Sustainability Science

NEW SCIENCE FOR AUSTRALIA'S TRANSITION TO SUSTAINABILITY

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CSIRO

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New Science for Australia's Transition to Sustainability

SUMMARY

This proposal describes a critically important area of emerging science in which CSIRO's investment would return strong social, financial, and environmental dividends: ***Sustainability Science***.

- Australia has pressing strategic needs for achieving a 'transition to sustainability'. Our current development path is not sustainable, and the world in which we live is changing rapidly. Without a sustainability transition, we face falling quality of life, and damage to our life support systems. International 'best guesses' put the timeframe for achieving this transition as less than two generations.
- New investment needs to be urgently focussed to promote new transdisciplinary research in emerging fields, and explore new ways of doing research. There is currently no coherent capacity in Australia to deal with the complex, interdependent social and natural systems that we need to understand. However, there are indications that research being undertaken internationally can provide insights into the myriad of challenges, and also that we can capitalise on the wealth of excellent science being undertaken in Australia. The opportunities for the development of new products and services enhancing sustainability are high.
- The options for achieving a competent research capacity in ***Sustainability Science*** involve taking advantage of existing activity, developing new processes and research areas, and providing environments in which creativity can flourish. Five key areas of focus are staff involvement and flexibility, institutional development and learning, development of different types of projects, capitalisation on existing expertise, and new styles of collaboration.
- What do we need?
  - Social processes fostering mutual learning leading to integrated outcomes;
  - Improved co-ordination of existing activity;
  - Integration, development, and application of earth systems science;
  - Improved understanding of the mechanisms and structures of natural system / social system interaction;
  - Development of a high level complex natural / social system integration and assessment / risk analysis capability;
  - Better access to external expertise through strategic partnership;
  - Creation of new institutional structures permitting extreme flexibility;
  - Commitment of CSIRO to engage forcefully with the Australian community

N. T. M. HAMILTON

INTRODUCTION

"If we do not change our direction, we are likely to end up where we are going."
Chinese Proverb

"To know the road ahead, ask those coming back."
Chinese Proverb

UN Secretary General Kofi Annan, in his Millennium Report on the role of the UN in the 21st century, challenged the international community to collaborate in efforts guaranteeing the peoples of the earth three fundamental freedoms: "freedom from want, freedom from fear, and the freedom of future generations to sustain their lives on this planet." He noted that the first two of these challenges are long standing issues incorporated in the UN Charter and pursued by a number of relatively mature, if not always effective, international institutions and arrangements. In contrast, he continued, the third challenge -- that of sustainability -- is new, reflecting threats that the UN's founders could not have imagined.

This challenge is reflected in the use of the term "***ANTHROPOCENE***" by Nobel prize-winning biogeochemist Paul Crutzen to describe the epoch we currently live in, emphasising the central role that humanity plays in the functioning of the Earth System. There is no longer a 'pure' natural world 'perturbed' by human activity, but just a very tightly coupled and very complex system of which humans are an integral part. It is extraordinary to think that we will be *the* major geological and biogeochemical force for many millennia, perhaps millions of years, to come. Indeed, it is our challenge and responsibility to determine our own future and that of the planet.

Australian researchers have the opportunity to help shape the future through the creation of a new type of science in the service of society: ***Sustainability Science***. This initiative would involve working in new ways and with new people to ensure that our region has a sustainable future. It will require the best fundamental science, the best problem solving techniques, and the best institutional structures we have ever imagined. It will require not just the Earth System sciences but political science, psychology, sociology, anthropology, evolutionary economics and more. Further, it will need people who recognise that human and biogeophysical systems are inextricably entwined and interdependent, and that traditional analytical disciplines alone are no longer capable of addressing the problems. Above all, it will require a tight re-engagement with the society in which we live.

> *As the magnitude of human impacts on the ecological systems of the planet becomes apparent, there is increased realization of the intimate connections between these systems and human health, the economy, social justice, and national security. The concept of what constitutes "the environment" is changing rapidly. Urgent and unprecedented environmental and social changes challenge scientists to define a new social contract. This contract represents a commitment on the part of all scientists to devote their energies and talents to the most pressing problems of the day, in proportion to their importance, in exchange for public funding. The new and unmet needs of society include more comprehensive information, understanding, and technologies for society to move toward a more sustainable biosphere – one which is ecologically sound, economically feasible, and socially just. New fundamental research, faster and more effective transmission of new and existing knowledge to policy- and decision-makers, and better communication of this knowledge to the public will all be required to meet this challenge.*

Jane Lubchenco, from the Presidential Address at the Annual Meeting of the American Association of the Advancement of Science, 15 February 1997.

Can Australia meet the challenge facing us? The role of science has not traditionally extended this far, perhaps contributing to the dislocation from our society. The adoption of the paradigm of the nature – society system as a complex system allows us to redefine our role, break down the disciplinary barriers, and make meaningful inroads into seemingly intractable problems. Ultimately, we have no choice: the severe biophysical constraints we face, coupled with our geopolitical position, make transition to sustainability Australia's only option.

VISION

To make the Australian region the global leader in the transition to sustainability.

CSIRO'S ROLE

As one of the world's largest and most diverse scientific research institutions, CSIRO has a quite extraordinary capacity to create diverse teams to tackle complex problems. Successfully achieving a regional transition to sustainability will, however, require far more than the expertise available within the organisation: indeed, it will require far more than 'scientific' expertise. Partnering with a wide range of organisations is a critically important strategy. It will also require doing the research in different ways than we are used to. To successfully achieve a sustainability transition, CSIRO itself will need to undergo something of a similar nature.

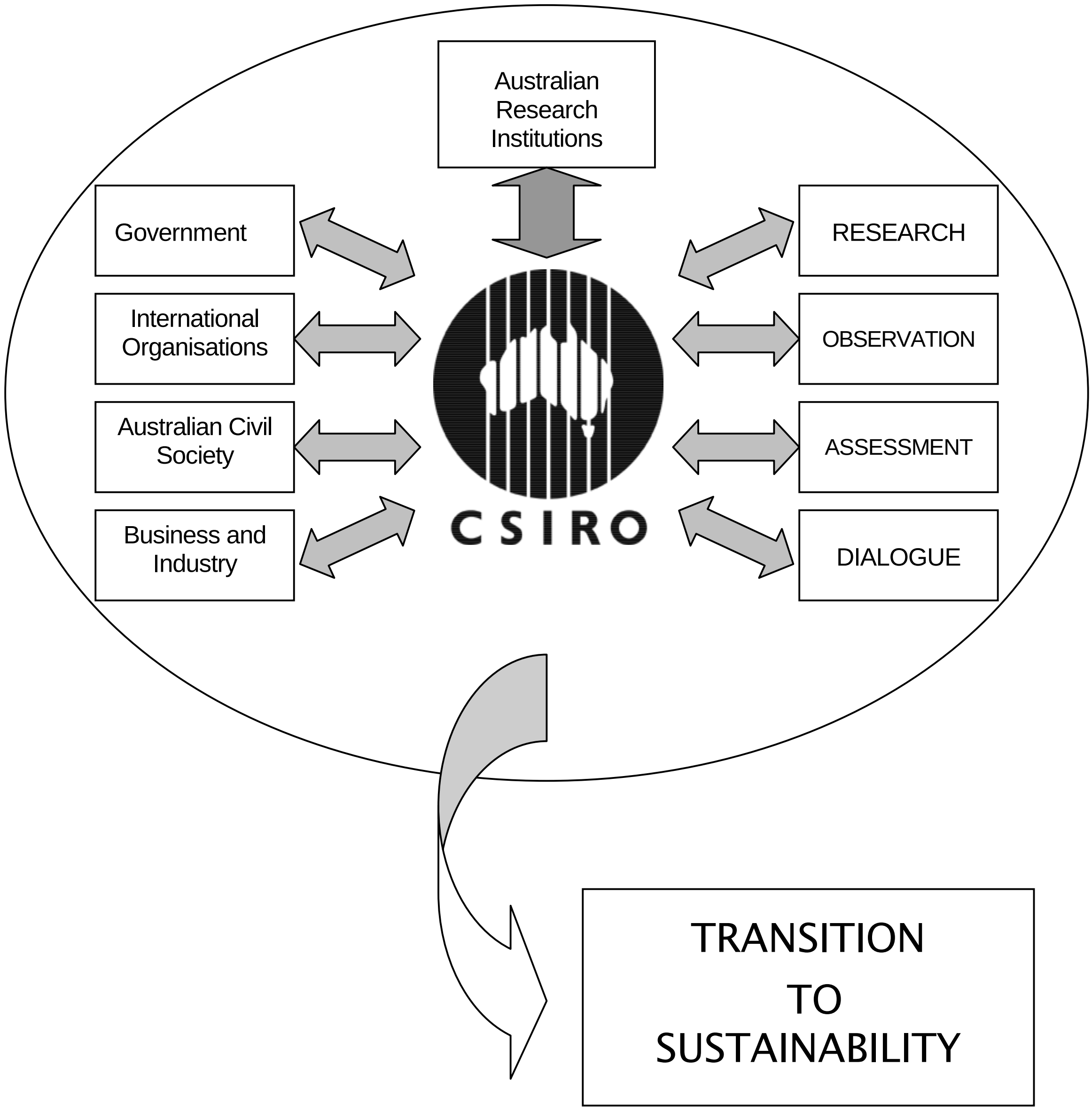
CSIRO's role in the transition to sustainability will vary over time. Initially, it will provide leadership in our region through development of the concepts and promotion of the ideas to all levels of society. CSIRO will create diverse teams of researchers from both inside and outside the organisation to define problems, innovative approaches, and establish social learning and participatory processes to ensure consistent engagement with stakeholders. It will foster the necessary public exploration and debate about our future, helping to shape our research strategies and developing ownership. Importantly, CSIRO will lead in the creation of environments and frameworks in which researchers can work together, across disciplines, institutional structures, and geographical space. Later, CSIRO may have a very different set of roles. As projects develop and are carried out, individual research teams may move in and out of the initiative as required.

In our globalizing world, regional and national strategies for sustainable development will be myopic unless they also are informed by a global perspective. However, Australia is a very special, indeed unique, component in the Earth System: our ecology, geography, and socio-economic structure are different from other nations. While it is critically important that we have a global understanding of the profound changes affecting the world, it is also critical that we have the capacity to understand our own part of the Earth System and how it functions. CSIRO's role in providing advice to the Australian government cannot rely alone on international research findings. The organisation's linkage with international research groups provides the opportunity to tap into the best integrative global science, while focusing on national goals. There is a need therefore, to develop a strong Australian capacity to better understand the Earth System through international linkage and national focus.

CSIRO is perfectly placed to provide advice on issues where the time horizons are longer; where the decisions are complex, involving many different types of expertise; where the risks are high, uncertainty great, and where public and private concern exists. The transition to sustainability clearly belong to this class of issues, and the primary concern is how best to use science to manage uncertainty. Openness is a crucial component. CSIRO has the opportunity to lead by example, going beyond 'best practice', to becoming Australia's foremost advocate for sustainability. It may be helpful to remember that CSIRO has been somewhere similar before: it was integral in Australia's post war nation-building, fostering the development of new industries, developing regional strategies, and understanding 'our' Earth System.

These ideas are risky. CSIRO needs to invest financially, and provide a unique learning environment. The complex problems to be addressed will require techniques yet to be developed. The rewards if we are successful are probably beyond anything science has yet achieved: a sustainable future. The risky nature of this initiative therefore requires a strong management structure, with planning and monitoring of progress of an extremely high standard. There are however a range of very exciting shorter term opportunities as well – the range of intellectually rich products and services that CSIRO will develop in the process of helping to achieve the transition.

There are several international models that have captured part of the essence of these concepts (see Appendix 1 for a candidate list), but none with all of the ideas together. CSIRO therefore has an opportunity for world class innovation in organisational structure as well as science.



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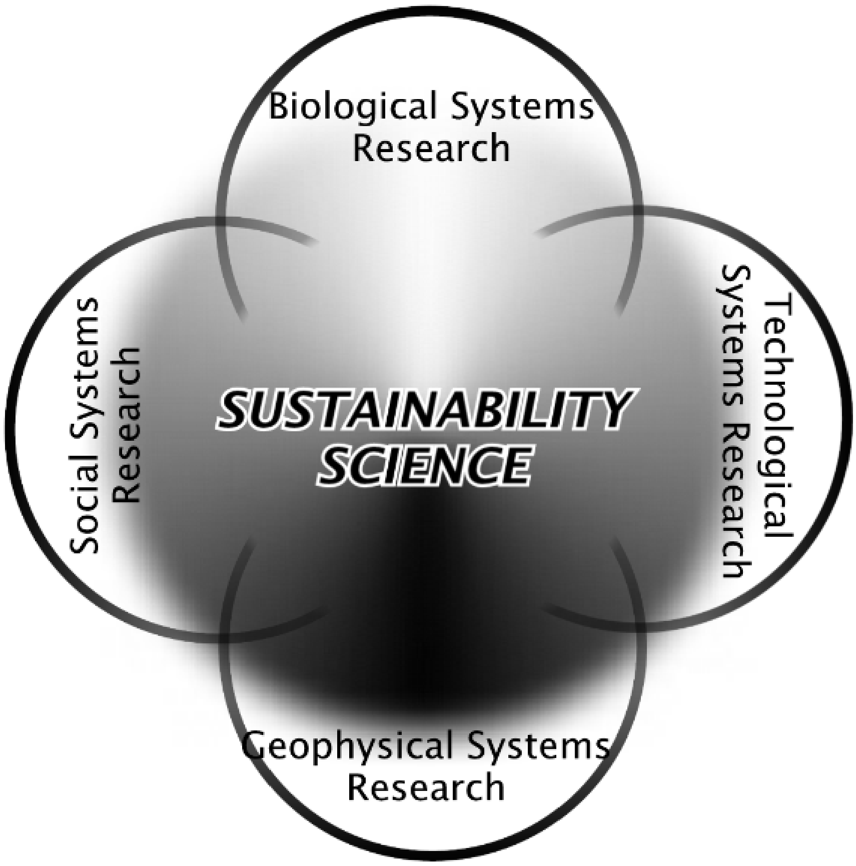
What is “Sustainability Science” ?

Sustainability Science is science in the service of a transition to sustainability, with the twin goals of meeting the human needs of a much larger and different regional population, while enhancing the earth’s life support systems. ***Sustainability Science*** focuses on the dynamic interactions between nature and society. This field is definitely ‘work-in-progress’, emerging from various global and regional programs of environmental and social systems research, and from the growing recognition across many disciplines of the need for synthesis and integration in order to solve fundamental problems. Substantial understanding of nature – society interactions has been gained in recent decades through research that includes human action on the environment and environmental impacts on humans, in social and development studies that seeks to account for environmental influences, and a small but growing body of interdisciplinary research. However, we urgently need to move beyond these beginnings to shape a better understanding of the rapidly growing interdependence of the nature-society system. The international attention centred on this theme has recently been expressed as the Amsterdam Declaration (Appendix 2), in which four international research programs (representing tens of thousands of researchers) outline a new agenda. It is important to acknowledge that there are both quantitative and qualitative differences in the style and amount of ‘sustainability science’ related activities being undertaken in Australia and internationally.

A growing body of evidence and experience suggests that the needed understanding must encompass the interaction of global processes with the ecological and social characteristics of particular places and sectors. The regional character of what ***Sustainability Science*** is trying to explain means that relevant research will have to learn how to integrate the effects of key processes across the full range of scales from local to global. It will also require fundamental advances in our ability to address such issues as the behavior of complex self-organizing systems, the responses (some irreversible) of the nature-society system to multiple and interacting stresses, and the options for combining different ways of knowing and learning so that social actors with different agendas can act in concert under conditions of uncertainty and limited information.

It would be premature here to suggest a comprehensive research agenda for a still-nascent ***Sustainability Science***. Indeed, there are several important tensions that must be recognized in the development of this agenda: that between broadly based and tightly focused strategies; that between integrative, problem-driven research and research firmly grounded in particular disciplines; and that between the quest for a generalisable scientific understanding of sustainability and the place-specific aspects that give rise to these issues. These are not ‘either – or’ choices, but are integral to the nature of the problem. However, it is clear that the new understanding developed by an Australian ***Sustainability Science*** initiative would offer significant benefits to the community.

Developing a useful ***Sustainability Science*** will require novel approaches for research linking the social and natural sciences, and studying adaptive management and policy; for technology development and diffusion, to provide the most useful and needed tools for navigating the choices; for institutions, to overcome barriers and find new funding mechanisms; and for understanding risk, through assessment, monitoring, and adaptation. Perhaps most challengingly, ***Sustainability Science*** will require the design of new ways of learning from the uniquely large-scale, long term experiments created each time a new technology, management scheme, or policy is tried out.



THE PRIMARY CHALLENGES

The U.S. National Research Council has identified three priority tasks for advancing the agenda on ***Sustainability Science***:

1. Development of a research framework that integrates local and global perspectives, to shape a place-based understanding of the interactions between society and the environment;

2. Initiation of focused research programs on a set of understudied problems central to a deeper understanding of those interactions; and

3. Promotion of the better utilization of existing tools and processes for linking knowledge to action in pursuit of a sustainability transition.

Without doubt, these are major challenges of equal applicability to Australia; they suggest the urgent need for strategic thinking about what we do, and how we do it.

More tangible research challenges to our ability to assist the transition to sustainability include:

- Understanding how the physical, chemical, geological, biological, social, political, and economic processes that comprise the Earth System are functionally interrelated;

- Understanding the details of the complex interactions between natural and social dynamics over the necessary range of temporal and spatial scales;
- Developing a more complete understanding of the key processes responsible for longer-term change and variability in the Earth System, and how they are reshaping nature – society interactions relevant to sustainability;
- Determining the vulnerability or resilience of the Earth System in different parts of Australia, and for particular types of ecosystems and human livelihoods;
- Bringing this new knowledge to application on key national and regional issues.

Developing strategies to help Australia cope with current and future change and successfully make the transition to sustainability will require scientifically credible, politically legitimate, effective, and practical solutions. This initiative proposes to go well beyond the normal scientific boundaries. It will need to measure its success against goals set by the Australian community, not by scientists.

The importance of thinking in terms of entire research systems when seeking to bring science and technology to bear on sustainability problems has long been recognized in the international agricultural and health sectors. Such systems incorporate and integrate not only elite laboratories that may be anywhere in the world, but also operational monitoring systems, field "extension" agents and intermediary R&D capacity at national and regional levels. Moreover, it is now clear that they must make provision for not only "piping" basic discoveries "down" to field level, but also for two-way communication that:

- adapts those discoveries to local conditions,
- conveys special needs encountered in the field "up" to elite laboratories that have the specialized resources to address them,
- integrates "local," context-specific knowledge with "exotic," generalizable knowledge to create effective solutions for particular problems, and
- entrains private and public sector agents in the knowledge production and application process.

In Australia, too, there are isolated examples of groups that have bridged the communication gap. CSIRO has many leading edge projects involving stakeholders, multidisciplinary teams, and successful applications. We must ask ourselves, though, how many political scientists does the organisation have access to, how many world class macroeconomic models, how many sociologists and historians? Can we really address systemic problems in which the underlying causes or constraints are cultural or political, with (mostly) hydrologists, mathematicians, and entomologists? Do we even have organisation-wide capacity to analyse the complex causal and synergetic relationships surrounding the issues we focus on? Complacency and self congratulation have been the downfall of organisations much larger than CSIRO, perhaps even empires.

Unfortunately, understanding the need for such problem-driven research systems and the functional capacities that they must exhibit has proven far easier than designing and implementing them. In fact, a recent international meeting identified the absence of effective national and international integrated research systems and the institutions to support them as the principal barrier to future progress in meeting the information needs of a transition toward sustainability. CSIRO structures today may be inappropriate for the transition, and a close look could reveal opportunities for “leapfrogging” into a new mode of operation.

Background

> The world's present development path is not sustainable. Efforts to meet the needs of a growing population in a globalizing, unequal and human-dominated world will continue to exert unsustainable pressures on the Earth's essential life-support systems. Worrying interactions among climate change, loss of biological diversity, increasing poverty and disease, and growing inequality combine to increase the vulnerability of humans and nature. Meeting fundamental human needs while preserving the life-support systems of Earth will require a worldwide acceleration of today's halting progress in a transition toward sustainability. A response as to how this transition might be achieved has begun to emerge in recent reports of national and international scientific organizations, as well as from independent networks of activists and scientists.
>
> Meeting the challenge of ***Sustainability Science*** will also require new styles of institutional organization to foster and support inter-disciplinary research over the long term; to build capacity for such research, especially in developing countries; and to integrate such research in coherent systems of research planning, assessment and decision support. We need to be able to involve scientists, practitioners, and citizens in setting priorities, creating new knowledge, evaluating its possible consequences, and testing it in action. This will require integration of this new active knowledge in particular locations and cultural settings through broader networks of research and monitoring.

Extracts from the Statement of the Friibergh Workshop on Sustainability Science
(http://sustsci.harvard.edu/keydocs/fulltext/FW_statement.htm)
Friibergh, Sweden, 11 - 14 October 2000

The world at the outset of the 21st century is already a crowded, consuming, diverse, and interconnected place. However, the global population is beginning to stabilize. Life expectancy is increasing in many countries. Famine has declined dramatically except in regions of political conflict and severe poverty. These positive trends in the human condition present an emerging opportunity for a transition to a sustainable global environment. The next few generations must choose to focus on ways to make progress simultaneously on meeting basic human needs, such as food, shelter, and gainful employment, and on nurturing and restoring the earth's ecosystems under conditions of constant and pervasive change.

The systemic changes to the Earth's biogeochemical cycles and social systems that we call "Global Change" form the core of the need for the sustainability transition. These changes are real, they are happening now, and they are accelerating. There is no past analogue for the state in which the Earth is currently operating. For many key environmental parameters, the Earth System has recently moved well outside the range of natural variability exhibited over at least the last 500,000 years. The *nature* of changes now occurring simultaneously in the Earth System, their *magnitudes*, and the *rates of change*, are all unprecedented. Human activities are significantly influencing the functions of the Earth System in countless ways: anthropogenic changes are clearly identifiable beyond the signal of natural variability, and are equal to some of the great forces of nature in magnitude and impact. The human enterprise drives multiple, interacting effects that cascade through the Earth System in complex ways, such that we can no longer understand Global Change in terms of a simple cause – effect paradigm. Cascading effects of human activities interact with each other and with local and regional scale changes in multidimensional ways. The effectiveness of any climate protection program, for example, is highly dependent on economic decisions by politics, multi-national companies or the financial market, as well as on our modelling ability. This sort of complex systems understanding indicates that investment in a broad range of projects with policy makers and industry can be a successful strategy.

Meeting the fundamental needs of Australians while preserving the Earth's life support systems will require an accelerated transition toward sustainability. A new and novel field, ***Sustainability Science,*** is emerging, seeking to understand the fundamental character of interactions between nature and society and to encourage those interactions along more sustainable trajectories. Such an integrated, place-based science will require new research strategies and institutional innovations to enable them. ***Sustainability Science*** needs to be widely discussed in the scientific community, reconnected to the political agenda for sustainable development, and become a major focus for research. The largely independent efforts of international programmes and numerous national projects have created the basis for an Earth System approach capable of addressing some of the tasks. The new science will employ innovative integration methodologies, organise itself without traditional boundaries, and embark on a fresh dialogue with stakeholders.

The Earth System approach views the Earth as a synergistic physical system of interrelated phenomena governed by complex processes involving the geosphere, atmosphere, hydrosphere and biosphere. Fundamental to this approach is the emphasis on interacting dynamic chemical, physical, biological and social processes, extending over spatial scales from microns to the size of planetary orbits, and over time scales of milliseconds to billions of years. In building on the traditional disciplines to study the Earth, the system approach has become widely accepted as a framework from which to pose disciplinary and interdisciplinary questions in relationship to humankind. Earth Systems understanding forms the foundation of NASA's science vision as well as the basis of the NSF Geoscience long range planning effort and other major US research initiatives, and also dominates European and Japanese science thinking.

Within the concept of the Earth as a complex and dynamic entity involving the disciplinary spheres for land, air, water and life, there is no process or phenomenon that occurs in complete isolation from other elements of the system. While this systems view is elegant and satisfying philosophically, the challenge to researchers attempting to quantify the breadth of the system's elements, states and processes is enormous. No individual, organisation or university is capable of developing the enormous depth and breadth of knowledge such a paradigm demands: only by joining teams from different disciplines within and among organisations in new and creative ways can these challenges be met. By doing so, we will provide the opportunity to develop new science on the functioning of the Earth System, better understanding of the coupling of human and natural systems, and ultimately navigate the transition to sustainability.

What causes these Global Changes?

How is our world changing, and what are the implications for Australia? One major factor is that we now live on a human-dominated planet. The growth of the human population and resource use are altering the Earth in an unprecedented manner. Through the activities of agriculture, fisheries, industry, recreation, and international commerce, humans cause three general classes of change. Human enterprises:
(i) *transform* the land and sea--through land clearing, forestry, grazing, urbanization, mining, trawling, dredging, etc;
(ii) *alter* the major biogeochemical cycles--of carbon, nitrogen, water, synthetic chemicals; and
(iii) *add or remove* species and genetically distinct populations--via habitat alteration or loss, hunting, fishing, and introductions and invasions of species.

The resulting changes are relatively well documented but not generally appreciated in their totality, magnitude, or implications. Further, the rates and spatial scales of most of these changes are increasing, and some of the changes are new. Novel chemical compounds--ranging from chlorofluorocarbons to persistent organic compounds such as DDT and PCBs--are being synthesized and released. Many of these physical, chemical, and biological changes entrain further alterations to the functioning of the Earth system.

The conclusions from this overview are inescapable: during the last few decades, humans have emerged as a new force of nature. We are modifying physical, chemical, and biological systems in new ways, at faster rates, and over larger spatial scales than ever recorded on

Earth. Humans have unwittingly embarked upon a grand experiment with our planet. The outcome of this experiment is unknown, but has profound implications for all of life on Earth.

The world is changing in myriad other important ways as well. Inequity within and among all nations has increased; new infectious diseases have emerged; there are dramatically more democratic governments; technology, communication, and information systems have undergone revolutionary changes; markets have become global; the biotic and cultural worlds have been homogenized; the rate of transport of people, goods, drugs, and organisms has increased around the globe; multinational corporations have emerged; and non-governmental organizations have increased. Most of these changes have profound implications for our future. Integration of the human dimensions of these global changes with the physical-chemical-biological dimensions is clearly needed.

The individual and collective changes described above are so different in magnitude, scale, and kind from past changes that even our best records and models offer little guidance concerning the scale or even the character of likely responses to these challenges. The future is quite likely to involve increasing rates of change; greater variance in system parameters; greater uncertainty about responses of complex biological, ecological, social, and political systems; and more surprises. The world at the beginning of the 21st century is a fundamentally different world from the one in which the current scientific enterprise has developed. The challenges for society are formidable and will require substantial information, knowledge, wisdom, and energy from the scientific community. Business as usual will not suffice.

Will society be more vulnerable to change in the future?

Future development paths (sustainable or otherwise) shape our vulnerability to the full range of changes in the Earth System, and the impacts of these changes will affect our prospects for sustainable development. Not all individuals and sections of society are equally vulnerable to the effects of change. Their capacity to cope with existing and anticipated changes in biophysical conditions, and their ability to perceive change and adapt accordingly varies considerably. Vulnerability is a consequence of the interaction of biophysical (e.g. biogeochemical cycling, atmospheric and oceanic circulation, etc) and socioeconomic factors (e.g. land tenure, access to credit, exploitation rights of renewable resources, etc.) as mediated by institutions. Understanding the link between Global Change and societal well-being, and promoting effective interventions to reduce vulnerability, requires an innovative, interdisciplinary approach.

Interpreting potential vulnerability requires lateral approaches: much of society's infrastructure is designed for extremes based on the limited perspective provided by short instrumental records. The paleoenvironmental record, however, provides insight into past rates of environmental change and system responses. Paleo records extend such perspectives into the past, providing important insights into concepts such as the probability of "hundred year floods" or the likely extent of coastal flooding from severe hurricanes. However, at the beginning of the 21st century, the vulnerability of societies to environmental changes is rapidly increasing - more and more people are affected by natural disasters every year. Areas with high population densities and limited resources (including fresh water) and regions with sensitive ecosystems are under threat from both environmental degradation and climatic changes. This is especially so in those regions already susceptible to environmental extremes, such as Australia.

Core Questions for Sustainability Science

To promote the research necessary to achieve such advances, we propose a candidate set of questions for ***Sustainability Science***. These focus research attention on both the fundamental character of interactions between nature and society and on society's capacity to guide those interactions along more sustainable trajectories.

Table 1: Core Questions of *Sustainability Science*

1. How can the dynamic interactions between nature and society in the Australian region – including lags and inertia – be better incorporated in emerging models and conceptualizations that integrate the Earth system, human development, and sustainability?

2. How are long-term trends in the development of Australia and its region, including consumption and population, reshaping nature-society interactions ?

3. How do ecosystems and biogeochemical cycles in the Australian region react to changes in climate, land-use, diversity, and human activity?

4. What are the key determinants of the vulnerability and resilience of the Australian nature-society system to multiple and interacting stressors, in particular places and for particular types of ecosystems and human livelihoods?

5. Can meaningful "thresholds", "limits" or "boundaries" be defined that provide effective warning of conditions beyond which the Australian nature-society systems incur a significantly increased risk of serious degradation?

6. What systems of incentive structures – including markets, rules, norms and scientific information – can most effectively improve Australian and regional social capacity to guide interactions between nature and society toward more sustainable trajectories?

7. How can Australia's operational systems for monitoring and reporting on environmental and social conditions be integrated or extended to provide more useful guidance for efforts to navigate a transition toward sustainability?

8. How can today's relatively independent activities of research planning, monitoring, assessment, and decision support in Australia be better integrated into systems for adaptive management and societal learning?

9. How to we effectively organize and manage the transdisciplinary scientific investigations required to underpin the transition to sustainability?

INTEGRATION

A great deal of world class science and knowledge generation is flowing from disciplinary research on parts of the Earth System. Australian scientists continue to make major contributions to this process. However, the biggest challenge for ***Sustainability Science*** is to develop the "science of integration", pulling all the pieces together in innovative and incisive ways, towards the goal of understanding the functioning of the Earth System as a whole. Most researchers and research managers think of integration as a technical issue. However, in reality integrated outcomes are a result of both social and technical processes, rather than the more usual view of being purely technical outcomes (like computer models). Without an effective process there can be no science. Research contributing to these ends needs new characteristics. It must:

- Continue to support and facilitate the study of the detail of the components of the Earth System, but from a systems perspective;
- Embed the insights of classical analytical science into complex systems analysis, directly addressing the synergies, interactions, and non-linearities that defy traditional approaches;
- Complement the 'bottom up' approaches with the development of explicit systems-level research strategies, focussed on the phenomena which emerge at larger scales in complex systems; and
- Above all, transcend disciplinary boundaries across the social and natural sciences, because ***Sustainability Science*** is concerned with issues lying well beyond any single field of study.

The necessity of ensuring integration through the ***Sustainability Science*** research process is paramount. Interaction, between models, stakeholders, and research partners, is crucial but insufficient. Below are listed some of the techniques by which high levels of integration may be achieved.

Development Process

Critical to the creation of transdisciplinary research is the active involvement of potential participants in problem definition. For ***Sustainability Science*** to be useful, the process of problem definition must be one of dialogue and learning with stakeholders. This is time and resource intensive. Recent analysis of some Co-operative Research Centres (and CSIRO is no different) shows that the social processes underlying effective problem formulation and integrative research are often overlooked -- yet it is only by understanding and working with those social processes that the mutual learning that leads to integrated outcomes can be achieved.

Problem Focus

A common and highly effective tool for enhancing integration is a very clearly identified and articulated problem, however complex it may be. The process of articulation of these problems crosses disciplinary boundaries, standardises language, and in some senses 'self selects' those who wish to move to the next stage of active participation in the research.

Modelling and Simulation

Every model is an attempt to simulate reality by means of simplified hypotheses that take account of interdependencies, and which are validated with empirical data. This means that constructing models is an excellent way to integrate disciplines. Simulation modeling of dynamic systems in particular focuses attention on those hypotheses that are either in need of critical review or which reveal gaps in the model.

Joint Instruments

Joint instruments further integration in the same way. These may involve the coordinated and complementary use of large-scale equipment (e.g. satellites, research ships or supercomputers), infrastructures and knowledge resources (e.g. databases or algorithms). Perhaps even a city could be seen as a joint instrument, being both a research environment and subject of study.

Interdisciplinary Facilities

This method of integration centres on creating research institutions with clearly defined cross-cutting foci, necessitating collaboration between natural scientists, engineers, economists and social scientists as appropriate, depending on the specific task at hand. They may be short of long term, problem specific or methodologically oriented.

Temporary Associations

These refer to the formation of medium-term, project-based networks between established institutions of specific disciplines in order to promote integration. Where necessary, authority should be assigned to joint management committees whose members are linked and committed ti integrative activities.

Support Structures and Programs

The main elements here are the establishment of priority programs of a cross-sectional nature, the strengthening of existing interdisciplinary research networks (for example by reorganization of research assessment, promotion of collaborative research centres treating a specific complex of topics, rather than methodically defined and geographically distributed centers), the establishment of new institutions focusing on global biogeochemical cycles, or instituting awards for environmental research that achieves “synthesis” between different disciplines.

Orientation to International Programs

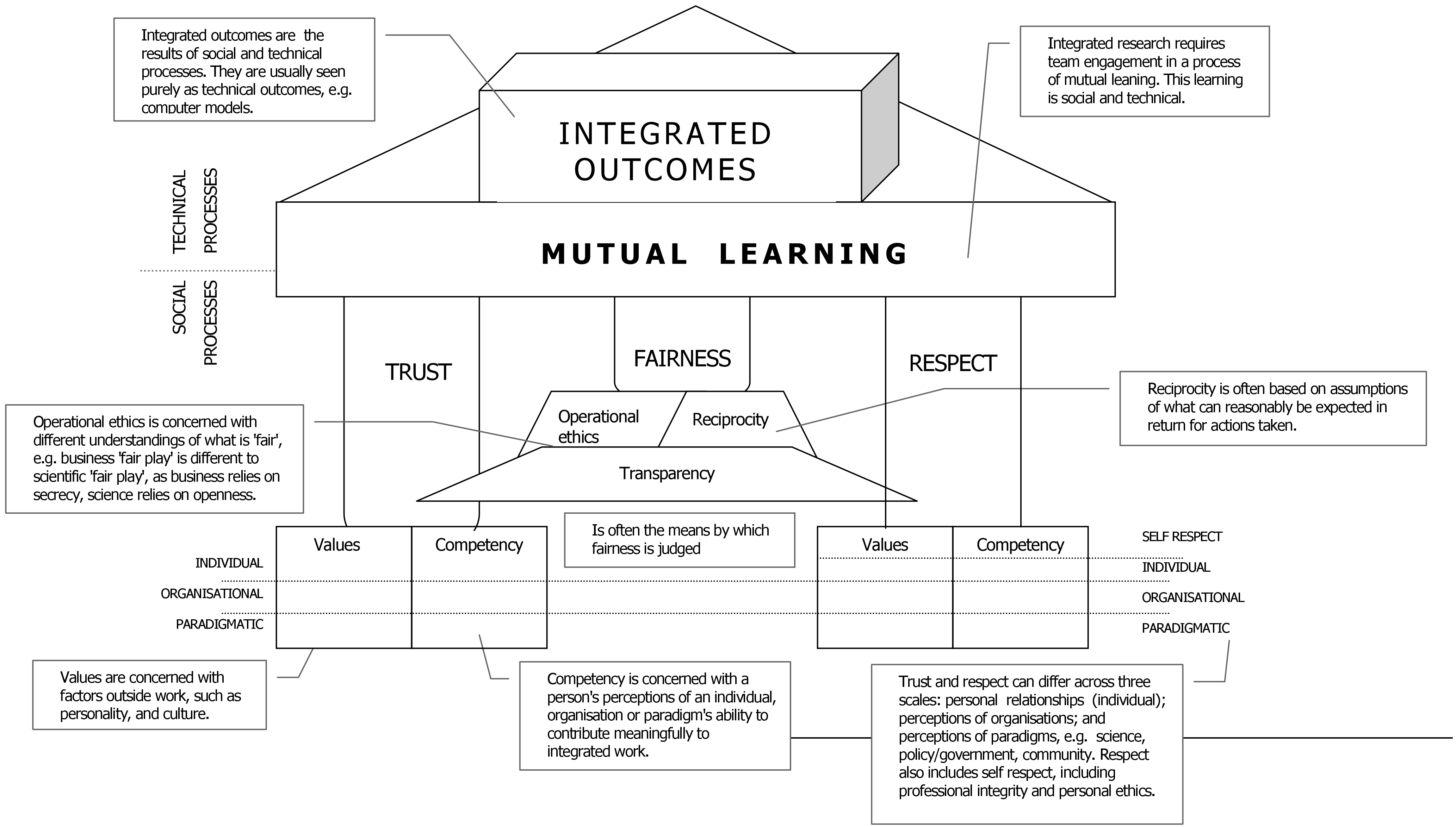
Greater involvement in international programs (e.g. the international programs on global change, or joint *capacity building* activities in developing countries of our region) is one way to overcome the lack of global perspectives in sustainability research. Another benefit of such collaboration is that it promotes the growth of international research networks, adding capacity to Australian science.

Education and Training

Integration is furthered by setting up undergraduate and advanced-level courses in sustainability-relevant subjects (e.g. agricultural ecology, biogeochemistry, geoecology, environment and business, systems analysis of human/environment relations), and the development of summer schools and academic exchange programs.

Social Processes and Integrated Outcomes: a model for Sustainability Science?

Modified after van Kerkhoff, 2001



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PARTNERSHIPS, METHODS AND TOOLS

It is at this stage difficult to precisely characterise the nature of activities that may be undertaken by this initiative. ***Sustainability Science*** is an emerging field, with no well-defined set of techniques or methods, but a very clear goal: to assist humankind in making the transition to sustainability. To meet this challenge, a very wide range of partners and tools will be required, both existing and not yet thought of. In practice, some of the most interesting and potentially helpful efforts to date have entailed mixed strategies drawing on a combination of several methodologies. For example, integrated assessment modelling, scenario building, decision analysis, and institutionally oriented efforts to incorporate such tools into regional systems of policy development and adaptive management may all be simultaneously required.

Partnerships

Partnership within CSIRO, and between CSIRO and other organisations, is a central concept of this proposal. While this initiative will begin within CSIRO, a large organisation already undertaking relevant world class research, and currently undertaking a new planning process to integrate and extend the portfolio, it cannot continue in this manner. We must engage new partners. It is likely that a very high proportion of new activity within the organisation could conceivably proceed under the banner of "sustainability science", but it must not be allowed to do so without a coherent rationale and framework developed with our partners. We must never forget the wealth of relevant activity in Australia's universities, corporations, CRCs, and government agencies. Extensive use will need to be made of the expertise available in other Australian research institutions, and indeed internationally. Further, we must engage the non-scientific community very effectively if we are to have the desired impact.

TOOLS

The list below is intended to be indicative only of a possible 'toolbox', illustrative of the depth and breadth of expertise necessary for this initiative. In many fields, CSIRO already has world class capability. In others, it has none at all and will require partnerships to be developed. There are of course many other 'tools' available, and the ***Sustainability Science*** initiative will utilize them as necessary.

Integrated Systems Analysis:

- Dynamic Systems Analysis
- Concepts of Integrated Modelling
- Soft and Set-Based Modelling
- Studies of Scalar Interdependencies and Linkage
- Risk Analysis and Assessment
- Assessing Uncertainty Implications
- Decision-Making Analysis

Climate System Modelling:

- Meteorological Data Bases
- Statistical Models
- Scenario Models
- Dynamic Regional Climate Models
- Ocean Models
- Climate System Models

Global Change and Natural Systems:

- Eco-Physiological Simulation Models
- Hydrological Simulation Models
- Forest Dynamics Models
- Ecosystem Dynamics Models
- Data Bases and Data Assimilation Techniques

Global Change and Social Systems:

- Economic Models
- Stakeholder Dialogues
- Macro- and Meso-Models
- Micro-Models
- Strategic Gaming
- Life Cycle Analysis and Industrial Ecology
- Multi-Level Models
- Conceptual Analysis
- Stakeholder Dialogues

Data & Computation:

- Modelling Environments for Complex and Adaptive Systems
- Simulation Builder
- Parallelization Tools
- Model Improvement Support
- Meta Data Model and Interfaces

- Information-Technology Infrastructure and Support
- Observation Systems
- Data Collection, Archiving, and Mining

METHODS

Methodological development of fields relevant to ***Sustainability Science*** is progressing very rapidly. In particular, the understanding of the character and treatment of uncertainties, the incorporation of human behaviour into models, and the simplification of complex integrated systems (we no longer need the 'model of everything' to make the transition) are critical areas of success. Significant challenges, however, remain. These include:

- Better representations of the complex dynamics of human behaviour;
- Better representations of multiple causes of global change, and human consequences and responses;
- Better understanding of self organising or 'auto-adaptive' systems;
- Involving 'users' and stakeholders more directly in the research design and analysis;
- Moving beyond 'business as usual' representations of future conditions, to a recognition of a wide range of potential future social, economic, and environmental conditions;
- Addressing the local and regional implications of Global Change and sustainable development.

NEXT STEPS

Many things before remain to be done before any sort of Sustainability Science initiative could be meaningfully considered. An inclusive and iterative process should be established to consider, among other issues, those listed below.

Problem Statement

What are the issues that could be addressed?

What are the expected deliverable outcomes?

Who buys in? Who benefits? How will Sustainability Science yield improved decisions?

What are the innovative techniques we will use?

Statements of Commitment

By CSIRO, to commit to experimental new approaches, and resources

By other participating institutions, commitment to interdisciplinary and inter-institutional collaboration

By each participating scientist, commitment to transdisciplinary science

By the relevant government agencies, by way of endorsement and partnership, and in kind services

By components of civil society, to work as part of a team towards a transition to sustainability

By funding agencies, to support the initiative

Statement of Proposed Activities

Outline of initiative research design

Schedule of proposed activities, timelines, milestones

Define baseline conditions: past studies, existing models, data sets, institutional arrangements

Identification of stakeholders

Involvement of stakeholders

Definition of anticipated impacts

Definition of organization structures and management arrangements

Definition of suitable process arrangements

FINAL WORDS: never forget the role of Creativity

During the very rapid development of this paper, several CSIRO scientists contributed ideas and opinions. All the input illustrates the creativity inherent in the organisation, and the desire to make the transition. Below are a few ideas (verbatim) that many will think are 'outside the box', but which should at least be considered. Have Fun!

- Do a quick run around of Divisions to see how much of CSIRO considers that it is working in this way. Scare up some animals for the floating zoo. E.g. a better understood description of CSIRO's current efforts and capabilities.
- Commence and maintain a pluralistic public discussion and debate on transitions to sustainability that is not beholden to the politics of the day. The CEO at the press club would be a good start.
- Team up scientists with economists, historians, philosophers etc to put a continuing set of discussion pieces in the mass media. The public is concerned about the environment but this does not translate into voting patterns. The debate needs to explore ways of bridging this gap.
- Engage with main-stream economics in addition to the less well developed school of ecological economics
- Produce a bunch of position papers and scoping studies for international global change journals
- Academy seminars and books
- Saturate the media sufficiently so that the armchair experts get going (con, especially)
- Figure out how many volunteers hours should be funded through the NHF to fix the MDB (The number should show how ridiculous the whole side show is).
- Engage in the science of the mundane in a spectacular manner as possible:
    - Is it possible to build a zero emissions house?
    - Is it possible to mass produce this house?
    - What are the ecological limits to urban settlements?

- Can we build smart materials that do not cost the earth?
- Zero emissions recreation (how on earth can one claim eco-tourism, when the tourist flew to their destination?)
- Can we turn buildings and cities into arcologies?
- Is it feasible to reproduce the Australian lifestyle into an Amery Lovins type environment, or do we actually have to change our behaviour?
- Can we afford to burn all that bloody coal?
- Can we alter the values profiles and cost structures of the market so we cannot afford to trash habitat for "jobs"? (How many tree hollows equal one job?)

- Create a super-sector (or equivalent) under the Chief Executive – Captain Planet's Floating Zoo.

Appendices

APPENDIX 1: Key International Organisations

Potsdam Institute for Climate Change Research (PIK)

http://www.pik-potsdam.de

The Potsdam Institute performs interdisciplinary research that contributes significantly to the study of global environmental change and the prospects of sustainable development. Recognizing that for climate impact research to be useful, it cannot be isolated from the rest of the Earth system – which comprises the material world of the geosphere as well as the biosphere and the world of the human mind – PIK strives to understand our planetary ecosystem as a whole and to develop, on the basis of Earth systems analysis, concepts for global environmental management. This means linking scientific insights and socio-political decision-making in the perspective of the sustainability transition – a perspective leading from current patterns of use and misuse of our global environment to sustainable development of humankind as a whole.

Tyndall Centre

http://www.tyndall.uea.ac.uk

The UK-based Tyndall Centre brings together scientists, economists, engineers and social scientists, who together are working to develop sustainable responses to climate change through interdisciplinary research and dialogue on both a national and international level – not just within the research community, but also with business leaders, policy advisors, the media and the public in general. Its research addresses both climate change mitigation and adaptation policy objectives with a particular emphasis on integrated assessments. Most importantly, its research applies across a range of scales in space and time – from the domestic to the global, and from the present through the coming centuries.

Forum on Science and Technology for Sustainability

http://sustsci.harvard.edu/index.html

The Forum on Science and Technology for Sustainability is an international virtual network that facilitates information exchange and discussion among the growing and diverse group of individuals, institutions, and networks engaged in the emerging field of science and technology for sustainability. It provides access to emerging ideas, relevant activities, key documents and web sites.

Research and Assessment Systems for Sustainability Program

http://sust.harvard.edu

The Sustainability Systems Program at Harvard University (within the Belfer Center for Science and International Affairs and Kennedy School of Government) designs and evaluates strategies with which the next generation of national and international global environmental change programs might effectively integrate and support its research, assessment and decision-support activities. In particular, it catalyzes three interrelated lines of work: broadening the global change agenda to engage directly the sustainability agenda; developing a place-based, integrated understanding of global change effects and vulnerabilities; and designing, supporting and managing systems that can better integrate research, assessment and decision support activities on problems of global change. The program team contributes to strategies for meeting these challenges through an international collaboration among a set of leading scholars and program managers involved in the production, assessment, and application of knowledge relating to global change.

Global Environmental Change Programmes

A cluster of interlinked international science programs addressing various aspects of environment, society and their interactions have been operating for more than a decade. Among the most developed of these are the **International Geosphere-Biosphere Programme (IGBP)**, **International Human Dimensions Programme on Global Environmental Change (IHDP)**, and the **World Climate Research Programme (WCRP)**. IGBP has worked towards an overall goal: to describe and understand the interactive physical, chemical and biological processes that regulate the Earth system, the unique environment it provides for life, the changes that are occurring, and how they are influenced by human actions. The IHDP seeks to understand how human actions contribute to global environmental change, why these actions are taken, how global environmental change feeds back into people's lives, and what actions can be taken by whom to respond to, reduce, and mitigate the effects of global environmental change. WCRP seeks to develop the fundamental scientific understanding of the physical climate system and climate processes needed to determine to what extent climate can be predicted and the extent of man's influence on climate. The programme encompasses studies of the global atmosphere, oceans, sea and land ice, and the land surface which together constitute the Earth's physical climate system.

Max Planck Institut fuer Biogeochemie

http://www.bgc-jena.mpg.de/

This important institute investigates long-term global interactions of the biosphere, atmosphere, geosphere and the oceans. The aim of research into biogeochemical cycles is to develop an understanding for the complex system earth with all its ecological implications on a global scale. Processes on microclimate, landscape, ecosystem and global levels are closely correlated and affect each other mutually.

Centre for Environmental Systems Research, University of Kassel

http://www.usf.uni-kassel.de/usf/

The Center for Environmental Systems Research applies a systems approach and an interdisciplinary approach to environmental research, with the aim of increasing the understanding of the functioning of environmental systems and the causes of environmental problems, and to identify „sustainable" pathways into the future, i.e. pathways that allow the development of a society in harmony with nature. The Center is unique because of its systems approach, namely the use of methods and instruments of systems thinking such as systems analysis and computer simulation, and because of its interdisciplinary approach, in particular, the coupling of social sciences with natural sciences. Another essential characteristic of the Center its problem-oriented approach, focussing on identification and solution of critical environmental problems.

Stockholm Environment Institute

http://www.sei.se

The Stockholm Environment Institute (SEI) is an independent, international research organization contributing to sustainability science at local, national, regional and global policy levels. The SEI research programmes aim to clarify the requirements, strategies and policies for a transition to sustainability. These goals are linked to the principles advocated in Agenda 21 and the Conventions such as Climate Change, Ozone Layer Protection and Biological Diversity. SEI along with its predecessor, the Beijer Institute, has been engaged in major environment and development issues for a quarter of a century.

At the international level, activities include supporting the United Nations Environment Programme's second Global Environmental Outlook initiative and coordinating the activity of the Global Scenario Group. At the regional level, collaboration is going on with the Baltic Agenda 21, using PoleStar, an interdisciplinary systems approach to global and regional long-term sustainability. At the national level it is working on capacity building for the implementation of Agenda 21 in Estonia and a project relating global scenarios to the Swedish national level.

RIVM (Netherlands National Institute of Public Health and the Environment)

http://www.rivm.nl

RIVM is a national research institute with responsibilities for governmental policy-making and supervision of public health, nature, and the environment. The specific function of RIVM lies in integration of knowledge covering a wide multidisciplinary research area. Data collected through monitoring - sentinel networks, diagnostics, and surveillance - are used in computer simulation models that are essential to predict future developments.
In addition, RIVM has links with the ministerial advisory councils, as well as with other planning agencies such as the Netherlands Bureau for Economic Policy Analysis (CPB), the Social and Cultural Planning Office (SCP) and the Physical Planning Agency (RPD).

RIVM developed the well known "Integrated Model to Assess the Global Environment" (IMAGE) model, a dynamic integrated assessment modelling framework for global change. The main objectives of IMAGE are to contribute to scientific understanding and support decision-making by quantifying the relative importance of major processes and interactions in the society-biosphere-climate system. To accomplish this, IMAGE provides dynamic and long-term perspectives on the systemic consequences of global change, insights into the impacts of global change, and a quantitative basis for analyzing the relative effectiveness of various policy options to address global change.

Center for Sustainability and the Global Environment, University of Wisconsin, Madison

http://sage.aos.wisc.edu/

The Center for Sustainability and the Global Environment (SAGE) acts as a catalyst at UW-Madison, bringing together teams of faculty, students and staff in the natural sciences, social sciences, engineering and other fields to study regional and global problems stemming from interactions between environmental systems, natural resources, and human activity. The center seeks to provide knowledge for better decision making by individuals, organizations, and governments, leading to more responsible environmental stewardship and greater environmental sustainability

To better understand global ecological processes, and to evaluate their potential response to human activity, SAGE is developing IBIS (the Integrated Biosphere Simulator) -- a new comprehensive numerical model of the Earth's terrestrial ecosystems. IBIS simulates the following processes in a single, physically-consistent framework:

- the energy, water, and carbon balance of the land surface
- plant physiological processes, including photosynthesis and respiration
- vegetation phenology (budburst, senescence/dormancy)
- plant growth and competition; vegetation dynamics
- nutrient cycling and soil biogeochemistry

International Research Institute for Climate Prediction

http://iri.columbia.edu/

IRI engages in scientific research and development with the goal of maximizing the utility and accessibility of climate forecast products for societies around the world.

IRI has several functional components working together to fulfill its mission:. Forecasting and prediction research - is responsible for the production of all IRI experimental forecasts at both global and regional scales.

- Climate forecast products –
- IRI forecasts,
- SST forecasts,
- Dynamical model prediction,
- Supplemental forecasts. Forecasting & prediction research.

Climate monitoring and dissemination - provides the link between IRI research and development in models and experimental forecast products and the IRI-affiliated network of applications activities, the network of collaborating research centers, and all other recipients of IRI data, forecast products, and forecast guidance.

- IRI climate digest - monthly climate global summary
- Climate monitoring - IRI Map Room, general monitoring and ENSO monitoring

- Data Library - data and interactive tools
- **Prediction research/model development** provides an evolving suite of coupled models and assimilation systems representing the state-of-the-art for seasonal-to-interannual climate forecasts. Modelling and prediction research projects.
- Applications research - connects geophysical forecasting and climate-related economic and social assessments, policy and decision-making
- Applications research projects under sector (agriculture, fisheries, health, water resources, etc.), region (Africa, Asian, America, etc.) and cross cutting issues.
- Training - trains multi-disciplinary teams and individuals in applying and efficiently using climate products and forecasts and facilitates and facilitates use of new tools.

Center for the Study of Institutions, Populations, and Environmental Change (CIPEC), Indiana University

http://www.cipec.org

CIPEC is a world leader in the interdisciplinary study of human – forest interaction, including deforestation and reforestation, by integrating the biological, social, and physical sciences. Four research centers and a large number of academic departments preceded the creation of CIPEC–and continue to provide a rich array of research opportunities and degree programs within which interdisciplinarity can be nurtured.

International Institute for Applied Systems Analysis (IIASA)

http://www.iiasa.ac.at/

IIASA is the pioneering institution known for its international, interdisciplinary research and its significant contribution to innovative analysis of policy-relevant, global issues. Its objective is to provide science-based insight into critical policy issues in international and national debates on global change. The research staff are extremely well connected in international science and policy circles, and it has a widely distributed and supportive network of alumni. It maintains continually evolving models and data sets on subjects from population to energy to natural resources to economics, complied over the course of long running research projects. IIASA is a major centre of international co-operation, with a charter to meet the technological, intellectual, and policy challenges of globalising societies.

Resilience Alliance

http://www.resalliance.org

The Resilience Alliance strives to address perceived gaps in the understanding and resolution of complex issues involving people and nature: the conceptual gap created by partial theories and concepts inherent in scientific disciplines; the knowledge gap between science and policy or between understanding and action; and the communication gap, created by limitations of existing media for scientific discourse. They are working to address the first gap by seeking consilience; the second by creating a virtual community of scholars and practitioners; and the third by exploiting the Internet to extend the scope and utility of scientific discourse. Three proposed activities – seeking consilience, building communities, and exploiting the media of the Internet – create the nexus called the Resilience Alliance. As a central focus, these activities aim to expand the use of the journal, *Conservation Ecology*, beyond the traditional.

United Nations Commission on Sustainable Development

http://www.un.org/esa/sustdev/science.htm

The Commission on Sustainable Development (CSD) was created in December 1992 to ensure effective follow-up of the United Nations Conference on Environment and Development (UNCED) and to monitor and report on implementation of the Earth Summit agreements at the local, national, regional and international levels. The Commission promotes "science for sustainable development," which involves strengthening the scientific basis for sustainable management, enhancing scientific understanding, improving long-term scientific assessment, and building up scientific capacity and capability. The Commission ensures the high visibility of sustainable development issues within the UN system and helps to improve the UN's coordination of environment and development activities. The CSD also encourages governments and international organizations to host workshops and conferences on different environmental and cross-sectoral issues.

Environmental and Societal Impacts Group, NCAR

http://www.esig.ucar.edu/

ESIG conducts multidisciplinary research on a broad array of issues related to interactions among society, the atmosphere, and natural and human-built systems. Its research identifies and clarifies linkages: among individual decision-making processes and economic and political systems, and between these societal processes and biological and physical systems. In addition to its original research, ESIG disseminates new knowledge through its many educational and outreach activities, a major emphasis of which is enhancing the societal “usability” of atmospheric and related science information, especially among underrepresented and vulnerable populations.

One of its key strategies has been to identify unique multidisciplinary research, application, and educational outreach “niches” related to the atmospheric sciences. Identifying such niches has been a catalyst to the growth of an international community of scholars who have focused on new approaches to reducing the threat of weather and climate-related societal problems, including finding ways to use forecast information to meet specific user needs. ESIG scientists have also been leaders in national and international weather and climate policy assessments.

APPENDIX 2: The Amsterdam Declaration on Global Change

The scientific communities of four international global change research programmes –the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environmental Change (IHDP), the World Climate Research Programme (WCRP) and the international biodiversity programme DIVERSITAS - recognise that, in addition to the threat of significant climate change, there is growing concern over the ever-increasing human modification of other aspects of the global environment and the consequent implications for human well-being.

Basic goods and services supplied by the planetary life support system, such as food, water, clean air and an environment conducive to human health, are being affected increasingly by global change.

Research carried out over the past decade under the auspices of the four programmes to address these concerns has shown that:

• **The Earth System behaves as a single, self-regulating system comprised of physical, chemical, biological and human component**s. The interactions and feedbacks between the component parts are complex and exhibit multi-scale temporal and spatial variability. The understanding of the natural dynamics of the Earth System has advanced greatly in recent years and provides a sound basis for evaluating the effects and consequences of human-driven change.

• **Human activities are significantly influencing Earth's environment in many ways in addition to greenhouse gas emissions and climate change.** Anthropogenic changes to Earth's land surface, oceans, coasts and atmosphere and to biological diversity, the water cycle and biogeochemical cycles are clearly identifiable beyond natural variability. They are equal to some of the great forces of nature in their extent and impact. Many are accelerating. Global change is real and is happening *no*w.

• **Global change cannot be understood in terms of a simple cause-effect paradigm.** Human-driven changes cause multiple effects that cascade through the Earth System in complex ways. These effects interact with each other and with local- and regional-scale changes in multidimensional patterns that are difficult to understand and even more difficult to predict. Surprises abound.

• **Earth System dynamics are characterised by critical thresholds and abrupt changes. Human activities could inadvertently trigger such changes with severe consequences for Earth's environment and inhabitants.** The Earth System has operated in different states over the last half million years, with abrupt transitions (a decade or less) sometimes occurring between them. Human activities have the potential to switch the Earth System to alternative modes of operation that may prove irreversible and less hospitable to humans and other life. The probability of a human-driven abrupt change in Earth's environment has yet to be quantified but is not negligible.

• **In terms of some key environmental parameters, the Earth System has moved well outside the range of the natural variability exhibited over the last half million years at least.** The *nature* of changes now occurring *simultaneously* in the Earth System, their *magnitudes* and *rates of change* are unprecedented. *The Earth is currently operating in a no-analogue state.*

On this basis the international global change programmes urge governments, public and private institutions and people of the world to agree that:

• **An ethical framework for global stewardship and strategies for Earth System management are urgently needed.** The accelerating human transformation of the Earth's environment is not sustainable. Therefore, the *business-as-usual* way of dealing with the Earth System is *not* an option. It has to be replaced – as soon as possible – by deliberate strategies of good management that sustain the Earth's environment while meeting social and economic development objectives.

• **A new system of global environmental science is required.** This is beginning to evolve from complementary approaches of the international global change research programmes and needs strengthening and further development. It will draw strongly on the existing and expanding disciplinary base of global change science; integrate across disciplines, environment and development issues and the natural and social sciences; collaborate across national boundaries on the basis of shared and secure infrastructure; intensify efforts to enable the full involvement of developing country scientists; and employ the complementary strengths of nations and regions to build an efficient international system of global environmental science.

The global change programmes are committed to working closely with other sectors of society and across all nations and cultures to meet the challenge of a changing Earth. New partnerships are forming among university, industrial and governmental research institutions. Dialogues are increasing between the scientific community and policymakers at a number of levels. Action is required to formalise, consolidate and strengthen the initiatives being developed. The common goal must be to develop the essential knowledge base needed to respond effectively and quickly to the great challenge of global change.

Berrien Moore III	Arild Underdal	Peter Lemke	Michel Loreau
Chair, IGBP	Chair, IHDP	Chair, WCRP	Co-Chair, DIVERSITAS