

time interval between the two successive  $k$ -peaks is  $2k+1$ . When  $k=1$  this is 3 as pointed out in the beginning.

It is not difficult to see that the joint law of

$$\left[ \sqrt{m} \left( \frac{\tau_{m,j}}{m} - \overline{2j+1} \right), j = 1, 2, \dots, k \right]$$

converges to a  $k$ -dimensional normal distribution with a nondiagonal covariance matrix as  $m \rightarrow \infty$ . The

asymptotic results (10) and (12) provide a series of large sample tests for testing the hypothesis that a sequence of numbers is random.

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## Biodiversity conservation information network: A concept plan

C. P. Geevan

*A network that ensures the availability of reliable, up-to-date environmental information is necessary to realize the objectives set out in Convention on Biodiversity (now a treaty) that followed from the Earth Summit at Rio, June 1992. The task of building a nature conservation information network should, therefore, be considered an important part of the biodiversity conservation agenda. This paper presents an outline of an hypothetical information network, designated as Conservation Information Network (CiNet), to meet requirements of bioresources conservation, mapping, inventorying and monitoring on a large scale. The dataflow framework presented takes into account the existing data networks in India.*

### Background

The Convention on Biological Diversity (CBD) that emerged from the United Nations Conference on Environment and Development (UNCED) or the Earth Summit at Rio de Janeiro, in June 1992 is now a treaty. The CBD covers almost every aspect of biodiversity conservation. Article 17 of CBD concerns exchange of information. However, it does not lay down any operational framework for achieving information exchange. Nevertheless, an information network that ensures the availability of reliable, up-to-date environmental information is necessary to realize the objectives set out in CBD. The existing information systems are considered to be inadequate to meet these challenges<sup>1</sup>.

The task of building a nature conservation information network should, therefore, be considered an important part of the conservation agenda. This paper presents an outline of an information network to meet requirements of bioresources mapping, inventorying and monitoring programme. The hypothetical network is designated as

Conservation Information Network (CiNet). The dataflow framework is presented taking into account the ready availability of well-developed data networks in India and the CiNet is conceptualized as an overlay network riding over the existing networks.

### Special interest groups on global networks

Computer networking has gone beyond setting up data links to creating information highways over which organizations and individuals are connected across the globe. The nature conservation efforts need to take advantage of these developments in information technology and create a niche for itself in the cyberspace. There are several important initiatives in this direction such as the INFOTERRA of the United Nations Environment Programme (UNEP) consisting of 170 national nodal points coordinated from the UNEP headquarters at Nairobi, the Environmental Resources Information Network (ERIN) in Australia with a biodiversity information system designed to meet the changing user needs, the Bio-diversity Information Network (BIN21) dedicated to the CBD with its secretariat at the Tropical Database

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in Brazil, the Long-term Ecological Research Network (LTER) based in the University of Washington and the projects in Capacity Building for Biodiversity Information Management begun by World Conservation Monitoring Centre (WCMC) based in the United Kingdom and the BioNET-International proposed by CAB International to pool the global resources in biosystematics. With the assistance from the United Nations Development Programme (UNDP) under CAPACITY 21, a large number of Sustainable Development Networks are also expected to be set up.

The capacity building project of WCMC is supported by the European Union and allows it to carry out the strategic development work as well as testing of networking and other cooperative approaches for biodiversity information management. BioNET-International is a Global Technical Cooperation Network of institutions and people concerned with biosystematics of invertebrates and microorganisms. The goal of this network, as stated, is the mobilization and enhancement of the world's biosystematic resources for the benefit of developing countries. BioNET will build and sustain biosystematic self-reliance in developing sub-regions and provide the biosystematic backup to biodiversity.

Several special interest groups and networks (SIGN) dedicated to biodiversity conservation have sprouted up all over the global computer network. These SIGNs provide various facilities to users. Some of these are available to the email subscribers to the list. Subscribers usually join a list by sending an email with requisite information to the listserver or the master of the list. The user's name, email address and other information are then added to the email database maintained by the SIGN.

### **Biodiversity information networks in India: current status**

There are a large number of Non-Government Organizations (NGO) and research organizations involved in conservation-related activities and research. India is not only rich in biodiversity, but can also boast of a large baseline information on this wealth. The repositories of this information are numerous and diverse, with some of the agencies being more than a century old. Invaluable information exists in a variety of forms: as specimens, field notes, reports and various kinds of computerized data.

Despite dramatic developments in information technology and quantum leaps in telecom facilities, the conservation efforts in India are yet to make the best use of the options available for information exchange, barring a few exceptions. The recent discussions on the mechanisms and scope of the information base for biodiversity conservation in India<sup>1</sup>, is an indication of

this realization. The information networks for biological conservation are at a formative stage, the front runner being the network initiative of the Foundation for Revitalization of Local Health Traditions (FRLHT).

The well-established and nationwide biological information network is the Bio-Technology Information System (BTIS) consisting of the Distributed Information Centres of the Department of Biotechnology supported by NICNET—the computer network of the National Informatics Centre (NIC). Another biological information service available is the access to the Medical Literature Analysis and Retrieval System (MEDLARS) over NICNET, provided to select institutions by NIC. The different institutions with access to MEDLARS do not, however, exist as inter-connected nodes.

Although FRLHT has taken an initiative in creating the Indian Medicinal Plants National Network of Distributed Databases (INMEDPLAN), it falls short of the larger needs of networking the conservation activity and bioresources mapping. This can only be met by the 'inter-networking' of several networks such as INMEDPLAN, BTIS and those in the offing like the Biodiversity Information System (BIS) of the Indira Gandhi Conservation Monitoring Centre (IGCMC) established by the World Wide Fund for Nature (WWF) and the Environmental Resources Information System (ERIS) being devised at Wildlife Institute of India (WII). The IGCMC proposals, unlike that of FRLHT, appear to favour an over-centralized system, rather than a true network of several fully autonomous, distributed information systems.

The INMEDPLAN is a network of organizations involved in identifying, documenting and reviving folk and traditional health systems and in the inventorying of medicinal plants. FRLHT has also attempted to bring about some sort of standardization in data compilation formats. A large number of organizations are also involved in the consultative process of standardization.

Although, the BTIS does not have conservation priorities, it provides rapid access to a wide variety of biological databases, besides those related to biotechnology. Moreover, considering the role that molecular biology and DNA fingerprinting are destined to play in biodiversity inventorying and monitoring, it is important to bring BTIS within the ambit of conservation network.

A recent study of biological databases available in India indicates that the majority of these are developed under BTIS<sup>2</sup>. Although the study does not appear to have examined the information resources available at reputed ecological research institutions, its overall conclusion that the contribution from sources other than BTIS is marginal, may have some validity. The same study also notes that the use of the available databases is restricted due to lack of electronic data transfer facility and networking. The BTIS users make use of NIC's



satellite-based network for data communication. However, BTIS does not function as a true on-line computer network due to certain limitations imposed by NICNET.

Both ERIS/WII and BIS/IGCMC/WWF are at an early developmental stage. It is important that the originators of these information systems lay down some long term networking and standardization goals as part of the design and development activity. What needs to be clearly recognized is that the highly centralized information systems relying on high performance computers are a thing of the past and the future belongs to inter-networking of special interest groups. With a highly decentralized and participatory approach to conservation, it becomes all the more important to anticipate the need for a truly extensive data network and take into account the multiplicity of end-user needs.

As important as access to information or even more, is the access to people and person-to-person communication on the network. It is such communication that makes the network come alive. The conservation effort in India, has an overwhelming need to create such a 'live' network, particularly because, informal networks of people and organizations exist and have been able to open up large areas of co-operative endeavour.

### Information sharing: some contentious issues

The CBD introduces new elements into the ticklish question of information sharing across political boundaries. Even where national boundaries are not involved, there are many important matters of protocol and copyrights as well as the rights of local communities that need to be addressed for the network to be operational. However, it is better to take on the bull by its horns.

It has been argued, albeit with good intentions, that electronic exchange of biodiversity information will open a Pandora's box of possible infringements of national rights over genetic resources caused by information flow over global networks. Other contentious issues relate to intellectual property rights (IPRs) and cultural heritage rights in the context of CBD.

There is a view that until and unless these issues are fully resolved, it will be rather premature to think of electronic networks. However, what needs to be taken note of is that most of the information that may be available on these networks will in case be published sooner or later in journals. Publication of findings *per se* cannot be and should not be stopped, irrespective of the media used. Once published in journals, anyone around the globe can put that information out on a network. Thus, any blanket ban on information transfers on network cannot make sense today, when scientific journals are being available on CD-ROMs and almost every important journal is providing back issues as CD-ROM volumes.

It needs to be noted that in countries where the IPRs are enforced, rather stridently, that has not become a damper to information flow on networks. These services are being made use of in India, too, by scientists at research institutes in physical sciences and molecular biology as well as by the software developers. The IPR issues need not be a detriment to the emergence of CiNet. Besides, the network will only allow access to information that is open to public. It does not permit anyone to access any kind of information; all access being subject to the restrictions imposed by the network administrators.

### The CiNet

The goal of CiNet is to create a voluntary, on-line 'live wire' network of researchers, government officials, ecosystem managers, executive decision makers, NGOs and local communities for biological conservation and sustainable development in India. It must be based on best available, cost-effective technologies and workable administrative arrangements. Instead of setting out to make large investments in infrastructure building, the network must make the best use of available facilities and function on a cost-sharing, no-profit-no-loss basis. To cut costs, the existing networks and access providers can be made active participants in this process.

The CiNet must play the following two roles: a) organize a loose network of organizations interested in conservation and b) establish a well-coordinated data network with features and functions similar to the special interest computer networks that exist elsewhere in the world.

The CiNet can succeed only by cooperating with other initiatives and by assuming an inter-networking role. The necessary administrative and technical protocols can be worked out to ensure meaningful cooperation and active collaboration among such organizations. The network must provide mechanisms at different levels for free information flow between these numerous organizations and between networks. The conceptual framework articulated here attempts to address the data flow challenges of the 'massive, decentralized' bioresources mapping exercise with the active participation of people, suggested by Madhav Gadgil<sup>3</sup>. He contemplates a 'nation-wide village level programme of mapping of natural and man-made habitats on the scale of a hectare or so'. The Panchayat Level Bio-Resources Mapping Programme, that he advances, involves teams of 'bare-foot ecologists' under the guidance of taxonomic experts and are referred to here as Bio-Resources Mapping Teams (BMT).

The proposed CiNet consists of a network of Distributed Biodiversity Information Centres (DBIC) for data compilation, information processing and dissemin-



nation services assisted by several Field Studies Units (FSU) and BMTs. Selected institutions active in ecological research and willing to assist the CiNet activities could act as Associate Resource Centre (ARC) for the DBIC. These ARCs will also function as value adding nodes on the CiNet. The ARCs are expected to 'add value' by way of analysis and critical evaluation of the data as well as assist the BMTs. The data flow framework of the network is given in Figures 1 and 2.

The distributed information systems can be networked via land and satellite links making use of the telecommunication facilities and datalinks already available in India. The CiNet National Centre (CNC) can also provide decision support services to the Ministry of Environment & Forests, Government of India (MoEF) and other governmental agencies. The CNC will also be responsible for the overall co-ordination and technical support for the CiNet. In addition, the CNC will also carry out appropriate clearing house functions as the information travels across the network. The clearing house mechanisms will ensure reliability of the network and enforce quality control and validation checks on the

data that is added to the central databases. The CNC must, therefore, have a technical secretariat for its clearing house functions. Ideally, the CNC could be located at a site where the best facilities and expertise in information technology as well as bioresources mapping, inventorying and monitoring are available.

### The user community

The end users of the network are envisaged at different levels of decision making and management:

- Macrolevel executive decision makers, national policy makers, planners, national institutions, national level NGOs such as WWF (India), inter-governmental organizations under United Nations, international development agencies and international institutions for the implementation of the CBD.
- Decision makers, policy makers, managers, scientists, NGOs and individuals at the state, district and community levels.
- Microlevel planners, community organizations and grass root level NGOs.

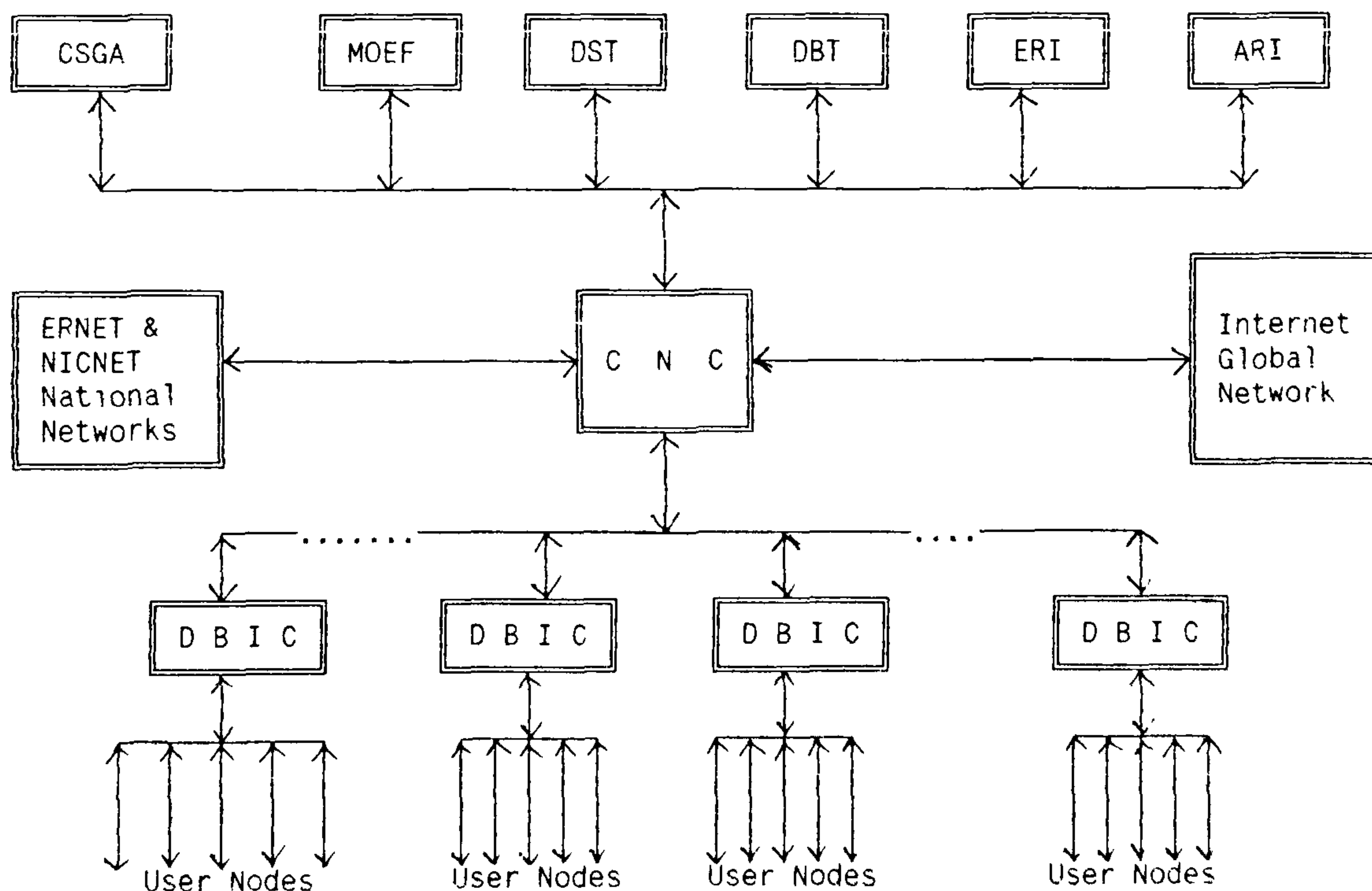
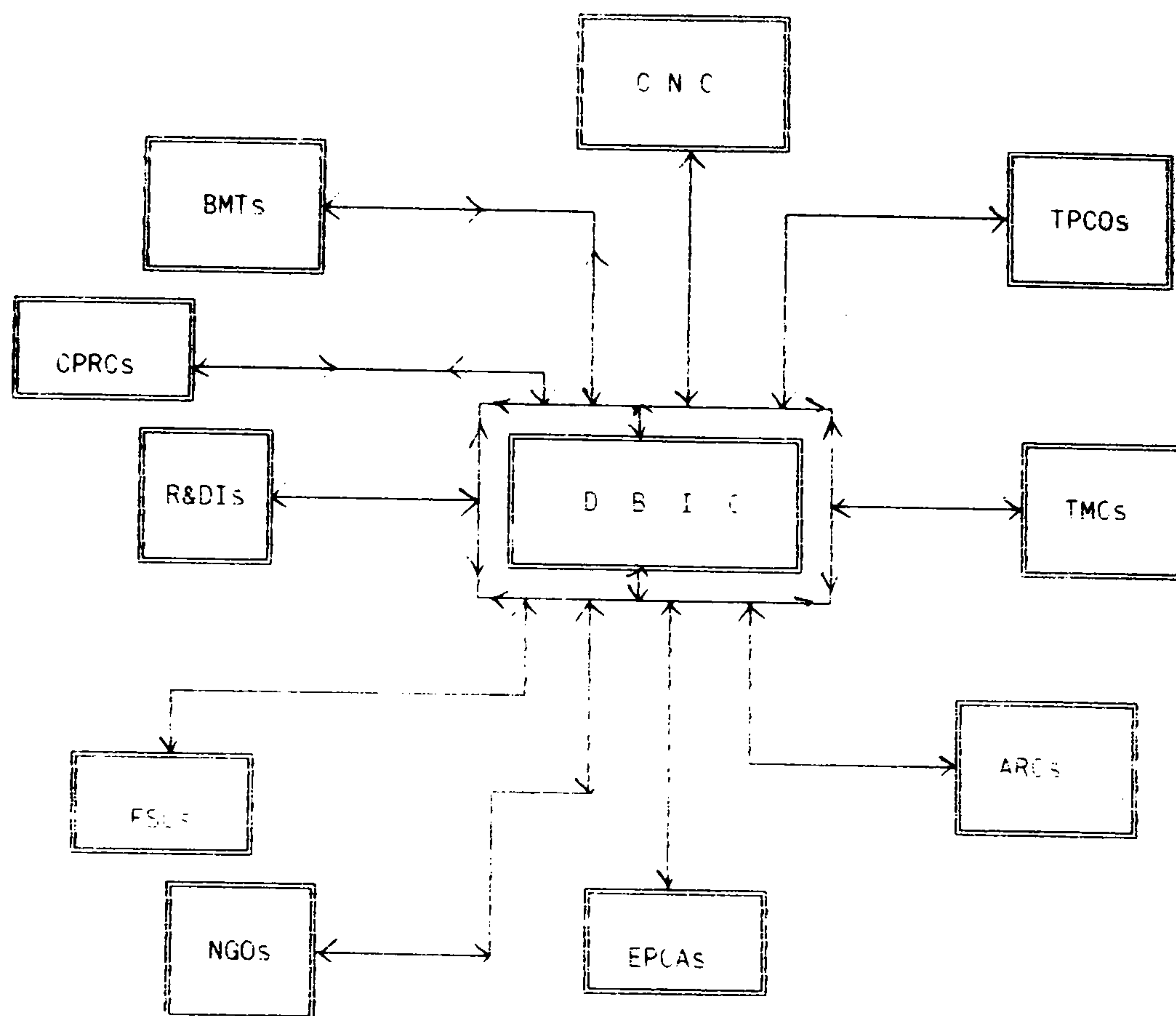


Figure 1 The logical CiNet with links to existing networks ARI, Agricultural Research Institutions, CNC, CiNet National Centre, CSGA, Central and State Government Agencies, DBIC, Distributed Bioresources Information Centre of CiNet, DBT, Department of Biotechnology, Government of India; DST, Department of Science and Technology, Government of India; ERI, Educational and Research Institutions, MOEF, Ministry of Environment and Forests, Government of India, User Nodes, See Figure 2



**Figure 2.** The logical network at a Distributed Bioresources Information Centre (DBIC) ARC, Associated Resource Centre; BMT, Bioresources Mapping Team; CNC, CiNet National Centre; CPRC, Common Property Resources Centre; DBIC, Distributed Information Centres of CiNet; EPCA, Environmental Protection/Conservation Authorities; FSU, Field Studies Unit; NGO, Non-Governmental (non-profit) Organizations, R&DI, R&D Institution; TPCO, Traditional People's Community Organization; TMC, Traditional Medicine Centre.

The CiNet can help the larger goals of biodiversity conservation by addressing the information needs of:

- protected area management
- short and long term ecological studies
- socio-economic studies and development programmes
- community-based development programmes
- adapting and improving the traditional methods of resource use
- local communities and bioresources mapping programmes.

### The CiNet databases

Some of the major databases that must be organized under the CiNet are:

- a) Data on the flora and fauna of India, with taxonomic details and information relevant for conservation of biodiversity.
- b) Environmental impact and status data.
- c) Sustainable resource use potential and practices; sustainable technological options; socio-economic profiles of sustainable resource use.
- d) Hydrologic and agro-climatic and meteorological data.
- e) Institutions, experts, resource persons and NGOs with information on area of specialization, infrastructure facilities, experience and catalogue information on educational software (printed materials and audio-visuals).
- f) Bibliographic data extracted from on-line databases and those compiled from Indian publications not covered by international bibliographic services.
- g) Metadatabases on information sources, specimen and



herbarium collections, map archives and photo/audio-visual libraries.

h) Socio-economic and demographic data relevant to ecosystem management and conservation.

## Standards

The most important question that the network builders need to recognize and deal with is that of data standards. Certain standardization process is already on. However, a lot more remains to be done. Considering the large amount of information available in different forms, drawing up standards is an urgent need.

Some of the entities that must be accorded high priority for standardization (in alphabetical order) are:

- Abundance codes for trends and status.
- Bibliographic formats.
- Biodiversity mapping grid identification codes relating it to survey of India toposheets.
- Biogeographic site descriptors.
- Biosystematics.
- Conservation status descriptors for different levels of taxa.
- Degradation/disturbed area classification.
- Descriptors of anthropogenic pressures on ecosystems.
- Directory of castes and tribes based on the data from Anthropological Survey of India's Peoples of India Project.
- Distribution classes associated with different taxonomic levels.
- Ecological classification/habitat types and classes.
- Faunal and floral attributes or a simplified taxa identification key system.
- Landuse-related descriptors.
- Location identity/site codes.
- Macro- and micro-climate types.
- Resource use-related descriptors.
- Soil-related descriptors.
- Species-species relationships/associations.
- Water: Nutrient and water quality-related indices.

## Geographical information system (GIS) and biodiversity maps

The CNC must be equipped with state-of-the-art workstation-based GIS facilities while at each DBIC, either a middle or entry level based GIS facility that can be run on a personal computer must be established or arrangements must be made for sharing GIS resources with a well-equipped ARC. The GIS makes it possible to make use of computers for the analysis of spatial data. The spatial data such as maps are first converted into computer readable form. This is achieved using hardware such as scanner or digitizer. GIS can also

make use of satellite imageries and compare such images taken at different times. It is also possible to overlay these computerized maps with information collected from ecological surveys by the FSUs. The data residing on well-structured databases can also be incorporated into the GIS to produce spatial representation and visualization of such data. It is also possible to undertake substantive statistical analysis of the spatially aggregated data.

The GIS facilities at the DBIC must provide facilities for updates and retrievals of spatial data for use by the FSUs. Therefore, besides computer systems, requisite input/output and display devices like large high resolution colour video display units, digitizers, scanners and colour printers need to be installed at the DBICs. These facilities only need to be added to the DBICs in a phased manner keeping in step with the growth of the bioresources mapping programme.

CiNet needs to work towards developing a comprehensive GIS-based bioresources map library and make it available on-line to the CiNet users. Since the spatial scales envisaged for the biodiversity map grids under the bioresources mapping programme is of the order of 1 to 10 hectare grids, the map libraries must organize spatial data on maps of very large scale. In practice, it will be difficult to organize map libraries for 1 hectare grids and it may be necessary to opt for larger biodiversity mapping grids of nearly 1000 hectares.

## Information-sharing mechanisms

The major databases of CiNet must be organized using database management system technologies that conform to industry standards. It is desirable that the large central databases of CiNet are well-structured based on relational database management concepts. Such well-structured databases can be used to hold the authenticated baseline data, with a bare minimum of essential details. It is also necessary to develop multimedia databases that can include text, pictures and sound. These databases will reside on servers providing access to data in several ways. However, as pointed out earlier, information on computers is not organized merely as well-structured databases; there is certainly a lot more to information sharing via networks, than databases. Besides well-structured databases, information needs of the network users have to be met in several other ways as well. A recent workshop that examined the linking mechanisms for BIN21 concluded that the best approach was for it to function as a SIGN having several participating nodes with web servers<sup>4</sup>.

Typically, the information on a network will consist of non-database entities such as documents, graphic objects, messages, news bulletins, reports on new findings, electronic journals, file archives, and large amounts



of information organized in a hypertext format. The network has to provide nodes with servers that can provide a host of services available on the Internet, which is a 'network of networks' linking computers all over the globe. The CiNet can be built by creating an exclusive network of members or by becoming a part of the global Internet community. The later option is cost effective and it is possible to make use of the Internet connectivity in collaboration with the Education and Research Network (ERNET) project. The ERNET infrastructure can be augmented to meet the needs of CiNet. It must be noted that the users will have varying degrees of difficulty in network access. Therefore, a host of linking mechanisms, that allow connectivity by means of low speed dialup telephone lines as well as high speed links over leased telephone lines, satellite links and public data networks, must be made available to the CiNet users.

The networks on Internet maintain mail lists, news bulletin boards, special interest groups, file archives and help individuals find the right information or the right contact. The main Internet tools are Gopher, World Wide Web (WWW) and the Wide Area Information Server (WAIS). The information available on Gopher servers are limited to text. Gopher organizes information in a hierarchical menu-based system, analogous to the table of contents of a book. The WWW uses hypertext links to connect together pieces of information contained in documents located at different nodes. The information in the documents is organized using the HyperText Markup Language (html). Files are transferred using the HyperText Transfer Protocol (http) and the File Transfer Protocol (ftp). The WAIS is a client-server tool that can be used to search and retrieve files, based on full text indexing of the contents or titles.

These Internet services can be organized on a cost-sharing basis with the major initiative coming from a large organization or university. The network must provide all or some of these facilities, besides off-line email. The CNC and each DBIC must set up a WWW or Gopher. The CNC need to operate listservers and bulletin boards. The CNC also need to provide access to major databases. The DBIC must provide user access to on-line searches on the databases located at any of the DBIC or CNC.

It is important that besides email, CiNet users have access to Internet services such as ftpmail and mail-gopher. The DOS or Windows-based PCs connected to the DBICs using modems can be provided shell accounts on the servers at the DBIC. Those nodes which can be connected to the DBIC servers using high speed links or leased telephone lines can make use of the services such as Gopher, WWW or WAIS. Each of the BMT, FSU or ARC must have *at least* email access, and if possible other facilities based on TCP/IP. The TCP/IP

(Transmission Control Protocol/Internet Protocol) is a way of packaging data for easy movement between many different computer systems. It consists of a collection of search, retrieval and communications utilities. Personal computers running DOS/Windows can make use of the network services by means of either the Serial Line Internet Protocol (SLIP) or the Point-to-Point Protocol (PPP) with the TCP/IP stack up and running on the PC, provided the DBICs offer SLIP or PPP accounts on the servers.

To facilitate network connectivity there are certain software and hardware needs. To enable simple email facility for a CiNet user equipped with a PC, all that is needed is a mail service account on the DBIC server, a telephone, a modem and a communication software loaded on the PC to enable terminal emulation after getting connected to the DBIC server. The DBICs, also need to have facilities for remote users to login via telephone lines and must therefore have the DBIC server also connected to the telephone lines through modem. The modem speeds in this can be even as low as 300 bits per second (bps) and faster modems can be used where higher speeds can be attained. The computer at the user end can also be a multi-user system running UNIX. If only a dialup link with the DBIC is possible, then an UUCP (Unix-to-Unix Copy) account can be created on the DBIC server to transfer email as a fully automated service.

If the user has access to better communication facilities such as the X.25 based connection or a leased high speed telephone line to a DBIC server, and the computer system at the user end is multiuser running any port of System V Release 4 UNIX complete with X/Windows Graphical User Interface and TCP/IP, then all the network services can be made use of. Email can be transferred using the Simple Mail Transfer Protocol (SMTP) rather than UUCP. Several other facilities such as FTP and TELNET for remote login to the CiNet servers will also become possible. A high speed modem is needed because if the user is to make the best use of network services, connectivity must be achieved at speeds of 14.4 kbps or above. Otherwise the network access can become very tiresome. High speed modems and interface cards are required at both ends.

Software support is needed by way of the communication protocols (TCP/IP and SLIP or PPP). Both the PC at the user's end of the CiNet and the DBIC server of the CiNet must be running either SLIP or PPP as well as the versatile TCP/IP. With the software and hardware (interface cards on the computers and the modems) in place, the user will have full access to all the public information resources on the CiNet as well as Internet, assuming that CiNet has full Internet connectivity.

The field units which are the key to the biodiversity mapping programmes also need to remain 'online' with



the DBICs. Very often the FSUs may be conducting surveys in remote locations with no possibility of access to telephone links. It is, indeed, possible to resort to wireless data transmission to access the nearest DBIC when such a need arise. There are, of course, certain legalities to be sorted out in order to realize this technical possibility because of the restrictions imposed by the laws governing wireless communication. Sometime in the near future, mobile telephones that can be used from any geographical location will be available. The costs of such systems may, indeed, be rather high at the introductory stage. When the use of such devices becomes more widespread and cheap, the FSUs can use it for establishing dialup links with the DBICs.

### Communication options

The CiNet is conceived as a loose network of organizations that can share information on a cost-sharing basis. It can make use of the different computer networks available such as the satellite-based NICNET services using Very Small Aperture Terminals (VSAT) and the ERNET services based primarily on terrestrial dial up links. ERNET, too, is expected to provide access via VSAT soon.

There is no need to go through the whole cycle of developing networks and physical links, since the network can be developed using the data communication facilities available in the public and private sectors. In a national context where many data networks already exist, the feasible low investment proposition is to make the best use of existing network infrastructures on a cost-sharing basis and let the CiNet 'evolve' on its own as the activity increases. ERNET with its vast experience in networking, can possibly play a pivotal role in establishing the required network facilities and CiNet can ride over the ERNET.

There are, indeed, several communication options available. Depending on what is appropriate at each level of the data flow, the best option has to be exercised. The national network of DBICs and the CNC that make up the CiNet need to be linked by high speed links. The VSAT based links is a reliable option. Another possible option is to go in for the INET facilities offered by the Department of Telecommunications (DOT) which allows X.25 based communications. The X.25 is the name for a widely used network layer protocol described by the International Standards Organization (ISO) and the International Telegraph and Telephone Consultative Committee (CCITT).

The wide area network (WAN) services can be implemented by establishing permanent physical connections using dedicated lines or private lines, by circuit-

switched physical connections based on dialup links and by demand digital service based on packet switching. A network of networks, typically, uses packet-switching methods. Rather than trying to establish a dedicated communication line between two computers located in the same or different network, which is rather clumsy when several computers are competing for connections, the inter-networking typically uses packet switching techniques. This is because packet-switching allows several computers to share communication links, by transmitting packets of information with an addressing system through the packet switching circuit.

Packet-switching has in-built error detection and correction mechanisms and provides dynamic re-routing of calls as well as interconnection of computers/terminals at different speeds. It will be far too expensive to build a private data network dedicated only to CiNet activity. The facilities provided by DOT on INET—a X.25 based Packet Switched Public Data Network—include permanent point-to-point connection between two end users of the circuit or multipoint connections between more than two end users.

Given the communication options available, the pros and cons need to be weighed carefully. While making the choice the following aspects are to be considered:

- a) The communication option must ensure high speed connectivity to major national and international networks, particularly the NICNET, ERNET and INTERNET.
- b) The communication link should not be prone to frequent breakdowns.
- c) The recurring costs must be kept low.
- d) The communication facility must support multiple protocols.

As network service providers, particularly in the private sector, make their bid for a slice of the Indian cyberspace, more options will be available for networking and CiNet itself can possibly become a value-adding, financially self-sustaining service provider with its specialized information resources.

### Conclusion

The conservation of biodiversity is an enormously complicated and difficult task requiring information flow on an unprecedented scale. The conservation efforts need networking of individuals, organizations and information systems. Co-operation and collaboration on such a wide scale will be possible only with the support of an appropriate information network, such as the one presented here. The user demand, technical expertise and communication infrastructure for the creation of such a network exist in India and the network proposed here is envisaged as a self-sustaining one that is well



integrated into the existing data networks, particularly the rapidly expanding Internet community.

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## Earth's core

S. K. Saxena

*The new techniques of heating solids with a laser at ultra high pressure in a diamond-anvil cell are providing us with new data on equation of state properties of solid and molten iron. The new data on iron melting, which extends to a pressure of nearly 2 megabar (200 GPa), permits the thermodynamic extrapolation of the melting data to pressures corresponding to the centre of the earth. The new studies on iron have also prompted a search for new phases of iron possible at high pressure and temperature. The currently available data point to a rather simple compositional model of the core which is identical to the meteorite irons or stony-irons. The adiabatic temperature of the earth's centre may lie between 5980 and 6680 K.*

SEISMIC data show that the earth's core consists of an outer part which has all the properties of a liquid and an inner core which is solid (Figure 1). The core, reaching to a depth of nearly 2900 km from its centre stores a substantial part of the planet's energy and, therefore, exercises significant influence on the dynamic processes in the mantle. From cosmochemical, geophysical and geochemical considerations, the dominant species in the core has to be iron. Iron occurs in four solid structural states, namely,  $\delta$  (bcc),  $\alpha$  (bcc),  $\gamma$  (fcc) and  $\epsilon$  (hcp). The  $\epsilon$  (hcp) is considered to constitute the bulk of the solid inner core. Although not experimentally shown but based on the available data on the compressibility of iron ( $\epsilon$ ), it appears that iron by itself has a density higher than the density of the core<sup>1</sup>. Therefore, it has been suggested by many geochemists that some additional light elements (e.g. sulphur, oxygen, Si) are mixed with iron to form a lower density inner core and a lower melting liquid outer core<sup>2</sup>.

To understand the state of the core, it is important that the thermodynamic properties of liquid and solid iron are determined. Recent developments in generating ultra-high pressures in diamond-anvil cells with laser heating have made it possible to study properties of material at the core pressures and temperatures. The purpose of this article is to report these technical develop-

ments, the recent findings on iron and the status of our understanding of the earth's core.

Figure 2 shows a summary of the currently available experimental data, until the year 1993, on phase equilibrium relations obtained from static devices, i.e. techniques with *in-situ* heating of a sample under pressure

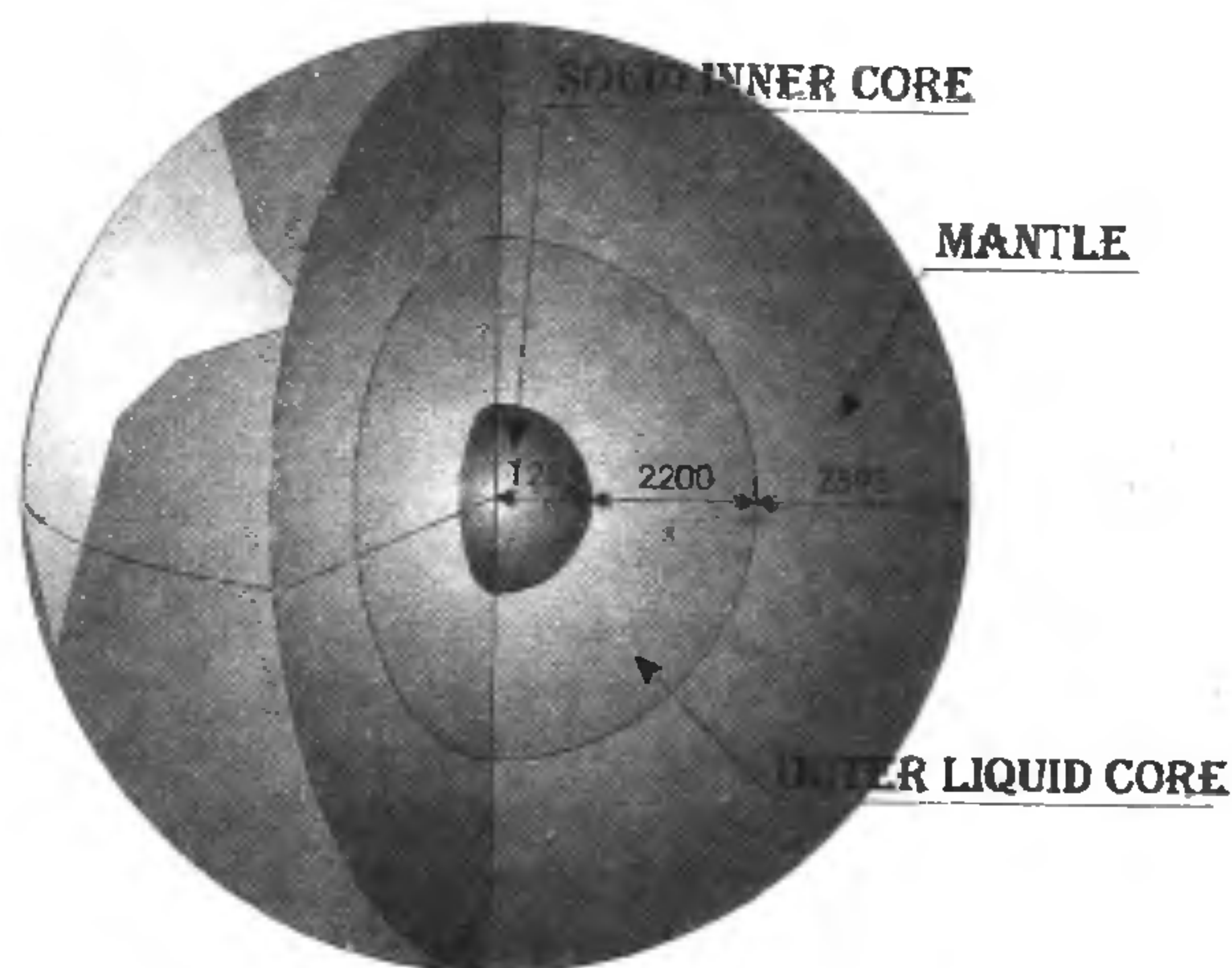


Figure 1. Earth's interior as determined by seismological data. The solid inner core with a radius of 1255 km is surrounded by a layer of molten iron with a shell thickness of ~ 2200 km reaching a depth of nearly 2900 km from the crust. The inner core density is close to  $13 \text{ g cm}^{-3}$  and its temperature is variously estimated as between 4000 and 8000 K.

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