



# Building the GSDI

An Open GIS Consortium (OGC) White Paper

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## 1 Introduction

Under the patronage of European Commission Member Dr. Martin Bangemann, a group of organizations including the European Umbrella Organization for Geographical Information (EUROGI), the Deutscher Dachverband für Geoinformation e.V. (DDGI), the Atlantic Institute, the Institute for Land Information and its Land Information Assembly (ILI/LIA), the Open GIS Consortium, Inc. (OGC), the US Federal Geographic Data Committee (FGDC), and Fédération Internationale des Géomètres (FIG), Commission 3 have organized the September 4-6, 1996 Emerging Global Spatial Data Infrastructure (GSDI) Conference in Bonn, Germany. The goal of the conference is to bring together a group of experts to begin a dialog about the GSDI, a dialog which hopefully will lead to one or more programs of action to implement and promote the GSDI, and to begin using the GSDI to improve the quality of life and preservation of the global environment.

The conference will help us to create a shared global "NSDI vocabulary" which will organize people's thinking and actions and form the basis of a curriculum for educating people who will participate in building the world's National Spatial Data Infrastructures (NSDIs), which, networked and used together, constitute the GSDI. This effort involves studying each component of an SDI: technology, legacy data, culture, academic resources, professional organizations, governmental agencies, and legal and regulatory structures. Once names, metrics, and a record of experience have been applied to each of these components, the next step is to begin developing a coordinated approach to teaching countries how to apply this knowledge to their particular circumstances and goals. An additional task for the attendees will be to discuss and perhaps propose creation of a body (or redirection of an existing body) that will take over this effort as its program, carrying forward a shared vision, providing global leadership, organizing for maximum benefit and minimal duplication of effort. The product of this paper and the presentations and discussions held at the conference will be a comprehensive conference document, "1996 National spatial Data Infrastructures: Towards a Global SDI," which might then become the strategic planning document for that body, as well as a tool for educating political leaders, high level managers, executives, and intellectual leaders.

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## **2 What is the Global Spatial Data Infrastructure and why should we care about it?**

The Atlantic Institute states that the goal of the GSDI should be "substantial development in both rich and poor countries," development that leads to sustainable and high quality ways of life. We are all at this conference because we know that we are at a moment in history when nations suddenly have urgent reasons and greatly improved means for developing National Spatial Data Infrastructures (NSDIs) and a GSDI. The GSDI is a building block we cannot do without as humanity moves into the next century. The rise in world trade and commercial competition unleashed by the end of the Cold War and the beginning of the information age; the rise of market economies in developing nations; the global threat to the air, water, soil, climate, and ecosystems that sustain us; global research agendas; and problems and opportunities attending population growth are among the reasons to build a workable GSDI. Advances in computing, data communications, information technology standards, GIS, GPS, and Earth imaging provide the improved means.

An NSDI can be defined as "the total ensemble of available geographic information that describes the arrangement and attributes of features and phenomena on the Earth within a nation's boundaries, as well as the materials, technology, and people necessary to acquire, process, store, and distribute such information to meet a wide variety of needs." [1] At the heart of a mature NSDI is the basic spatial data: a network accessible multi-layer, multi-purpose cadastre covering topography, geology, hydrology, vegetation, wildlife habitat, wetlands, floodplains, zoning, utilities, roads, railways, canals, buildings, census data, titles, parcel structure, and geodetic network. For our purpose of analyzing NSDIs and the GSDI and deriving plans for NSDI and GSDI development, we will consider separately the essential components of a spatial data infrastructure: technology, legacy data, culture, academic resources, professional organizations, governmental agencies, and legal and regulatory structures. It is important to keep in mind that we already have a GSDI, however incomplete, and the GSDI is growing by leaps and bounds in a largely chaotic fashion. Technology greatly reduces the time to NSDI implementation: A developing country can build in ten years what took Germany 200 years. The conference attendees are in a position to guide and organize this imminent and inevitable explosive growth so that we may all achieve maximum benefit from it.

Geographic data, or "geodata," data which describes phenomena directly or indirectly associated with a location and time relative to the surface of the Earth, has been collected in digital form for

more than 25 years. The overall rate of collection increases rapidly with advances in technologies such as high resolution satellite-borne imaging systems and global positioning systems (GPS), and with the growing number of people and organizations who are collecting, using, and adding value to raw geodata. The number of users grows geometrically as geodata and geoprocessing resources become increasingly available and easy to use, and as people become more aware that indexing data by location is a fundamental way to organize and use digital data.

The software that uses and produces geodata is itself varied and complex. We define geoprocessing to be any kind of digital computing that uses geodata, including: geographic information systems (GIS), land information systems (LIS), Earth imaging and image processing, storage of geodata in databases of all kinds, digital surveying methods, GPS, navigation, meteorology, seismology, CAD that uses geodata (as in facilities management and civil engineering), digital cartography, flight simulation, and others. Geoprocessing software helps users answer questions such as: Where is something located? Where is a certain condition or pattern of spatial relationships found? What has changed in a given area over a given span of time? What is the best route? What if certain conditions were changed? [2]

As populations grow, as environments deteriorate, and as global trade and competition increase, governments and businesses have a growing need for geodata and geoprocessing in applications such as environmental management, planning, economic development, land registration, emergency response, health and public safety, military command and control, traffic management, agriculture, education, fleet management, and business geographics. Geoprocessing technologies are advancing rapidly to meet these needs, radically extending our ability to produce, acquire, store, analyze, compare, overlay, integrate, transform, communicate, format, and display geodata.

At the same time, the world's general information technology (IT) industry is creating an extraordinary technological infrastructure to support geoprocessing in the service of these applications. We can define the GII (Global Information Infrastructure) as the general IT infrastructure and the total ensemble of available digital information, as well as the materials, technology, and people necessary to acquire, process, store, and distribute digital information to meet a wide variety of needs. The GII is developing rapidly as its technologies advance, as communication networks are built, and as individuals, businesses, governments, and other organizations in every country begin to use the new network-available digital products and information services. Because geoprocessing holds such promise as a part of the solution to so many human needs, spatial data is, or needs to become, an integral part of the GII.

The advances in technology are dramatic and are essential to GSDI development, but they are not sufficient. Everyone with experience in NSDI development can attest to the difficulties inherent in integrating the elements of an NSDI. The technological obstacles are being overcome, but the cultural and institutional obstacles can be overwhelming. Different groups of geodata providers and users view the world very differently, and this is reflected in the heterogeneity of their geodata and geoprocessing methods and in their human and institutional resistance to sharing and cooperation. Geodata heterogeneity and geoprocessing heterogeneity will increase unavoidably as a result of the proliferation of applications, but, over time, technology and cooperation will make heterogeneity less significant as an obstacle. Human and institutional resistance can be addressed with dialog and negotiation. A basic goal of NSDI-building is to make it possible for groups to routinely and easily integrate data from various sources, and this will require progress in institutional arrangements. The technical obstacles to data sharing and integration are being addressed through commercial/technical arrangements, such as vendor conformance to standard application programming interfaces (APIs) which enable real-time communication between diverse geoprocessing systems that use diverse data formats. Geographic information communities collaborating to integrate their data will need to negotiate, but they will be assisted by tools such as semantic translators [2].

Figure 1: GSDI diagram: GSDI is like a wheel with technology as its hub, each spoke a different country. Each country has these SDI components or levels: legacy data, culture, academic

resources, professional organizations, governmental agencies, and legal and regulatory structures (for land tenure, privacy, intellectual property, environment, census, etc.). Links exist between countries at each of these levels.

Building the GSDI is a long term project, but some aspects of the project will proceed rapidly, in either a chaotic or a designed fashion. To maximize the benefits, people in a position to influence this progress must learn, analyze, communicate, imagine, innovate and plan together. Hopefully this conference will initiate new relationships and strengthen existing relationships between individuals and between organizations whose missions will include GSDI building.

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### **3 What benefits will the GSDI bring, and to whom?**

As the GSDI develops, it will provide the following benefits:

-- The GSDI will be essential in leveling many of the infrastructure inequalities - physical, educational, economic, healthcare, etc. - of developed and developing economies, which will lead to: fewer national and international crises; a safer world with less physical suffering; new and expanded markets for both developing and developed economies; more people liberated from poverty, able to apply their talents and energies effectively toward larger purposes; and overall cultural enrichment. Geotechnology, for example, would play an important role in a worldwide tax/incentive scheme applied to extractors of non-renewable resources and to polluters, a scheme which would harness the power of markets in preserving the global environment.[6]

-- Students and researchers will use the GSDI to access geodata and remote geoprocessing resources from a multitude of geodata providers and geoprocessing service providers. As technological and design advancements increase ease of use, and as technological and institutional advancements increase ease of access, more academics and commercial and government researchers will take advantage of geographic information in their pure and applied research. Information products of this research will further increase the scope, depth, and importance of the GSDI. All geodata refers to one finite Earth: As geodata accumulates, it provides an increasingly deep layered resource for knowledge and understanding.

-- The GSDI will help establish a level playing field globally for localities and businesses of all sizes by providing open access to business-related geographic information. The GSDI will lead to a more globally distributed geotechnology industry, as well as open participation in international standards initiatives and open access to standards products and international business partnerships.

-- Networking the world's geodata and geoprocessing resources will increase the critical mass, overall importance, and benefit to society of geoprocessing applications, which will evolve and proliferate, benefiting vendors, users, telecommunications companies, and populations served by all of these.

-- Geodata will be used by citizens in their everyday wayfinding and transportation, electronic consumer purchasing, education, and interactive entertainment, and also in tasks that will be part of the many existing and yet-to-emerge types of jobs that will involve geodata and geoprocessing.

-- Designers of virtual environments and visualization tools will make use of humans' spatial visualization abilities, including our almost innate ability to understand maps and aerial views. Visualization of data in terms of its geographic components will help people see patterns and generate and convey information and knowledge.

-- Maps of all kinds powerfully condition our thinking about the world beyond our immediate viewspace. GIS, which enables interactive viewing and intersection of multiple spatially coincident maps representing diverse cultural and natural themes, promotes holistic, cross-disciplinary

thinking. Widespread viewing and use of geographic information potentially promote broad public global awareness in the same way that views from orbiting spacecraft expand the world views of astronauts, as reported by astronauts.

Ultimately, almost everyone will benefit from the GSDI, in the same sense that almost everyone benefits from telephone networks, medical research, and international trade shows. The benefits flow outward over time, raising societies in terms of prosperity, organization, and cultural richness.

The GSDI will happen because of technological and commercial advances in geoprocessing and network computing, and these advances will cause dislocations. For example, centimeter-accurate GPS will change the work of surveyors and will put some surveyors out of business. Building the GSDI will require many people to learn new skills, but these will in most cases be valuable, future-oriented skills, and GSDI growth will create new opportunities for geographic information generalists and specialists.

Most GSDI building will occur within NSDIs as the result of national, regional, and local initiatives, and in many cases the local benefits of geoprocessing and geodata collection will be profound. For example, public land information systems (LIS) and land registration will promote equality of opportunity for citizens in less developed countries by formalizing land tenure. When a nation's poor people can legally buy and sell property and use their property as collateral for loans to begin building businesses, the whole nation begins to see improved prosperity, as shown by Peruvian economist Hernando de Soto.[3]

What are the risks of GSDI development? The benefits of the GSDI will far outweigh its costs and risks, but there are several risks to keep in mind:

-- A developing country might have a reasonable fear of exploitation of its natural resources and indigenous peoples in the vulnerable period before the nation has advanced far enough in democracy, law, business sophistication, resource management, and regulatory effectiveness to protect its own interests.

Precautions: Governments and NGOs can extend aid to develop democracy, law, business sophistication, resource management, and regulatory effectiveness. Consultants can help governments understand and protect their citizens' interests. NGOs can appeal to consciences of affluent consumers and developers to limit abuses. Can/should/will the world community police development, mineral extraction, habitat destruction, and exploitation of unprotected minorities? These are questions beyond the scope of this paper but within the domain of concern of many GSDI builders.

-- From the developing nation's point of view, any advance in communication and transportation threatens local culture.

Precautions: Change is inevitable. Cultural exchange programs can build awareness of others' and one's own culture, and cultural heritage programs can preserve at least the artifacts and arts of culture, and can enrich the larger culture. Enlightened leaders in developing countries can instill pride and endeavor to maximize benefits of Western technology and culture while minimizing harm, by understanding implications of choices of introduced technology and institutions. The GSDI will be a useful tool for people working to ameliorate the effects of technology-supported growth.

-- Oppressive governments may use geospatial technologies for citizen surveillance and control, internal warfare, or war against neighboring countries.

Precautions: The world community can isolate oppressive and warlike regimes and enact legal measures to limit technology sales to despots. In Western democracies, we must pay close attention to rights of privacy, civil rights, and international affairs with respect to our governments' potential abuse of new information technologies, including geospatial technologies.

Because so many applications of geoprocessing bear directly on long range planning for global environmental problems, it is likely that the GSDI community will contain a high percentage of people with a long range perspective on what might be called "the human project." As an organized community of people focussed on the long-term development of an important component of the GII, the GSDI community will be well positioned to monitor the social effects of emerging information technologies and explore ways of steering technology. Toward this end, the GSDI community might investigate "pre-standards", "meta-standards," conceptual schema, formal descriptive and modeling techniques, convergence architectures, and high-level modeling of social needs (sustainable development, broadly defined) toward the end of steering R&D and market activity. Ultimately, there may develop important links between technology standards and international standards for "green" products, "green" government procurements, occupational health and safety, fuel transport, resource extraction, etc.

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## **4 What needs to be done to promote and organize GSDI growth?**

We have defined the Global Spatial Data Infrastructure (GSDI) as a composite of the world's National Spatial Data Infrastructures (NSDI). Building a useful GSDI in a reasonable period of time will involve forming a coordinated global approach to building NSDIs. Through conferences, shared ideas and reports, publications, email dialog, and international institutional collaboration, NSDI builders will:

- Learn from each other and avoid much duplication of effort. Education is perhaps the most critical element in this early phase of GSDI development.
- Acquire knowledge, models to apply, and experts to consult.
- Develop globally applicable products and methods, including metadata content standards and interoperable software, so that data created for one local use will be applicable, in many cases marketable, for other local and global uses.
- Create an essential set of databases (basic data layers, called "the Framework" by the US Federal Geographic Data Committee) [5], institutional arrangements, procedures, organizations, experts, and information system tools for solving issues facing the whole Earth or multi-nation regions of the Earth. (Significant planning toward this goal has been done in the EARTHMAP initiative, now a project of the US National Academy of Sciences/National Research Council (NAS/NRC). See <http://cdserver.er.usgs.gov>. Tom Usselman of NAS/NRC has staff responsibility for this project and will be speaking at the Conference.)
- Establish some common forms of institutional arrangements geared to benefit a wide variety of users represented at international conferences of various kinds. This kind of organization and cooperation among like agencies that serve their different national governments and national agendas will surely help to create better communication and cooperation between national governments, and indeed, the GSDI is meant to be an infrastructure usable by everyone, not just the experts and specialists who will give it form in the next decade.

The general information technologies and geographic information technologies at the hub of the GSDI are essential, and in Section 5.1 we look at what needs to be done to ensure a solid technology foundation. But technology is only the hub (see figure 1), not the wheel. As the diagram shows, each NSDI in the GSDI has its own culture, legacy data, academic resources, professional organizations, governmental agencies, and legal and regulatory structures. Every country has this list of NSDI components, but in each country the components look different and in many countries every component seems a separate obstacle to NSDI success. Because the problem is essentially a communication problem, the solution begins with elaborating the SDI

vocabulary. We need to enumerate and analyze SDI components so we can organize our own thinking and actions and then teach others. Section 5 of this discussion paper begins to elaborate the SDI vocabulary.

Once we have elaborated an SDI vocabulary, it informs our thinking and becomes the content of a curriculum to support NSDI and GSDI implementation. In both rich and poor countries, education bears directly on every NSDI component. Old ways become obsolete: Just as today's emerging nations may, a decade from now, boast modern wireless telephone systems that are better than the developed nations' wire-based systems, they may also boast legal structures and institutions that are better suited to the new digital realities. Poor countries can progress rapidly if served by individuals and teams who can integrate their understandings of local and global culture, government, economics, and technology. Today's experts in developed countries need to re-educate themselves for new opportunities: GPS and digital orthophotos will unemploy some surveyors; but environmental issues, global competition, and rising aspirations of populations are greatly expanding the demand for geotechnologists willing to learn to serve in new ways.

The barriers to the GSDI and its business and social benefits are:

- Lack of understanding by high level politicians and managers, and lack of leadership by experts who are in a position to create common understanding of the value and issues of spatial data infrastructures at these high levels and who are also in a position to educate middle and low level decision makers and their staffs who can collectively press for progress in this area.
- Lack of coordination within and between geographic information communities regarding metadata content standards, geographic feature semantics, and operational details of sharing and integrating data.
- Cultural inertia: the tendency to maintain established structures and to preserve cultural and institutional behavior.
- The perceived uncertainty of financial returns to governments, who do not view spatial data as infrastructure which ought to be financed like other infrastructure.
- Lack of a planning framework.

GSDI builders need to address these issues.

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## **5 The GSDI vocabulary**

The subsections of this section have the following headings:

- 5.1. Technology
- 5.2. Geodata: Legacy data and New data
- 5.3. Culture
- 5.4. Academic resources
- 5.5. Professional organizations
- 5.6. Governmental agencies
- 5.7. Legal and regulatory structures (for land tenure, privacy, intellectual property, environment, census, etc.)

Under each of these headings we 1) identify the issues that need to be addressed, 2) look at what is already in place, and 3) suggest courses of action.

As part of the project that begins with this conference, project participants from different professional domains could look at each of the GSDI applications, recording for each application details corresponding to each of the seven categories listed above. Below is a first attempt at comprehensive list of applications. The number of applications is already growing rapidly, and will continue to grow as the GSDI develops.

-- Agriculture and forestry -- Climate research, agronomy, biology, ecology, geology, other sciences -- Urban and regional planning -- Automated mapping and facilities management -- Military surveillance -- Natural resource discovery, exploitation, and management -- Water resource management -- Global and local environmental monitoring, advance of environmental sciences -- Support for "green" standards -- Cable, microwave, and cellular transmission installation planning -- Part of cross-cultural education/training, distance learning, research collaboration -- Part of global inventory, electronic libraries, electronic museums and galleries -- Global emergency/crisis management -- Global access to health care resources - telemedicine - better care for rural trauma victims -- Online government geographic information -- Online multimedia yellow pages with distance calculation and way-finding -- Global maritime information and rescue system, air traffic control -- Road traffic management, parking management -- Route guidance, dynamic route planning, multimodal trip planning, and traveler services -- Intelligent vehicle highway systems (IVHS) -- Emergency road services and 911 emergency response systems -- Commercial vehicle operations -- Mobile communications -- Maintenance of the individual's information context and connection (personal logical network) as the individual moves through space, bridging media and modality; mapping electronic locations of devices (addresses) to their physical locations; using concepts of reach space, co-location, and near-by. -- Traffic/weather information -- Product distribution/warehousing optimization -- Virtual reality landscapes from Earth images for: military, disaster relief, and rescue preparedness; civil engineering, landscape architecture; and interactive entertainment -- Parolee tracking -- Security monitoring and intrusion response -- Special wayfinding for elderly and disabled -- Business siting, market research, and other business geographics applications -- Geographic matching of prospective employees with available jobs, or prospective service providers with prospective clients -- Public administration networks -- Land tenure systems -- City information services -- Precision farming (GPS-guided controlled delivery of nutrients and chemicals based on Earth imagery or automated GPS-located soil or crop sampling) -- Small farm and garden services and locale-specific resources

Each NSDI could be characterized by listing the people, organizations, information, products, and services involved in each of these application areas. University groups, professional and industry associations, government agencies, and/or corporations could begin planning for each NSDI by looking at the complementarities, common needs, costs and benefits, priorities, and implementation schedules for each of these applications. We need to appreciate that every country needs to base its infrastructure on practical realities and local and national needs, and we need to appreciate the wide range of interested and affected communities who might want to be participants in the planning.

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## **5.1 Technology components of the GSDI**

These are the central facts concerning technology and the GSDI:

- Technology is an absolute prerequisite, an essential part of the GSDI.
- The strictly technical problems are the easiest to solve.

-- GPS, Earth imaging, spatial database technologies, and geoprocessing interoperability are advancing very rapidly.

-- Much of the GSDI technical infrastructure is being built for us by the world's general information technology (IT) industry as they build the GII: Computers keep getting faster and the telecommunications and distributed computing hardware/software/standards infrastructure which supports distributed geoprocessing is spreading like wildfire.

-- Information technology, including geoprocessing technology, has its own momentum and its own program: Like oil creeping into a hinge, it finds its way into governments, businesses, universities, and homes. GSDI builders need to understand that this progress can be influenced but not controlled, guided but not stopped. Technology development and diffusion is inextricably linked to our capitalist socio-economic system, so controlling and guiding development and delivery of a technology requires an understanding of the entire business context of the technology, and a willingness to work within that context.

With respect to technology, the goals of GSDI builders should be:

-- Keep abreast of new geoprocessing technologies, products, and technology trends, and communicate this information to NSDI implementers in all countries. Enlist the help of vendors, associations, and publishers that sponsor or participate in geotechnology conferences and exhibitions, for these groups are eager to help educate new buyers and users.

-- Promote liberalization of the telecommunications sector, so that users of geographic information can take advantage of global interconnectivity and interoperability. This means promoting electronic commerce, encryption and security measures, an economic information network, and the global electronic market infrastructure for small and medium-size businesses.

-- To fully synergize geographic and non-geographic information technologies (including new geodata-producing technologies, such as GPS and high-resolution low-orbiting Earth imaging systems), geoprocessing technology initiatives must be closely coordinated with broader IT initiatives. The GII and the GSDI are essentially the result of technology convergence. GSDI-supporting technologies include, for example: microprocessors and memory chips, digital communication (cabled and over the air), networks, data compression, digital storage, distributed object architectures (and middleware and componentware), Earth imaging digital cameras, GPS and electronic/optical distance measurement, synthetic aperture radar, software interfaces, lasers and fiberoptics, display technologies, security and electronic commerce systems; and human/machine interfaces. This is primarily the work of vendors, but users can work directly with vendors and in standards fora to explore and communicate ways in which supporting technologies can serve GSDI needs.

-- Support standards development organizations and consortia that work for better interoperability. These groups, which are themselves an important part of the GSDI community, promote the development and deployment of interoperable geoprocessing technology, which is based on standards. GSDI success depends on the "Inter" role of standards: internationality, interoperability, interconnection, interworking. Interoperability is the hallmark of the GII and the GSDI, which we envision as a "system of systems," "network of networks," providing seamless access and use of geodata and geoprocessing resources. Interoperability depends on standards and vendor community agreements. Work to ensure that a basic technology platform becomes available to all.

IT is advancing rapidly, watched and analyzed by many, and many are working toward cross-industry, cross-domain, cross-border understanding. The GSDI community needs to be part of this progress. Users need to articulate, in whatever fora possible, specific needs for: open systems to accommodate heterogeneity; flexible systems that integrate new and legacy resources; and scaleable systems that size from residence to global enterprise. By participating in standards processes, users can identify their top standards issues and their most common or critical scenarios, then work with all interested elements of the standards community -- standards

developers, vendors, and integrators -- to create application programming interface (API) specifications, content and format specifications, and protocol specifications. Users and vendors can work together to decide whether to approach these as formal standards, defacto standards, or narrow normative approaches.

It is important to keep in mind that interoperability is finally delivered by vendors and integrators, not by standards organizations, consortia, standards, specifications, user groups, test suites or certification schemes. Government-imposed standards and too-slow-to-market de jure standards often fail. Vendors, working single-mindedly to attract and satisfy customers with differentiated products and new technology, together with national interest initiatives, are the driving force behind the GSDI, and this behooves every sector of the GSDI community to understand the vendors' needs and to seek cooperative arrangements that recognize those needs, all the while demanding interoperability.

The Open GIS Consortium, Inc. (OGC) will be one participant in building the GSDI. OGC provides a forum for vendors, integrators, researchers, agencies, data suppliers, and users to create shared geoprocessing interoperability technologies and to discover opportunities for working together, commercially and otherwise. OGC members are creating geoprocessing interoperability specifications (the OpenGIS Specification, informally called "OGIS") [2], but they also use OGC to help reach the goal of interoperability in other ways. The technologies and technology product delivery channels are evolving so rapidly that old organizational models and business models need to be revised or replaced. Negotiations between vendors and between vendors and standards-setting organizations enable new arrangements to be made and realistic goals to be set. OGC provides opportunities for GSDI builders who are users, consultants, agencies, or integrators to benefit from participation in cooperative R&D and pilot application programs and from vendor-delivered seminars as well as specification-writing activities. OGC has special membership levels by which major users of geotechnology can work with the vendor members to create agency-specific, government-specific, industry-specific, discipline-specific, or world region-specific extensions to the OpenGIS Specification. These tailored specifications make it possible for a geographic information community to ensure that multiple competing vendors will offer needed products that are interoperable with each other and interoperable with the community's legacy systems.

Both the GSDI user community and the vendors benefit when vendors listen to users and cooperate with other vendors: -- Vendors and users benefit from less duplication of effort.

-- Both benefit from faster time to market.

-- Vendors benefit from having more time to recoup R&D investment (because R&D projects complete sooner and costs are shared)

-- Patent pooling increases the likelihood of each contributor's return on their fraction of the R&D investment.

-- Collaborative promotion, beginning prior to standard product release, helps vendors to share the cost of educating the market to create "pull-through" mass market demand.

-- Standards expand markets.

-- "Poets make poems from poems": A rich pool of community-owned intellectual property creates prosperity. At the same time, however, protecting intellectual property rights provides incentive for innovation.

Users benefit because standards minimize the risk of market chaos, maximize equitable competition, create more ordered procurement programs, and maximize layered and derivative product differentiation, ultimately lowering prices and increasing choice and functionality.

To accelerate standard-setting, GSDI builders involved in the standards process should focus on realistic targets, study and adopt effective working group processes (e.g., small commercial

teams develop proposals, larger consensus groups choose between proposals), and be sure that the process causes vendors to use standards strategically, not for divisive ends, but for inclusive and expansive ends. To fully exploit synergies of new information technologies, close coordination is required -- conferences, liaisons, communication and education of all kinds help map needs for commonality.

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## **5.2 Geodata: Legacy data and New data**

In recent years, there has been considerable discussion of geodata issues in building NSDIs and the GSDI, because heterogeneous data incompatibility has been a problem throughout the history of digital geographic information.

Data heterogeneity occurs at several levels. Different geoprocessing systems from different vendors use different internal formats for representing geographic data, and integrating information represented in these different formats has required data transfer using batch translation programs. This is a time-consuming and error-prone process, even with the help of data transfer standards. In addition, data produced at different times by different people for different purposes inevitably have different metadata schemas and geographic feature semantics, and different users have different institutional and technical ways of managing their data files.

Legacy data represents in many cases a huge past and ongoing labor investment, and in many cases the amount of data stretches the budgets of the agencies storing and maintaining it. But today's legacy data is only a tiny fraction of the data that will have been accumulated by the turn of the century, because of the accelerating growth of GPS, Earth imaging, and the number of users of geoprocessing software of all kinds. Fortunately, CPUs and data storage devices continue to become faster and less expensive and spatial databases continue to become more useful, but from the point of view of NSDI and GSDI planning, a number of questions need to be considered:

-- How can legacy databases and new data be integrated, and what institutional arrangements can be made within and between countries and disciplines, particularly to standardize on metadata schemas and feature definitions?

-- What global repositories of geodata will be available? What ought to be available? What ought not to be available? (Consider privacy, security, intellectual property rights, taxpayer rights to publicly funded data, salability of data, implications for economic development, national security, danger of exploitation, etc.)

-- The market for value-added information and information brokers will grow rapidly. What legal, commercial (e.g., Internet-based delivery and payment), and institutional arrangements will be necessary so that value-added data resellers and brokers can be valuable contributors to the GSDI?

-- What can/should the GSDI community do about proprietary data formats that limit access to data created by users whose geoprocessing systems are incompatible with the systems of partner users? To a great extent, geoprocessing interfaces based on OGC's OpenGIS Specification will solve this problem, but if vendors publish the specifications for their proprietary formats soon, many more users will be able to share data in the near term, and access will be more efficient in that fewer processing resources will be required.

Legacy geodata provides a basis for current work and current education, but taking a long view, today's legacy geodata constitutes only the first tiny installment in our GSDI archive. Dozens of geodata standards groups have attacked the data incompatibility problem, and from their work we are evolving more accurate and more organized methods of collection, classification, and description. This work is crucial to the GSDI. As mentioned earlier in this paper, geographic

information communities collaborating to integrate their data will need to negotiate, but they will be assisted by tools such as semantic translators [2]. In addition, geoprocessing software (and non-geoprocessing software such as databases, graphical user interfaces, and virtual reality simulations) compliant with the OpenGIS Specification will be able to communicate in real-time with other OpenGIS-compliant software. A particular GIS, for example, will be able to query a remote relational database management system and extract specified data layers for a specified geographic region.

The GSDI must be able to provide geodata to anyone, anywhere, anytime. GIS users have found that their biggest investment lies in data conversion, development of custom applications, and learning curve. As technology advances, costs for these three activities will go down. As high quality, ready-to-use commercial and public geodata becomes available, relatively fewer people and dollars will be involved in data conversion, development of custom applications, and training people in pre-processing data. More people and dollars will be involved in the higher level activities of creating information and knowledge from geodata.

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### **5.3 Culture**

A wide variety of cultural issues enter into the discussion of NSDIs and the GSDI. In the context of this conference, our main concern is overcoming cultural obstacles to NSDI and GSDI development. But to do this effectively, we need to consider the cultural impacts of NSDI and GSDI development, and we need to have open minds about what is positive and what is negative, because technology insertion is a change-causing cultural act which has been studied little compared to its powerful effects on our lives, and which is particularly potent in the case of information technologies like printing, radio, and networked computing.

-- GIS coordinators in the US and around the world are familiar with how much work it takes to educate people about the benefits of GI technology, and the work it takes to bring this technology into the budgets of managers and the work lives of working people who are unfamiliar with computers. The problems are problems of business re-engineering: The introduction of IT upsets organizations, forcing people to give up comfortable and familiar tasks and routines. In some cases individuals successfully meet the challenge and find opportunities for satisfying personal growth, in other cases individuals feel threatened and unable to perform in new ways. This can happen at all levels in an organization, and considerable education and communication are necessary before the organization moves to the higher level of organization and efficiency enabled by the technology.

-- We can imagine and hope that SDI development will lead to a more wholesome, globally shared land ethic. But the "right" philosophy for managing land information depends on a wide variety of cultural factors, and the cultural issues are likely to wide-ranging even within a single country. The land ethic of hunter-gatherers in Namibia is quite different from the land ethic in industrial cultures; they have, arguably, much to teach industrial cultures about our relationship to the Earth; and yet the newly introduced concept and institution of land ownership is one of the factors threatening their existence. To consider another extreme example, the propertied power elites in countries that have not made the transition to democratically established rights of land ownership and personal freedom present an entirely different cultural/political obstacle to GSDI development. Each country is a mosaic of cultural and social groups. Careful study would probably show that within each group there are some shared beliefs and attitudes toward land, technology (e.g. inexpensive GPS-equipped cell phones), and development, and toward the technocrats, agricultural specialists, public health officials, and others who might somehow involve them in their country's NSDI.

-- In the US, cultural/economic/political factors have caused and continue to preserve gross differences in land records systems from county to county and state to state. The system works

well enough, most Americans believe, but the more organized German cadastre system requires far fewer lawyers to resolve disputes.

-- By what is shown and not shown, by what is emphasized in their design, by the language and spellings of the place names, by what is said in the accompanying text, by the history and cultural context of their symbols and cartographic genres, and by their cost and means and pattern of distribution, paper maps themselves have powerful cultural effects [10]. The same is true of digital geographic information, and this is part of the cultural component of every NSDI.

As we develop powerful new technologies for managing land information, more people will be looking at, using, and managing land information. What will that mean in the cultural context of each country, and in the context of each application listed in the introduction to Section 5? All we can say is that in our planning, we must be aware that building the GSDI will require cultural work, and it will have cultural effects.

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#### ***5.4 Academic resources Education at all levels is necessary to implement a GSDI that meets our goals. Education should have the highest priority in the GSDI agenda.***

Geography education and curricula involving spatial thinking can begin with young children, and geoprocessing applications can help guide them to both local and global contacts. A child's real neighborhood and physical relationships to real - not abstract or virtual - terrain, things, and people, is the main staging ground for a child's imagination and land ethic (which can be seen as the deepest foundation of the GSDI). The National Geographic Society and other organizations run successful programs in which children collect data, such as rainfall measurements and water samples, which become part of serious studies and which involve geographic analysis and display. Boundless opportunities exist for this kind of hands-on educational activity which involves the real world, other people, geography, and sometimes computers.

Universities have been important GSDI builders and drivers of GI technology. GI is an important tool in many disciplines, so universities have been an important market for technology providers, and academic researchers have advanced the technology by building their own tools or building new tools for vendors when appropriate tools weren't available. Geographic information created by academia in the physical sciences, life sciences, and social sciences comprises a very significant part of today's archive of geodata, and academia's contribution is certain to continue. Also, now many university departments are devoted entirely to research and education in geoprocessing technologies.

In every nation, universities are likely to play an important role in NSDI and GSDI building, at the levels of training practitioners, creating new geo-information, and participating in policy-influencing activities such as this conference. Each country and discipline, and also the international group attending this conference, should ask, "What is the research agenda?"

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#### ***5.5 Professional associations***

The role of professional organizations in building NSDIs and the GSDI is related to the role of academia. We need to leverage existing local intellectual assets and build new intellectual assets, and coordinate so that all contribute more directly to the GSDI. Professional associations of surveyors, GIS users, urban planners, remote sensing specialists, cartographers, geographers, foresters, etc. are already doing valuable work for the GSDI. We need to show leadership in

helping them to see their role in creating an infrastructure that will let others benefit more from their work and let them benefit more from others' work. By going this extra mile, associations will in many cases create improved professional opportunities for their members.

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## **5.6 Governmental agencies**

Governmental agencies will certainly play a key role in building NSDIs and the GSDI. We are moving into an increasingly data rich environment, where the emphasis shifts from collecting data to organizing institutions to support and use the spatial data infrastructure. Because of network technology, information is increasingly a corporate resource, so distributed land information systems will become more common. The questions will continue to be, "Who has it?" "Who wants it?" "How can you get it?" and "What are the terms of trade?" The answers will increasingly be, "Many people have pieces of it and the pieces will fit together well." "Many people want it." "You find it easily on the network through browsers, brokers, and clearinghouses." and "The terms of trade involve permissions, passwords, copyright agreements, and per-pixel electronic charges against the buyer's or borrower's account."

Agencies will need to continue to work collaboratively on metadata content standards and common geographic feature definitions, and they will need to investigate, contribute to the specification of, and then buy software that implements the interoperability they need. Much of the GSDI will be based on an elaborate network of agreements created on an as-needed basis between pairs and groups of agencies at all levels of government.

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## **5.7 Legal and regulatory structure**

Legal and regulatory structures will play a major role in NSDIs and the GSDI. A nation's NSDI will be tightly linked to land policy and land tenure rules, and these will shape administrative structures and policies. Policies will need to be created to deal with indigenous rights, privatization of land and land resources, formal vs. informal and customary systems, and rules that protect the environment. Public access to NSDI data should promote community-level solutions. Decentralization of land administration institutions may occur.

Developing countries will see increased prosperity result from formalized cadastres and land registration. Such countries are recognizing the positive relationship between land ownership and farm productivity, and between land ownership and small business development.

Developed countries can help developing countries define adaptable regulatory frameworks for land tenure, privacy, intellectual property, environmental protection, census, and other concerns.

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## **5.8 Conclusions and overall plan for action**

The Emerging Global Spatial Data Infrastructure Conference conferees face an important and exciting challenge: give form to a key part of the GII, the part that deals most directly with critical issues of international cooperation and sustainable development. The conferees are all leaders in their countries and professional worlds, and are in a position to implement programs that will lead to the benefits described in this paper. There is not yet a plan for action because there has not yet been enough discussion of vision, of what should be done and what can be done. That is why

this conference was organized. On the afternoon of September 6, in discussion groups and in a plenary, conferees will be asked to consider a plan for action.

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