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Nuclear Data Libraries and Online Services

An introduction to the data types and services available from the IAEA Nuclear Data Section

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September 1998

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Abstract: The IAEA Nuclear Data Section provides convenient, costfree access to the world's most comprehensive collection of numerical nuclear physics data. These nuclear data libraries result from a worldwide cooperation of nuclear data centres coordinated by the IAEA. An introduction is given to the various nuclear data types and libraries with particular emphasis to online services via the Internet. This paper summarizes a presentation for the IAEA Workshop on "Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety" held at ICTP Trieste, Italy, 23 February - 17 March 1998.

September 1998

NUCLEAR DATA LIBRARIES AND ONLINE SERVICES

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The IAEA Nuclear Data Section provides convenient, cost-free access to the world's most comprehensive collection of numerical nuclear physics data. These nuclear data libraries result from a worldwide cooperation of nuclear data centers coordinated by the IAEA. Here we summarize the various nuclear data types and libraries available with particular emphasis to online services via the Internet. The URL address of the IAEA Nuclear Data Services is **http://www-nds.iaea.or.at**.

1 Introduction

The IAEA holds the most comprehensive collection of nuclear data libraries worldwide. The data are available free of charge to scientists in IAEA member states on computer media (diskettes, magnetic tapes, CD-ROM), hardcopy, or online through the Internet (Worldwide Web, Telnet, FTP).

Nuclear data describe the properties of atomic nuclei and the fundamental physical relationships governing their interactions. These data characterize fundamental physical processes which underlie all nuclear technologies. Important examples of nuclear data include cross sections, half-lives, decay modes and decay radiation properties, and γ-rays from radionuclides. The scope of the data collections includes all 85 natural elements with 290 stable isotopes and more than 2500 radionuclides.

The applications of nuclear data today include all areas of nuclear science and technology:

- Energy applications: Fission power reactors; fusion reactor technology
- Non-energy applications: Waste management and environment; radiation safety; safeguards; nuclear medicine; materials analysis and process control; basic research (e.g. nuclear astrophysics) and education.

2 The data centers and their services

Both the collection and the distribution of nuclear data are organised on a world-wide scale. Two international networks are coordinated by the IAEA Nuclear Data Section: the Network of Nuclear Reaction Data Centers (Fig.1) and the Nuclear Structure and Decay Data Network (Fig.2). The data centers participating in these networks are involved in the various stages of data preparation between measurement and application (i.e. compilation, review and/or evaluation, processing, distribution, see Fig.3).

The major nuclear data centers are:

- IAEA Nuclear Data Section, Vienna, Austria
- OECD NEA Data Bank, Paris, France

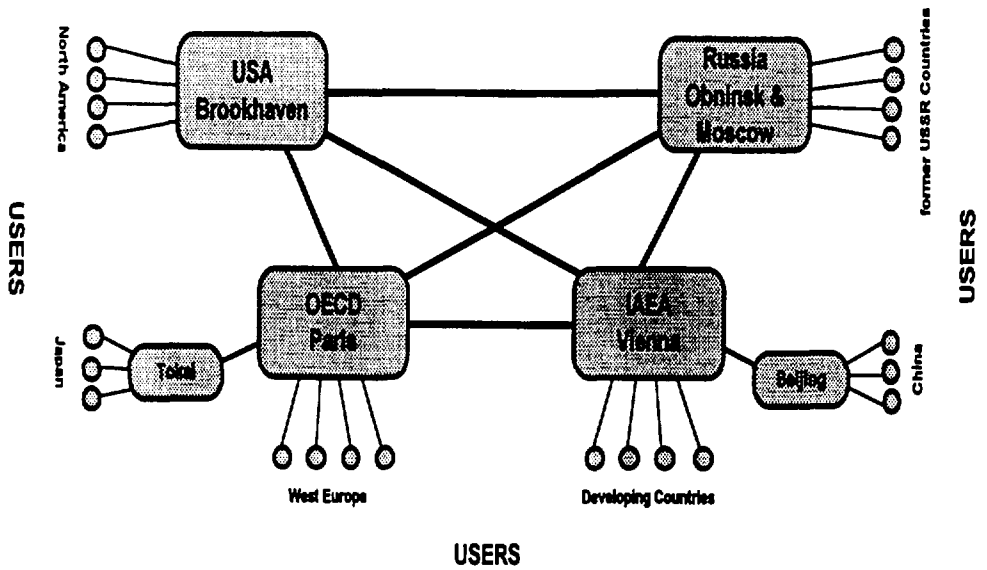

Figure 1: The Nuclear Reaction Data Centers Network

- U.S.National Nuclear Data Center, Brookhaven, USA
- Russian Nuclear Data Centers, Obninsk and Moscow, Russia
- Radiation Safety Information Computational Center, Oak Ridge, USA
- Chinese Nuclear Data Center, Beijing, China
- Japanese Nuclear Data Center, Tokai, Japan

Additional specialized data centers cooperate with the major centers in the various data center functions (in particular data compilation and evaluation). The sharing of work on a world-wide basis in the various areas of work (including data distribution) is defined partly geographically and partly by data types (scope) and is coordinated by the IAEA Nuclear Data Section, partly by organising regular data centers coordination meetings.

The type of nuclear data service varies with the type of information and the hardware configuration available. The main services offered by the IAEA Nuclear Data Section (to scientists in IAEA member states, in particular in developing countries) and the other major data centers are:

- Data upon request (**Vienna**)[2]: complete files on magnetic tapes, CD-ROM, diskette or by FTP; retrievals on diskettes, printout, by e-mail or FTP
- Documents upon request (**Vienna**): manuals and data library documentation; handbooks; meeting reports; research reports
- Interactive online retrieval by WWW and/or Telnet (**Vienna**, Brookhaven[3], Paris restricted to members of NEA Data Bank): available 7 days a week, 24 hours a day

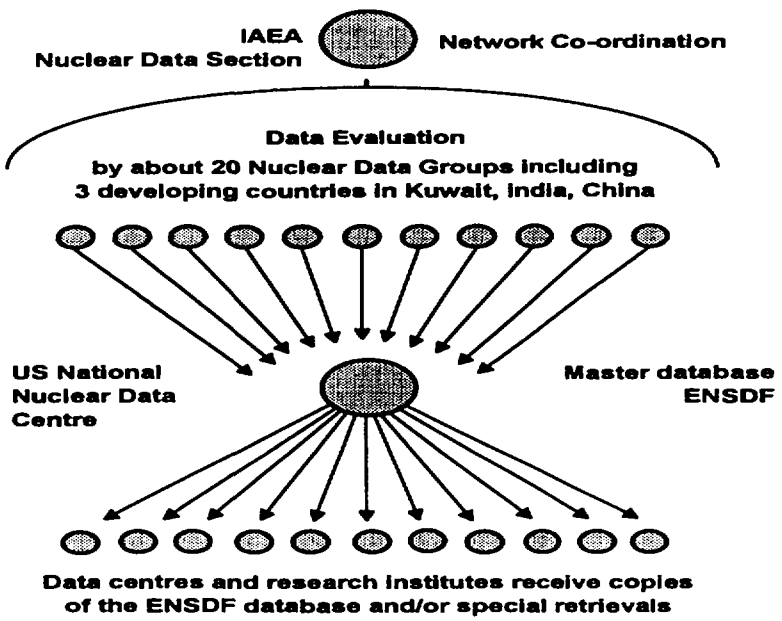

Figure 2: The Nuclear Structure Data Centers Network

- Computer codes: nuclear reaction models (Paris); processing (partly Oak Ridge [4]); fission reactors (Paris); utility programs, PC packages (**Vienna**)
- Processed data (Paris, partly Oak Ridge)

3 Nuclear Data Types

Nuclear data are commonly categorized in two main groups: nuclear reaction data, describing the interactions of various projectiles such as neutrons, protons or photons with target nuclei, and nuclear structure and decay data, describing nuclear levels, half-lives and radioactive decay radiations. For both groups, the type of information given can be experimental data or evaluated data (both numeric) or bibliographic.

- **Bibliographic data**: Typical examples are: CINDA - Computerized Index of Neutron DAta (bibliographic references to neutron reaction data, covering the period from 1935 to present. It is published regularly as a book [5] and also available online); NSR - Nuclear Science References (bibliographic data base for low and intermediate energy nuclear physics, covering the period from 1910 to present. Published in *Nuclear Data Sheets* and also available online).
- **Experimental data**: The most important example is EXFOR [6] (EXchange FORmat - computerized system for the storage, retrieval and international exchange of experimental nuclear reaction data, including explanatory text. This library contains

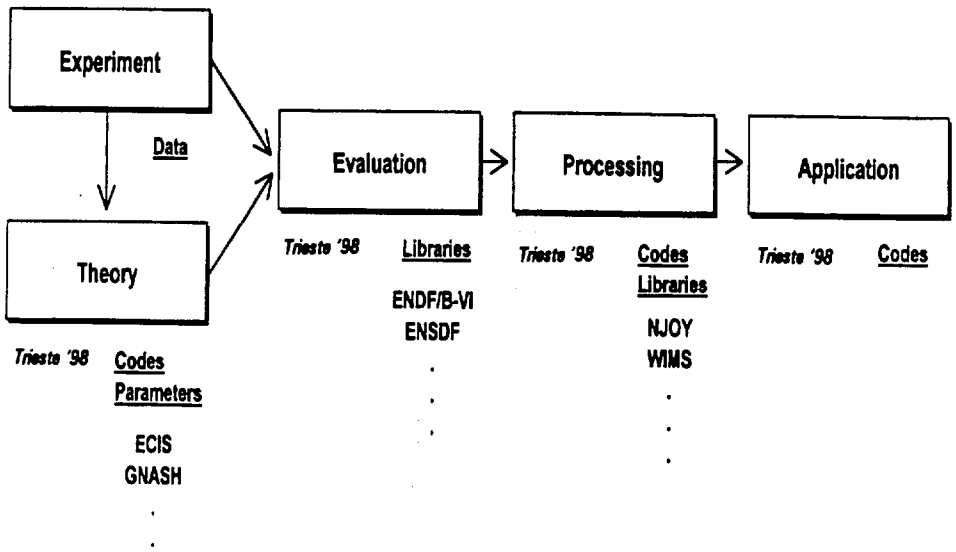

Figure 3: From experimental nuclear data to applications (Laboratory → Data Center → User). Major codes and libraries used in the nuclear data workshop *(Trieste '98)* are indicated.

reaction data for incident neutrons, charged particles and photons and is available online). CSISRS (Cross Section Information Storage and Retrieval System) is the US equivalent of EXFOR.

- **Evaluated data:** Evaluation is the process of analyzing experimentally measured nuclear physics data and combining them with the predictions of nuclear model calculations in order to arrive at a recommended value of the quantity. They are stored in specifically defined "formats" (collections of rules and procedures for computerized storage of data); often the name of the format is identical with the name of the library. Two important formats are ENDF-6 (Evaluated Nuclear Data File)[7] for reaction data and ENSDF (Evaluated Nuclear Structure Data File) for structure and decay data. For neutron reaction data, there are several major evaluated data libraries originating in USA, Russia, Europe, Japan, and China, whereas the ENSDF library is the major library for structure and decay data. In addition, there are many other evaluated data libraries for specific purposes.

- **Reaction data:**

  - Incident neutrons: This is the most complete collection, to be found in the specialized bibliography CINDA, the experimental data library EXFOR and the major evaluated libraries[8] ENDF/B-6[9] (USA), BROND-2 (Russia), JEF-2 (Europe), JENDL-3 (Japan), CENDL-2 (China), and FENDL-2 (IAEA, fusion applications). These libraries cover the neutron energy range from 10^{-5} eV to 20 MeV with a high degree of completeness; data for higher energies are partly

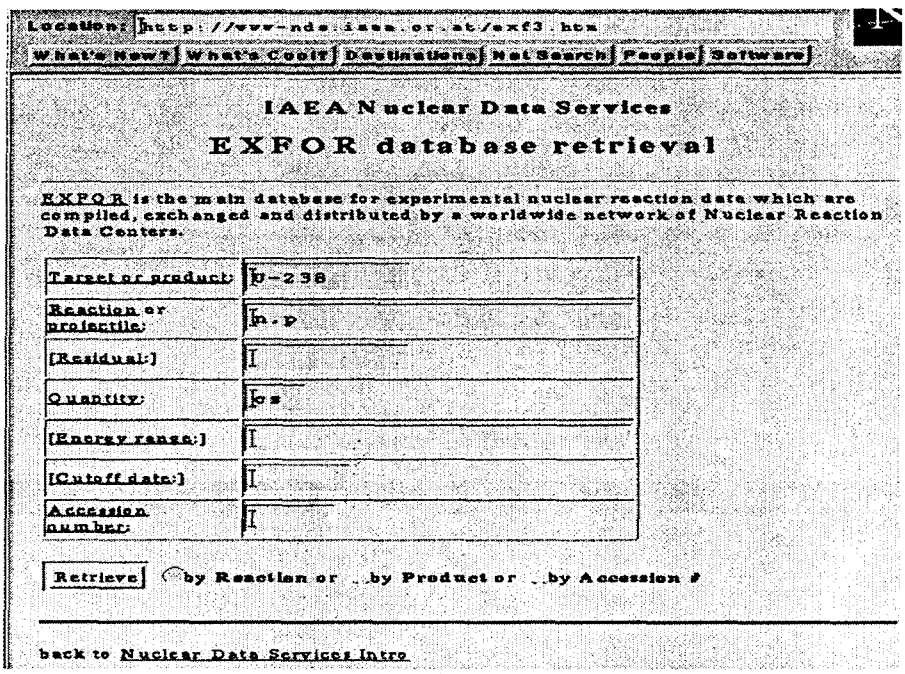

Figure 4: Example of a database retrieval form at the *Nuclear Data Services* web page: EXFOR

included also.

- Incident charged particles and photons: less complete collection in EXFOR; only few evaluations available.

- **Structure and decay data**: Half-lives, decay schemes, nuclear level properties, energies and intensities of γ-rays and emitted particles, atomic masses. The major library is ENSDF (Evaluated Nuclear Structure Data File) which contains evaluated experimental data for most known nuclides (more than 2500) and is published in the journal *Nuclear Data Sheets*. A number of libraries, publications and computer programs are derived from or related to the ENSDF database, such as NUDAT [10](NUclear DATa), the "Table of Isotopes" [11], the "Nuclear Wallet Cards" [12](properties of nuclear ground and isomeric states), or the "Isotope Explorer" [13], a computer program for viewing ENSDF and for interactive access to nuclear structure and decay data. Other libraries include: NUBASE[14], a library of nuclear and decay properties, containing mass, half-life, decay modes of ground and isomeric states for more than 3000 nuclides; "Atomic Masses 1995" [15], a mass evaluation for more than 2900 nuclides.

4 Nuclear Data Libraries at IAEA

The IAEA Nuclear Data Section holds a total of about 100 nuclear data libraries representing an enormous value. These include the bibliographic libraries CINDA and NSR;

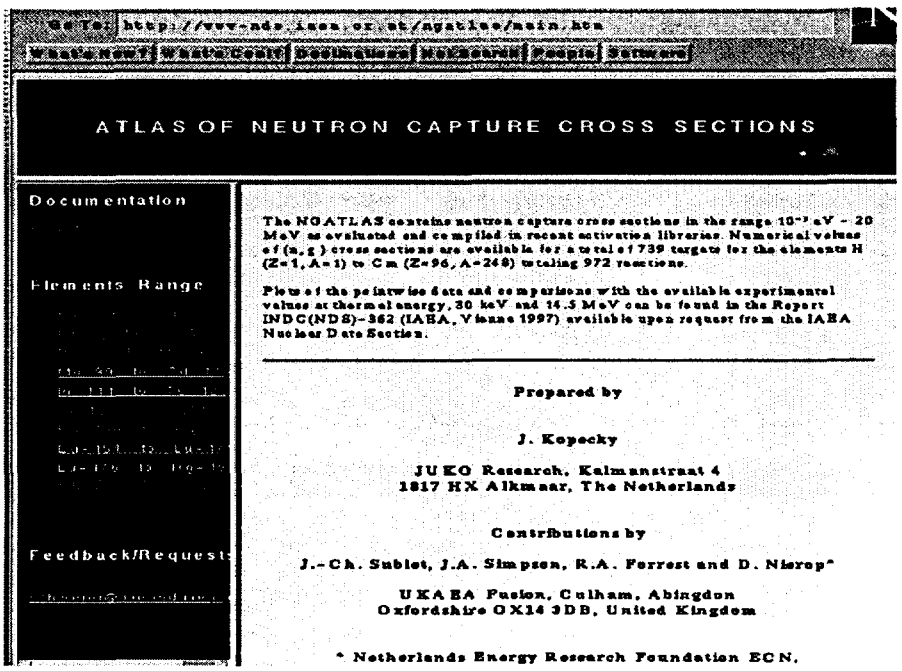

Figure 5: The NGATLAS web page

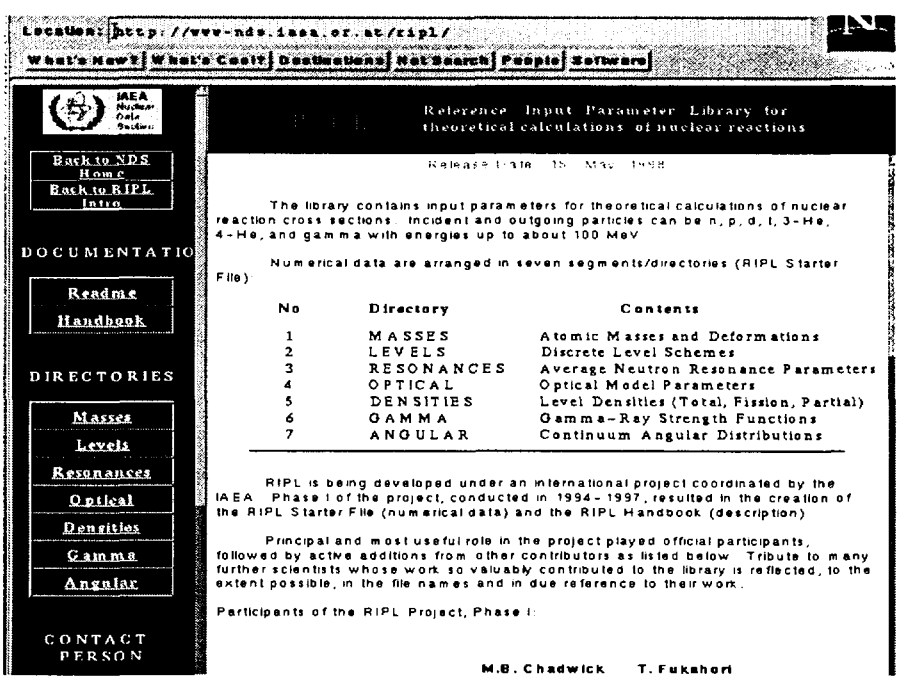

Figure 6: The RIPL web page

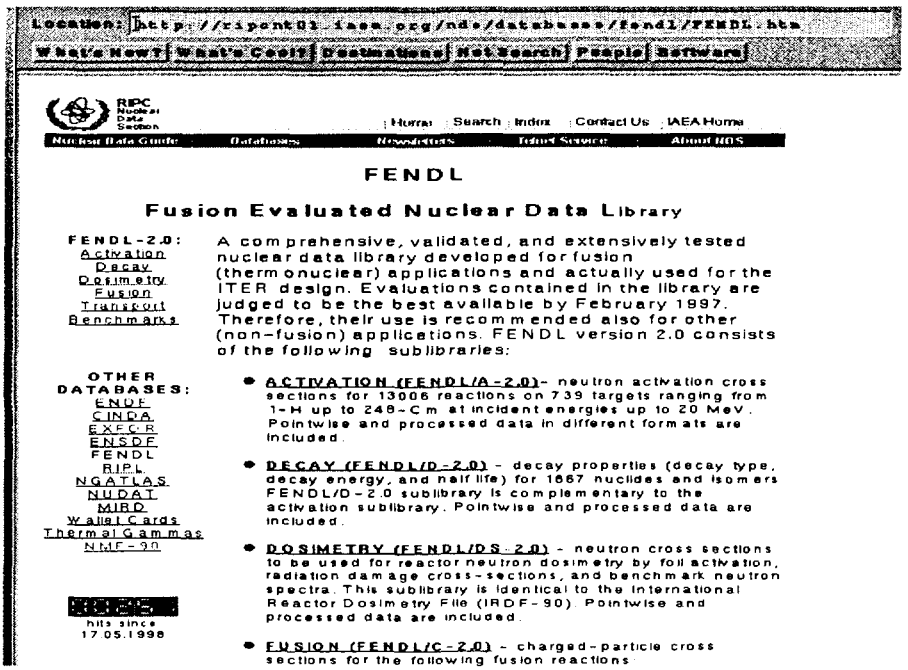

Figure 7: The FENDL web page

the experimental reaction data library EXFOR; all major evaluated neutron data libraries; various special purpose neutron data libraries (e.g. for thermal neutron scattering, fission products, actinides, neutron activation, and others); structure and decay data libraries; many special purpose files and libraries (partly for use on personal computers) for special applications. All libraries and the related documentation are available free of charge to scientists in IAEA member states. An overview is given in the document *"Index of Nuclear Data Libraries available from the IAEA Nuclear Data Section"*[16].

Selected examples of special purpose libraries:

- FENDL-2 (Fusion Evaluated Nuclear Data Library)[17]: This is a recent example of a worldwide effort coordinated by the IAEA. The complete library includes basic evaluated neutron reaction data for 63 materials as well as derived working libraries (processed data). Aimed primarily at fusion applications, the data are useful also for a variety of other applications. The major "customer" for FENDL is ITER (International Thermonuclear Experimental Reactor), the common fusion project of USA, Russia, Europe and Japan (design activity 1992-1998). FENDL-2 consists of 810 files (1 Gbyte of data) and is available online from the IAEA Nuclear Data Section.

- X-ray and γ-ray standards for detector calibration (XG Standards)[18] : This is a PC diskette which contains for selected nuclides their half-lives and the energies and emission probabilities of γ-rays and X-rays suitable for detector and efficiency calibration.

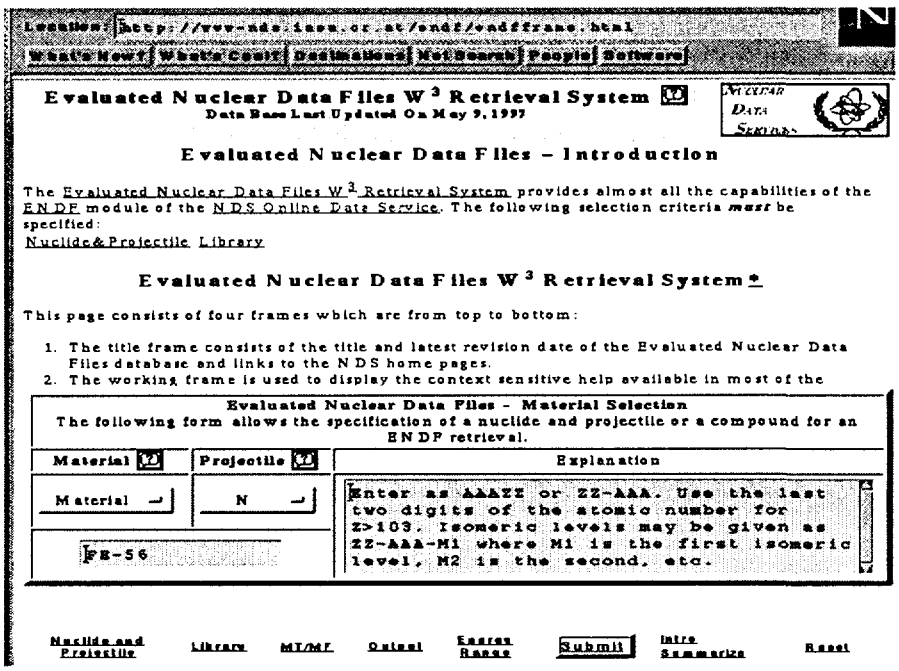

Figure 8: The ENDF web page

- Nuclear Data for Safeguards (SGNucDat): a PC database (also available as a handbook[19]) containing nuclear data needed for the development and application of nuclear materials accounting techniques.

5 Online Services

Distribution via electronic networks has become a main way of distributing numerical nuclear data in the past years. The IAEA Nuclear Data Section, like most of the other nuclear data centers, is offering a variety of electronic services while at the same time the more conventional data services (e.g. mailing data on tapes or diskettes) will be continued for the foreseeable future. The basis of the electronic services is the Internet, a "network of networks" which links many thousands of local networks and millions of computers. Within the Internet protocol, several methods of data transfer are in use:

- **Worldwide Web** (Other names: WWW, W3, Web). Originally developed by CERN, Switzerland, for the high energy physics community, now in use as a medium for scientific, commercial and any other type of information. It is based on hypertext (text containing links to other documents allowing the user to conveniently navigate between documents and websites). The *IAEA Nuclear Data Services* web page can be found at the web address (URL) *http://www-nds.iaea.or.at* and contains interactive access to most of the main databases including EXFOR, CINDA, ENSDF, NUDAT,

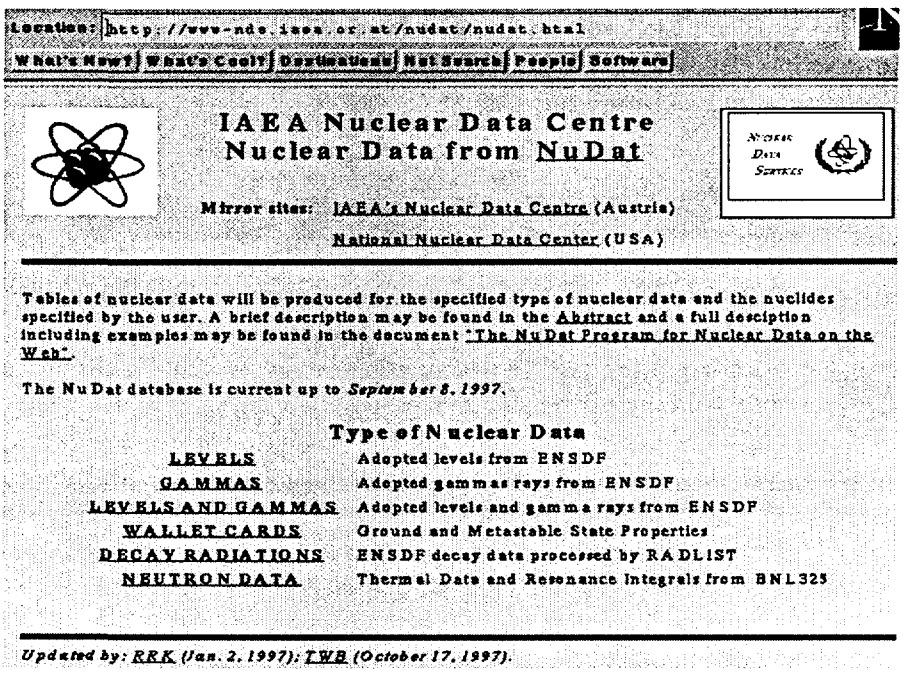

Figure 9: The NUDAT web page

ENDF (collection of main evaluated cross section libraries), NGATLAS (atlas of neutron capture cross sections [20]) and others (Figs.4-9); an overview of all nuclear data libraries and databases available from the IAEA (the *IAEA Nuclear Data Guide*); access to download complete files (such as FENDL-2, IRDF-90, Atomic Mass Evaluation) as well as to various documents, manuals (in PostScript) and nuclear data utility programs; the latest issues of the IAEA's Nuclear Data Newsletter, and a link to the Telnet nuclear data service NDIS.

- **FTP** (File Transfer Protocol). The IAEA Nuclear Data Section keeps several accounts for file transfer requiring no password (all accessible by the FTP address *iaeand.iaea.or.at*): ANONYMOUS (read-only), contains several complete libraries, utility codes and documents for public use; FENDL2 (read-only), contains the data library for fusion applications FENDL-2; NDSOPEN (read and write), used for bilateral file exchange; NDSONL (read-only), contains files saved by users of the Telnet-based online system NDIS (Nuclear Data Information System) to "local area"; RIPL (read-only), contains the new Reference Input Parameter Library [21].

- **TELNET**: the standard Internet protocol for remote login. This is the method used to connect to the IAEA's first online nuclear data service NDIS which was introduced in 1992. The starting command for NDIS is *telnet iaeand.iaea.or.at*, then the username *iaeands* has to be entered. A detailed manual is available online in PostScript or as a hardcopy [22]. This type of online service has lost some of its importance to the rapidly

expanding WWW technology but is still considered very useful by many users and will be kept in parallel for the forseeable future. NDIS provides access to the main interactive nuclear databases (as listed above under WWW) as well as to PostScript documents and utility programs.

6 Future developments

Within the Internet-based services, the shift towards Web-based interfaces, as a convenient alternative to FTP- and Telnet-based services, is in good progress and will continue. However, in consideration of the varying needs, in particular of users in developing countries having very diverse hardware and networking infrastructure, all currently used distribution methods, including conventional mail services, will be continued at least for the next several years.

The data available online will be supplemented gradually with "minor" (specialized) databases (so far typically distributed on diskettes) and with more electronic versions of hardcopy documents and reports. At present, the limiting factor for electronic distribution of large documents or full libraries is often the capacity of the network connection (bandwith). Possible solutions are the distribution of databases on CD-ROM (possibly with a web-type user interface) and the possibility of (automatic) updates through Internet; and the creation of regional copies of the "Nuclear Data Services" website (the "mirror site" concept). It may be necessary to implement both solutions in parallel to satisfy all users' needs for the coming years.

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username: IAEANDS for interactive Nuclear Data Information System
usernames: ANONYMOUS for FTP file transfer;
FENDL2 for FTP file transfer of FENDL-2.0;
RIPL for FTP file transfer of RIP;
NDSONL for FTP access to files sent to NDIS "open" area.
Web: http://www-nds.iaea.or.at