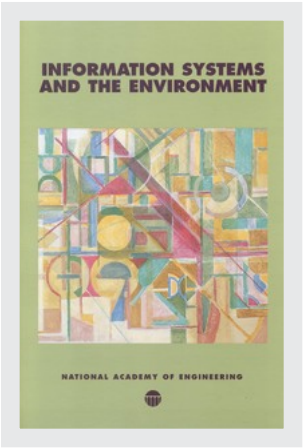

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Knowledge Networking for Global Sustainability

New Modes of Cyberpartnering

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By a conservative count, there were more than 50 million Internet users worldwide in 1995, a figure that was projected to exceed 200 million by the turn of the century. In retrospect, this projection substantially underestimated the number of Internet users today. For example, although most current usage is concentrated in the United States, which accounts for about 50 percent of worldwide web use, more than 80 percent of web users are expected to be outside the United States. Far more compelling is the expansion of the e-economy and its impacts on the traditional economy. In 2000, it was estimated that the e-economy in the United States generated $830 billion in revenues; in January 2001, the e-economy supported more than 3 million workers. The "new" economy appears to be taking a notable place alongside the "old" economy.

This broad pattern is distinct from, but related to, another major global trend—the remarkable increase in worldwide concerns about and attention to environmental problems, coupled with concerns about transitions toward sustainability (Alker and Haas, 1993). This second trend is the direct result of a growing awareness that industrialization in the West has led to increasing, pervasive pollution of the environment. Environmental degradation was, and continues to be, an inescapable feature of the old economy. Thus, we are faced with a major global dilemma.

Broadly construed, the global dilemma is this: *If* the combined impacts of human activities and conditions, shaped by prevailing social norms and values, continue to place serious strains on life-supporting properties, threaten natural and social systems, and generate propensities for social conflict and violence, *then* the historical patterns of unrestricted growth that have been so successful in

the past can no longer provide reasonable guidelines for moving toward viable futures for the population of this planet (Choucri and North, 1993). And the broad-based consensus about the implications of the dilemma is this: *If* societies understood the extent of the dilemma, *then* they would engage in efforts to identify strategies to ensure their security, survival, and sustainability.

It is fair to say that there has been (and continues to be) a proliferation of efforts to arrest erosions in life-supporting properties that are directly traceable to human actions. The quest for sustainability is a distinctive feature of contemporary thought in both scholarly and policy circles. Even the business community is beginning to talk about corporate social responsibility in search of sustainability. Yet, few coherent frameworks have been developed to guide decision and policy making. The development of effective strategies has been impeded by some major obstacles, both in theory and in practice. First, considerable ambiguities remain about the meaning of "sustainable development" and the conditions necessary for the viability of natural and social systems (Lang, 1994; Rothenberg, 1993). Second, there has been an explosion of all types of information of varying quality and reliability, as well as considerable difficulties in tracking the significance of information or follow-up actions (see, for example, Tolba et al., 1992). Third, technologically, even relatively simple concepts such as global conferencing have not been translated into routine practices. Finally, information and knowledge exchange has been limited by infrastructure disconnections and limited feedback.

None of these obstacles alone is insurmountable, but together they have severely impeded the effective use of advances in information technologies and their deployment for knowledge-sharing and management. They have also impeded the exercise of political will for acting on emergent knowledge about environmental degradation or addressing a wide range of environmental problems or moving towards transitions to sustainability. These obstacles are all independent in origin, dynamics, technological foundation, and policy priorities, but they appear to be converging in ways that may lead to a paradigm shift in our understanding of how knowledge-based uses of advanced information technologies can be effectively used on a global scale.

If there is a serious commitment to sustainability as an alternative to the conventional economic growth model, then the search for—or development of—a sustainability model must draw upon relevant knowledge and evolving interpretations of collective experiences, best practices, new theories, innovative technologies, and new social modalities—in all economic sectors, all geographic regions, and at all levels of development (Choucri, 1993). This paper introduces the Global System for Sustainable Development (GSSD), an Internet-based knowledge-networking system predicated on an internally consistent framework for organizing knowledge and for guiding action pertaining to the broad domain of sustainability. As a distributed system, GSSD combines the power and

resources of the Internet with new strategies for knowledge-sharing on a global basis (Choucri, 1995).

GSSD also serves as the core platform for the Global Partnership on Cyberspace for Sustainability, which was introduced at the Fifth Session of the United Nations Commission on Sustainable Development, May 1997, and subsequently at the Special Session of the General Assembly, June 1997, known as "Earth Summit +5." At those meetings it was suggested that a viable partnering platform on a global scale would require the following characteristics:

- effective representation of the knowledge base related to sustainability
- efficient electronic capabilities that represent the frontier of advances in information technology
- mirror-site options in locations overseas and in languages other than English

By providing new venues for cyberpartnering, GSSD transcends conventional, disciplinary foci and encourages interdisciplinary analysis and understanding. It provides guidelines for transitions from centralized management to distributed knowledge generation and knowledge sharing. It also facilitates a change from conventional web posting to interactive, adaptive knowledge exchange and e-conferencing. The core concept of GSSD is sufficiently broad to include both the scientific tradition and the more policy-based, pragmatically oriented traditions of business and industry and governments.

THE GLOBAL SYSTEM FOR SUSTAINABLE DEVELOPMENT

The GSSD is an adaptive, interactive system for knowledge networking, knowledge management, and knowledge sharing for use in conjunction with Internet resources. Its goals are (1) to define the dimensions and dilemmas of changing from current policies and strategies based on imperatives of growth, (2) to identify policies and strategies that facilitate social and environmental sustainability, and (3) to track the range of policy responses nationally and internationally. The GSSD knowledge base is organized as a hierarchical, embedded system of topic-specific, cross-indexed, content-rich Internet resources in the following areas:

- human activities and conditions
- sustainability problems associated with human activities
- scientific and technological solutions
- economic, political, and regulatory solutions
- evolving international actions and responses

Since the GSSD knowledge base is evolving, dynamic, and adaptive, its content changes as new evidence and insights are developed or as new theoretical or policy perspectives emerge.

Basic Features

GSSD can be described as an integrated knowledge system consisting of a coherent, conceptual framework; a transparent, knowledge-sharing strategy; specific product-oriented applications; and distributed updates, streamlined maintenance, search and browser facilities, and multilingual functionalities and mirror sites. GSSD operates as a metasystem (i.e., a network of networks). The GSSD knowledge base is an evolving collection of topic-specific abstracts of Internet materials, prescreened for content and quality, cross-referenced, and indexed; a link is provided from each content-specific abstract to the web site for the original source. In other words, the value-added of the GSSD knowledge base is its content, quality, coherent framework, *and* its e-connections to the original Internet materials. The selection and inclusion of sites is subject to systematic procedures.

The integrated design for the GSSD knowledge system is derived from a dynamic, multifaceted, interdisciplinary, and international approach to the domain of sustainable development (Becker and Jahn, 1999; Choucri, 1999). GSSD is structured to accommodate updates of knowledge, changes in intellectual orientation, and concurrent, disparate perspectives, as well as diverse information systems and structures. Designed in embedded and hierarchical terms, GSSD consists of "rings" representing nested substantive crosscutting news into domains of knowledge (Figure 1). The structure of the system is informed theoretically by ongoing research about how patterns of behaviors in international relations can be traced to interactions among variables in populations, resources, and technologies (Choucri and North, 1975, 1989, 1993). The operation of the system as a whole does not depend on a particular perspective or on the underlying research or evolving findings. The GSSD core is a "placeholder" for current assumptions, with the understanding that they might be revised in light of new knowledge, better analysis, and overall improvements in the quality, scale, and scope of our understanding.

The design structure for the substantive content (Figure 2), which is formulated in terms of subject or topic "slices," takes into account sector-specific economic activities (Figure 2, top) as well as broad sociopolitical domains of human activity (Figure 2, bottom). These multiple perspectives are important because subject slices are usually examined on a stand-alone basis without reference to interconnections; and expertise, by definition, follows this conventional specialization (or fragmentation) of knowledge, often undermining the potential for integration and interconnections. Table 1 lists key features of the overall knowledge-base system spanning the 14 slices and the 5 rings.

Knowledge Strategy

As indicated above, the GSSD platform consists of a system of detailed, internally consistent characterizations of the contents of the key dimensions of

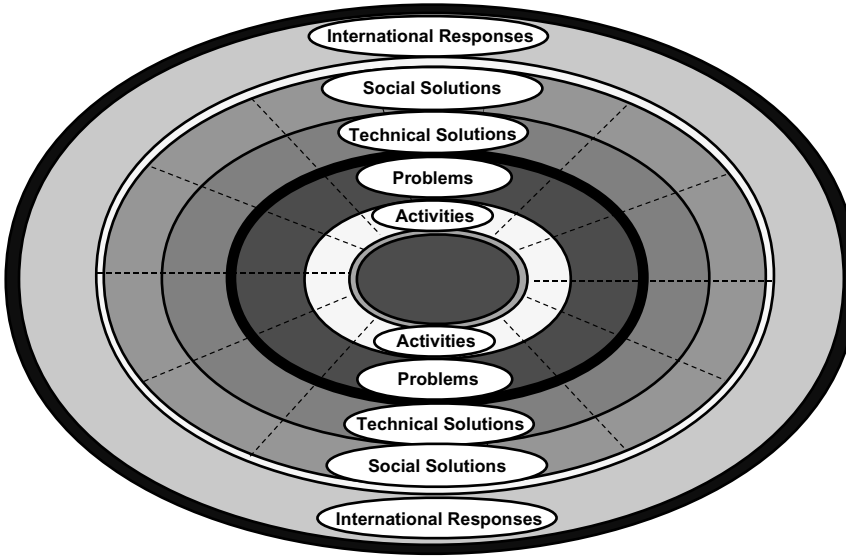

FIGURE 1 Dimensions of sustainability framework: rings or perspectives. SOURCE: MIT, 2001.

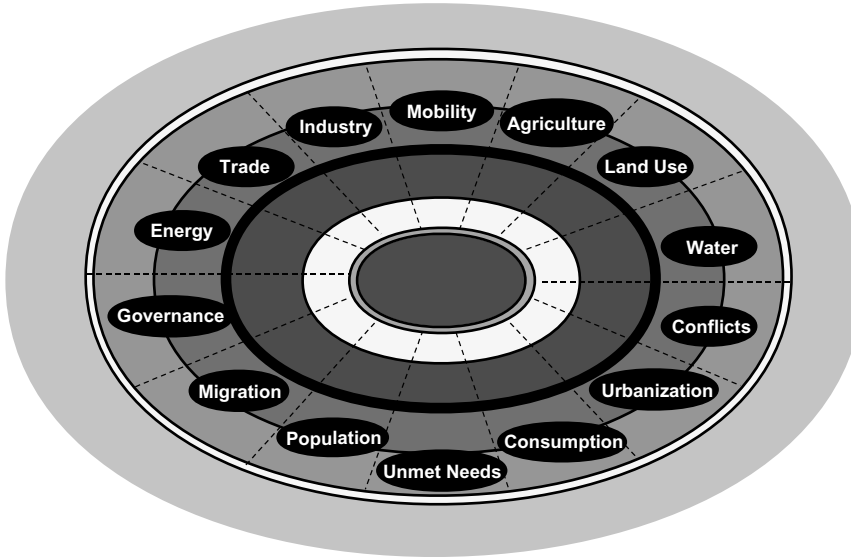

FIGURE 2 Structure of knowledge system: slices or topics. SOURCE: MIT, 2001.

TABLE 1 GSSD Knowledge Base: Illustrative Features

Type:	Metric and nonmetric
Subject:	Concepts, theories, cases, agreements, indicators, models, etc.
Status:	Private, public, mixed
Uses:	Preset, or customized, for search, browser, and navigation options
Content:	Cross-referenced, indexed abstracts of Internet resources
Structure:	Hierarchical, nested, system design
Coverage:	Selective and quality controlled; decentralized knowledge provision
Languages:	English base, with Chinese, Arabic, French and shortly Italian, Japanese, and Spanish operations. If original entries are not in English, materials are provided in all supported languages.

sustainable development, defined in terms of individual topics (slices) and their attendant content (rings). The system has four rings across all slices and one ring that transcends all of the slices or topics. The four rings common to all slices address (1) a topic or activity, (2) problems generated by a particular activity, (3) the technical and scientific solutions to such problems at any point in time, and (4) the social, economic, and regulatory solutions available to date. These details are shown in Figures 1 and 2. Each of the 14 substantive dimensions for the broad domain of sustainable development is further differentiated in terms of a detailed "slice outline," which refers to the full-blown characterization of the contents of each subject (or slice).

The knowledge content of individual topics, namely, the slice outline, is organized as a set of conceptual, as well as practical, functions. Each slice outline consists of concepts and subconcepts that are used as "tags" to index individual items in the knowledge base. These tags enable characterization of current knowledge so that updates can be made easily; provide guidelines for populating the system, namely, the selection of prescreened, "spidered" web sites; and ensure a certain degree of internal consistency in the development of the GSSD knowledge system in terms of the selection of indicative web sites. (In a different idiom, the slice outline is akin to a table of contents combined with an index for a printed book. It can also be thought of as a subject-based directory.)

If we consider the 14 topic-specific slices as reflecting the domain of sustainable development—problems and potential solutions—then the outer ring of GSSD (the fifth ring) is not connected to any specific slice. It transcends all of the substantive issues (i.e., all slices) thus representing access to knowledge (data, policies, actions) pertaining to different types of coordinated international responses and global accords, large-scale policy measures designed to address sustainability-related problems. Figure 3 shows the contents of this ring.

FIGURE 3 Global sustainability strategies: types of coordinated action. SOURCE: MIT, 2001.

The value of the GSSD network of networks is enhanced by indexed connectivities across different sustainability-related issues and domains of human activity. Its "metafeature" is defined by the strategy of networking among networks. Hence, the knowledge strategy is fundamentally one of networking, sharing, generating synergism, and building in correctives—in the sense that the GSSD knowledge base evolves over time, drawing on a wide range of Internet resources and information systems.

Key Applications

An overview of GSSD applications and capabilities is accessible from the GSSD home page at the "Introduction" button, and a more detailed review is presented in the individual applications buttons. For example, Figure 4 shows a screenshot "Using GSSD." All applications are based on the assumption that users will interact with the system in one (or more) of the following modes: an *access user* (to obtain knowledge types, or basic data, through search options and navigation tools); a *knowledge provider* or input user (to place contents of prescreened web sites in the system's knowledge base); a *knowledge developer* (to enable the organization of local knowledge and its formatting for use in global

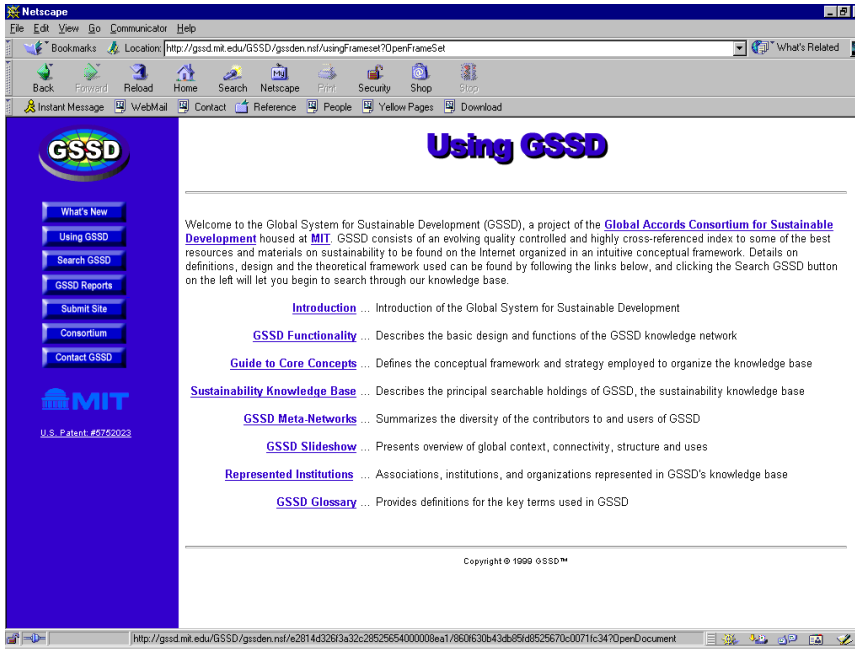

FIGURE 4 Using GSSD: highlights of system functions. SOURCE: MIT, 2001.

networks); or a *multimode e-user* for wide-area connectivity, knowledge management, and networking. The multimedia mode, currently in experimental form, will enable a user to network through audio and video facilities and, more important, to engage in real-time (almost laboratory conditions) survey research on a worldwide basis. For many social science and most policy-relevant uses, survey applications of this type would provide unparalleled opportunities for accessing and measuring select groups in targeted modes or the global community as a whole.

System Access, Navigation, and Search

Access to the system is obtained via icons representing intersections of slices and rings. Clicking on an icon takes a user directly to a requested list and brief synopsis of Internet sites. After clicking on the cell of interest, the user has direct access to that site and essentially exits GSSD. This application can be characterized as passive use of GSSD. (A text-based version of GSSD is currently under development.)

Users have six options for exploring or drawing upon the GSSD knowledge base. Two of these are in conventional search mode, (1) a simple search

(text search) or (2) an advanced search (reflecting specific requirements). The four other options involve more detailed access or search strategies: (3) selection by slice, (4) selection by ring, (5) selection by concept, or (6) selection by cell (i.e., a more fine-grained or detailed feature of a broader concept). The search and navigation options operate over the entire GSSD and can be used with a high degree of specificity for targeted segments of the data. The screen shot in Figure 5 shows four of the six "search types" at an aggregate level.

Knowledge Management

The system input application decentralizes the tasks of knowledge management, maintenance, screening, and quality control. This function is currently performed by the GSSD system administrators but is intended for distributed use in collaborating institutions. Automated input and update capabilities will eliminate the need for any programming on the part of the user. As shown in Figure 6, only a few items of information are required as user inputs to automatically update the system. This feature will facilitate data entry and hence facilitate implementation of decentralized capabilities.

FIGURE 5 GSSD search: four of the six strategies. SOURCE: MIT, 2001.

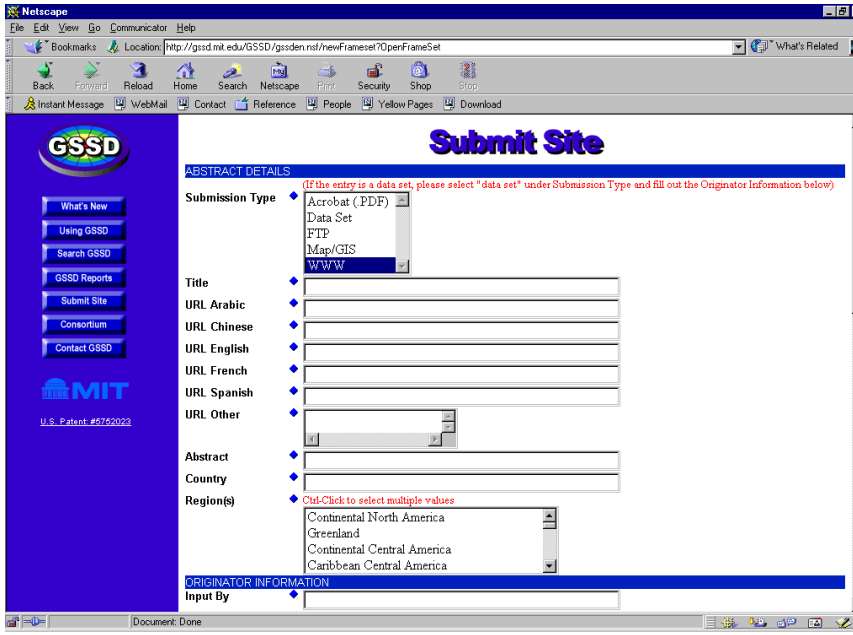

FIGURE 6 A GSSD submit site. SOURCE: MIT, 2001.

Multilingual Functions

A recently developed feature of GSSD—the provision of multilingual functionality—is especially useful in a world that is increasingly e-connected. The Internet today is an English-speaking medium in a non-English-speaking world; cyberspace is increasingly populated by non-English speakers. The multilingual capability of GSSD involves a multiple-language interface and workflow that currently includes Arabic, Chinese, English, and French. Current GSSD multilingual functionality enables:

1. **Improved access to knowledge.** Reducing the difficulties facing non-English speakers will enable them to find specific items or information on the Internet through retrieval of abstracts. The abstract (description) of each site in the GSSD knowledge base is translated into all of GSSD's supported languages. The translated abstracts are then available for e-searches through the system's six search modes.
2. **Strategic use of resources.** GSSD's abstracts will inform the user in advance of translation where the most fruitful information is housed, thus significantly improving access and efficiency.

3. **Expansion of knowledge base.** A platform for non-English content enables non-English-speakers to make their own data widely available and increases the amount of local knowledge on the global network.

Knowledge Networking and Strategic Partnering

The GSSD knowledge network is defined as an organized system of discrete actors endowed with knowledge-producing capacity combined through common organizing principles. The actors retain their autonomy; their interaction increases the value of the network to the actors; and the entire knowledge network expands the overall stock of knowledge. Access to interactive knowledge networking enables stakeholder communities to express their preferences and make explicit inputs into decisions. Knowledge metanetworking thus generates new possibilities for empowering individuals and many new modes of interaction among multiple voices ("cyberpartners") that have previously not been heard.

Strategic partnering makes dual outcomes possible: (1) *globalization* of knowledge via greater diffusion; and (2) *localization* of knowledge via representation of local technical and linguistic features. In practice, cyberpartnering can be undertaken in several ways: (1) via mirror siting the GSSD system; (2) distributed knowledge inputs and content provision; and (3) translation to enable multilingual functionality. The current cyberpartners are located in China (Ministry of Science and Technology), the Middle East (American University, Beirut, and ArabDev, Cairo), and France (Ecole des Mines, St. Etienne) and are planned for Central and Latin America as well as Japan and Italy. The institutional needs of cyberpartners can be addressed effectively with very modest resources and can thus significantly enhance diversity on the Internet.

TOWARD A PARADIGM SHIFT

Rapid advances in information technology, the rate at which new users are coming on line, and the growing politicization of environmental and sustainability concerns worldwide suggest that a paradigm shift in the diffusion and use of information technology may be taking place. This change is enabled by technological innovations, but it is driven by powerful synergism generated by a cooperative search for an improved knowledge-management strategy. In its simplest form, the shift is from a paradigm of the unilateral posting of information on the Internet to a paradigm of e-networking and e-conferencing; from centralized to decentralized information management; from uncritical acceptance of information to the evaluation of content and the critical appraisal of the implications; and from one-way communication to multidirectional interaction.

The most important element of this shift by far is the potential leveling of the playing field in knowledge access and management worldwide and its implications for users and providers of knowledge and for demands bearing on the design

of new information technologies and systems. The role of GSSD in this changing context can be best understood in terms of its three features: (1) content and connectivity; (2) distributed and decentralized capabilities; and (3) linkages across diverse knowledge and policy communities.

Content and Connectivity

The GSSD strategy focuses heavily on relating *content* (e.g., information, knowledge, data) to *connectivity* (i.e., linkages across topics, subjects, issues, etc., on the basis of substantive meanings) in order to enhance overall *capacity* (performance, choice, and decision). At the simplest level, this means, for example, that Internet resources that address both construction activity and the erosion of agricultural land can easily be taken into account, as relevant, when a search is performed for either one or the other. In practice, these linkages might improve modes of inquiry and/or types of decisions. They would also encourage, if not induce, a more critical appraisal of matters of content.

Distributed Capabilities

The conjunction of new technologies and evolving patterns of information management is turning conventional modes of knowledge development and management upside down. The traditional way of managing information is by centrally controlling operations. The new way is through greater decentralization and the distribution of operational control. The challenge is to ensure reliability and relevance.

The GSSD strategy concentrates on two forms of distributed input (or knowledge provision), knowledge nodes and mirror sites. Both are fundamental to overall system performance. Nodes are knowledge entry points that are slice-specific (topic-specific) and are managed by users with appropriate expertise. Mirror sites function as exact clones of GSSD, with regional input capabilities to ensure the decentralization of the provision of knowledge. Inputs at one mirror site are automatically mapped onto and reflected in the GSSD system as a whole (i.e., in all of the mirror sites). Figure 7 shows key functions.

Linkages across Knowledge and Policy Communities

The underlying premise of the GSSD design is that interconnectivity across knowledge communities generates added value—in other words, the whole is likely to be greater than the sum of its parts—and that the implications of additions, revisions, or changes in knowledge can be better understood if barriers to connectivity across knowledge communities are reduced. The GSSD enables interdisciplinary and multidisciplinary practices to be pursued more easily,

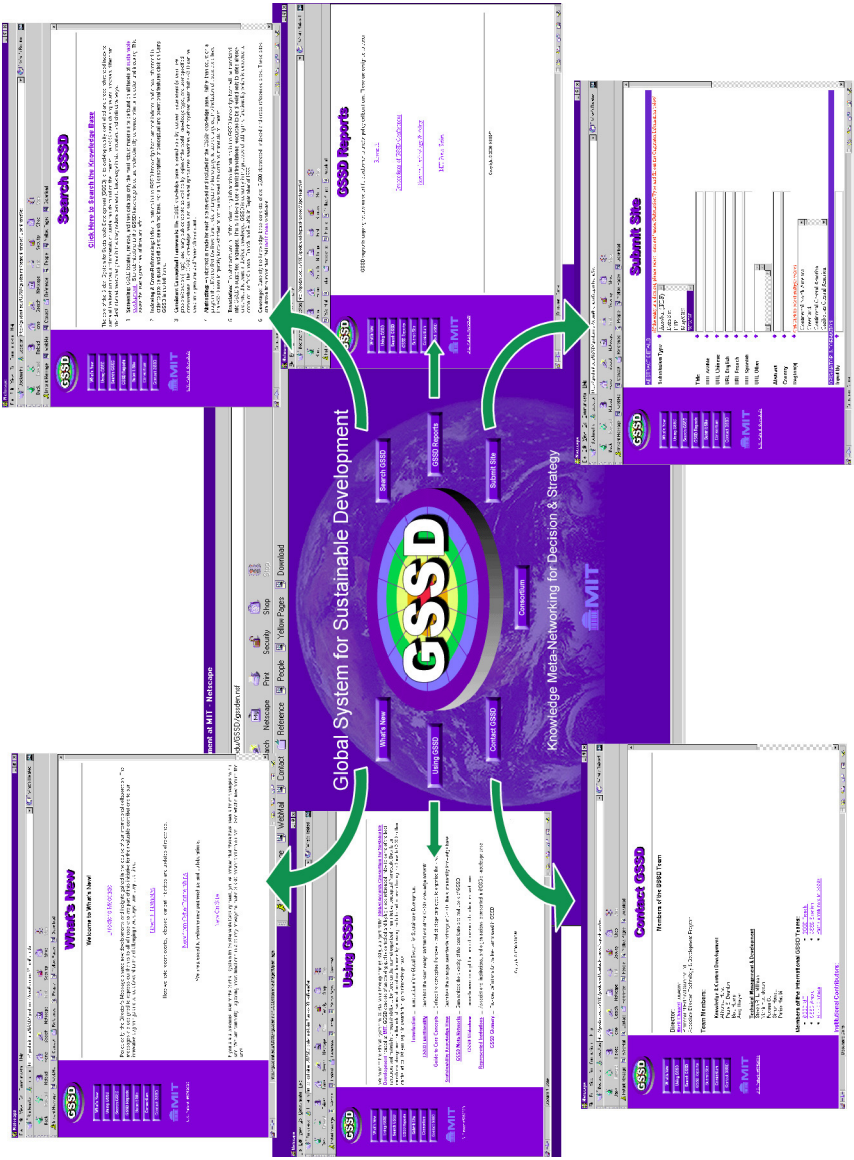

FIGURE 7 Basic layout for Global System for Sustainable Development (GSSD). SOURCE: MIT, 2001.

thereby enabling the generation of new forms of knowledge. The combination of slices and rings and the continuous adaptive updating of knowledge represent the significant facets of the system.

CURRENT STATUS AND CYBERPARTNERSHIP

During the early stages of development, GSSD was implemented on a server written in Mac Common Lisp designed for Macintosh machines (Keene, 1989). The server was built at the Massachusetts Institute of Technology's Artificial Intelligence Laboratory in conjunction with the White House initiative on "re-inventing government." Subsequently, GSSD was adapted to a Lotus Domino Server system that could support a broader user base and enable multilingualism. Other operating modalities currently are being explored for scalability purposes. In reality, all system decisions tend to be shaped by the research environment, not by development from operational imperatives. A research environment is, by definition, experimental, exploratory, and frontier oriented. It encourages new uses and users and new modes of operation, while seeking to "routinize" GSSD capabilities at both local and global levels.

At this writing, the first full version of the GSSD system is in place to support the Global Partnership on Cyberspace for Sustainability. Each slice has been populated with a first round of knowledge (data, analysis, policy experiments, initiatives, strategies, etc.) to test system capabilities in substantive and operational terms. To be effective as a distributed knowledge management system, however, GSSD will require regular maintenance to remove obsolete entries (dead links), add new materials (new links), and, as much as possible, monitor the quality and relevance of the knowledge base to sustainability. Because of their enormous scale and scope, these tasks cannot be centralized; they will require an effective decentralization strategy, which is still experimental and has not been fully articulated. So far, we have proceeded by trial and error. The system's wide-area networking capabilities have also not been realized fully, and critical decisions still have to be made about "best" hardware and software options.

The development of the system has revealed pragmatic challenges to routine maintenance and the need for new decisions. GSSD strategies for nodes and mirror sites are forcing attention on vital operating challenges—over and above those directly related to the research environment. The very nature of advances in information technology and the increase in uses and users is forcing changes in conventional modes of communication and interaction worldwide—in both the scientific and policy domains (Benedikt, 1994). Since the old model of knowledge centralization is being superseded by a new model of distributed knowledge-building and networking, key principles of cyberpartnering are taking shape. These include:

- reinforcing the synergism inherent in the operational division of labor in knowledge provision and information management
- encouraging the sustained decentralization of input capabilities
- reinforcing shared assessments and understandings of quality and quality control
- enabling electronic networking among human and e-networks
- supporting two-way top-down as well as bottom-up communication, nationally and internationally, buttressed by lateral networks

Although technological advances have "pulled" users toward this mode of knowledge sharing and management, the global quest for trajectories toward sustainable development has provided a substantial "push" for a decentralized, distributed, and equal access to cyberspace. This new model is the basis of the Global Partnership on Cyberspace for Sustainability.

The conventional maxim that "knowledge is power" has special implications in this context. The Global Partnership on Cyberspace for Sustainability empowers the scientific and policy communities with the most advanced information technologies. It facilitates collaboration among communities and provides mechanisms for addressing the challenges of sustainability in a coherent and integrated way. All of this improves the possibilities of moving along sustainability trajectories and enhances potentials for global collaboration in the process (Choucri, 1995; UNDP, 1994).

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