Science and Technology for Sustainable Development

Consensus Report of the Mexico City Synthesis Workshop, 20-23 May 2002
Summarizing findings from a two-year consultation process conducted by the International Council for Science, the InterAcademy Panel, the Third World Academy of Sciences, and the Initiative on Science and Technology for Sustainability

This paper presents the consensus conclusions of the Mexico City Synthesis Workshop on Science and Technology for Sustainable Development, hosted by the National Autonomous University of Mexico (UNAM) on behalf of a joint Organizing Committee from the International Council for Science (ICSU), the Third World Academy of Sciences (TWAS), and the Initiative on Science and Technology for Sustainability (ISTS).[1] The Workshop brought together leaders of, and participants in, more than a dozen fact-finding studies, discussions, conferences and workshops conducted over the two years leading up to the World Summit on Sustainable Development (WSSD) by international scientific and technology community (see Table 1). Each of these contributing sessions had addressed the question "How can science and technology contribute more effectively to achieving society's goals of sustainable development?" from a particular perspective. These perspectives included global views from international science organizations, regional views grounded in grass-roots efforts to harness science and technology in support of sustainable development, assessments of potential contributions from global change science, and critical analyses of experience in designing institutions and financing for science and technology directed toward solutions to sustainability problems.

Findings of the individual sessions were summarized in a background paper for the Mexico City Workshop which is included here as Annex 2. Participants in the Workshop reviewed the background paper and the individual contributing reports in addition to bringing their own rich backgrounds of experience to the table. They then formulated the present consensus report.[2] This was presented to President Vicente Fox of Mexico at the close of the Workshop and tabled by ICSU at the 4th Preparatory Workshop for the World Summit on Sustainable Development, immediately following the Mexico City Workshop. The consensus findings of the Mexico City Workshop are summarized below.

[1] The Organizing Committee consisted of Jose Sarukhán, William Clark, Robert Corell, Gisbert Glaser, Mohamed Hassan, Calestous Juma, Robert Kates, Akin Mabogunje, and Thomas Rosswall. Further information on the Mexico City Workshop, including copies of the background papers prepared for it, and the material presented there, is available at http://sustainabilityscience.org/ists/synthesis02.htm.

[2] Participants in the workshop and authors of this consensus report are listed in Annex 1. Please send comments or questions to the Workshop secretariat, c/o Professor William Clark (william_clark@harvard.edu).

Table 1: Chronological Listing of Activities Synthesized at the Mexico City Workshop

(Further details on these contributing activities are provided in Annex 2. Unless otherwise noted, copies of the reports from each are available through the 'Events' section of the *Forum on Science and Technology for Sustainability*, http://sustainabilityscience.org.)

- Tokyo Symposium organized under the auspices of the World's Scientific Academies; Tokyo, Japan, 15-18 May 2000. [Interacademy Panel. 2000. *Transition to Sustainability in the 21st Century: The Contribution of Science and Technology*. Tokyo: IAP, http://www4.nationalacademies.org/intracad/tokyo2000.nsf/all/home.]
- Friibergh Workshop organized under the auspices of the ISTS; Friibergh, Sweden, 11-14 October 2000. [ISTS/Friibergh. 2000. *Sustainability Science*. Friibergh: ISTS. Summarized in R. W. Kates et al. 2001. "Sustainability science." *Science* 292: 641-642.]
- Amsterdam Global Change Open Science Conference organized under the auspices of the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme (IHDP), and the World Climate Research Programme (WCRP); Amsterdam, Netherlands, 10-13 July 2001. [IGBP. 2001. *Global Change and the Earth System: A Planet Under Pressure*. IGBP Science Series, No. 4. Stockholm: IGBP, http://www.igbp.kva.se//uploads/ESO_IGBP4.pdf ; and IGBP. 2002. *The Amsterdam Declaration on Global Change – Challenges of a Changing Earth*, http://www.sciconf.igbp.kva.se/fr.html.]
- Abuja Regional Workshop organized under the auspices of the ISTS; Abuja, Nigeria, 13-15 November 2001. [ISTS/Abuja. (A. Mabogunje, ed.) 2001. *African Perspectives on Sustainability Science*. Abuja: ISTS.]
- Report produced under the auspices of ICSU and the WFEO in collaboration with the IAP, ISSC, and TWAS as Dialogue paper to the 2nd Preparatory Committee of the WSSD. 28 January 2002. [ICSU. 2002a. *Report of the Scientific and Technological Community to the World Summit on Sustainable Development (WSSD)*. ICSU Series on Science for Sustainable Development, No. 1. Paris: ICSU, http://www.icsu.org/Library/WSSD-Rep/vol1.pdf.]
- Chiang Mai Regional Workshop organized under the auspices of the ISTS; Chiang Mai, Thailand, 4-6 February 2002. [ISTS/Chiang Mai. (L. Lebel, ed.) 2002. *Sustainability Science: Knowledge, Technology and Institutions for Sustainability Transitions in Asia*. Chiang Mai: ISTS.]
- Paris Workshop organized under the auspices of the Global Change Science Programmes; Paris, France, 4-6 February 2002. [Global Change. 2002. *Sustainable Development: The role of international science*. Bonn: IHDP].
- Trieste Workshop organized by TWAS under the auspices of the ISTS; Trieste, Italy, 6-9 February 2002. [TWAS. 2002. *Lessons Learned from the Workshop on Science, Technology and Sustainability: Harnessing Institutional Synergies*. Trieste: TWAS/ISTS.]
- Bonn Regional Workshop organized under the auspices of the ISTS; Bonn, Germany, 27 February - 1 March 2002. [ISTS/Bonn. 2002. *European Science for Sustainability: Achievements and Challenges*. Bonn: ISTS.]
- Santiago Regional Workshop organized under the auspices of the ISTS; Santiago, Chile, 5-7 March 2002. [ISTS/Santiago. (G. Gallopín, ed.) 2002. *Report on the Latin American and Caribbean Regional Workshop on Science and Technology for Sustainable Development.* Santiago: ISTS.]
- Ottawa Regional Workshop organized under the auspices of the ISTS; Ottawa, Canada, 25-26 March 2002. [ISTS/Ottawa. 2002. *Science and Technology for Sustainability: North American Challenges and Lessons.* Ottawa: ISTS.]
- Cambridge Workshop organized under the auspices of the ISTS, ICSU, and TWAS; Cambridge, Massachusetts, USA, 10-12 April 2002. [ISTS/Cambridge. 2002. *Mobilizing Science and Technology for Sustainable Development*. Cambridge: ISTS.]
- Report produced under the auspices of the ICSU and the WFEO in collaboration with the IAP, ISSC, and TWAS as Summary by the Scientific and Technological Community for the Multi-Stakeholder Dialogue Segment of the WSSD PrepCom IV Meeting, draft of 23 April 2002. [ICSU. 2002b. *Science and Technology as a Foundation for Sustainable Development*. Paris: ICSU.]

1) **Sustainable development** has occupied a place on the global agenda since at least the Brundtland Commission's 1987 report *Our Common Future*. The prominence of that place has been rising, however. UN Secretary-General Kofi Annan reflected a growing consensus when he wrote in his Millennium Report to the General Assembly that "Freedom from want, freedom from fear, and the freedom of future generations to sustain their lives on this planet" are the three grand challenges facing the international community at the dawn of the 21st century. Sustainability has become a "high table" issue in international affairs, and on many regional, national, and local agendas. Though visions of sustainability vary across regions and circumstances, a broad international agreement has emerged that its goals should be to foster a transition toward development paths that meet human needs while preserving the earth's life support systems and alleviating hunger and poverty – i.e., that integrate the three pillars of environmental, social and economic sustainability. This should be achieved through forms of governing that are empowering and also sensitive to the needs of future generations.

2) **Science and technology (S&T)** are increasingly recognized to be central to both the origins of sustainability challenges, and to the prospects for successfully dealing with them. Science and technology brought us the CFCs that preserved our foods, cooled our homes… and depleted the ozone layer. But they also brought us the research and monitoring programs that raised the ozone alarm, and the substitute technologies that have allowed us to continue meeting the needs that CFCs have fulfilled in a manner less damaging to the environment. Science and technology have also played a central role in bringing about the increases in agricultural yields and distribution systems that have helped to keep the most of the world from famine… but only at the cost of significant environmental degradation. Promoting transitions toward sustainability in the 21st century will require much more than improvements in the production and effective use of science and technology but the latter will be essential components of most solutions.

The Contributions of S&T to Sustainable Development

3) **Past contributions**: The consultative process synthesized here identified a rich variety of ways in which S&T has already contributed to sustainable development around the world. For example, scientific measurement and analysis identified the social, economic and environmental dangers associated with global changes in the climate and ozone layer. The Consultative Group on International Agricultural Research (CGIAR), at its best, has designed and implemented regional crop breeding and testing systems which incorporate a mix of farmer practices, indigenous knowledge of crops, and modern breeding methods. Mexico's National Commission on Biodiversity (CONABIO) built a GIS-based data system for the country that has enhanced the self assessment capacity on biodiversity of the country's citizens, firms, and other stakeholders, providing a range of decision-support services. At the local scale, typical of a multitude of successful efforts is the Azraq Oasis Conservation Project in Jordan which combined local knowledge with modern science to restore degraded land systems to the state in which they support both nature and society.

4) **Near-term prospects**: Evidence reviewed in our consultations suggests a wide range of science and technology based activities that, if vigorously pursued over the next five years, could yield tangible improvements in local and regional sustainability. Some of these activities involve the creation of new knowledge, others the better and more wide-spread application of knowledge that already exists. Which specific activities merit highest priority should be decided through consultation with affected stakeholders struggling with sustainable development action programs in particular places around the world. Nonetheless, the following examples suggest the range of contributions that could reasonably be expected from the S&T community over the near term:[3]
   a) Advances in the ability to forecast anomalous climate conditions some months in advance have raised the prospect of significantly reducing the vulnerability of food and water systems to drought. Initial experience makes it clear that realizing this potential requires parallel development of integrated application and use programs. Existing successes in Peru and elsewhere could be deepened and extended to other regions of the world.
   b) Some "eco-labeling" and other certification programs have begun to have an impact on consumer choice, for example in European purchases of tropical hardwoods. The effectiveness of such efforts depends both on the credibility of the certification process and the marketing of the certified product. Early successes with forest products, coffee, and other crops could be extended to a range of biological resources and production processes.
   c) It has become increasingly clear that shaping more sustainable practices in a globalizing world often requires an integrated view of systems in which production and consumption may occur half a world apart. Pilot analyses of aquaculture systems in Thailand have shown that such integrated assessments can open up a much broader and potentially more effective and equitable range of options for society.
   d) As shown in the Scolel Té project of Chiapas, Mexico, experience in building successful agroforestry programs can be extended to provide carbon sequestration services to global society while at the same time helping to promote sustainable livelihoods in rural communities.
   e) Much of the innovation required for a transition to sustainability will take place in grassroots organizations and small enterprises that are too small to support their own R&D labs. Work in India shows the enormous potential of providing modest public support of networking and R&D centers to amplify the impact of such enterprises.
   f) The expected doubling of the world's urban population within the lifetime of today's young professionals presents one of the greatest challenges, and greatest opportunities, for a transition toward sustainability. Emerging views of cities as self-organizing, complex, adaptive systems have profound implications for governance and policy. The S&T community can bring data-sets, visualization, and scenario development techniques to help catalyze interactions among researchers and agents of change from different regions.

[3] For further information on these examples see National Research Council. 1996. *Learning to Predict Climate Variations Associated with El Niño and the Southern Oscillation: Accomplishments and Legacies of the TOGA Program.* Washington, D.C.: National Academy Press, http://books.nap.edu/books/0309053420/html/index.html; L. Lebel et al. 2002. "Industrial transformation and shrimp aquaculture in Thailand and Vietnam: Pathways to ecological, social and economic sustainability." *Ambio* (in press); Anon. 2002. Scolel Té: Climate change and rural livelihoods – Project for carbon sequestration and community forestry in Chiapas, Mexico (http://www.eccm.uk.com/scolelte/).

5) **Constrained future:** For each success story about using science and technology to promote sustainable development, there are many missed opportunities and outright failures. We still do not have reliable baseline data on the state of the earth's ecosystems and biodiversity to match the progress of the last decades in documenting the state of human development. There are threats to sustainable development where S&T might make a contribution but simply has not been mobilized to the task at hand. Much knowledge remains untapped due to the failure of educational systems around the world to encourage an awareness of ecological relationships and a regard for experimental learning in those whose experiences and behaviors will be central to any transition toward sustainability. There is much potentially useful science and technology that is laboriously produced but never applied. There are too few scientists and engineers working on sustainability issues, too little institutional capacity to carry out the needed work, and not nearly enough financial support for the magnitude of the task at hand. Until and unless these constraints are relaxed, the contribution of S&T to a sustainability transition will remain far below its potential. We turn next to how our consultations suggest that this might be accomplished.

Sustainability, Science and Technology: Toward a "New Contract"?

6) **A "New Contract"?** While the relevance of S&T to sustainable development is generally acknowledged, a large gap persists between what the S&T community thinks it has to offer and what society has demanded and supported. In recognition of this gap, the S&T community is increasingly calling for a "new contract" between science and society for sustainable development.[4] Under the contract, the S&T community would devote an increasing fraction of its overall efforts to R&D agendas reflecting socially determined goals of sustainable development. In return, society would undertake to invest adequately to enable that contribution from science and technology, from which it would benefit through the improvement of social, economic, and environmental conditions. Our consultations identified a number of specific steps that the S&T community would have to take for the "contract" idea to move from inspiring rhetoric toward practical reality. These are summarized in the following paragraphs:

7) **Increasing the demand and supply for S&T:** Making the "new contract" a reality will require changes in both the "demand" and the "supply" sides of science and technology for sustainable development. Increasing the demand for S&T will require increasing public and political awareness of the nature and magnitude of the challenges posed by transitions to sustainability. It will also mean convincing society that it can look to the S&T community for contributions to *solutions* and increasing the supply of contributions. This will require building the capacity needed to scale up those contributions adequately to address the magnitude of the sustainability challenges. Partnerships with all major stakeholders will be necessary, including the private sector, the public health sector, and civil society. Indigenous and traditional knowledge must play a greater role in addressing sustainability challenges.

[4] See the background paper for the Mexico City Workshop, included here as Annex 2, for notes on the multiple sources of the call for a new contract.

8) **Beyond business as usual:** To become an attractive partner for society in the proposed "new contract," the S&T community needs to complement its traditional approaches with several new orientations. R&D priorities should be set and implemented so that science and technology contribute to solutions of the most urgent sustainability problems as defined by society, not just by scientists. S&T for sustainable development needs to become an enterprise committed to empowering all members of society to make informed choices, rather than providing its services only to states or other powerful groups. Finally, given the inevitably unpredictable and contentious course of social transitions toward sustainability, S&T needs to see its role as one of contributing information, options, and analysis that facilitate a process of social learning rather than providing definitive answers.

9) **Focus on socio-ecological systems in particular places**: The substantive focus of much of the R&D needed to promote sustainable development will have to be on the complex, dynamic interactions between nature and society ("socio-ecological" systems), rather than on either the social or environmental sides of this interaction. Moreover, some of the most important interactions will occur in particular places, or particular enterprises and times. S&T for sustainable development therefore needs to be "place-based" or "enterprise-based," embedded in the particular characteristics of distinct locations or contexts. This means that S&T will have to broaden where it looks for knowledge, reaching beyond the essential bodies of specialized scholarship to include endogenously generated knowledge, innovations, and practices. Devising approaches for evaluating which lessons can usefully be transferred from one setting to another is a major challenge facing the field.

10) **More than credibility:** For knowledge to be effective in advancing sustainable development goals, it must be accountable to more than peer review. In particular, it must be sufficiently reliable (or *credible*) to justify people risking action upon it; sufficiently relevant (or *salient*) to decision makers' needs; and sufficiently democratic and respectful in its choice of issues to address, expertise to consider, and participants to engage (i.e., socially and politically *legitimate*). Evidence presented in our consultations suggests that these three properties are tightly interdependent, and that efforts to enhance one may often undermine the others. In particular, a simple focus on maximizing one of these attributes (e.g., is the science *credible?*) is an insufficient and counterproductive strategy for contributing to real world problem solving where a mix of all three attributes is essential. The interdependence of saliency, credibility, and legitimacy poses substantial challenges to the design of institutions for mobilizing R&D, assessment, and decision-support for sustainable development.

Institutional Innovations Needed to Fulfil the Contract

11) **Linking knowledge and action:** The prospects for successfully navigating transitions toward sustainability will depend in large part on an improved dialogue between the S&T community and problem-solvers pursuing sustainability goals. Significantly, this needs to be done in ways that enhance the ability of problem-solvers at all levels to harness S&T from anywhere in the world in meeting their goals. It will be essential to understand what sorts of

institutions can best perform these complex bridging roles (i.e., act as "boundary organizations") – between science and policy, and across scales and across the social and natural science disciplines – under a wide range of social circumstances. In addition, in a rapidly changing world of interdependence, such institutions need to be agile. There is a clear demand for systematic efforts to analyze comparatively the performance of experiments in the design of institutions for linking knowledge and action to identify how and under what conditions some "boundary organizations" work better than others, and above all to help the groups running the existing institutions to learn from one another.

12) **Partnerships with the private (business and industry) sector:** Partnerships between the S&T communities and the private sector will be essential in promoting sustainable development, but forming effective partnerships is proving to be quite difficult. In many but not all regions, the private sector employs a substantial fraction of the scientists and engineers whose talents are most relevant to the quest for sustainability. When incentives are right, this private capacity has contributed to the production of public goods as well. But there is also a risk of undersupplying public goods when too much of the total pool of R&D talent is in private hands, and focused on delivering private value. There are few models for resolving this tension. On other fronts, joint work clearly needs to be done in devising useful criteria and assessment methods that can help to guide private investments into more sustainable processes and products. More generally, there is a need for means of effectively engaging private sector scientists and engineers in multi-stakeholder efforts to address societies' most urgent problems. Discussions should be carried out on the potential of including in ongoing work on the private sector's "Global Compact" some explicit provision for deployment of private S&T in the service of public sustainability goals.

13) **Capacity building**: S&T cannot effectively contribute to sustainable development without basic scientific and technological capacity. It is necessary to build capacity in interdisciplinary research, understanding complex systems, dealing with irreducible uncertainty, and to integrate across fields of knowledge, as well as harness and build capacity for technological innovation and diffusion in both the private and public sectors. The consultations showed particularly deep concerns about the shortage of science and engineering resources in developing countries and a decline of existing S&T in some countries. Science teaching at all levels must be enhanced, including efforts to "train the trainers." Efforts are required to support the mobility of scientists, to provide incentives for the development of a diverse technology community, and to facilitate the participation of women. Exchanges of scientists and engineers are a proven method of capacity enhancement. Since in matters of sustainable development it seems that scientists and engineers in all regions of the world have something to teach one another, such exchanges must include South-to-North, as well as North-to-South and South-to-South dimensions. This will require building and maintaining the quality of key institutions of learning, provision of adequate infrastructure, and responding to the challenge of "brain drain." These requirements can only be met if appropriate strategies and policies are fully integrated in national development goals, including the enhancement of life-long learning, support for creative use of information technologies, and maintaining S&T knowledge for sustainable development in the public domain. In addition, young scientists should be empowered to

participate in developing the science and technology agenda, and there should be an increase in their number drawing in particular from traditionally under-represented groups.

14) **Financing challenge:** With a few important but relatively small and under-funded exceptions, efforts to "sustain the lives of future generations on this planet" still lack dedicated, problem-driven and solution-oriented R&D systems with attendant funding mechanisms for research and technology innovation. The array of current multi-lateral and regional development funds and banks has been instrumental in the financing of *development* projects throughout the world. These organizations, however, are less suited for building S&T capacities. While these organizations have recently attempted to broaden their portfolios to meet sustainable development needs better, the mandate, structure, culture, project appraisal, and evaluation techniques of these banks have made it difficult to provide the support required for sustainability transitions. Addressing these needs, particularly in the emerging economies and developing countries around the world, is a fundamental prerequisite for facilitating sustainable development.

Next Steps

15) **Setting agendas for S&T in the service of sustainability:** A major conclusion from our consultations is that a great deal of the help that science and technology can provide to sustainable development must emerge from solution-focused R&D conducted in close collaboration with "local" stakeholders and decision makers. How "local" such collaborations need to be is itself a matter of some debate. It is clear, however, that agenda setting at the global, continental, and even national scale will miss a lot of the most important needs. It is therefore of primary importance that the S&T community's "next steps" in helping sustainable development not be overly influenced by the priorities of banks, foundations, or states operating at these "macro" scales. The transcendent challenge is to help promote the relatively "local" (place- or enterprise-based) dialogues from which meaningful priorities can emerge, and to put in place the local support systems that will allow those priorities to be implemented. Locally- or regionally-focused educational institutions and NGOs will almost certainly occupy a central place in those systems, and need to reach out to link with the larger S&T community.

16) **Building an empirical foundation**: The need for priority setting that reflects local needs notwithstanding, S&T will be severely hampered in promoting sustainability until it has developed a much firmer empirical foundation for its efforts than is available today. A determined effort to move from case studies and pilot projects toward a body of comparative, critically evaluated knowledge is therefore urgently needed. In addition, progress toward sustainability will require a constant feedback from observations. Such observations are necessary to provide reference points for theoretical debates and models on strategies for vulnerability reduction, and metrics for measuring practical progress – or its absence. In order to ensure the data streams needed to form the empirical basis of sustainability science, the observations of the natural sciences and of economic reporting should be augmented in the fields of socio-economic indicators, world views, and society-biosphere interactions. An observation system for sustainability science will need to be based on a large sample of

comparative regional studies, emphasizing meaningful, relevant and practical indicators. Standards for documentation and access to data will also have to be developed. At least some of these foundation-building activities seem particularly well suited to the work of international science programs and collaborative efforts among the world's scientific academies.

17) **Strengthening core concepts and methods:** Despite the need for a "place-based" or highly contextualized character of much of the science and technology needed to promote sustainability, the need to deepen and strengthen work on certain core concepts arose repeatedly in our consultations. Many of these concepts were outlined at the Friibergh Workshop on Sustainability Science early in our consultations, and have been further developed in community-wide discussions on the web-based Forum on Science and Technology for Sustainability (http://sustainabilityscience.org). Three topics, however, emerged from our consultations as meriting special attention:
    a) *Adaptiveness, vulnerability, and resilience* in complex socio-ecological systems: Sustainability depends on building and maintaining the adaptive capacity needed to deal with the shocks, surprises, and longer-term structural transformations that are increasingly characterizing our world. Existing understanding of adaptiveness, vulnerability, and resilience has tended to adopt either nature- or society-oriented views of the world. Needed are new tools and concepts that facilitate management of these properties for the tightly linked socio-ecological systems that are at the heart of the sustainability challenge. Such understanding will have to address the embedding of particular socio-ecological systems – and their adaptive capacity – within larger regional and global contexts.
    b) *Sustainability in complex production-consumption systems:* There have long been independent calls for deeper understanding of how the environmental impacts of production, on the one hand, and consumption, on the other, can be lowered. An important insight emerging from our consultations is that the greater need is for an integrated understanding of the relations between consumption and production. These are becoming increasingly complex as globalization increasingly separates locations at which production and consumption occur. Incentives and technologies work on both ends of the production-consumption chain, and an integrated understanding of their impacts on sustainability is badly needed as a guide for targeting policy.
    c) *Institutions for sustainable development:* The systems of rules, procedures, and expectations that guide social interactions shape both the challenges of, and the opportunities for, sustainability. Experience reviewed at the Mexico City Workshop makes it clear that the ability of our institutions to deal with the cross-scale aspects of interactions among politics, markets, and knowledge will be especially important in determining the prospects for sustainability. Our consultations not only highlighted the wealth of experience in institutional experimentation that is underway around the world, but also revealed a deep thirst for systematic efforts to analyze comparatively and dispassionately the performance of those experiments, to identify how and under what conditions some institutions advance sustainability goals better than others, and above all to help the groups running the existing institutions to learn from one another.

18) **A proposed funding mechanism:** Moving forward in supporting S&T for sustainable development will require the restructuring of existing funding mechanisms at local, national, regional, and global scales to increase funding efficiencies and synergies by supporting integrated projects that address multiple goals and involve diverse stakeholders, as well as substantial increases in investments in S&T. It is also proposed that a multi-national funding mechanism be designed and implemented specifically to meet the unique needs of harnessing S&T for sustainable development. To move forward in the development of a "Science and Technology for Sustainable Development Fund" it will be necessary to organize a participatory design process with the expertise and interest to explore the potential benefits of such a Fund. As a step toward such a fund, participants in the Mexico City meeting will seek to collaborate with other interested parties in forming a study team to prepare an initial proposal to establish a Fund, which will then be reviewed by a "Founders Conference."

19) **Shaping a partnership on S&T for sustainable development**: The participants in the consultations reported here invite others to join with them in a decade-long partnership to address the critical challenges of sustainable development. We propose three initial foci for this partnership:

a) *Strengthen the ability of locally-based initiatives to harness science and technology from around the world in support of their efforts to solve their most urgent sustainable development problems.* Much of the opportunity for advancing sustainable development is centered at the sub-national scale, in particular regions, places, and enterprises. Problem-solving efforts centered at such scales must nonetheless address the impacts and opportunities of cross-scale interactions. Several experiments in collaboration among scientists and problem-solvers in addressing such globally embedded but locally centered problems are already in place. We propose to build on these existing institutions and arrangements and – in collaboration with regional partners – to foster the process of local dialogue, to create funding opportunities, and to collaborate in the research and development needed to support local action over the long term.

b) *Facilitate engagement of young scientists and technologists in efforts to support environmentally sustainable human development around the world.* The capacity for science and technology to contribute to sustainable development depends greatly on whether today's young scientists and engineers can find ways to contribute. Around the world, these graduate students, new job seekers, post-docs, and entry-level doctors, engineers, and professors face a range of obstacles that inhibit their contributions. To address the needs of this generation we propose to strengthen programs for training young individuals from the developing world in interdisciplinary research and assessment approaches central to harnessing science and technology for sustainable development. For young scientists and engineers everywhere, we will invite them to join us in creating workshops and other opportunities that can facilitate their full engagement in cutting-edge efforts to apply science and technology to sustainable development.

c) *Build a global community of scientists and engineers for sustainable development.* Scientists and engineers around the world working on sustainable development problems have no natural forum in which to learn from one another through exchange of experiences and debate of ideas. To help provide such a forum, we will promote a biennial conference in which young scientists, doctors, and engineers can interact with senior scholars and practitioners engaged in linking S&T to sustainable development.

We will also expand the virtual forum, library, and bulletin board of the web-based "Forum on S&T for Sustainability" (http://sustainabilityscience.org).

20) **In conclusion:** Reflecting on the myriad discussions within the international S&T community over the last two years, we are struck above all by the urgency of the sustainable development challenge, and by the potential contribution of S&T to meeting that challenge through participation in the design of more robust and adaptive strategies of development. We note the renewed commitment of the S&T community around the world to serve as an active partner in realizing that potential. We understand that living up to this commitment will require substantial changes in the way that we and our colleagues do our work. These include a realization that knowledge is more likely to be used if it is produced through collaborative processes that allow for greater participation in setting S&T agendas by social stakeholders; that attention needs to be devoted to practical solutions as well as to conceptual understanding; that progress will require integrated analysis of the complex interactions between nature and society; and that many of those interactions most important for sustainable development take place at local to regional scales. Although S&T has made substantial contributions to sustainability goals, scaling up those contributions to a level commensurate with the magnitude of the sustainable development problem will require leadership in designing more effective communication between the S&T community and society; capacity building through education; the recruitment of our best young scientists and engineers to work on sustainability issues; closer collaboration with the private sector; and an array of innovative financing mechanisms. We approach the task before us in awe of its magnitude and urgency, but energized by the enthusiasm of our colleagues, students, and many of the great leaders of our time.

END

Annex 1: Participants in the Mexico City Workshop and authors of this consensus report

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Annex 2

Science, Technology and Sustainable Development

Summary of Findings from a Two-Year Consultation Process conducted in preparation for the World Summit on Sustainable Development
by
The International Council for Science
The Initiative on Science and Technology for Sustainable Development
The Third World Academy of Sciences
The InterAcademy Panel

Prepared as a background paper for the Mexico City Synthesis Workshop on Science, Technology and Sustainable Development
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"How can science and technology contribute more effectively to achieving society's goals of sustainable development?" During the two years leading up to the World Summit on Sustainable Development (WSSD) in August 2002, organizations representing the international scientific and technology communities conducted more than a dozen fact-finding studies, discussions, conferences, and workshops that addressed this question from a wide range of perspectives. The present paper attempts to draw together in one place some of the more widely shared findings and conclusions of those efforts, and to connect them with a longer tradition of debate on the role of international science in sustainability going back to at least the Stockholm Conference on the Human Environment. Its goal is to provide background for the many discussions regarding the role of science and technology in sustainable development that are taking place in the context of the World Summit and other national and international S&T planning efforts currently underway.

Historical Context

Sustainability concerns have occupied a place on the global agenda since at least the 1980s, with publication of the International Union for the Conservation of Nature's (IUCN) *World Conservation Strategy* and the Brundtland Commission's report *Our Common Future*.[1] The prominence of that place has been rising, however. UN Secretary-General Kofi Annan reflected

[1] International Union for the Conservation of Nature. 1980. *World Conservation Strategy: Living resource conservation for sustainable development*. Gland: IUCN; World Commission on Environment and Development. 1987. *Our Common Future*. Oxford: Oxford University Press; W. C. Clark. 1986. "Sustainable development of the biosphere: Themes for a research program." pp. 5-48 in William C. Clark and R.E. Munn, eds. *Sustainable development of the biosphere*. Cambridge: Cambridge Univ. Press.

a growing consensus when he wrote in his Millennium Report to the General Assembly that "Freedom from want, freedom from fear, and the freedom of future generations to sustain their lives on this planet" are the three grand challenges facing the international community at the dawn of the 21st century.[2] Sustainability has become a "high table" issue in international affairs, and on many regional, national, and local agendas.

Science and technology are increasingly recognized to be central to both the origins of Secretary-General Annan's three challenges, and to the prospects for successfully dealing with them.[3] Science and technology brought us the CFCs that preserved our foods, cooled our homes… and depleted the ozone layer. But they also brought us the research and monitoring programs that raised the ozone alarm, and the substitute technologies that have allowed us to continue meeting the needs that CFCs have fulfilled in a manner less damaging to the environment. Science and technology have also played a central role in bringing about the increases in agricultural yields and distribution systems that have helped to keep most of the world from famine… but only at the cost of significant environmental degradation. Promoting transitions toward sustainability in the 21st century will require much more than improvements in the production and effective use of science and technology. But no serious analysis has suggested that it will be possible to meet the sustainable development challenge without intelligent and effective use of science and technology to do the job.

Despite the importance of achieving sustainability, and the centrality of science and technology to strategies for doing so, a great imbalance exists in the resources and attention devoted to harnessing science and technology in the service of Secretary-General Annan's three transcendent goals.[4] Efforts to achieve "freedom from fear" are supported by a mature, well-funded, problem-driven R&D system based in the world's military establishments. Efforts to achieve "freedom from want" have created and been supported by several effective R&D systems, for example those engaged in international agricultural research and in certain global disease campaigns. In contrast, efforts to achieve sustainability are relatively new because, in the words of the Secretary-General, the "founders of the UN could not imagine that we would be capable of threatening the very foundations for our existence."[5] As a result, efforts to harness science and technology for sustainability have largely had to draw on R&D systems built for other purposes – begging monitoring data from the world's military establishment, piggy-backing on the already over-extended international agricultural research system, and borrowing insights gained from basic research programs on global environmental change. With a few important but relatively small and under-funded exceptions, efforts to "sustain the lives of future

[2] K. Annan. 2000. *We, the Peoples: The Role of the United Nations in the 21st Century*. New York: United Nations, http://www.un.org/millennium/sg/report/full.htm.

[3] United Nations Development Program. 2001. "Making new technologies work for human development: The Human Development Report 2001." Oxford: Oxford Univ. Press; World Bank. 1998. "Knowledge for development: The World Development Report for 1998/9." Oxford: Oxford Univ. Press; J. D. Sachs. 2000. "A new map of the world." *The Economist* 355: 81-83 (24 Jun 2000).

[4] See the report on the Global Change Open Science Conference, forthcoming as W. Steffen, J. Jäger, D. Carson, and C. Bradshaw, eds. *Challenges of a Changing Earth. Proceedings of the Global Change Open Science Conference, Amsterdam, NL, 10-13 July 2001*. Berlin: Springer-Verlag (cited here as Global Change Programmes, 2002), especially the plenary address by William Clark on "Research systems for sustainability," (cited here as Clark, 2002, and available at http://sustainabilityscience.org/keydocs/fulltext/BC_ResSys_Amsterdam02.pdf).

[5] Annan, 2000, op. cit.

generations on this planet" still lack dedicated, problem-driven R&D systems of anything like the scale or maturity of those devoted to security and development per se.

Calls for strengthening S&T programs targeted on sustainable development built slowly during the 1990s following the UN Conference on Environment and Development (UNCED) in Rio. Many of the earliest and most thoughtful contributions to this discourse came from the developing world through the work of individual scholars and of institutions such as the Third World Network of Scientific Organizations (TWNSO), the Commission on Science and Technology for Sustainable Development in the South (COMSATS), the Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI), and the South Center.[6] A further regional perspective was provided by the African Academy's *Millennial Perspective on Science, Technology and Development*.[7] European thinking of the late 1990s was exemplified in Schellnhuber and Wenzel's *Earth Systems Analysis: Integrating Science for Sustainability*, the European Union's *Fifth Framework Programme*, and a special issue on "Sustainability Science" published by the *International Journal of Sustainable Development*.[8] A number of national academies of science or other advisory bodies – including those of Brazil, Germany, Japan, the United Kingdom, and the United States also addressed the links between sustainability and global change.[9] Many of these perspectives were brought together in UNESCO's *World Conference on Science for the 21st Century*, help in Budapest in 1999.[10]

[6] Third World Network of Scientific Organizations (TWNSO), http://www.ictp.trieste.it/~twas/TWNSO.html; Commission on Science and Technology for Sustainable Development in the South (COMSATS), http://www.comsats.org.pk; Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI), http://www.sristi.org/; South Center at http://www.southcentre.org/ (see particularly the *Elements for an Agenda of the South: Report of the NAM Ad Hoc Panel of Economists*, section 4 on "science and technology" at http://www.southcentre.org/papers/nam/namfinal-02.htm#P287_47302). See also policy statements by the International Foundation for Science (IFS), http://www.ifs.se/index.htm; the International Science Programme (ISP), http://www.isp.uu.se/Home.htm; and the Millennium Science Initiative (MSI), http://www.msi-sig.org/MSI-SIG_summary.htm.

[7] African Academy of Sciences' *Tunis Declaration: Millennial Perspective on Science, Technology and Development in Africa and its Possible Directions for the Twenty-first Century* (Fifth General Conference of the African Academy of Sciences, Hammamet, Tunisia, 23-27 April 1999), http://www.unesco.org/general/eng/programmes/science/wcs/meetings/afr_hammamet_99.htm.

[8] H. J. Schellnhuber and V. Wenzel, eds. 1998. "Earth System Analysis: Integrating Science for Sustainability." Berlin: Springer-Verlag; European Commission. 1998. "Fifth Framework Programme: Putting Research at the Service of the Citizen," http://www.cordis.lu/fp5/src/over.htm; S. Funtowicz and M. O'Connor, eds. 1999. "Science for sustainable development." Special issue of *International Journal of Sustainable Development* 2: 3.

[9] C. E. Rocha-Miranda, ed. 2000. "Transition to Global Sustainability: The Contributions of Brazilian Science." Rio de Janeiro: Academia Brasiliera de Ciências, http://sustainabilityscience.org/keydocs/brazilsci.htm; Series of Annual Reports by the German Advisory Council on Global Change (WGBU), particularly its *World in Transition: The Research Challenge, Annual Report 1996*. Berlin: Springer-Verlag, 1997, http://www.wbgu.de/wbgu_publications.html; United States National Research Council, Board on Sustainable Development. 1999. *Our Common Journey: A Transition Toward Sustainability*. Washington, D.C.: National Academy Press, http://www.nap.edu/catalog/9690.html; Science Council of Japan. 2000. *Towards a comprehensive solution to problems in education and the environment based on a recognition of human dignity and self-worth*. Science Council of Japan; Royal Society. 2000. *Towards sustainable consumption: A European perspective*. London.

[10] UNESCO. 1999. *World Conference on Science for the 21st Century: A new commitment*. http://www.unesco.org/bpi/science/content/press/anglo/4.htm.

With the turn of the Millennium, discussions on science, technology and sustainability intensified significantly. On the political side, impetus was provided by the World Summit on Sustainable Development (WSSD) in August 2002. In the policy arena, international environmental assessments were increasingly called on to address sustainability issues.[11] And on the scientific side, national and international stock-taking on the first decade of global environmental change research and planning for the decade ahead provided additional opportunities for rethinking the relationships among science, technology and sustainability. In response to this increased attention, during the two-year period leading up to the World Summit organizations representing the international scientific and technology communities conducted more than a dozen fact-finding studies, discussions, conferences, and workshops that addressed the question "How can science and technology contribute more effectively to achieving society's goals of sustainable development?"

These "consultations" reflected a wide range of perspectives (see Table 1 in the "Consensus Statement" to which this document serves as Annex 2). The InterAcademy Panel (IAP) of the World's Scientific Academies led the way with a May 2000 symposium on the contributions that science and technology could make to a transition toward sustainability.[12] The Global Change Research Programmes – IGBP, IHDP, WCRP, and Diversitas – made sustainability a focus of their forward-planning efforts at a major Open Science Conference in Amsterdam (July 2001) and a smaller follow-up meeting in Paris (February 2002).[13] The International Council for Science (ICSU) was invited, along with the World Federation of Engineering Organizations (WFEO), by the UN Commission on Sustainable Development (CSD) to serve as the official representative of the scientific and technological community during the preparation for the World Summit. In this capacity ICSU brought together the IAP, the Third World Academy of Sciences (TWAS), and a number of other international scientific organizations in a survey of progress made and lessons learned in efforts to apply science and technology to sustainability since the 1992 Rio Conference.[14] The Initiative on Science and Technology for Sustainability

[11] Robert Watson, John A. Dixon, Steven P. Hamburg, Anthony C. Janetos, and Richard H. Moss. 1998. *Protecting Our Planet, Securing Our Future*. Nairobi: UN Environment Programme, http://www-esd.worldbank.org/planet/; Intergovernmental Panel on Climate Change. 2001. *Special Report on Climate Change and Sustainable Development, IPCC Plenary Seventeenth Session*. Nairobi, 4-6 April 2001, http://www.ipcc.ch/meet/p17.pdf; Millennium Ecosystem Assessment, http://www.millenniumassessment.org/en/index.htm.

[12] World's Scientific Academies' *Transition to Sustainability in the 21st Century* (Tokyo Summit of May 2000), http://www4.nationalacademies.org/intracad/tokyo2000.nsf/all/home.

[13] The Global Environmental Change Programmes have made "global sustainability" a center point of their research planning for the coming years (see IGBP. 2001. *Global change and the earth system: A planet under pressure*. IGBP Science Series, No. 4. Paris: ICSU, http://www.igbp.kva.se//uploads/ESO_IGBP4.pdf; and IGBP. 2001. *The Amsterdam Declaration on Global Change – Challenges of a Changing Earth*. Global Change Open Science Conference, Amsterdam, 13 July 2001, http://www.sciconf.igbp.kva.se/fr.html; Paris Workshop organized under the auspices of the Global Change Science Programmes on *Sustainable Development: The Role of International Science*. Paris, 4-6 February, 2002, (Bonn, IHDP, cited here as Global Change, 2002).

[14] World Summit on Sustainable Development. 2002. *Role and Contributions of the Scientific and Technological Community (S&TC) to Sustainable Development*. Secretary-General's Note for the Multi-Stake Holder Dialogue Segment of the Second Preparatory Committee. Addendum No. 8: Dialogue Paper by Scientific and Technological Communities. United Nations Economic and Social Council E/CN.17/2002/PC.2/6.Add.8. Advance Copy, 28 January 2002. Prepared by the International Council for Science (ICSU) and the World Federation of Engineering Organizations (WFEO), http://sustainabilityscience.org/keydocs/fulltext/wssd_stc_020128.pdf. Cited here as ICSU et al., 2002a; subsequently issued in final form as International Council for Science. 2002. *Report of the Scientific and Technological Community to the World Summit on Sustainable Development*. ICSU Series on Science for

(ISTS) – an ad-hoc, international group of scholars working on problems of environment and development – organized with the Third World Academy a series of global and regional workshops to assess what on-the-ground efforts to promote human well-being while protecting the earth's life support systems most need from science and technology in different parts of the world.[15] Finally, ISTS, TWAS, and ICSU jointly organized a pair of workshops on institutions to harness science to sustainable development (Trieste, February 2002; Cambridge, April 2002)[16]

Sustainable Development, No. 1. 20pp, http://www.icsu.org/Library/WSSD-Rep/vol1.pdf. ICSU and WFEO also prepared the follow-up document "Science and technology as a foundation for sustainable development: Summary by the scientific and technological community for the multistakeholder dialogue segment of the WSSD PrepCom IV meeting. (Report available at http://sustainabilityscience.org/ists/synthesis02/icsu_s+t_2pager_wssd-prepcom4.pdf; cited here at ICSU et al., 2002b).

[15]The Initiative is an open, ad-hoc group of environment and development scholars devoted to linking science, technology and sustainable development. Its co-convenors are Akin Mabogunje and Robert Kates. It was founded through a call from participants at the Friibergh Workshop on Sustainability Science in October 2000 (see Robert Kates et al. 2001. "Sustainability Science." *Science* 292:641-2, http://sustainabilityscience.org/keydocs.htm#sustsci). Further information on the Initiative is available on its web site at http://sustainabilityscience.org/ists. The Initiative conducted the following regional workshops under a steering committee consisting of the individual leaders named below and chaired by Robert Corell: **Abuja, Nigeria:** 13-15 November 2001, organized locally by the Nigerian National Committee on Sustainability Science, chaired by Professor Akin L. Mabogunje, Development Policy Centre, Ibadan, Nigeria (report at http://sustainabilityscience.org/events/africa-sustsci0111_ws-statement.pdf; cited here as ISTS/Abuja, 2001); **Chiang Mai, Thailand:** 4-6 February 2002, organized locally by Chiang Mai University and University Kebangsaan Malaysia, co-chaired by Dr. Louis Lebel, Faculty of Social Sciences, Chiang Mai University and Science Coordinator for the Southeast Asian Regional Committee (SARCS) for START, Bangkok, Thailand, and Dr. Mohammed Nordin Hassan, Institute for Environment and Development (LESTARI), University Kebangsaan Malaysia, Bangi, Malaysia (report at http://sustainabilityscience.org/ists/docs/ists_regws_chiangmai_synthesis.pdf; cited here as ISTS/Chiang Mai, 2002); **Bonn, Germany:** 27 February - 1 March 2002, organized locally by the International Human Dimensions Programme on Global Environmental Change (IHDP), chaired by Dr. Jill Jaeger, Executive Director, International Human Dimensions Programme on Global Environmental Change, Bonn, Germany (workshop supported by the German Federal Ministry for Education and Research; report at http://sustainabilityscience.org/ists/docs/ists_regws_walberberg.pdf; cited here as ISTS/Bonn, 2002); **Santiago, Chile:** 5-7 March 2002, organized locally by the Economic Commission for Latin America and the Caribbean (ECLAC), co-chaired by Dr. Gilberto Gallopín, Regional Advisor on Environmental Policies, Division of Environment and Human Settlements, Economic Commission for Latin America and the Caribbean, UNESCO, Santiago, Chile, and Armando Rabuffetti, Director, Inter-American Institute for Global Change Research, São Paulo, Brazil (report at http://sustainabilityscience.org/ists/docs/ists_regws_santiago_summary.pdf; cited here as ISTS/Santiago, 2002); **Ottawa, Canada:** 25-26 March 2002, organized locally by Environment Canada, the Policy Research Institute, and the North American Free Trade Agreement Commission for Environmental Cooperation (this workshop focused on regional-scale issues of science and technology for sustainability in Canada, Mexico, and the United States; report at http://sustainabilityscience.org/ists/docs/ists_regws_ottawa_rpt.pdf; cited here as ISTS/Ottawa, 2002). Results of the individual workshops are also available on the Forum on Science and Technology for Sustainability, http://sustainabilityscience.org. A summary of the workshop findings is provided in ISTS. 2002. "Summary Insights and Perspectives from the Regional Workshops of the Initiative on Science and Technology for Sustainability." Prepared by the Regional Workshop Chairs. Edited by Robert W. Corell and Noelle Eckley, http://sustainabilityscience.org/ists/synthesis02/ists_regws_synthesis_020503.pdf (cited here as ISTS/Regional Summary, 2002). A consolidated record of the regional workshops is available at http://sustsci.harvard.edu/ists/events.htm.

[16] Trieste Workshop organized locally by the Third World Academy of Sciences under the auspices of the ISTS on *Science, Technology and Sustainability: Harnessing Institutional Synergies* (Trieste, Italy, 6-9 February 2002), co-chaired by Mohamed Hassan, Calestous Juma, and William Clark (report at http://sustainabilityscience.org/ists/docs/twas_rpt_v1_020222.pdf; cited here as ISTS/Trieste, 2002); Cambridge Workshop organized locally by Harvard University's Weatherhead Center for International Affairs under the auspices of the ISTS, ICSU, and TWAS on *Mobilizing Science and Technology for Sustainable Development*

and a synthesis workshop in Mexico City (May 2002) that brought leaders of these various efforts together to produce a consensus statement on science, technology and sustainable development that ICSU carried forth into the World Summit preparatory process.[17]

The present paper was initially prepared on behalf of the joint ICSU/TWAS/ISTS Organizing Committee for the Mexico City workshop noted above. It attempts to draw together in one place some of the more widely shared findings and conclusions of the last two years' international consultations listed in Table 1, and to connect them with a longer tradition of discussion on the role of international science in sustainability noted above. It remains, however, one individual's synthesis of the extraordinarily rich and diverse set of conversations documented in the meeting reports listed in Table 1 of the consensus report. For a broadly-based consensus on the issues synthesized here, the reader is referred to the report of the Mexico City Synthesis Workshop on Science and Technology for Sustainable Development that precedes this background document.

Sustainability, Science and Technology: Toward a "New Contract"?

The consultations conducted over the last two years that form the basis for this report make it clear that harnessing S&T to do its part in supporting transitions toward sustainability will require much more than a continuation of present practices. They also suggest that although many scientists and engineers today are concerned about sustainable development issues and believe that their work may ultimately be relevant to those issues, few see their agendas as driven primarily by questions of sustainable development. Those who do focus a substantial portion of their work on sustainable development questions frequently see their work as under-appreciated by their peers and under-utilized by decision makers.

For their part, most decision makers – from local to global levels and across the public and private sectors – generally seem to acknowledge the past role of S&T in supporting improvements in human well-being and environmental conservation. Many of those same decision makers, however, are not now particularly inclined to see investments in, or deference to, S&T as part of their strategies for advancing sustainable development. While many reasons are given it seems clear that many in the decision-making and policy communities – and, indeed, in society at large – view S&T as, at best, an enterprise far better at raising problems than at delivering solutions.[18] Those less generous perceive S&T as irrelevant to most of the choices they face, or as biased – intentionally or not – in the interests it serves, or as arrogant and naïve beyond measure in its dealings with the rest of the world, or as just another interest group pleading for special treatment.

(Cambridge, Massachusetts, USA, 10-12 April 2002), co-chaired by William Clark, Mohamed Hassan, Gisbert Glaser, and Calestous Juma (report at http://sustainabilityscience.org/ists/docs/ists_cfia_rpt_final.pdf; cited here as ISTS/Cambridge, 2002).

[17] **Mexico City, Mexico:** 20-23 May 2002; organized locally by the National Autonomous University of Mexico (UNAM) under the joint sponsorship of ISTS, TWAS and ICSU; co-chaired by William Clark, Robert Corell, Gisbert Glaser, Mohamed Hassan, Calestous Juma, Robert Kates, Akin Mabogunje, Thomas Rosswall, and Jose Sarukhán; http://sustainabilityscience.org/ists/synthesis02.htm (cited here as ISTS/TWAS/ICSU/Mexico City, 2002).

[18] This topic is particularly well developed in ISTS/Ottawa, 2002, op. cit.

Whatever the reasons, society and its leaders invest far less in R&D targeted on sustainable development issues – and indeed on science targeted on social goals generally – than many scientists deem appropriate. Perhaps not surprisingly, this perception is widely shared across the science and technology communities of the more and less developed countries. More interestingly, virtually all professional analysts of economic growth agree that long-term rates of social return on R&D are far above those recovered from most other social investments, and that social investment in science and technology should generally be increased. A few private foundations, government programs, and international organizations have attempted to bring more resources to efforts that seek to harness S&T for sustainable development. Nonetheless, a large gap remains between what the S&T community thinks it has to offer sustainable development and what society has been willing to pay for those services.

With a view to addressing this unsatisfactory situation, the S&T community has recently called for a "new contract between science and society for sustainable development."[19] Under the contract, the S&T community would devote an increasing fraction of its overall efforts to R&D agendas reflecting socially determined goals of sustainable development. In return, society would undertake to invest adequately to enable that contribution from science and technology. The "new contract" is an attractive idea that has achieved a good deal of positive attention in the relevant S&T community. The consultations leading up to the World Summit suggested, however, that it is time to devote some serious attention to what it would take for the contract to move from inspiring rhetoric toward practical reality. A broad consensus is emerging that this will require changes in both the "demand" and the "supply" side of science and technology for sustainable development.

First, if more social resources are to be devoted to science and technology for sustainable development, society's demand for S&T targeted on sustainable development goals will need to be increased. This will almost certainly require that scientists convey to decision makers and society at large a deeper appreciation of the nature and urgency of the sustainable development problem. In addition, however, the consultations leading up to the World Summit suggest that increasing the social demand for science and technology will require that we convince decision makers that the S&T community can deliver *solutions* to the problems of sustainable development. This is crucial, since the demand of decision makers for information about problems about which they can't do anything is going to remain very small indeed. Some progress has been made since Rio on the first of these requirements: the world is, after all, about to hold a Summit on Sustainable Development, and the UN Secretary-General has named

[19] See Federico Mayor (Director General of UNESCO). 1989. "Message: A new contract between science and society." Director's Message for UNESCO Conference *Science for the 21st Century: A new commitment*. http://www.unesco.org/bpi/science/content/press/anglo/4.htm; Sheila Jasanoff et al. 1997. "Conversations with the Community: AAAS at the Millennium." *Science* 278: 2066-67, http://www.sciencemag.org/cgi/content/full/278/5346/2066; Jane Lubchenco. 1998. "Entering the Century of the Environment: A New Social Contract for Science." *Science* 279(5350): 491-497, http://www.sciencemag.org/cgi/content/full/279/5350/491; International Council for Science (ICSU) and the World Federation of Engineering Organizations (WFEO). 2002. "Science and Technology as a Foundation for Sustainable Development: Summary by the Scientific and Technological Community for the Multi-Stakeholder Dialogue Segment of the WSSD PrepCom IV Meeting." Prepared in consultation with the InterAcademy Panel (IAP), the Third World Academy of Sciences (TWAS), and the International Social Sciences Council (ISSC). http://sustainabilityscience.org/ists/synthesis02/icsu_s+t_2pager_wssd-prepcom4.pdf.

sustainability as one of the three great challenges for the Millennium. On the latter part of the "demand" requirement, however, there is much more work to be done. A message that emerged loud and clear from the consultations summarized here is that we need to do a much better job in convincing decision makers that science and technology, properly supported, can contribute practical *solutions* for the sustainable development problems to which we have called so much attention.

Making the "new contract" a reality will also require changes on the "supply" side. We need to figure out what changes in the world's S&T system would most improve its ability to deliver the kind of useful knowledge and know-how that society and its leaders want for solving sustainable development problems. Moreover, we will need to implement those changes and construct the needed capacity at the same time we deliver the early successes in decision support needed to keep the "negotiations" on the contract going, and to justify increasing social investment in S&T for sustainable development.

These "supply" and "demand" perspectives on science and technology in the sustainable development debate imply what some find an unattractive "marketing" character to the work before us. But better "marketing" – including "market research" on what is wanted, active creation of increased demand, and delivery of a valued product – sounds very much like what is needed for a community that thinks it has more to offer than what its customers are currently willing to buy.

The consultations leading up to the World Summit did not directly address how better to "market" science and technology for sustainable development, but they did suggest a broad consensus on four related issues: (i) How should the S&T community (re)orient its approach to sustainable development in order to become a more effective partner in the "new social contract"? (ii) What should be the agenda for the next generation of R&D for sustainable development to be performed under the contract? (iii) What institutional initiatives are most needed to support implementation of this agenda? (iv) What specific steps or partnerships are most needed to move the contract along?

How should the S&T community (re)orient its approach to sustainable development?

Perhaps the strongest message to emerge from the consultations conducted by the S&T community in preparation for the World Summit is that if we are to contribute more effectively to sustainable development, we must resist the temptation to simply continue our present practices and agendas under new labels. Instead, we will have to take time as individuals, institutions, and programs to reflect on the radical implications of challenges facing us, and the "new contract" for meeting those challenges. In particular, we need to reconsider what science and technology conducted under the auspices of sustainable development should be for, what it should study, where it should look for knowledge, how it should "certify" knowledge, and how it should set its specific R&D agenda. Let us consider these in turn.

What is it for?

Sustainable development is an active, often contested, social endeavor in which the stakes are high, knowledge is seldom neutral, and S&T is rarely equally accessible to all stakeholders. S&T for sustainable development therefore needs to clear about what goals – and whose goals – it is trying to advance. Disinterestedness is not an option. Participants generally agreed that S&T for sustainable development should make clear to itself and to the decision-making community that it is for achieving social goals, solving problems, empowering people, and promoting social learning.

For S&T to contribute more effectively to sustainable development, it will have to take society's goals of sustainable development seriously. These goals vary for different groups in different places, with much debate over just what is to be developed, what is to be sustained, in what relation, and for how long. Nonetheless, a broad consensus has begun to emerge that sustainable development – and the S&T that would support it – should seek to advance fundamental human and social needs while protecting the earth's life support systems and biological diversity.[20] The "new contract" between the S&T community and society must start with scientists and engineers taking seriously the sustainable development goals of decision makers and, more generally, of stakeholders in setting its priorities.

S&T needs to contribute to solutions for sustainable development … not just to the identification of problems. Society generally acknowledges the important role of S&T in calling attention to potential problems resulting from the interactions between human development and the environment. But society and its leaders are generally much more receptive to warnings about dangers ahead when those warnings are accompanied by practical guidance on how the dangers might be averted. For it to be more valued and supported by society, the S&T community needs to devote substantially more effort to helping particular decision makers solve particular sustainable development problems. This means listening harder to hear what decision makers believe their most important problems to be, devoting our R&D talents to creating options for mitigating those problems, and turning our assessment efforts much more toward helping decision makers evaluate alternative technologies and policies.[21]

To the extent that science and technology helps to contribute means for advancing social goals, it becomes increasingly important to consider whose goals it is serving. The consultations undertaken in the two years leading up to the Summit expressed a strong consensus that science and technology for sustainable development should be oriented and conducted in such a way as to empower individuals, communities, and regional decision makers to shape their own futures.[22] It should seek to avoid disproportionately enhancing the power of the large-scale social organizations – whether states, multinationals, or international organizations – that can most readily pay for or otherwise command its services. This injunction reflects both practical and moral reasoning. On the practical side, much of the behavioral change that will need to occur as part of transitions toward sustainability will take place at the "local" level. Science and technology that engages individuals at those levels is simply more likely to influence their behavior than ideas and technologies thrust on them from "above." On the moral side, many

[20] See especially IAP, 2000; Kates et al., 2001, op. cit.; ICSU et al., 2002a.
[21] ICSU et al., 2002a, op. cit.; ISTS/Regional Summary, 2002, op. cit.; ISTS/Bonn, 2002, op. cit.
[22] See especially ISTS/Chiang Mai, 2002, op. cit.; ISTS/Bonn, 2002, op. cit.

involved in the consultations summarized here see a tight connection between the agendas of sustainable development and those of human rights and security. For them, there is a concomitant responsibility for S&T performed in the service of sustainable development to support efforts to enhance empowerment and self-determination at the individual level.

Pathways toward sustainability cannot be plotted with any precision in advance, in part due to the complexity of the natural work, in part due to the unpredictability of human action and invention. S&T should not, therefore, aspire to design optimal blueprints or to plot rigid trajectories for sustainability. Rather, it should help societies and individuals to explore alternative pathways, to evaluate options for action, and to learn from both the successes and the failures of the "experiments" constituted by management and policy initiatives. In particular, the consultations emphasized the need for the science and technology community to help facilitate "learning forums" through which societies and their leaders could benefit from a critical but sympathetic examination of others' experience in grappling with the challenges of sustainable development.[23]

What should it study?

Human activities and the environment are tightly coupled, mutually determined systems. Focusing on one component while treating the other as a boundary condition is increasingly unlikely to provide reliable insights into long-term, multi-scale system dynamics. Participants in the consultations generally agreed that S&T for sustainable development should focus its work on socio-ecological systems, place-based interactions, and complexity.

S&T that seeks to support transitions toward sustainability will generally need to focus on the nature-society or "socio-ecological" system as its unit of analysis. Usable knowledge about the behavior of such systems will require an integrated understanding of not only biogeochemical, climatic, ecological, and speciation processes, but also the workings of politics and markets, social institutions, human behavior, and technological innovation.[24]

The most appropriate scale on which to focus analyses of socio-ecological systems will need to be determined on a case by case basis. Such determinations will be a central challenge for S&T seeking to support sustainable development. Nonetheless, on the basis of experience with many of the systems we understand best, it seems that increasing attention will need to be given to "place-based" work at "regional" scales that can capture the uniquely intersecting characteristics of relevant social, ecological, and decision-making systems.[25]

Complexity, uncertainty, time lags, conflicting interests, and cross-scale linkages will be essential characteristic of such systems, and need to be addressed head-on by S&T activities committed to supporting sustainable development.[26]

[23] Ibid.
[24] ISTS/Santiago, 2002, op. cit.
[25] Kates et al., 2001; ISTS/Chiang Mai, 2002, op. cit.
[26] See especially ISTS/Bonn, 2002, op. cit.

Where should it look for knowledge?

S&T for sustainable development will need to draw on a much wider range of knowledge sources than has conventionally been the case. Participants in the consultations leading up to the Summit generally agreed that we need to look for knowledge in, and to integrate knowledge from both "universal" knowledge and place-based knowledge from all the world's regions.

"Universal knowledge" can be derived from formal experimentation, comparison, and conventional scientific analysis. Especially important contributions can certainly be made by drawing on the revolution in our integrated understanding of earth system science that has grown over the last two decades. Classical disciplinary knowledge from both the natural and social sciences also clearly has a crucial role to play.[27]

But S&T for sustainable development will also have to draw upon knowledge generated endogenously in particular places and operational contexts around the world. Such "place-based" knowledge cannot be simply imported or transferred from other regions, or from the stock of universal knowledge. Rather, it resides in local people and in their landscapes, their technologies, and their cultural artifacts.[28]

This "place-based" knowledge is an enormously rich if often underutilized resource in all parts of the world – less and more developed. It thus makes harnessing S&T to sustainable development an endeavor in which all peoples and regions of the world can – indeed must – contribute fundamental knowledge and insights. We need to ask what each region has to teach the rest of the world. (See the discussion of "learning forums" above).[29]

How should it "certify" knowledge?

The science and technology community has traditionally been granted a special place at the table of social decision making on grounds that the knowledge it brings to that table is more likely to be true, or reliable, or instrumentally effective than other forms of knowledge. For it to play a useful role in promoting sustainable development, it is clearly necessary that the S&T community work to strengthen the basis of its claims as a source of credible knowledge. However, it follows from much of the preceding discussion that "credibility," while necessary, is not a sufficient property to strive for in efforts to enhance the contribution of science and technology to sustainable development. The consultations summarized here suggest for knowledge to be effective in advancing sustainable development goals, it must be widely viewed not only as reasonably likely to be true (i.e., "credible"), but also as relevant to decision makers needs (i.e., "salient") and as respectful and fair in its choice of issues to address, expertise to consider, and participants to engage (i.e., "legitimate"). Unfortunately, evidence presented in the consultations suggests that these three properties are tightly interdependent, and that efforts to enhance one may often undermine the others. This interdependence poses substantial challenges to the design of institutions for mobilizing science and technology for sustainable development.[30]

[27] See Global Change, 2002, op. cit.

[28] See especially Global Change, 2002, op. cit.; ISTS/Chiang Mai, 2002, op. cit.; ISTS/Santiago, 2002, op. cit.; ISTS/Trieste, 2002, op. cit.

[29] See especially ISTS/Chiang Mai, 2002, op. cit.

[30] See especially ICSU et al., 2002a, op. cit.; ISTS/Santiago, 2002, op. cit.

How should it set its agendas?

For most sustainable development issues, there are multiple perspectives on the key problems, causes and solutions. S&T seeking to justify itself as supporting sustainable development should expect to be called upon to justify its selection of problems to focus upon, even as it challenges society to reexamine its own priorities. Providing such justification will require that our agenda-setting processes pay attention to consultation, scale, and criteria for selection.

Agendas should be based on broad consultations among affected parties (stakeholders) to establish needs; to make the best use of existing knowledge, experience, and opportunities; and to guide priorities for allocation of scarce attention, human resources, and funding. In particular, those whose choices or behaviors we seek to inform with S&T for sustainable development need to be involved in defining the questions that S&T for sustainable development undertakes on their behalf.

Which sustainability-enhancing knowledge is most needed clearly depends on which spatial and temporal scales are adopted in particular agenda-setting consultations. Global agenda-setting efforts have been underway since at least the work of the Brundtland Commission. But because key "socio-ecological" contexts vary so greatly from place to place around the world, priority knowledge needs can be expected to vary too. Care must be taken that overall S&T agendas reflect priorities determined at sub-regional and even local scales as well as global ones. Special care must be taken to match the scales of agenda setting for S&T to the scales at which the decisions most important to a sustainability transition will be made. As one potentially practical measure for exercising such care, the community might consider whether we ought to propose some sort of "subsidiarity" principle by which agenda setting for S&T would be relegated to the lowest level of decision making consistent with the characteristics of the problem/solution in question.

The agenda of S&T relevant to sustainable development could readily expand to encompass the agenda for most of science and technology. This would not be useful. In identifying which *additional* S&T is most needed to support sustainable development, the preceding discussion suggests that agenda-setting efforts should give priority to a relatively small set of R&D questions that are (i) driven by sustainable development goals, (ii) focused on providing solutions to specific problem-solvers' needs, (iii) synthetic and integrative in approach, and (iv) conducted in ways that attend to not only credibility, but also saliency and legitimacy of the resulting product. The next section of this paper attempts to apply these criteria to the discussions about agendas of science and technology for sustainable development that were carried out in the context of the consultations summarized here.

Agendas of S&T for Sustainable Development

What should have priority on the agendas of science and technology for sustainable development? As suggested in the preceding paragraphs, the meetings leading up to the World Summit stressed the need to shape such agendas through close and continuing consultation between scientists and decision makers and other stakeholders grappling with specific sustainable development problems. The need for institutional arrangement to promote more, and

more productive, such consultations at all levels is itself arguably the top priority to emerge from our efforts. Closely related is the need for building the capacity required to move beyond consultations to appropriately scaled R&D efforts. Some suggestions on how to move forward with these crucial infrastructure tasks are presented in the section on "Institutions." But some consultations between the science and decision-making communities are already well along, and a good deal of R&D valuable for sustainable development is already underway. Even as we work to deepen and broaden ongoing efforts, it is possible to report on what has already emerged as a partial consensus with respect to sustainable development goals that S&T should help to promote, specific problem-solving challenges for a sustainability transition to which S&T should have something to contribute, and underlying conceptual and methodological questions on which better understanding is needed if S&T is to realize its potential contribution to a sustainability transition.

Common goals for sustainable development

A remarkable feature of the last decade has been the emergence of a widely-shared set of international goals or norms for sustainable development. These have grown from the Brundtland Commission's general injunction to "meet the needs of the present without compromising the ability of future generations to meet their own needs;" through the Rio Declaration, the World Scientific Academies' focus on "meeting current human needs while preserving the environment and natural resources needed by future generations;" to the significantly more explicit goals for "development, poverty alleviation, and protecting our common environment" enshrined in the UN Millennium Declaration. Many of these goals are backed by quantitative targets approved in formal international conferences and treaties, though this is true to a greater extent in the social than environmental realm.

Problem-solving frameworks

Linked to the common goals noted above has been the emergence of several commonly used frameworks for classifying the problem-solving challenges that the S&T community should consider in setting its priorities for R&D in support of efforts to meet sustainable development goals. These may be summarized under the headings of "environment," "development," "sustainable development," and "integrative perspectives."

One stream of problem-solving perspectives has reflected goals of environmental protection. Dating back to the report of the Stockholm Conference and, a decade later, UNEP's "The World Environment 1972-1982," this approach has focused on such predictable "problem" areas as "air quality," "water quality," "land use," etc.

A second framework emerging from the development arena has tended to focus on problem solving in support of specific economic or social sectors such as "food production" or "education."

A significant innovation of the Brundtland Commission was its attempt to break away from this conventional "environment vs. development" framing of the problem agenda, and to shape a common agenda for sustainable development. The Commission proposed to organize global problem-solving efforts for sustainable development under the headings drawn from and, to a certain extent, combining the two agendas. These included human health and population, human

settlements, food security, energy, industry, biological resources, and the global commons. Numerous subsequent efforts have sought to extend or modify the Brundtland framework. Two additional themes received special attention in the consultations summarized here: water and consumption[31].

The Brundtland framework, with or without modifications, leaves unaddressed the problems associated with interactions across environmental stresses and social sectors. In the absence of a compelling integrating framework, established structures of both government and the academic disciplines have continued to focus problem-solving efforts in general, and R&D in particular, on individual environmental, social, or economic sectors rather than on the sustainable development of coupled "socio-ecological" systems per se. A special need in shaping agendas for S&T in the service of sustainable development is to articulate such integrated research, assessment, and monitoring programs. One promising approach to integration has been the emergence of the "place-based," integrative frameworks for addressing sustainable development problems discussed earlier in this paper. The potential that such frameworks have to promote the application of cutting-edge S&T to the resolution of sustainable development problems is suggested by recent progress in regional applications of El Niño forecasting and the "syndromes" approach promulgated by the German Advisory Council on Global Change (WBGU).

Candidates for an agenda of problem-driven S&T in support of sustainable development: The relationships among the conventional problem-driven frameworks for agenda setting summarized above are suggested in Figure 1.[32]

[31] See especially IAP, 2000, op. cit.; and ISTS/Bonn, 2002, op.cit.

[32] This particular version of the figure is drawn from U.S. National Research Council. 1999. *Our Common Journey: A Transition Toward Sustainability*. Washington, D.C.: National Academy Press. Comparable figures appear in several of the workshop reports on which this paper draws, notably that of the Chiang Mai session (ISTS/Chiang Mai, 2002).

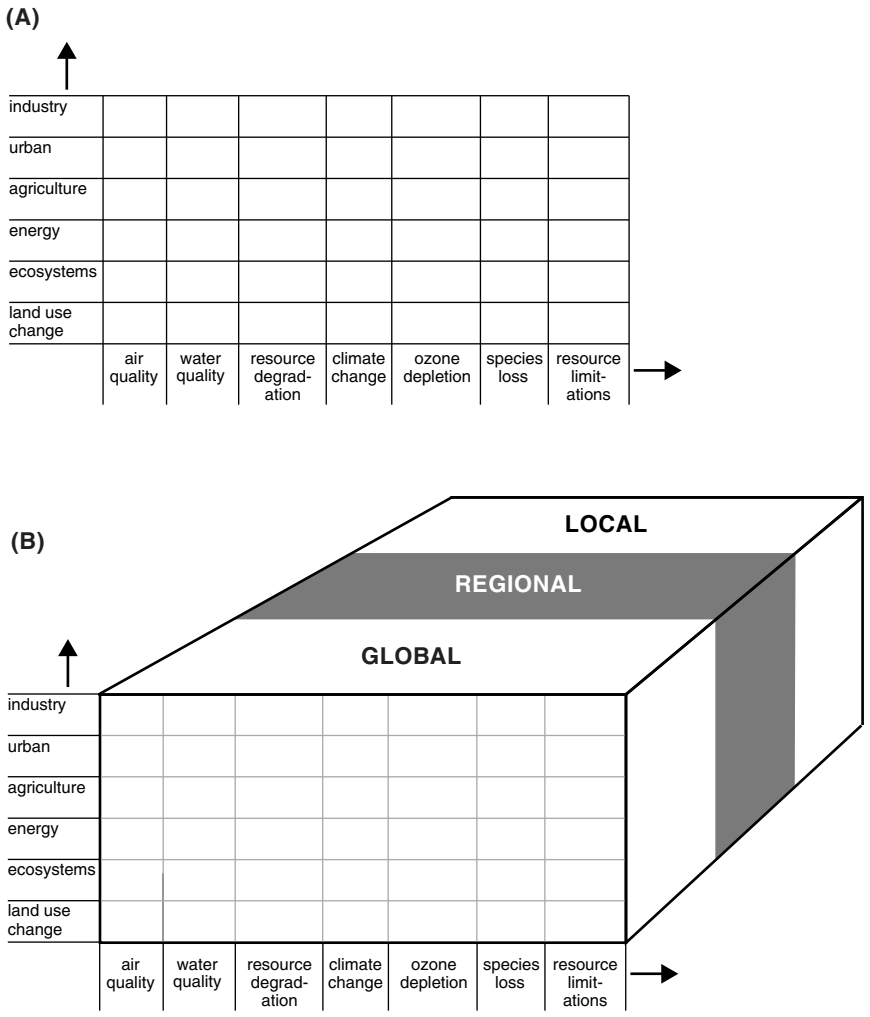

Figure 1. From National Research Council. 1999. *Our Common Journey: A Transition Toward Sustainability.* Washington, D.C.: National Academy Press, http://sustainabilityscience.org/keydocs.htm#ocj.

Many candidate R&D questions raised in the consultations on which this paper is based fall within individual cells of the figure, reflecting a relatively narrow focus on interactions between a single set of human development activities and a single dimension of the environment (e.g., Table 3 in the report of the Chiang Mai Workshop[33]).

There are also a number of suggested R&D initiatives that seek partial integrations "across" particular rows (e.g., "How can energy systems be redesigned to reduce their pressures on the earth's life support systems?") or "down" particular columns (e.g., "How can human development be promoted in ways that avoid dangerous perturbation of the climate?").

Finally, there exist a number of proposals for more fully integrated R&D seeking to provide insights into how complex interactions of multidimensional socio-ecological systems can be more sustainably managed, usually in some "place-based" or regional context (e.g. the upland forest management issues noted in the Chiang Mai report[34]).

Priority setting for problem-solving R&D

Few of the proposals for R&D to support problem-solving in the name of sustainable development noted above seem to have emerged from systematic application of the criteria for priority setting outlined earlier (or, indeed, from the application of any explicit criteria) to the list of plausible candidates.

The S&T community might wish to explore such a structured priority-setting exercise with a view toward identifying candidates for "Type-II partnerships" (between the S&T and decision-making communities) on a sample of sustainable development problems where S&T could make a substantial, tangible, and immediate contribution to solutions.

If it chooses to pursue such a priority-setting exercise, the community could consider experimenting with the "subsidiarity principle" mentioned earlier, i.e., giving priority at a given scale of decision making (international, national, local) only to R&D that cannot be better tailored to decision making at finer scales.

Many candidate R&D questions that have been proposed for attention at the international level do not obviously meet the criteria for priority problem-driven R&D questions that have emerged from the consultations summarized here. What, for example, is the global decision problem for which R&D on water systems is likely to offer a solution? On the other hand, some specific problem-solving R&D almost certainly does merit priority attention at the international scale. One possible example is the program on managing the global carbon cycle that has emerged from ICSU's Earth System Science Partnership.[35] The community might conduct a critical analysis of candidate international S&T programs for sustainable development to ask whether individual research projects do indeed merit (or might merit with amendments) priority status under the criteria that have emerged from the consultations summarized here. If this seems too daunting or premature, we should at least put in place a process for conducting such a review.

[33] ISTS/Chiang Mai, 2002, op cit.
[34] Ibid.
[35] See http://www.igbp.kva.se/cgi-bin/php/list.show.php?section_id=37&article_id=49&onearticle=.

A further implication of the findings from the consultations summarized here is that problem-driven priorities for S&T must ultimately reflect the "place-based" realities of particular "socio-ecological" settings. Although the geographic scale of such settings will vary, we discovered through our regional workshops that for a very substantial fraction of the problem-solving R&D needed to advance a sustainability transition, the most appropriate scale for setting priorities is well below the continental level, and frequently below the national level as well. A major challenge to science and technology for sustainable development will be to support agenda setting at appropriately local scales, rather than allowing global agenda setting to dominate our outlook. This is a lesson learned a decade ago by those focusing on the *politics* of sustainable development after the Rio Conference, as evidenced in the proliferation of "Local Agenda 21" movements around the world. These "place-based" agenda-setting efforts for political initiatives have been one of the bright spots in the post-Rio evolution of action on sustainable development, but have moved ahead with relatively little recognition or support from the science and technology community. An important task for our community in the coming years should be to harness a healthy S&T component to these "Local Agenda 21" sustainable development initiatives. More generally, we should ask whether we can already make a compelling case based on our criteria for particular regional R&D efforts.

Independent of scale, the community should make a concerted effort to identify very specific and urgent sustainable development problems for which enhanced use of S&T could almost certainly enable solutions. Agreeing on such a list that speaks to the fears, concerns, and needs of a wide cross-section of society must be part of our opening bid for the "new social contract" we hope to negotiate.

Candidates for an agenda on underlying conceptual and methodological questions

Efforts to harness S&T for problem-solving in support of sustainable development raise a number of fundamental questions about the nature of complex, interactive socio-ecological systems. While pragmatic R&D can help contribute to solutions even when such fundamental questions remain unresolved, a parallel program of R&D on underlying conceptual and methodological issues raised by our problem-solving efforts must be part of a program to harness S&T to sustainable development. Several of the workshops and studies within the two-year consultation reported on here have attempted to identify and explore candidates for a research agenda on such questions.[36]

From a global perspective, for example, the Friibergh Workshop on Sustainability Science highlighted seven "core questions" for priority attention by the R&D community.[37] The international programs on Global Environmental Change, through their GAIM effort, have endorsed a program of 23 core questions for the next generation of Earth Systems Science research, including several items directly pertinent to our ability to harness S&T for the solution

[36] See ISTS/Regional Synthesis, 2002, op. cit.
[37] Kates et al., 2001, op. cit.

of sustainable development problems.[38] Forums for the further development of these questions have been established and are increasingly active.[39]

A number of the regional workshops conducted over our last two years of consultations articulated "bottom up" perspectives on what their participants saw to be the most important needs for deeper understanding of core conceptual and methodological questions. These generally varied to reflect the particular concerns of each region – another reason to emphasize the importance of setting agendas at local as well as global scales.[40] Nonetheless, three conceptual questions emerged as matters of high priority concern across a wide range of regions and development circumstances. All are consistent with the original Friibergh and GAIM lists. But their appearance on a wide range of global *and* regional agendas, and their sharpening through discussion there, makes them particularly high priority candidates for research to support problem-solving for sustainable development:

*** Adaptiveness, vulnerability, and resilience** in complex socio-ecological systems: The Chiang Mai Workshop crystallized a view expressed by many in our consultation: "Sustainability depends on … [the] dynamic quality of maintaining adaptive capacity and opportunities…. [because] the real world is full of surprises or disturbances and longer term structural transformations… New tools and concepts are needed to understand transitions of complex adaptive systems. These highlight the importance of disturbance, diversity and novelty in determining the resilience, and hence sustainability of ecosystems and their linked human enterprises."[41] Such understanding will have to address the embedding of particular socio-ecological systems – and their adaptive capacity – within larger regional and global contexts. This topic has also been identified as meriting high priority in a separate report to the ICSU Rainbow Series, drawing on the extensive work of the Resilience Alliance.[42]

*** Sustainability in complex production-consumption systems:** There have long been independent calls for deeper understanding of how the environmental impacts of production, on the one hand, and consumption, on the other, can be lowered. An important insight emerging from the consultations summarized here is that the greater need is for an integrated understanding of the complex relations between consumption and production. These are becoming increasingly complex as globalization increasingly separates locations at which production and consumption occur. Incentives and technologies work on both ends of the production-consumption chain, and an integrated understanding of their impacts on sustainability is badly needed as a guide for targeting policy.[43]

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[38] John Schellnhuber and Dork Sahagian. 2002. "The twenty-three GAIM questions." *Global Change Newsletter* 49 (April 2002), http://www.igbp.kva.se//uploads/NL_49.pdf.

[39] See, for example, the "Integration" section of the *Global Change Newsletter* published by the IGBP (http://www.igbp.kva.se) and the Forum on Science and Technology for Sustainability (http://sustainabilityscience.org/questions.htm).

[40] See ISTS/Regional Synthesis, 2002, op. cit.

[41] ISTS/Chiang Mai, 2002, op cit.

[42] ICSU, 2002. *Resilience and Sustainable Development*. Series on Science for Sustainable Development, No. 3. 37pp. Paris: ICSU.

[43] See especially ICSU et al., 2002a and 2002b, op. cit.; ISTS/Bonn, 2002, op. cit.; ISTS/Chiang Mai, 2002, op. cit.

*** Institutions for linking science and decision making across scales:** It follows from many of the findings reported here that the prospects for successfully navigating transitions toward sustainability will depend in large part on our ability to improve the dialogue between the S&T community and problem-solvers pursuing sustainable development goals. Significantly, this needs to be done in ways that enhance the ability of local problem-solvers to harness S&T from anywhere in the world in meeting their goals. We need to understand what sorts of institutions can best perform these complex bridging roles – between science and policy, and across scales – under a wide range of social circumstances.[44] The consultations reported here not only highlighted the wealth of experience in institutional experimentation that is underway around the world, but they also revealed a deep thirst for systematic efforts to analyze comparatively the performance of those experiments, to identify how and under what conditions some "bridging" institutions work better than others, and above all to help the groups running the existing institutions to learn from one another. This is a challenge that research surely can and must address.[45]

When embroiled in priority-setting efforts, it is easy to lose track of the fact that much R&D with potential relevance for sustainable development is already underway, and many findings are already beginning to accumulate in particular local and regional settings around the world. Part of the R&D effort in the years ahead must be to assess, test, and evaluate the generality of these findings. The community should consider options for advancing this scientific reflection on our ongoing endeavor. One specific suggestion to emerge from the consultations was to establish comparative case studies across regions for the purpose of identifying more explicit and generalizable principles regarding the conditions under which current knowledge is suitable for application now.[46]

What institutional initiatives are needed to support implementation of these agendas?[47]

The institutional initiatives needed to support agendas of S&T for sustainable development follow closely from the reorientations in the practice of science itself suggested in the section on "Institutions." There the focus was on what S&T professionals would need to *do* in their work to better support social goals of sustainable development. Here the focus shifts to the institutions that would be necessary to support individual scientists and engineers seeking to carry out such R&D agendas. (Note that "institutions," as the term has been used in the consultations summarized here, is not synonymous with "organizations." We follow Young in treating "institutions" as "systems of rules, decision-making procedures, and programs that give rise to social practices, assign roles to the participants in these practices, and guide interactions among

[44] "Institutions" as we use it here is not synonymous with "organizations." We follow Young (Oran R. Young. 1999. *Governance in world affairs*. Ithaca, NY: Cornell University Press.) in treating "institutions" as "systems of rules, decision-making procedures, and programs that give rise to social practices, assign roles to the participants in these practices, and guide interactions among occupants of the relevant roles." "Institutions" thus include organizations, but also norms and expectations that transcend those organizations.

[45] See especially ISTS/Trieste, 2002, op. cit.; ISTS/Cambridge, 2002, op. cit.; ICSU et al., 2002b, op. cit.; and ISTS/Chiang Mai, 2002, op. cit.

[46] ISTS/Chiang Mai, 2002, op. cit.; ISTS/Trieste, 2002, op. cit.

[47] This question was the central topic of ISTS/Trieste, 2002, op. cit., and ISTS/Cambridge, 2002, op. cit., and is covered at length in the reports of those workshops.

occupants of the relevant roles."[48] "Institutions" thus include organizations, but also norms and expectations within which individual organizations are embedded.)

The consultations summarized here made it clear that institutions supportive of the mobilization of science and technology for sustainable development are not impossible to design and implement. At the international level, some relatively successful international programs linking S&T to sustainable development goals have already been developed to address problems ranging from increasing agricultural productivity, to combating human disease, to protecting the earth's ozone layer.[49] Likewise, at the regional level, there already exist efforts such as START's South East Asia Regional Center and IIASA's RAINS assessment for acid rain in Europe that have made a good beginning in implementing integrated, problem-driven, place-based research and applications programs in support of sustainable development.[50] Finally, the workshop on "Harnessing Institutional Synergies for Sustainable Development" organized by the Third World Academy of Sciences highlighted dozens of effective local-level institutions for mobilizing S&T to contribute to the solution of pressing sustainable development problems.[51]

To date, however, these successes reflect idiosyncratic, if invaluable, exceptions rather than general rules. This observation emphasizes the previously noted research need for a systematic and critical effort to learn from both successes and failures of the past lessons that have the most to offer the design of effective institutions for promoting transitions toward sustainability.[52] Such learning will in turn require a determination to move beyond advocacy of existing programs that have been built for other (often excellent) reasons, toward a critical dialogue about the science and technology strategies most needed to support sustainable development per se. Above all, it will demand a unified campaign by the scientific, engineering, and development communities to build the political support needed to implement – at a scale worthy of the challenges before us – an R&D system for sustainable development.[53]

In the meantime, however, the consultations summarized here – together with the findings of other groups – have highlighted a number of challenges that institutions for harnessing S&T to sustainable development will need to address, and some specific reforms and initiatives that can be justified on the basis of evidence already in hand.

Mobilizing appropriate S&T for sustainable development[54]

There is a dual challenge here. The first is to assure that the S&T conducted in the name of sustainable development will be focused on the most pressing problems of sustainable development as defined by stakeholders in those problems. Meeting this challenge requires institutions that avoid the pitfalls of R&D agendas set to reflect topics of most concern to donors, or to people selling particular technologies, or to scientists pursuing the latest theoretical developments in their fields. (All of these may be fine things to do, but they are unlikely to address priority needs of sustainable development.)

[48] Young, 1999, op. cit.
[49] ISTS/Trieste, 2002, op. cit.; Clark, 2002, op. cit.
[50] See IIASA RAINS at http://www.iiasa.ac.at/~rains/, and the SE Asia START effort at http://www.start.or.th/.
[51] ISTS/Trieste, 2002, op. cit.
[52] See also ISTS/Bonn, 2002, op. cit.; ISTS/Chiang Mai, 2002, op. cit.
[53] Clark, 2002, op. cit.
[54] See especially ICSU, 2002a, op. cit.; ISTS/Trieste, 2002, op. cit.; and ISTS/Cambridge, 2002, op. cit.

The second challenge is to assure that the most appropriate S&T is indeed mobilized in the service of particular problems. Meeting this challenge requires institutions that select the most appropriate expertise for the task at hand rather than allowing particularly "favored" disciplines or technologies to monopolize the input of S&T to problem-solving efforts.

Institutions meeting these challenges need to have one foot in the politics of problem definition, responsive to issues of appropriate participation and representation, and the other foot in the world of science and technology, responsive to issues of expertise and quality control. The consultations summarized here suggested that this stressful situation is not generally well dealt with by institutions that spend most of their time doing either pure politics, or pure science. Instead, more success has been had by a variety of "boundary-spanning institutions." Such institutions set themselves between science and politics, partially responsible to both – but not expected to operate fully by the norms of either. At their best, they facilitate two-way communication, and provide neutral "sites" for the "co-production" of useful knowledge by scientists and problem-solvers.[55]

Examples of institutions that have played this "boundary-spanning" role in the arena of science, technology and sustainable development include several of the best international scientific assessments (e.g., IIASA's RAINS effort on European acidification), regional decision support operations such as those involved in facilitating the use of El Niño climate forecasts, and local organizations such as India's Honey Bee network.[56]

Integrate science, technology, and knowledge generally in problem-solving efforts

The consultations reported here also revealed general agreement that more effective use of S&T in problem-solving for sustainable development will require much more integrative R&D institutions.

The needed integration will often encompass the communities engaged in promoting not only environmental conservation, but also human health, social services, and economic development.

We will need to entrain formal expertise not only from university-based natural and social sciences, but also from engineering. Better ways must be developed to tap relevant formal expertise (from all these sources) that resides in the private sector.

Even more challenging, we will need to find ways of identifying, utilizing and honoring the vast resources of informal expertise derived from practical experience in grappling with particular sustainable development problems in particular social and ecological settings.

More generally, promoting sustainable development requires institutions that can integrate what have too often been the "island empires" of research, monitoring, assessment, and operational decision support.

[55] See especially ISTS/Ottawa, 2002, op. cit.; and ISTS/Trieste, 2002, op. cit.
[56] ISTS/Trieste, 2002, op. cit.

Examples of institutions that have successfully performed all of these integration functions are rare to non-existent, though a number of efforts reviewed in the consultations summarized here have made a start. The community might usefully devote some attention to identifying effective models.[57]

Facilitate a balance of flexibility and stability

It will be important to do a better job of facilitating a balance of flexibility and stability in efforts to harness S&T to sustainable development. The challenges of sustainable development are rapidly changing, requiring that S&T efforts to respond to those challenges be flexible enough not to be stuck fighting the last war. On the other hand, experience reviewed in the consultations summarized here argues that it takes time and patience to build up trusting relationships between the S&T and decision-making community, to learn from experience, and to evaluate serious efforts to promote stability. These countervailing pressures driven by the need to learn and adapt in a complex and rapidly changing world, coupled with glaring capacity deficiencies in particular regions of the world, generate conflicting demands on the next generation of S&T institutions: adapt but remain stable. In light of the highly differentiated needs and capabilities in different places around the world, no single institutional model is likely to be optimal. Needed is probably a portfolio of institutions for managing S&T for sustainable development that can handle these tensions.

One response has been to reform existing long-term research organizations to make them more responsive to changing needs (e.g., CGIAR). Another is the use of task forces or ad-hoc teams of experts commissioned to address particular problems (e.g., the World Commission on Dams, the Millennium Ecosystem Assessment). A third model – one felt to be particularly promising by participants in the consultations summarized here – combines the previous two approaches by means of permanent secretariats that accumulate experience, trust and learning, but which convene ad-hoc teams to provide flexible strength on particular topics (e.g., the InterAcademy Panel, the Canadian Policy Research Institute).[58]

Strategic approach to infrastructure and capacity building[59]

Priority needs for investment in infrastructure and capacity were shown by the consultations summarized here to vary dramatically around the world. There exists general agreement, however, on a number of points. First, any strategy for enhancing the infrastructure and capacity needed to connect S&T to sustainable development must balance investment in individuals, organizations, and networks.[60] Second, in those regions where basic education – the most fundamental source of R&D capacity – is underdeveloped, priority must be given to building the educational base and enhancing an appreciation for the methods and potential contributions of science.[61] More generally, one of the greatest needs is for institutions that support cross-scale linkages among experts and problem-solvers.[62] These will need to be structured to facilitate "vertical" connections between the best research anywhere in the world and practical experience

[57] ISTS/Chiang Mai, 2002, op. cit.
[58] ISTS/Ottawa, 2002, op. cit.; ISTS/Trieste, 2002, op. cit.
[59] This is a central topic of ICSU et al., 2002a and 2002b, op. cit., and is developed in Global Change, 2002, op. cit.
[60] ISTS/Trieste, 2002, op. cit.
[61] ICSU et al., 2002b, op. cit.; Global Change, 2002, op. cit.; ISTS/Abuja, 2001, op. cit.; ISTS/Bonn, 2002, op. cit.; ISTS/Chiang Mai, 2002, op. cit.; ISTS/Ottawa, 2002 op. cit.
[62] See especially the discussion of scale in ISTS/Chaing Mai, 2002, op. cit.; and ISTS/Trieste, 2002, op. cit.

in particular field situations. At the same time they will need to foster "horizontal" connections among regional research and application centers to promote learning from one another. Finally, it will be essential everywhere to identify existing strengths and to build on them rather than seeking to create capacity from scratch.

Financing issues[63]

It is clear that a restructuring of the funding for S&T at all levels from the local to the global will be essential if it is to substantially increase its contribution to sustainability.[64]

The strategies for funding the science aspects of S&T for sustainable development differ markedly from those appropriate to the technology aspects, e.g., science funding often involves granting and contracting mechanisms while technology funding could involve venture capital or direct industrial investments. The financial issues addressed herein are primarily focused on the science aspect of the S&T agenda. It is clear that more detailed analyses of the whole range of issues regarding the technology aspects of sustainable development, including financial strategies, are essential and must be addressed.

There are two modalities for funding the S&T aspect of a sustainable development effort: Mode A - where the approach is a "partnership" where the science and technology aspects are an integral part of and funded within a overall sustainable development effort,[65] and Mode B - where the research in support of sustainable development seeks to develop fundamental concepts and knowledge, models and methods, and application strategies. The funding mechanisms for these two modalities are likely to differ.

Existing and novel funding mechanisms involving philanthropic foundations, businesses, and governmental and intergovernmental bodies should be explored to support these endeavors. Efforts to address sustainable development issues or to increase scientific capacity will take place within a context of very different funding patterns, environmental concerns, and research orientations.

A view was advanced by some participants that moving forward in supporting S&T for sustainable development might require a multinational funding mechanism that is designed specifically to meet the unique needs of harnessing S&T for sustainable development.[66] Such a funding capability would have a broad mandate for building social, human, and technical capacity, enhancing education, supporting research institutions, and improving scientific capacity and technology innovation, development and dissemination, particularly in emerging economies and other developing countries. Such a funding mechanism would be founded on – but would likely need to extend – the remarkably effective financial leveraging strategies of existing

[63] These issues were a special focus of ISTS/Cambridge, 2002, op. cit.; many of the conclusions at that workshop drew on the earlier ISTS regional workshops.
[64] See the conclusions of ICSU et al, 2002a; and Clark, 2002, both op. cit.
[65] On this, see especially the arguments in ISTS/Abuja, 2001, op. cit.
[66] See the arguments developed in ISTS/Santiago, 2002, op. cit., and elaborated in ISTS/Cambridge, 2002, op. cit. Both of these draw extensively upon conversations with Francisco Sagasti, and material presented in Francisco Sagasti and Keith Bezanson. 2001. *Financing and providing global public goods: Expectations and prospects*. Stockholm, Sweden: Ministry of Foreign Affairs.

multinational development banks, and emerge as part of a new generation of financing facilities. Such a international funding facility could include:

- A diverse portfolio of products (e.g., innovation and venture capital funds, education funds, loans, grants, start-up funds, etc.) that could meet heterogeneous needs in different types of countries;
- The ability to leverage resources to build countries' own research capacity and appropriate technology;
- The capacity to tap resources from private capital markets, which have grown enormously during the last two decades, and which are increasingly paying attention to sustainability issues – for example, through the emergence of "green" investment funds and institutions;
- Engagement of multiple shareholders, including foundations, NGOs, countries, private banks, citizen groups, and the development banks;
- An evolving and flexible structure; and
- Responsibility for and authority in the management of the facility by the potential beneficiaries of S&T funding.

The community should give the highest priority options to moving forward the creation of this or other funding mechanisms. Without them, all of the talk and consultations and high hopes of the last two years will be unable to amount to much more than a business as usual that we can no longer afford.

[END]