global Change Research (IGFA).

5. Decision makers at all levels need timely, reliable access to the knowledge generated by science and engineering to introduce rational policies that reflect a better understanding of complex technical, economic, social, cultural and ethical issues concerning society, the earth, and its environment. The important role played by scientists and engineers in informing and advising policy processes is expanding rapidly, and will continue to be an important part of global environmental governance but it is also increasingly extending its purview to the broader issue of governance of sustainable development. Indeed the report of the Secretary-General to the Millennium Assembly of the United Nations (A/54/2000), entitled "We the peoples: the role of the United Nations in the twenty-first century", recommends as a priority for the twenty-first century the need for more accurate scientific data.

6. The role of science and engineering in the current policy-making process at national and global levels regarding the three pillars of sustainable development — social, economic and ecological — is insufficient. The environmental science supporting the ecological pillar is rapidly evolving and the most visible area of activity. Current research has rapidly advanced the understanding of development and poverty alleviation that is focused on the economic and social pillars. While progress has been steady in the economic area, the scientific underpinning of the social pillar is less developed and requires increasing attention, including follow-up to the World Summit for Social Development.

7. In the 10 years since the Rio Earth Summit, many concepts, which seemed quite new or surprising at the time, have found general acceptance and there is growing awareness of sustainable development. In the Amsterdam Declaration,[4] four global environmental research programmes provided a powerful review and synthesis of our knowledge in this field and urged Governments, public and private institutions and the public to promote the development of "An ethical framework for global stewardship and strategies for Earth system management" and "a new system of global environmental science".

8. Sixty scientific academies of the InterAcademy Panel on International Issues (IAP) in May 2000,[5] stressed that scientific, technological and health capabilities can produce substantial progress over the next two decades towards a sustainable human future and that this progress will demand a threefold effort by the scientific and technological community: to promote the use of existing knowledge more widely and effectively; to generate new knowledge and beneficial technologies; and to work with Governments, international organizations and the private sector to promote a worldwide transition to sustainability.

9. The 1999 UNESCO/ICSU World Conference on Science, entitled "Science for the Twenty-first Century: A New Commitment", held at Budapest, bringing together scientists, engineers, and public sector decision makers from 155 countries, signalled a new determination within the scientific and technological community to forge a partnership with society. Two documents[6] were adopted which set out detailed principles and guidelines of a shared and sustaining vision of the symbiotic relationship between science and society that very much reinforced and advanced the objectives of Agenda 21 and especially chapter 31. Participants in the World Conference of Scientific Academies, Tokyo, process are encouraged to examine these documents, as they provide a very valuable and detailed picture of the scientific and technological community's views and commitments on a wide range of issues critical to sustainable development.

10. In addition to such major statements and conferences, the scientific and technological community has undertaken a multitude of research projects and programmes, meetings, and operational activities throughout the world — and on a wide range of scientific and technological issues relevant to sustainable development. Rather than present a long report card cataloguing these many initiatives, this paper will focus on sharing several key themes that highlight the lessons learned and illustrate the contribution of science, engineering and technology to sustainable development since Rio and in the future. Our goal is to provide examples of how we have contributed towards sustainable development and how we must increase and redirect efforts in future.

11. The scientific and technological community's preparatory process for the Summit has itself been highly pertinent to the points raised in chapter 31 concerning greater collaboration. Building on our first experience at the multi-stakeholder dialogue on energy and transport at the ninth session of the Commission on Sustainable Development, we have brought together five key international scientific and engineering institutions as well as contributions from many other scientific institutions and individuals, to prepare this paper. We see this collaborative effort at communication and integration as a critical step towards meeting the commitments within this paper, chapter 31 and the decisions arising out of the Johannesburg Summit.

12. This paper is structured as follows: following the introduction, section I draws attention to the role of the scientific and technological community in the alleviation of poverty and inequity in the transition to sustainable development; section II provides a series of examples of progress achieved and lessons learned since Rio related to a few priority themes; section III reviews the critical cross-cutting factor of ethics in relation to science, engineering and society; and section IV provides brief conclusions.

I. Poverty, inequity and sustainable development

13. Poverty and inequity threaten the daily survival of millions of people, particularly women and children. Poverty and inequity are also key catalysts of conflict and wars which often lead to drastic setbacks in the economic and social progress already achieved. The scientific and technological community recognizes that there will be many excellent reports, descriptions and indicators of the tragic level and consequences of poverty and inequity in other documents available to the Summit process.

14. Since Rio in 1992, and specifically over the past three to four years, poverty and inequity have risen higher on the agenda of the scientific and technological community. Our major concern is that, to date, science, engineering and technology have not played their full role in the world's attempts to respond to these fundamental challenges to sustainability. The scientific and technological community is convinced that there is already a very wide range of relevant, accessible and often inexpensive technologies and processes available to meet the basic needs of the poor and socially excluded. These include, among others: (a) progress on health and sanitation, particularly in the fields of infectious diseases, health of mother and child, improved hygiene, access to clean water and sanitation, and family planning practices; (b) research in the life sciences which are undergoing a major revolution through genetics and biotechnologies; (c) development of agriculture (drawing on specialized scientific and technological resources like those of the Consultative Group on International Agricultural Research (CGIAR)), based on studies of soils, land-use and land-cover change, improved irrigation practices and use of water, more sustainable use of agricultural chemicals, production and use of genetically modified plants, and use of radiation in the conservation of foods, as well as the appropriate use of traditional knowledge; (d) research in the field of energy including energy efficiency improvements, the control of emissions of greenhouse gases, and increased use of renewable energy sources such as solar, biomass and wind as well as studies on clean coal, use of natural gas, fuel cells, and research on safety and waste management for nuclear energy; and (e) the contribution of science to peace (as aimed at by Amaldi and Pugwash Conferences) and to the reduction of conflicts and the prevention of terrorism, which is essential for sustainable development. The basic needs of the poor and excluded must increasingly be taken into account in the setting of scientific and technological priorities.

15. One example of what the scientific and technological community may do to help alleviate poverty is in the area of disaster reduction and relief. Wherever disasters strike, invariably the poor suffer most in lives lost and costs to property. Events, such as El Niño, can be predicted up to six months before their occurrence. However, many national Governments are ill prepared to receive and use the information. Unused predictions do not generate public confidence and the packaging and dissemination of data for various stakeholders are a major obstacle to saving lives. There are many opportunities for the scientific and technological community to provide support for mitigation, advance preparation and relief activities related to such disasters.

16. Better technological choices, improved through scientific research and engineering knowledge, exist for many other areas related to poverty alleviation. The scientific and technological community is committed to working with all stakeholders and especially the major research funding agencies, the development assistance community and the private sector to establish a better balance in research priorities with a view to alleviating poverty and inequity.

II. Themes to illustrate progress in science and technology

A. Getting to decision-making: integrated assessments

Progress achieved

17. Opening up the decision-making process and increasing cooperation at all levels between the public, scientific and technological community and decision makers is a key programme area in chapter 31 of Agenda 21. A crucial role in the global governance of sustainable development that has found widespread acceptance since the 1992 Rio Conference has been played by the instrument of authoritative statements based on scientific assessments.

18. A good example of this is the substantial impact of the Intergovernmental Panel on Climate Change (IPCC) on policy. Assessments and outlooks were initially developed to inform the scientific community and over time they have evolved to provide advice to policy makers. Assessments have grown in importance and deal with many issues including climate, ozone, biodiversity, ecosystems, energy, water, large dams etc. The climate story goes back to the International Geophysical Year in 1957 when ICSU and others organized a systematic look at our planet and made the first carbon dioxide (CO_2) measurements in Hawaii. The World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) created IPCC in 1988 to provide input into the decision-making process by conducting rigorous assessments of the latest scientific literature. IPCC

completed its First Assessment Report in 1990, which summarized the state of knowledge of climate change and helped to launch the United Nations Framework Convention on Climate Change.[7] The Second Assessment Report in 1995 led to the negotiation of the 1997 Kyoto Protocol to the Convention.[8] The Third Assessment Report in 2001, which is likely to play a key role as Governments assess the adequacy of measures to protect the climate system, increases its focus on the regional implications of climate change and examines climate change in the context of development, equity and sustainability.

19. Another striking example of the value of integrated knowledge relates to the problem of ozone depletion. It shows how basic research has had huge impact in this domain following the discovery by F. S. Rowland and M. Molina of chemical reactions that destroy ozone. This scientific discovery eventually led to the establishment of the international stratospheric ozone assessment and the development and implementation of the Montreal Protocol on Substances that Deplete the Ozone Layer.[9]

Lessons learned

20. One of the lessons learned is that bringing together policy makers and the scientific and technological community to produce and approve the reports ensures that all key stakeholders take ownership of the findings. Publication of the reports and dissemination by the Web ensures that the results are accessible to policy makers, members of the public and the media. The experience has identified six key conditions vital to getting information to decision makers:

- *Saliency*: an important problem/solution seen as urgent by society;
- *Clarity*: a core message that is succinct, with quantitative indicators;
- *Credibility*: transparent, representing the view of prominent scientists;
- *Constructiveness*: action-oriented, offering policy options without being prescriptive;
- *Legitimacy*: supported by government, private sector and civil society;
- *Vision*: basic and applied knowledge that provides early warning.

21. Another important lesson is that high-quality, independent research results are essential for a reliable integrated assessment. For example, IPCC was able to take advantage of the rapid expansion in global environmental change research as represented, for example, by the Tropical Ocean and Global Atmosphere (TOGA) project from 1985 to 1995 which significantly enhanced our understanding of the role of oceans in climate processes. In 1986, ICSU established the International Geosphere-Biosphere Programme (IGBP) connecting global change and the climate science of the World Climate Research Programme. Collaboration is now extended to the International Human Dimensions Programme (IHDP) and DIVERSITAS, a global biodiversity research programme. The results of these programmes since 1992 have been synthesized and reviewed at the Open Science Conference in Amsterdam[10] which brought together a much wider scientific community, including policy makers and the private sector. The ICSU Scientific Committee on Problems of the Environment (SCOPE) mandate includes the carrying out of assessments.

22. The Global Biodiversity Assessment (GBA) prepared in 1995 provided a detailed review of all aspects of biodiversity but it did not establish an appropriate authorizing environment so its results have not been used by policy makers. Learning from these past experiences, the Millennium Ecosystem Assessment[11] has recently become operational and has negotiated an effective authorizing environment prior to its launch.

23. Other lessons learned point to the need for increased collaboration by a wide variety of stakeholders in a broad, open and interdisciplinary manner. For assessments to be useful, they must directly involve policy makers, scientists (in the pure and applied sciences), social scientists, non-governmental organizations, and the private sector. Increased efforts to mobilize the participation of members of more disciplines, especially social scientists, and scientists from a wide range of geographical and linguistic backgrounds, are also required.

24. Systematic observations and reliable indicators are essential to the success of integrated assessments. Continuing investment is necessary in the existing observation infrastructure, for example, the Integrated Global Observing Strategy (IGOS), the Global Ocean

Observing System (GOOS), the Global Climate Observing System (GCOS) and the Global Terrestrial Observing System (GTOS), to increase reliability, improve models, and make global data available for decision-making locally. Consideration also should be given to developing additional integrated assessments including coastal zone management, desertification, agriculture, health and megacities.

B. Changing patterns of consumption and production

Progress achieved

25. Chapter 4 of Agenda 21 and the Commission on Sustainable Development have both devoted considerable attention to the issue of changing production and consumption patterns. The equitable use of global resources is a debated but fundamental aspect of sustainable development. The richest 20 per cent of the world accounts for 80 per cent of consumption; the poorest 20 per cent accounts for a little over 1 per cent. Over the next 50 years, growth rates of consumption could continue well beyond those of population but this must be achieved in a sustainable way. Lifestyles of affluent countries in Europe and North America have become the model for consumers in developing countries. If those currently living in poverty consumed at the rate of an average North American, global consumption of energy and materials would increase sixfold. Reduction of consumption is resisted and is often seen to threaten lifestyles, competitiveness and profitability. Economic wealth and quality of life, however, need not decline as a result of changing consumption patterns.

26. Science and technology is important both to facilitating enhanced efficiency in production processes all across the globe and to helping improve the quality of life and working conditions/opportunities for the poor through sustainable consumption patterns. The scientific and technological community is also aware that, through both technology and behavioural change, we need to confront the challenge of the transition to more sustainable consumption patterns in the North.

27. IAP gathered global leaders in science, engineering and technology in Tokyo at its Conference on Transition to Sustainability in the Twenty-first Century in May 2000 and identified consumption as one of the six most important and challenging issues in the transition to sustainability. UNEP has recently published the "Youth and Sustainable Consumption Handbook" and at the Borgholm youth summit it was stated that, concerning consumption, the Western lifestyle must be on the agenda at the World Summit on Sustainable Development.[12]

28. The report of the scientific and technological community to the Commission on Sustainable Development at its ninth session in April 2001[13] concerning sustainable energy and transport provides a number of proposals on ways to significantly contribute to enhancing the sustainability of the production and use of energy and transport services.

29. There is evidence that less energy and materials-intensive industries and services can become an increasing source of progress in changing production and consumption patterns. Over the last decade, several approaches have been explored to reduce energy and resource consumption through production process and product design. The concept of "cleaner production" gained recognition as a cost-effective approach. The UNEP Sustainable Consumption Programme applies the "life cycle approach" to consumer needs by understanding consumption and encourages cost-effective improvements.[14] Green chemistry, a potential scientific breakthrough, enables the recycling of waste, and production of environmentally safe products and has the potential of lower initial investment cost. With scientific and engineering knowledge, public pressure and private action changes in consumption and production patterns are slowly being made. Aluminium cans weigh 40 per cent less than a decade ago. In Europe, car manufacturers must recycle 85 per cent of a vehicle by 2005, with the figure rising to 95 per cent by 2015. The scientific and technological community is making, and will continue to make, significant contributions to these processes of eco-efficiency.

Lessons learned

30. Currently, we have not made nearly enough progress in sustainable production and consumption and are confronted with a massive implementation gap. Current technology fixes, end-of-pipe solutions, and efficiency improvements are vital but insufficient. Our current approaches are too narrow and linear and system innovations are required that pursue changes and transformation that combine societal, institutional and technological changes. Partnerships are needed among developed countries and developing countries,

the private sector, the scientific and technological community and others, with the goal of identifying and implementing opportunities to leapfrog to efficient technologies and new models and approaches to providing food, energy, transport and water as well as more sustainable cities. The implementation gap is of particular relevance to the social sciences and they must focus on developing new approaches to bringing knowledge to the attention of decision makers to enable them to narrow the implementation gap. The necessary behaviour changes are possible given the political will, science and technology and an informed society.

C. Capacity-building and education

Progress achieved

31. Capacity-building for science and technology refers to the full array of science and technology infrastructure and governmental and other support necessary for a country to create and maintain a productive and independent scientific and technological community. The development of such capacity is a permanent challenge in **all** countries, as there are always new science and technology developments on the horizon. Today, there are particularly deep concerns about the shortage of science and engineering resources in developing countries. They suffer on three counts: (a) they do not produce enough scientists and engineers for their own requirements, as education and training infrastructure is inadequate; (b) they spend scarce foreign currency to send their students for training in developed countries; and (c) when their efforts are successful in generating new scientists and engineers, people are enticed to leave to work in other countries.

32. In addition, the worldwide trend in enrolment in science and engineering appears to be declining. The earning prospects in other fields have reinforced the inclination of parents and students towards other careers. Studies by science and technology academies have shown that the loss of interest in mathematics and science, particularly problematic with girls, begins in primary school and accelerates through the secondary school years. By the time the students reach university, it is already too late for any remedy. These studies have identified one of the problems to be the science education system itself. Too often, the current model of science education is very formal and constructed from a collection of unrelated facts learned by memory.

33. To supplement the relative inefficiency of knowledge transfer, more and more emphasis has been placed on enquiry-based education, with a strong experimental component, plus museums and activity centres, clubs or other out-of-school activities. Also, today Internet or other multimedia products offer direct access to science and technology content. Many members of the scientific and technological community have been involved in both formal and "out-of-school" science and technology programmes during the past decade.

34. To increase the number of young people engaged in science, many countries have gone back to basics, that is to say, primary and secondary school science and mathematics education and the career development of mathematics and science teachers. Academies like the United States of America National Academy of Sciences and the French Académie des Sciences have launched large-scale programmes (respectively, "Hands On" and "La main à la pâte") to renovate primary school science education. Similar programmes have now been launched in a number of countries, including Australia, Brazil, Chile, China, Israel, Malaysia, Mexico, Morocco, Nigeria, Senegal and Sweden.

35. ICSU has set up a Committee on Capacity-Building in Science (CCBS) to address these issues. ICSU/CCBS has been organizing a series of international conferences on primary school science and mathematics education commencing in Beijing, November 2000, Kuala Lumpur, October 2001 and Rio, September 2002, aimed at building regional networks for science education. Such meetings facilitate the exchange of experiences in science education from many countries and regions. IAP has launched a special international programme on science education and has also convened a meeting in Monterrey, Mexico, that will lead to a series of regional events. Many other science education programmes are under way and the report of UNESCO as task manager for chapter 36 of Agenda 21 reviews action in this field.

36. Addressing capacity-building programmatically is relatively new and is evolving rapidly, often in response to new science and technology challenges. The Global Change System for Analysis, Research and Training (START) was established in 1992 in response to the shortage of developing country expertise in

environmental change and sustainable development. As one of seven regional centres, the START Regional Research Centre for Temperate East Asia in China used fellowships, workshops, Internet and research training involving scientists from every country in East Asia and has now also developed a major research project on aridification and its implications for human sustainability and mitigation strategies in northern China.[15] START, with the International Foundation for Science (IFS) and the Third World Academy of Sciences (TWAS), has developed a Decadal Plan for Capacity-Building, a large-scale effort to increase the number of scientists trained in multidisciplinary research, assist in career establishment, enhance skills, and retain scientists in their careers.

37. TWAS has a long-standing programme of research grants and lectureships targeted at least developed countries. The centres of excellence of the Third World Network of Scientific Organizations (TWNSO)[16] serve as a model for institutional capacity-building. IAP is supporting capacity-building of African academies. The Inter-Academy Council (IAC) is conducting an in-depth and wide-ranging study of capacity-building and brain drain in developing countries. The World Federation of Engineering Organizations (WFEO) and the International Federation of Consulting Engineers (FIDIC) have been working on building the capacity of engineering institutions in developing countries on a bilateral basis, including accreditation of courses, recognition of degrees and registration of professionals and pairing on infrastructure projects. The ICSU scientific unions, national scientific members and interdisciplinary bodies are also carrying out a wide range of capacity-building activities, including the ICSU Committee on Science and Technology in Developing Countries (COSTED).

Lessons learned

38. While only a very few examples since Rio have been mentioned above, there have been a multitude of capacity-building initiatives for science and technology undertaken all across the world. Each year millions of young people, scientists and engineers and others have participated in hundreds of thousands of training programmes, fellowships, educational exchanges, special symposiums, congresses, and awareness-building activities offered by Governments, public and private educational institutions, the private sector, foundations, international organizations and many others.

39. One of the most important lessons we have learned is that our approach to date has been too fragmented and uncoordinated to achieve the “critical mass” necessary to enable many countries to effectively take advantage of science and technology to accelerate the meeting of their own development objectives. This critical mass must be complemented by adequate infrastructure, including high-quality universities, modern, well-equipped and well-maintained laboratories, independent research funding mechanisms and especially peer-review mechanisms, access to basic communications including the Internet, and adequate salaries and career recognition.

40. The scientific and technological community must catalyse Governments and industry to invest more in education, training and research and development, especially in developing countries. They are not likely to solve, even in the medium term, the problem of the increasing shortage of scientists and engineers necessary to satisfy the requirements of the expanding knowledge economy. Efforts should be made to support the mobility of scientists and engineers to promote the exchange of experience and capacity that will benefit all parties.

41. Increased priority should be given to promoting and facilitating the participation of women in this training. Women remain an underutilized intellectual resource worldwide, particularly in science and technology disciplines, and yet they profoundly shape the attitudes towards sustainable lifestyles that policy makers hope to achieve. Educating and employing women could significantly accelerate a country’s transition from “developing” to “developed” via a more sustainable path.

42. Consideration should be given to promoting more exchanges of scientists and engineers within the South. A number of countries have extensive science and technology capacity that they could share with other developing countries. Innovative programmes and policies to facilitate and support such exchanges are needed. Some developing countries are able to provide accessible and affordable science and engineering education for students from other developing countries.

43. The challenge of brain drain, which is not exclusive to developing countries, must be placed higher on our policy agenda. New partnerships and

dialogue between receiving and sending countries and the scientific and technological community are necessary and urgently required to respond to this problem. Our goal is to develop new model agreements or "rules of the game" that will help to resolve these issues in the next five years.

44. The establishment of regional sustainable development centres/networks in representative locations in poverty-stricken areas of the world is a high priority. Such centres/networks could be linked by effective communication networks with senior scientists and engineers serving as advisers and mentors in critical fields. The centres could serve as focal points for capacity-building for students from developing countries and as training centres for visiting volunteer engineers and scientists.

45. Professional educational programmes that include the goals of sustainable development are also needed for scientists and engineers throughout their professional careers. We also need to develop a science-literate civil service capable of technology management and a civil society that understands these challenges and their importance to human welfare and sustainable development.

46. The scientific and technological community is committed to strengthening partnerships within the field of capacity-building and education with all other stakeholders, but particularly the education community, the development assistance community and the private sector.

D. Information and communications technology

Progress achieved

47. Information and communication are central to the role of science and technology in sustainable development. Strategies for sustainable development are dependent on scientific studies and new technologies. Better communication between the scientific and technological community, decision makers and the public is essential for the effective use of this information. Chapter 31 of Agenda 21 calls for full and open sharing of data as well as transfer of skills. The discovery of new information as well as the sharing and proper use of it is a responsibility and a challenge of the scientific and technological community.

48. In the past 10 years, there has been greater progress in the development of information and communication technology than at any time in human history. These changes are transforming the way in which the world economy operates and present both challenges and opportunities. This technology, with potential for improving cooperation and information exchanges, has opened new fields of research and information processing. To date, this technology has not been fully exploited.

49. Space systems and remote sensing technologies are examples of new technologies, that have contributed towards our understanding of global systems. Currently, researchers using space data processing and interpretation are developing land/atmosphere/ocean models to further our understanding of earth systems by examining areas such as the ocean (ocean circulation, ocean waves, air-sea interaction etc.), ozone chemistry and trace gases and their interaction with climate change, sinks and sources of greenhouse gases, changes in land use and land cover (key for estimating global and regional carbon cycles), desertification and urban environments. More generally, science and technology are equally fundamental to pursuing solutions to human health and social issues, ranging from key human health questions such as acquired immunodeficiency syndrome (AIDS) to sustainable transportation.

50. Large-scale production and analysis of new information are a prerequisite of sustainable development. However, rapid technological changes have led to a digital divide between developed and developing countries (the have-nets and the have-nots), since in many countries the infrastructure does not exist to access this information. Several efforts have been made to increase infrastructure in developing countries. For example, in Chennai, India, the M. S. Swaminathan Research Foundation set up Internet centres to provide access to the information on the Internet to villagers. There are over 30 such experiments under way in India alone. The International Centre for Theoretical Physics (ICTP)/ TWAS have added an Internet eJournals delivery programme to complement their donations programme for scientific journals. Other partnerships, such as SciDev.NET, involving *Nature* and *Science* and the scientific and technological community, have launched networks dedicated to reporting on science. The International Network for the Availability of Scientific

Publications (INASP) has implemented a partnership between university faculties and research and information specialists to facilitate access to knowledge in developing countries. These efforts need to be amplified, especially for public-health information, such as in the World Health Organization (WHO) developing programme to provide medical information over the Internet to the developing world.

51. UNESCO and ICSU have sponsored two Conferences on Electronic Publishing in Science (1996, 2001) which brought together scientists and publishers to discuss the rapid changes in this field. Despite important efforts to promote the availability of knowledge by groups such as the ICSU Committee on the Dissemination of Scientific Information, INASP and the World Data Center, providing the infrastructure, training and affordable access to updated scientific information remains a major challenge. Dissemination of information to developing countries lacking adequate telecommunications networks, reliable electricity supplies, technological training, and other key infrastructure, has been particularly difficult. For example, the World Data Center was established 50 years ago to provide data to scientists, assure data preservation, improve data quality, and promote a policy of full access for scientists in all countries. While successful in these goals, the World Data Center has not succeeded in extending its base operations outside of the industrialized countries.

52. Intellectual property rights, patents and copyrights also have an important role in the global dissemination of information. Currently, learned journals and databases are often available only at prices that are prohibitive for developing countries, although some organizations are now providing new approaches to facilitate access over the Internet. The requirement for ongoing upgrades for computer hardware and software is expensive, further preventing transfer of accumulated knowledge to developing countries. Of particular concern is the tightening of the intellectual property rights laws relating to databases pioneered by the European Union (EU), which could make the access to the basic scientific information necessary for development prohibitively expensive. Over the past decade, there has also been an increasing concern related to the evolving commercialization of scientific data and information which risks challenging the principle of full and open access to data and information for research and education.

Lessons learned

53. The scientific and technological community seeks to build, maintain and innovate tools and knowledge for better understanding earth and social systems. At the same time, we seek to increase communication and dissemination of this information to policy makers and the public. Currently, the greatest challenge lies in distributing information to developing countries. Increased capacity-building, and increasing infrastructure, training and affordable access are essential for the global communication of information. The scientific and technological community must also remain vigilant in order to protect the principle of full and open access to information.

III. Ethics, science, engineering and society

54. Chapter 31 of Agenda 21 sets out as a key objective the need to develop, improve and promote international acceptance of codes of practice and guidelines recognized by society. Since Rio, some progress has been made in the development of codes of practice and guidelines within the scientific and technological community. Engineers and medical doctors are bound by professional codes of ethics that state categorically that public interest — life, safety, and property — overrides private interest in the practice of their profession. WFEO incorporated a Code of Environmental Ethics into its Engineering Code of Ethics. The engineering community also endorsed the Earth Charter, which calls upon member Governments, professionals and civil society to accept a moral and ethical guide of conduct and to commit to sustainable development. The ICSU Committee on Responsibility and Ethics in Science is completing an analysis of 115 codes of practice and standards from within the scientific and technological community.

55. Society depends on scientists and engineers as responsible individuals, to guard against negligence and misconduct and to safeguard mankind. Ethical challenges include: conflict of interest, whistle-blowing, human rights, free migration of professionals, and research funding. In addition, scientists and engineers are increasingly being called upon to become

more engaged with the public and policy makers on highly emotive issues such as food safety, genetically modified organisms, gene technology, stem cells, cloning, use of animals in research, and nuclear energy, to name a few. The view of scientists and engineers solely as "independent" knowledge generators has been irrevocably altered by changes in society. Scientists now acknowledge they must take responsibility for the implications of their results, potential uses and abuses, and impacts on people and societies.

56. Ethics are particularly central to the integrity of the process and results of research and design activities carried out by individual scientists as well as to the consequences of the application of science and technology to solving problems. Both aspects require more attention and enhanced dialogue in partnership with other stakeholders. We wish to draw attention to several key issues concerning codes of ethics and guidelines. First, codes from many bodies deal only with the responsibility and ethics of scientists who are members of the relevant organizations and mainly concern such factors as honesty, integrity, transparency etc. Second, many codes deal exclusively with activities within a national context and do not explicitly provide for international activities. Third, there appears to be less coverage within current codes of the social or community responsibilities of scientists, including their role in sustainable development. Fourth, there appears to be a need for more effective and visible efforts to monitor and implement existing codes. Fifth, mechanisms to promote interaction between the institutions adopting codes and other stakeholders within society regarding the development and monitoring of these codes have not yet been sufficiently developed.

57. The UNESCO World Commission on the Ethics of Scientific Knowledge and Technology has made important progress, including the preparation of reports on "The Ethics of Outer Space", "The Ethics of Energy" and "The Ethics of Freshwater Use". UNESCO is also carrying out an important programme of work on bioethics which has included the adoption of the Universal Declaration on the Human Genome and Human Rights.

58. Scientific knowledge and new technologies continuously challenge society's values. Scientists and engineers have an obligation to contribute to this discussion. No sector of society has more knowledge about issues that generate ethical dilemmas and also no sector has a greater capacity to help to resolve them than the scientific and engineering sector. For this reason, it is important to promote ethical sensitivities beginning with individual scientists and engineers. An important opportunity exists for enhancing the understanding of ethics throughout the scientific and technological community and society by ensuring that these issues are integrated within our education programmes at all levels. This will require collaboration by the scientific and technological community, and especially academies of science, with national and local education authorities, and other relevant ministries, as well as the public.

59. Closely related to these ethical concerns is increasing awareness that cultural diversity is a factor that must be effectively integrated within efforts to achieve sustainable development. Each country faces its own challenges and requirements guided by its own culture and values. The scientific and technological community welcomes the opportunity to engage in an open and constructive dialogue with policy and decision makers and society that will enable us to better reflect the wide diversity of culture and values throughout the world.

60. The 1999 World Conference on Science devoted considerable attention to the issue of ethics and science. A major document from this Conference, the Science Agenda: A Framework for Action, highlighted, inter alia, the following points: "ethics and responsibility of science should be an integral part of education" (sect. 3.2, para. 71); "the international scientific community, in cooperation with other actors, should foster a debate, including a public debate, promoting environmental ethics and environmental codes of conduct" (ibid., para. 73); and "Governments should encourage the setting up of adequate mechanisms to address ethical issues concerning the use of scientific knowledge and its applications" (ibid., para. 76).

61. The scientific and technological community is committed to extending its efforts regarding ethics and society and will increase its capacity to implement and monitor its codes of ethics and guidelines in collaboration with others. At the same time, efforts will be made to extend existing codes as appropriate to deal with sustainable development. Science and technology organizations and individual scientists will also be encouraged to carefully consider their possible adherence to the Earth Charter.

IV. Conclusions

62. This paper has presented some of the significant contributions that science, engineering and technology have made and presents some suggestions for future commitments. The international scientific and technological community can provide assistance at the strategic level by contributing to the decision-making cycle in respect of: (a) proactively seeking opportunities, generating early warning, and finding new ways of understanding complex interdependent aspects of sustainable development; (b) engaging extensively with policy formulation and implementation, by providing reliable information for setting policy goals; and (c) helping policy evaluation by monitoring implementation, providing assessments of change, learning from experience, and integrating new information.

63. To achieve these goals, science and engineering must fully engage with societal needs — a meaningful dialogue must be established with policy makers at all levels. Over the next five years, the scientific and technological community is committed to significantly enhancing the active participation of scientists and engineers within: national sustainable development commissions; all levels of government, as advisers to heads of State, heads of international agencies, parliaments etc.; and private sector boards of directors. Furthermore:

- The scientific and technological community needs to include strengthened elements of problem-solving by building upon the results of traditional disciplines and curiosity-driven processes while also becoming more focused on society and its needs.

64. To reflect the contract between science and society, there are three cross-cutting requirements for accomplishing these goals:

- The world must reverse its under-investment in science and engineering. This implies a significant increase in investment. It is clear that investments in these areas are tremendously productive, with economic and social returns much greater than those on many other investments. Investments in research and development (R&D) in the developed world are typically only 2-3 per cent of GDP; in much of the developing world, less than 1 per cent. The global total R&D must be much higher. Within overall R&D investment, a target for sustainable development, possibly 20-25 per cent of the total, may be appropriate;
- The international science and technology community must scrupulously nurture its commitments to ethics and to the pursuit of human welfare. The science, engineering and technology community will increase its legitimacy at the national and international levels by operating in a coordinated, transparent, balanced, and merit-based way, and providing inputs that are credible, independent and valid. At the national and international levels, the science and engineering community must encourage widespread development and application of codes of ethics through debate and consensus with the general public;
- Objective, transparent indicators are a critical requirement for tracking progress. The scientific and technological community will work to establish clear indicators for all its commitments and to assist policy makers and the general public in tracking its performance towards sustainable development.

Notes

[1] *Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992,* vol. I, *Resolutions Adopted by the Conference* (United Nations publication, Sales No. E.93.I.8 and corrigendum), resolution 1, annex II.

[2] The United Nations Conference on Science and Technology for Development (1979) concluded that developing countries should be helped not only with the transfer of technology but also with the transfer of knowledge.

[3] Science, which includes the natural and social sciences, constitutes a multidisciplinary body of knowledge about nature and society gained through observation and experimentation. While its primary functions are descriptive and explanatory, science also affords guidance on normative goals such as improvements in the human condition, promotion of civil rights, and wiser ways of living. Engineering involves the practical applications of this knowledge and of empirical experiences to create structures, facilities, processes and products. Those processes and products that have become established by the acceptance of society and its marketplace are commonly classified as technology.

[4] Amsterdam Declaration on Global Change, Challenges of a Changing Earth: Global Change Open Science Conference, Amsterdam, the Netherlands, 13 July 2001.

[5] "Transition to Sustainability in the 21st Century: The Contribution of Science and Technology", a statement of the world's science academies, World Conference of Scientific Academies, Tokyo, May 2000.

[6] Declaration on Science and the Use of Science Knowledge; and Science Agenda: Framework for Action.

[7] United Nations, *Treaty Series*, vol. 1771, No. 30822.

[8] FCCC/CP/1997/7/Add.1, decision 1/CP.3, annex.

[9] United Nations, *Treaty Series*, vol. 1522, No. 26369.

[10] See Amsterdam Declaration, July 2001, in which four research programmes "recognize that, in addition to the threat of significant climate change, there is growing concern over the ever-increasing human modification of other aspects of the global environment and the consequent implications for human well-being".

[11] Implemented by UNEP, UNESCO, the World Bank, the World Resources Institute and ICSU, including the United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, particularly in Africa (United Nations, *Treaty Series*, vol. 1954, No. 33480); and the Convention on Wetlands of International Importance, especially as Waterfowl Habitat (ibid., vol. 996, No. 14583).

[12] Youth Conference on Environment and Sustainable Development, Borgholm, Sweden, 2001 (http://www.youth.se/default.asp).

[13] E/CN.17/2001/6/Add.2, discussion paper contributed by the scientific and technological communities.

[14] Global Ministerial Environment Forum, held in Malmö, Sweden, in May 2000, endorsed the approach and encouraged implementation.

[15] Sponsored by the Natural Science Foundation of China and the Chinese Academy of Sciences.

[16] See TWNSO/United Nations Development Programme (UNDP), *Sharing Innovative Experiences*, vol. 1, *Examples of Successful Initiatives in S&T in Developing Countries* (New York, UNDP, 1998), and vol. 2, *Examples of Successful Initiatives in Conservation and Wise Use of Indigenous and Medicinal Plants in the South* (Karachi, Pakistan, 2000).