PROGRESS REPORT ON THE AVAILABLE ANALYTICAL TOOLS FOR ACCELERATOR SHIELDING ANALYSIS 2002

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Abstract

Given the new developments in accelerators, especially spallation neutron sources, new analytical tools and applications have recently been developed, tested, and used. An ongoing need exists to distribute the codes, their data, and the benchmarks used in validating the design parameters for shielding energies and particles involved in the applications. What is presented is the fruit of the efforts of the data centers that identify, collect, test, and disseminate the tools necessary for proper accelerator shielding analysis around the world. The OECD Nuclear Energy Agency Data Bank (NEA DB), the ORNL Radiation Safety Information Computational Center (RSICC), and the Research Organization for Information Science and Technology (RIST) have continued to lead the European, American, and Japanese nuclear communities, respectively, to state-of-the-art software and data that fit their needs. The following contains a listing of those tools that are available and most applicable to today's accelerator shielding analyses.

[1] Managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 with the U.S. Department of Energy.

Introduction

Over the past decade, SATIF meetings have been about every 2 years and updates from NEA DB and RSICC analytical tool centers [1,2] have provided information on the Data Centers' activities [3,4,5,6] to the experts in accelerator radiation analysis. At the last SATIF-5 meeting in July of 2000, Sartori, et al. [7] displayed useful tables that outlined information available from NEA DB and RSICC. This paper will augment those fifteen (15) tables (see Appendix 1) [7] as they are excellent visual guides to where computational and data growth has occurred since the SATIF-5 meeting.

The three main areas of accelerator application tools at the Centers include:

1. basic nuclear data, derived application data libraries, group constants, continuous energy data,
2. computer codes for different accelerator system modeling aspects, and
3. integral experiments data base

An excellent flow chart showing the interaction and relationship between the above 3 areas is shown in Figure 1b of Appendix 2 below [7].

Software Use and Distribution Goals

Issues surrounding the existence of analytical tool centers in the world constantly re-emerge that require the centers to validate their existence and costs. The value added of the Centers' role as middleman allows the necessary third-party review and processing before the software tool hits the world market. Each Center has well-practiced procedures for software quality assurance when issuing an available analytical tool to the recipient. A Center's quality assurance issues pertain to:

1. complete tool documentation and testing for specified platforms, hardware, and data,
2. proper code storage, handling, and delivery,
3. tool version control and notable errors and issues lists,
4. proper code installation and use,
5. feedback to authors and customers on errors discovered or new development needs,
6. maintenance of export control and sensitivities related to certain software and entities,
7. development of educational and dissemination information to encourage modelling uses with the best available data and analytical tools, and
8. promulgating the information, data, and tools to the public, via World Wide Web (WWW), file transfer protocol (ftp), email, conferences, workshops, and postal services.

The growth of the international accelerator community has recently ballooned requiring more of the strict data and software quality assurance (SQA) that the reactor and nuclear safety community has required for some time. As power levels and the energy/nucleon of these new international accelerators increase, better benchmark data and higher quality cross sections are exponentially more important due to the need for increased accuracy of final dose estimates at shutdown, minimization of construction costs, and decreased limits on absorbed dose for facility personnel.

Other areas of SQA involve the accurate prediction of limiting dose to accelerator materials. As experiments are made larger and more powerful, this has been an emerging problem, where particle energies and currents are sufficient to cause catastrophic heating and failure of a wide array of accelerator (plasma) components such as vacuum boundaries, shutters, and source targets. These accidents would cause irreparable damage to experiments and operations, in addition to threatening the safety of facility personnel.

SATIF-5 Summary

Many of the computational areas specified in the SATIF-5 Executive Summary [8] have undergone improvements in recent years due to more strict radiation transport, transfer, and transformation modeling requirements. Using codes from the Monte Carlo methods, and/or deterministic codes, a better understanding of the fluence of particles at deep penetrations has emerged. The same is true of the data collection and analysis that forms the basis of generation rates for various reactions. Covariance analyses allow one to determine the effects of uncertainties in cross-section evaluations on calculated results.[2] At some time in the future, these codes will merge into a seamless operation on parallel systems to best predict the true 3-D fluence within the accelerator structure and for all surrounding materials (e. g. dirt).

Recent Accelerator Applications

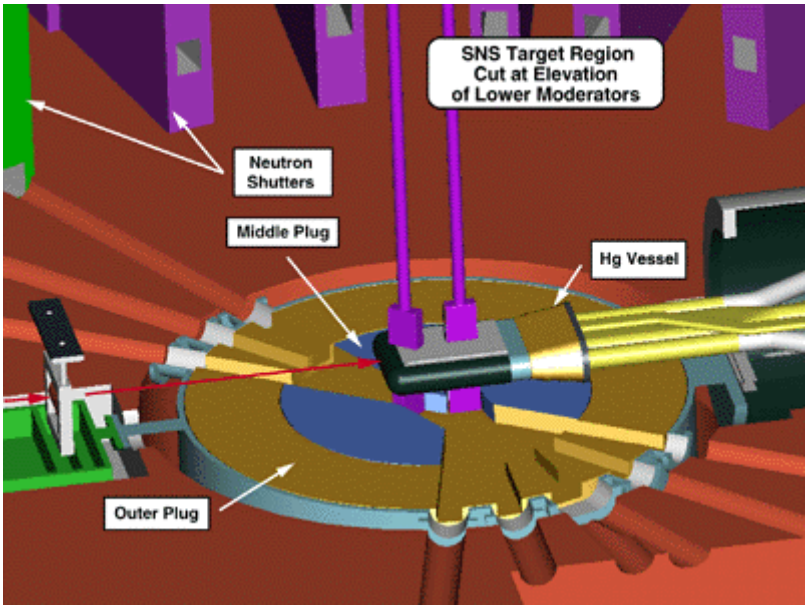

Figure 1 SNS Target Area and Beam Lines (ref. ORNL WWW site http://www.sns.gov/partnerlabs/ornl. gov/partnerlabs/ornl.htm)

The SNS, Spallation Neutron Source (2 MW of 1 GeV Protons on a mercury target) will be operational in 2006. It is being built as a cooperative effort between six US National Laboratories. The responsibility for the design of the target and surrounding shielding was assigned to ORNL. Since the neutrons emerging from the target are thermalized by scattering through cells filled with water (to produce room-temperature neutrons) or through containers of liquid hydrogen at a temperature of 20 K (to produce cold neutrons), spallation neutrons must lose at least 10-12 orders of magnitude in energy before entering the beam lines. The use of codes and data based upon improvements to older transport developments, and the merging of two methods, stochastic and deterministic, was necessary to accurately describe and analyze the necessary shielding areas. Newly

[2] SAMMY M6B - (Beta Version: Code System for Multilevel R-Matrix Fits to Neutron and Charged-Particle Cross-Section Data Using Bayes' Equations.)

developed codes (to be released soon), M2T, M2D, and M2A (stand for Monte Carlo - to- TORT, Monte Carlo - to - DORT, and Monte Carlo - to - ANISN) and have been useful for providing source terms to insert into the 1, 2, and 3 dimensional deterministic computations at various depths into the target and beam dump or shutter areas.

The SNS target project development team used a robust, well-defined benchmark-validated 'tool box' of software to design and analyze the SNS target and surrounding shielding areas. The primary codes and data that have been (or are being) used are:

1. MCNPX and MCNP and their associated libraries
2. DOORS v3.2 (ANISN, DORT, TORT, and associated utility codes, GRTUNCL, GIP, etc.)
3. Monte Carlo to ANISN (M2A), Monte Carlo to DORT (M2D), and Monte Carlo to TORT (M2T) interface codes, (locally developed at ORNL and to be packaged with DOORS eventually)[3]
4. ORIHET95 - Buildup and Decay code, originally part of HERMES code system (similar to ORIGEN)
5. Activation Analysis Sequence (AAS) locally written code to link the MCNPX and MCNP transport codes to the ORIHET95 code
6. HILO2K, DABL69, BUGLE96 broad group data libraries,
7. VITAMIN B6 fine group library, and
8. FENDL Neutron Cross Section Activation Data Library

Note: HETC (from the latest version of CALOR), LAHET 2.8, and HILO86 were used initially, however, the MCNPX code has proved to be a more user-friendly tool for analysis.

Updated Codes and Data Libraries released since SATIF-5

NEA-DB and RSICC accelerator analytical tools released for the period of July 2000- March 2002 follow**.** Some of these tools are not specific to accelerator applications but could be useful in lower-energy transport analysis of particles generated from primary and secondary reactions within the accelerator target or shield.

In Japan, the Research Organization for Information Science and Technology (RIST) has a collection of analytical tools that are useful for various accelerator applications in Japan. Of the codes available at RIST, three are mentioned below that neither RSICC nor the NEA DB offer as packages at this time. Acquisition of codes for public use are a very important function of Centers, such that improvements and widespread knowledge of their availability can be supplied in the future.

A total of thirty-two new or updated accelerator analytical tools have been added to the public collection via the NEA DB or RSICC Centers since the last SATIF meeting (July 2000). These are listed below with underlined html links to their respective WWW abstracts at the NEA DB and RSICC organizations.

C00693/MNYCP/00 (NEA 1638) ANITA-2000
(Code System to Calculate Isotope Inventories from Neutron Irradiation for Fusion Applications)

[3] Professor Ron Pevey of the University of Tennessee, Knoxville, TN is directing the final computational changes to the merger of the Monte Carlo and deterministic codes with proper documentation for future public use of these new codes (release expected FY02).

Contributed by: ENEA - Centro Ricerche, Energia 'E. Clementel,' INN-FIS-MACO, Bologna, Italy, through the NEA Data Bank, Issy-les-Moulineaux, France.

P00513/MNYWS/00 (NEA 1627) BOT3P1.0

(Code System for 2D and 3D Mesh Generation and Graphical Display of Geometry and Results for the DOORS Deterministic Transport Codes)

Contributed by: ENEA Nuclear Data Center, Bologna, Italy, through the OECD Nuclear Energy Agency Data Bank, Issy-les Molineaux, France.

P00333/MNYCP/03 CHENDF 6.12

(Codes for Handling ENDF/B-V and ENDF/B-VI Data)

Contributed by: National Nuclear Data Center, Brookhaven National Laboratory, Upton, New York

DCHAINSP2001 (RIST Japan)

(High-Energy Particle-Induced Radioactivity Calculation Code)
Computer/ OS:HP, Sun ,DEC/ UNIX, Linux
Programming Language:FORTRAN77
Author: Fujio Maekawa, Center for Neutron Science, Japan Atomic Energy Research Institute (JAERI)
References: "DCHAIN-SP2001: High energy particle-induced radioactivity calculation code," Tetsuya Kai, Fujio Maekawa et al., JAERI-Data Code(2000)

D00213/MNYCP/00 (NEA DB – NEA1644) DECDC 1.0

(Nuclear Decay Data Files for Radiation Dosimetry Calculations)
Contributed by: Department of Health Physics, Tokai Research Establishment, JAERI, Tokai, Ibaraki, Japan

NEA 1564 EASY-99

(The European Activation System (EASY))
EASY-99 is a complete tool for the calculation of activation in materials exposed to neutrons. It can be used for any application (fusion, transmutation, fission and accelerator) where the neutron energy does not exceed 20 MeV. EASY-99 consists of the inventory code FISPACT-99 and the EAF-99 file, which contains various libraries of nuclear data.

P00497/PC586/00 (NEA DB – IAEA1169) EMPIRE-II

(Statistical Model Code System for Nuclear Reaction Calculations, Version 2.13.)
Contributed by: IAEA, Vienna, Austria through the OECD Nuclear Energy Agency Data Bank, Issy-Les Molineaux, France

C00581/IBMPC/02 (NEA DB - IAEA1388/01) FOTELP-2KG

(Photons, electrons and positrons transport in 3D by Monte Carlo techniques)

FOTELP-2KG is a new compact version of the previous FOTELP/EM code designed to compute the transport of photons, electrons and positrons through three-dimensional material and sources geometry by Monte Carlo techniques.
Contributed by: Institute of Nuclear Sciences "Vinca", Physics Laboratory (090) Beograd, Yugoslavia through the NEA Data Bank, Issy-les-Moulineaux, France

C00697/PC586/01 (NEA DB) GUI2QAD-3D

(Point Kernel Code System for Neutron and Gamma-Ray Shielding Calculations in Complex Geometry, Including a Graphical User Interface.)

Contributed by: Safety Research Institute, Kalpakkam, Tamilnadu, India

M00000/MNYCP/00 HIMAC
(Recent experimental data are summarized in this paper on differential neutron yields in Energy and angle produced by 100, 155 and 180 MeV/nucleon He, 100, 155, 180 and 400 MeV/nucleon C, 100, 180, 400 MeV/nucleon Ne, 400MeV/nucleon Ar, Xe and Fe, 272 and 435 MeV/nucleon Nb and 800 MeV/nucleon Si ions stopping in thick targets of C, Al, Cu, Pb and Nb.)
Contributed by: Quantum Radiation Division, Electrotechnical Laboratory, JAPAN
Department of Quantum Science and Energy Engineering, Tohoku University, JAPAN
Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

NEA-1656/01 ZZ IEAF-2001
(Intermediate Energy Activation File IEAF-2001)
The Intermediate Energy Activation File IEAF-2001 is a compilation of neutron-induced activation cross sections in ENDF-6 data format for activation analyses in fusion technology and intermediate energy applications. The IEAF-2001 data library contains neutron-induced activation cross sections in the energy range 10^{-5} eV to 150 MeV for 679 target nuclides from Z=1 (hydrogen) to 84 (polonium). The total number of reaction channels with activation cross-section data is 134,431. The European Activation File EAF-99 served as basis for the activation data below 20 MeV neutron energy. Threshold reaction cross sections were evaluated on the basis of geometry dependent hybrid exciton and evaporation models using a modified version of the ALICE code. The IEAF-2001 data library can be processed with standard ENDF processing tools such as NJOY. A groupwise IEAF-2001 data library has been prepared for 256 energy groups in GENDF data format. The IEAF-2001 CD-ROM contains both the pointwise ENDF and the groupwise GENDF data files.
Contributed by: U. Fischer, D. Leichtle, U. v. Möllendorff and I. Schmuck ;Association FZK-Euratom Institut fuer Reaktorsicherheit (IRS) Forschungszentrum Karlsruhe Postfach 3640, 76021 Karlsruhe, Germany and
Yu. Konobeyev, Yu. A. Korovin, P.E. Pereslavtsev, Obninsk Institute of Nuclear Power Engineering (INPE) Studgorodok 1, 249020 Obninsk, Russian Federation

INTEL-BERMUDA (RIST)
(Radiation Shielding Calculation for Fusion Reactor, Accelerator and Reprocessing Facility.)
Computer/ OS: FACOM-M780, SUN/ MSP, UNIX
Programming Language:FORTRAN77, C++
Authors: Akira Hasegawa, Dept. of Nuclear Energy System, Japan Atomic Energy Research Institute (JAERI)

C00696/MFMWS/00 (NEA DB)LAHET 2.8
(Code System for High Energy Particle Transport Calculations)
Contributed by:Los Alamos National Laboratory, Los Alamos, New Mexico

P00137/MNYCP/06 (NEA DB) MARLOWE
(Computer Simulation of Atomic Collisions in Crystalline Solids Version 15a.)
Contributed by:Oak Ridge National Laboratory, Oak Ridge, Tennessee

NEA- (too be determined) MCB:
(A continuous energy Monte Carlo burnup simulation code)
Contributed by: Jerzy Cetnar, Jan Wallenius and Waclaw Gudowski Department of Nuclear and Reactor Physics , Royal Institute of Technology through the NEA Data Bank, Issy-les-Moulineaux, France

A code for integrated simulation of neutronics and burnup based upon continuous energy Monte Carlo techniques and transmutation trajectory analysis has been developed. Being especially well suited for studies of nuclear waste transmutation systems, the code is an extension of the well validated MCNP transport program of Los Alamos National Laboratory. Among the advantages of the code (named MCB) is a fully integrated data treatment combined with a time-stepping routine that automatically corrects for burnup dependent changes in reaction rates, neutron multiplication, material composition and self-shielding. Fission product yields are treated as continuous functions of incident neutron energy, using a non-equilibrium thermodynamical model of the fission process. In the present paper a brief description of the code and applied methods are given.

P00500/MNYCP/00 (NEA DB) MCNP-VISED 4C2
(Visual Editor for Creating MCNP4C2 Input Files)
Contributed by: Visual Editor Consultants, Richland, Washington

C00701/ALLCP/00 (NEA DB) MCNP4C2
(Monte Carlo N-Particle Transport Code System)
A new LA150U photonuclear library of particle emission data for nuclear events from incident neutrons, protons and photons with energies up to 150 MeV is included in the MCNP4C2 package.
Contributed by: Los Alamos National Laboratory, Los Alamos, New Mexico

D00200/ALLCP/00 (NEA DB) MCNPDATA
(Standard Neutron, Photon, and Electron Data Libraries for MCNP4C)
Contributed by: Los Alamos National Laboratory, Los Alamos, New Mexico

C00705/MNYCP/00 (NEA DB) MCNPX2.1.5 (new 2.3.0 release expected in a few weeks)
(Monte Carlo N-Particle Transport Code System for Multiparticle and High Energy Applications)
MCNPX extends the CCC-660/MCNP4B code to all particles and all energies. Neutron tabular data are used as in MCNP4B; above the table energy limits, physics modules are used. Current physics modules include the Bertini and ISABEL models taken from the LAHET Code System (LCS) and CEM. An old version of FLUKA is available for calculations above the range of INC physics applicability. MCNPX eliminates the need now present in LCS to transfer large files between separate codes. MCNPX is released with the LA150N library, and further 150 MeV libraries will follow shortly for protons and photonuclear interactions. In addition, variance reduction schemes (such as secondary particle biasing), and new tallies have been created specific to the intermediate and high-energy physics ranges. The 'mesh' and 'radiography' tallies have been included for 2 and 3-dimensional imaging purposes. Energy deposition has received a substantial reworking based on the demands of charged-particle high-energy physics. An auxiliary program, GRIDCONV, converts the mesh and radiography tally results for viewing by independent graphics packages.
Contributed by: Los Alamos National Laboratory, Los Alamos, New Mexico

D00205/ALLCP/01 (NEA DB) MCNPXDATA
(Standard Neutron, Photon, and Electron Data Libraries for MCNPX)
This release includes LA150N, the photon libraries MCPLIB1 and MCPLIB02, the electron library EL, and MCNP4A libraries used with the MCNP4C and 4C2 transport codes.
Contributed by: Los Alamos National Laboratory, Los Alamos, New Mexico

CCC-0156/01 (NEA DB) MECC-7
(Medium-Energy Intranuclear Cascade Code System, note: modified for modern computer systems)
MECC-7 calculates the results of nuclear reactions caused by a medium-high energy particle colliding with a nucleus. The incident particles may be protons or neutrons with energies from about 100 to 2500 MeV or charged pions with energies from about 100 to 1500 MeV. Target nuclei may be

any element heavier than carbon. MECC-7 writes a history tape containing data regarding the properties of the particles escaping from the nucleus as a result of the particle-nucleus collision. The data consist of the type of escaping particles, their energies, and angles of emission. I4C utilizes the data on the MECC-7 history tape to calculate particle multiplicities and various cross sections, such as the inelastic cross section or the doubly-differential cross section for energy-angle correlated distributions. I4C also carries the nuclear reaction through an additional phase, that of evaporation, and calculates evaporation residual nuclei (radiochemical) cross sections and the particle multiplicities and energy spectra of particles "boiled off" from the nucleus after the cascade has stopped.
Contributed by: OEC NEA Data Bank, Issy-les-Moulineaux, France

D00207/MNYCP/00 (NEA IAEA 1376) MENDL-2P

The library includes proton cross-sections for 504 nuclei with atomic number from 13 to 84 at the energies up to 200 MeV. The total number of reactions is equal to 87,196. This version has been converted to ENDF-6 format and verified through the ENDF-6 format utility codes. MENDL-2 proton cross-sections are calculated on the basis of ALICE-IPPE which differs from the ALICE-91 as follows:

The algorithm for the level density calculation according to the generalized superfluid model was tested, corrected and improved. The Pre-equilibrium cluster emission calculation is included in the code. Calculation of the alpha particle spectra is performed taking into account the pick-up and knock-out processes. The phenomenological approach is used to describe direct channel for the deuteron emission. The triton and He-3 spectra are calculated according to the coalescence pick-up model of Sato, Iwamoto, Harada.
Contributed by:Yu.N.Shubin, V.P.Lunev, A.Yu.Konobeyev, A.I.Dityuk; Institute of Physics and Power Engineering 249020 Bondarenko Sq. 1 OBNINSK, Kaluga Region, Russian Federation
and Dr. Arjan KONING NRG Nuclear Research and Consultancy Group;Building 34.333 Westerduinweg 3, P.O. Box 25 NL-1755 ZG PETTEN, The Netherlands
through the OEC NEA Data Bank, Issy-les-Moulineaux, France

C00694/SUN05/00 (NEA 0974) NMTC-JAERI97
(Monte Carlo Nucleon-Meson Transport Code System)
Contributed by: Center for Neutron Science, Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, JAPAN through the OECD NEA Data Bank, Issy-les-Moulineaux, France

OSCAR (RIST Japan)
(Calculation of yields of nuclear reaction products for particle accelerator.)
Computer/ OS:FACOM M780/ MSP
Programming Language:FORTRAN77
Author: Kentaro Hata, Dept. of Material Science, Japan Atomic Energy Research Institute (JAERI)
References:"OSCAR, A code for calculation of the yield of radioisotopes produced by charged-particle induced reactions", Hata K., Baba H., JAERI-M 88-184(1988)

C00682/MNYCP/02 (NEA-1525/05) PENELOPE-2001
(A Code System for Monte Carlo Simulation of Electron and Photon Transport)

PENELOPE performs Monte Carlo simulations of coupled electron-photon transport in arbitrary materials and complex quadric geometries. A mixed procedure is used for the simulation of electron and positron interactions (elastic scattering, inelastic scattering and bremsstrahlung emission), in which 'hard' events (i.e. those with deflection angle and/or energy loss larger than pre-selected cutoffs) are simulated in a detailed way, while 'soft' interactions are calculated from multiple scattering approaches. Photon interactions (Rayleigh scattering, Compton scattering, photoelectric effect and electron-positron pair production) and positron annihilation are simulated in a detailed way.

Contributed by: Universitat de Barcelona and Institut de Tècniques Energètiques, Universitat Politècnica de Catalunya in Barcelona, Spain, and Universidad Nacional de Cordoba, Argentina, through the Nuclear Energy Agency Data Bank, Issy-les-Moulineaux, France

D00212/MNYCP/00 POINT-2000
(Temperature-Dependent, Linearly Interpolable, Tabulated Cross Section Library Based on ENDF/B-VI, Release 7)
Contributed by: Lawrence Livermore National Laboratory, Livermore, California

P00226/IBMPC/01 PRECO2000
(Exciton Model Preequilibrium Code System with Direct Reactions)

PRECO-2000, also known as PRECOM (M for Millennium), is a two-component exciton model code for the calculation of double differential cross sections of light particle nuclear reactions. PRECO calculates the emission of light particles (A = 1 to 4) from nuclear reactions induced by light particles on a wide variety of target nuclei. Their distribution in both energy and angle is calculated. Since it currently only considers the emission of up to two particles in any given reaction, it is most useful for incident energies of 14 to 30 MeV; but the preequilibrium calculations are valid up to 100 MeV.
Contributed by: Triangle Universities Nuclear Laboratory, Duke University, Durham, North Carolina

P00158/IRISC/07 (NEA DB) SAMMY-M6B
(Beta Version: Code System for Multilevel R-Matrix Fits to Neutron and Charged-Particle Cross-Section Data Using Bayes' Equations.)

The SAMMY code is used for analyses of neutron-induced cross section measurements, primarily for experiments performed on time-of-flight facilities such as the Oak Ridge Electron Linear Accelerator. Analysis of neutron cross-section data in the resolved-resonance region has three distinct aspects, each of which must be included in any analysis code: First, an appropriate formalism is needed for generating theoretical cross sections. Second, a plausible mathematical description must be provided for every experimental condition that affects the values of the quantities being measured. Third, a fitting procedure must be available to determine the parameters values which provide the "best" fit of theoretical to experimental numbers. SAMMY incorporates state-of-the-art treatments for each of these three requirements: Reich-Moore R-matrix theory for the first, Bayes' method for the third, and a wide variety of techniques for the second (including Doppler- and resolution-broadening, finite-size corrections, etc.). Recent enhancements in the code include the extension to charged particles (so that, for example, proton or alpha-particle scattering experiments can be analyzed in addition to neutron-induced reactions), and additional options for treatment of resolution broadening.
Contributed by: Oak Ridge National Laboratory, Oak Ridge, TN

P00294/MNYCP/02 (NEA 0829) SCAT-2B
(Code System for Calculating Total and Elastic Scattering Cross Sections Based on an Optical Model of the Spherical Nucleus, Versions SCAT-2 and SCAT-2B.)
Contributed by: Centre d'Etudes de Bruyeres-le-Chatel, France; and Bucharest University, Faculty of Physics, Bucharest Magurele, Romania, through NEA Data Bank, Issy-les-Moulineaux, France

C00667/SUN05/00 SHIELD
(Monte Carlo Transport Code for Simulating Interaction of High Energy Hadrons with Complex Macroscopic Targets.)

The SHIELD code considers interaction of high energy particles with condensed matter, including hadron-nucleus interactions inside the target, generation and transportation of secondary particles, deposition of energy and production of radionuclides in the target. The modern version of

the SHIELD code allows simulation of the transfer of nucleons (including low energy neutrons), pions, kaons, antinucleons, and muons in energy range up to 1 TeV. Recently, the transfer of ions (arbitrary A,Z-nuclei) was added. The ionization loss and straggling (optionally) are taken into account as well as the main modes of the mesons decay. The transfer of neutrons (E_n<14.5 MeV) is simulated on the basis of the 28-group neutron data system BNAB.
Contributed by: Institute for Nuclear Research of the Russian Academy of Science (RAS), Moscow, Russia.

CCC-646/IBMPC/03 (NEA DB) SKYSHINE-KSU
(Code System to Calculate Neutron and Gamma-Ray Skyshine Doses Using the Integral Line-Beam Method)
Contributed by: Kansas State University, Manhattan, Kansas

NEA DB IAEA1382/01 SRNA-2KG
(Proton Transport Using 3d By Monte Carlo Techniques)
SRNA-2KG performs Monte Carlo transport simulation of protons in 3D source and 3D geometry of arbitrary materials. The proton transport is based on a condensed history model, and on a model of the compound nuclei decay that is created in nonelastic nuclear interactions by proton absorption.
Contributed by: Institute of Nuclear Sciences VINCA Physics Laboratory Belgrad, Yugoslavia, through the OECD NEA Data Bank, Issy-les-Moulineaux, France

P00498/PC586/00 (NEA 0461) STAPREF
(Code System to Calculate Nuclear Reactions Cross Sections by the Evaporation Model)
Contributed by: Radiation Physics and Chemistry Problems Institute, Minsk-Sosny, Belarus and the Institut fur Radiumforschung und Kerphysik der Osterreichischen, Akademie der Wissenchaften, Vienna, Austria, through the OECD NEA Data Bank, Issy-les-Moulineaux, France.

C00638/MNYCP/04 TART2000
(Coupled Neutron-Photon, 3-D, Combinatorial Geometry, Time Dependent, Monte Carlo Transport Code System)
Contributed by: Lawrence Livermore National Laboratory, Livermore, California

CCC-709/MNYWS/00 TDTORT
(Time-Dependent, Three-Dimensional, Discrete Ordinates, Neutron Transport Code System)
Contributed by: Oak Ridge National Laboratory, Oak Ridge, Tennessee

SINBAD Integral Accelerator Benchmark Additions since SATIF-5

The SINBAD 2002 collection due to be released this summer (2002) from RSICC and NEA DB have added data sets for comparing accelerator radiation transport computational analysis with the experimental benchmark data. In particular, five (5) sets of benchmark analysis have been added to SINBAD and were performed as part of the SQA on the MCNPX[4] high-energy transport code. A total of ten sets of benchmarks have been performed by Georgia Tech and all will be added to the SINBAD collection.

Table 15a in Appendix 1 lists the updated SINBAD information on fission, fusion, and accelerator benchmarks that have been added (or are in the process of being added) since the SATIF-5

[4] The major capabilities of LAHET™ and MCNP™ have now been combined into merged code MCNPX™.

meeting. A recent paper on SINBAD development is due to be published soon [9] that describes the details of progress with integral shielding benchmarks.

Current Collections at RSICC and NEA DB

High-Energy (>20 MeV) Data Libraries

Listed below in Table 1 are the currently available high-energy (>20 MeV) data libraries that have been recently analyzed for content and characteristics and are available at the NEA Data Bank and the RSICC data center. Associated with the package name (DLC---) are the particles in the reactions, with the relative upper energies measured or computed, for the target materials specified.

A valuable comprehensive list of the available data libraries at the **NEA Data Bank** can be viewed via the http://www.nea.fr/html/dbprog/appldatlib.htm area on the WWW.

Table 1. Identified Data Collections with Possible Utility in Accelerator Applications

DLC	Name	Particles	Upper Energy (Mev)	Materials
001	LEP	Pi-mesons, protons, neutrons	400	^{12}C, ^{16}O, ^{27}Al, ^{52}Cr, ^{65}Cu, ^{100}Ru, ^{140}Ce, ^{184}W, ^{207}Pb, ^{238}U
022	FLEP	Protons, neutrons	400	C, O, Al, Cr, Cu, Ru, Ce, W, Pb, U
084	MENSLIB	Neutrons	60	H, B, C, N, O, Si, Fe, W
119	HILO86	Neutrons, photons	400	H, ^{10}B, ^{11}B, C, N, O, Na, Mg, Al, Si, S, K, Ca, Cr, Fe, Ni, W, Pb
128	LAHIMACK	Neutrons, photons	800	^{1}H, C, O, Al, Si, Fe, Pb
166	PNESD	Protons	1000	^{2}H, ^{3}He, Li, Be, ^{9}Be, ^{11}B, C, ^{12}C, Al, ^{27}Al, Si, ^{28}Si, S, Ar, Ca, ^{40}Ca, ^{42}Ca, ^{44}Ca, ^{48}Ca, Ti, ^{48}Ti, ^{49}Ti, ^{50}Ti, V, ^{51}V, Cr, ^{52}Cr, ^{53}Cr, Mn, Fe, ^{54}Fe, ^{56}Fe, ^{57}Fe, ^{58}Fe, Co, ^{59}Co, Ni, ^{58}Ni, ^{60}Ni, ^{62}Ni, ^{64}Ni, Cu, ^{63}Cu, ^{65}Cu, Zn, ^{64}Zn, ^{66}Zn, ^{68}Zn, ^{70}Zn, Kr, ^{89}Y, Zr, ^{90}Zr, ^{91}Zr, ^{92}Zr, 94Zr, ^{96}Zr, Nb, Mo, Rh, Pd, Ag, Cd, In, Sn, ^{116}Sn, ^{117}Sn, ^{118}Sn, ^{119}Sn, ^{120}Sn, ^{148}Sm, Ta, ^{181}Ta, Au, ^{208}Pb, ^{209}Bi, Th, U
187	HILO86R	Neutrons, photons	400	H, C, N, O, Mg, Al, Si, K, Ca, Fe
189	MCNPXS*	Neutrons, photons, electrons	Varied	Z=1-94 for photons and electrons, large list of nuclides for neutrons
200	MCNPDATA*	Neutrons, photons, electrons	Varied	Z=1-94 for photons and electrons, large list of nuclides for neutrons
205	MCNPXDATA*	Neutrons, photons, electrons	Varied	Z=1-94 for photons and electrons, large list of nuclides for neutrons
208	ELAST2	Electrons, positrons	100	Z=1,100

*The three MCNP libraries have different limits for different particles. For neutrons, the limit may be as low as 20 or 30 MeV. Some libraries have photon data that extend to 100 GeV. Other data collections go up to 100 MeV. There is a library called LA150 that extends ENDF/B-VI to 150 MeV. See M. B. Chadwick et al., NSE 131, 293-328(1999).

In addition to these data collections, there are almost one-hundred (100) multi-group neutron and/or neutron-photon libraries that can be used for shielding analyses for energies below 20 MeV. There are also another fifty (50) or so point-continuous energy libraries of cross sections, dose factors, and other functions with utility for other kinds of analyses that may be needed. These lower energy data collections are very useful since many "accelerators" produce neutrons and photons that must be shielded to < 1 mrem/hr levels. Therefore, data for accelerator shielding analyses must be available for all energies.

Accelerator Analytical Tools

The following thirteen codes have possible application to accelerator shielding and contain links to their respective abstracts at RSICC.

BISON-C
Auxiliary Codes or Data: BIS60.XSV:
(42-group neutron cross section set for 60 nuclides obtained from JENDL-3.)
AC22.IX: Burnup library.
BIS60.RSC: Response function file.
Contributed by: Faculty of Physics and Nuclear Techniques, University of Mining and Metallurgy, Cracow, Poland.

BISON-C calculates time-dependent functions and parameters of a nuclear system with external source including burnup, k-effective, neutron and gamma-ray flux, neutron reaction rates, and system power in complex heterogeneous blanket structures. It is applicable for research of transmutations in accelerator driven subcritical systems.

CALOR95
CALOR95: Monte Carlo Code System for Design and Analysis of Calorimeter Systems, Spallation Neutron Source (SNS) Target Systems, etc.
Auxiliary Codes or Data: HETC, MORSE, EGS4
Contributed by: Oak Ridge National Laboratory, Oak Ridge, Tennessee.

CASIM
CASIM: Monte Carlo Simulation of Transport of Hadron Cascades in Bulk Matter.
*contributed by:*Fermi National Accelerator Laboratory, Batavia, Illinois.

EASY-97
EASY-97: A Multipurpose Activation and Transmutation Code System.
Contributed by: UKAEA/EURATOM Fusion Association, Oxfordshire, United Kingdom.

E-DEP-1
E-DEP-1: Heavy Ion Energy Deposition Code System.
Version P5.00, packaged by RSIC December 1986, employs improved stopping powers and includes several minor corrections and improvements from the previous CDC version.
Contributed by: Naval Research Laboratory, Washington, D.C.

EGS4
EGS4: Monte Carlo Simulation of the Coupled Transport of Electrons and Photons.

Auxiliary Codes or Data: MORTRAN 3: Macroprocessor to Convert MORTRAN to ANSI Fortran.
PEGS 4: Data Processor for EGS.
EGS_Windows: Graphical tool for displaying acceleration and geometry data files.
Contributed by: Radiation Physics Group, Stanford Linear Accelerator Center, Stanford University, Stanford, California.
National Laboratory for High Energy Physics (KEK), Oho-machi, Tsu-kuba-gun, Ibaraki-ken, Japan.
National Research Council of Canada, Ottawa, Canada.
Institute for Applied Physiology and Medicine, Seattle, Washington.

FLUKA-TRANKA
FLUKA-TRANKA: Three-Dimensional High-Energy Extranuclear Hadron Cascade Monte Carlo System for Cylindrical Backstop Geometries.
Auxiliary Codes or Data: CASCA: Core of Cascade Calculator (Cylindrical Geometries).
Contributed by: Radiation Group, European Organization for Nuclear Research (CERN), Geneva, Switzerland

HERAD
HERAD: Three-Dimensional Monte Carlo Computer Code System for Calculating Radiation Damage from Ion Beams.
Auxiliary Codes or Data: POTEN: Preparation of binary files for input.
Contributed by: University of Wisconsin, Madison, Wisconsin.

HERMES-KFA
HERMES-KFA: Monte Carlo Code System for High-Energy Radiation Transport Calculations.
Contributed by: Forschungszentrum Juelich GmbH, Germany through the Nuclear Energy Agency Data Bank, Issy-les-Moulineaux, France.

HIC-1
HIC-1: Monte Carlo Code System for Calculating Heavy Ion Reactions at Energies > 50 MeV/Nucleon.
Auxiliary Codes or Data: CONVERSION: Cross Section and Evaporation Data BCD-to-Binary Converter Code.
NUCLEAR CONFIGURATION: Cross-Section Data Generator.
CASCADE: Intranuclear Cascade Code.
EVAPORATION: Intermediate-to-Final History Data Processor.
ANALYSIS: Final History Data Analysis Spectral Data Tables Generation.
FLRAN, FLOTR, FLTRN: Random Number Generators.
Contributed by: Oak Ridge National Laboratory, Oak Ridge, Tennessee.

MAGIK
MAGIK: A Monte Carlo Code System for Computing Induced Residual Activation Dose Rates.
Contributed by: Oak Ridge National Laboratory, Oak Ridge, Tennessee

RACC-PULSE
RACC-PULSE: RACC Code System for Computing Radioactivity-Related Parameters for Fusion Reactor Systems Modified for Pulsed/Intermittent Activation Analysis.
Auxiliary Codes or Data: CONVERTFLUX: Routine to convert ONEDANT and TWODANT flux data.
RACCDLIB: Decay constant data
RACCXLIB: Transmutation cross section data

Contributed by: University of Wisconsin, Madison, Wisconsin.

TRANSPORT
TRANSPORT: Charged Particle Beam Transport Systems Design Code System (First- and Second-Order Matrix Multiplication).
Auxiliary Codes or Data: CSECT: Utility routine.

The original first-order TRANSPORT computer program was written in BALGOL at Stanford Linear Accelerator Center (SLAC). The BALGOL version was translated into FORTRAN by Massachusetts Institute of Technology (MIT) and later debugged and improved at SLAC. In 1971-72, National Accelerator Laboratory (NAL) completely rewrote the program and developed an efficient second-order fitting routine using the coupling coefficients (partial derivatives) of multipole components to the optics. This version was implemented at SLAC in 1972 and subsequently carried to CERN in 1972. CERN made further contributions to the program structure and improved the convergence capabilities of the first-order fitting routines. A standard version of the resulting program has now been adopted at SLAC, NAL, and CERN.

Contributed by: Fermi National Accelerator Laboratory (NAL), Batavia, Illinois.
Stanford Linear Accelerator Center (SLAC), Stanford, California.
CERN, Geneva, Switzerland.

Future Work on Collections

RSICC DLC Group Libraries

In scanning almost 200 data collections at RSICC, information has been gathered about each collection by reviewing the previously scanned and archived ADOBE ACROBAT® PDF documents describing the collections. An Access® database was constructed to mirror key information for intelligent searching of the DLC collections. The Access® database contains the following fields:

1) DLC number,
2) name of the collection,
3) title of the collection,
4) references for the collection,
5) date for the collection,
6) data contributors,
7) particle types,
8) number of neutron groups (if applicable), and
9) number of photon groups (if applicable).

Additionally, the inclusion of 5 more fields were recently added to more fully describe each collection:

10) applications for the collections,
11) nuclides in the collection,
12) brief descriptions of just what the collection is and what it is intended for,
13) upper energy of the data in the collection (if applicable), and
14) energy group structures associated with the collection.

The reasoning for the above field additions are to help people do focused searches over the collections and allow ease of tracking the progress for updates to each former set of data.

The Access® database was used to create a text file that can be searched by a FORTRAN or Cold Fusion® program. This could be expanded to allow customers to search all of the files simultaneously to locate data collections of interest on the WWW.

Identified Analytical Tools for Public Distribution

A very important function of the Centers is to find and acquire, test and process, package and disseminate software analytical tools that have been designed around the nuclear science of accelerator particles and energies. With the long-term focused effort of the SATIF- working groups, there will be a continuing need to identify tools that have been/are being developed in all parts of the world community in support of the science and engineering behind new accelerator applications and upgrades.

The following packages have been/are being requested for submission by the parent organization to the Centers for packaging and public distribution:

SINBAD Integral Accelerator Benchmark Experiments for SQA

SINBAD has many new accelerator benchmarks from the Japanese, European, FSR, and American experimental facilities. For a cursory look at upcoming accelerator benchmarks to be added this coming year or two, see Table 2 below. Links to both the NEA DB and RSICC SINBAD WWW homepages are http://www.nea.fr/abs/html/nea-1552.html and http://www-rsicc.ornl.gov/BENCHMARKS/SINBAD.html, respectively, and contain further information on the SINBAD international database efforts.

Table 2. SINBAD Future Accelerator Benchmarks

Accelerator applications	Facility
ROSTI data & target yield series	CERN
RIKEN (quasi-monoenergetic neutron field using the 7Li(p,n)7Be reaction 70-210 MeV	RIKEN
High Energy Neutron Spectra Generated by 590-MeV Protons on a Thick Lead Target	PSI
Transmission of Medium Energy Neutrons Through Concrete Shields	AVF Osaka-U.
Neutron Production from Thick Targets of Carbon, Iron, Copper, and Lead by 30- and 52-MeV Protons	INS Tokyo-U.
The Nucleon-Meson Cascade in Iron Induced by 1 and 3-GeV Protons	ORNL
68 MeV proton on thick Cu target	JAERI
113 MeV proton on thick Fe target	LANL
Shielding experiments through concrete and iron with high energy proton and heavy ion accelerators (100 - 800 MeV protons, 20 -120 cm concrete and 20 - 60 cm iron)	HIMAC, KEK
MCNPX Benchmark Computation #6 TRIUMF – 492 MeV Protons on Graphite	Georgia Tech; Jeremy Sweezy; Nolan Hertel

MCNPX Benchmark Computation #7 Neutron Spectra from 0.5-1.5 GeV Protons on Thick Lead Target	Georgia Tech; Jeremy Sweezy; Nolan Hertel
MCNPX Benchmark Computation #8 Transmission of Quasi-Monoenergetic Neutrons Generated by 43-MeV and 68-MeV Protons Through Iron and Concrete.	Georgia Tech; Jeremy Sweezy; Nolan Hertel
MCNPX Benchmark Computation #9 Total Neutron Yields from 100-MeV Protons on Pb, Li, Cu, Fe, and Th.	Georgia Tech; Jeremy Sweezy; Nolan Hertel
MCNPX Benchmark Computation #10 Neutron Fluxes in and around Iron Beam Stop Irradiated by 500 MeV Protons.	Georgia Tech; Jeremy Sweezy; Nolan Hertel

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[2] Radiation Safety Information Computational Center (RSICC) within the Oak Ridge National Laboratory (ORNL); Oak Ridge, TN, USA; http://www-rsicc.ornl.gov/rsic.html

[3]"Sharing of Computer Codes and Data for Accelerator Shield Modelling", by R.W.Roussin and E.Sartori, in *Proceedings of the Specialists' Meeting on Shielding Aspects of Accelerators, Targets and Irradiation Facilities,* held in Arlington, Texas (U.S.A.) on 28-29 April 1994, published as an OECD document ISBN 92-64-14327-0.

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[5] "Progress Report on the Collection of Computer Codes and Data Sets for Accelerator Shielding Analysis" by B.L. Kirk, E. Sartori, and P. Vaz in *Proceedings of the Third Specialists Meeting on Shielding Aspects of Accelerators, Targets and Irradiation Facilities (SATIF-3)*, held at Tohoku University, Sendai, Japan, on 12-13 May 1997, published as an OECD document ISBN 92-64-16071

[6]"Progress Report on the Collection of Computer Codes and Data Sets for Accelerator Shielding Analysis", J. B. Manneschmidt, B. L. Kirk, H. T. Hunter, E. Sartori, and P. Vaz, in *Proceedings of the Fourth Specialists Meeting on Shielding Aspects of Accelerators, Targets and Irradiation Facilities (SATIF-4),* held at Gatlinburg, TN, USA, on 17-18 September 1998, published as an OECD document ISBN: 92-64-17044-8

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[8] "Executive Summary of the Fifth Meeting of the Task Force on Shielding Aspects of Accelerators, Targets, and Irradiation Facilities," unpublished report OECD NEA DB, 2000.

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-APPENDIX 1-

Table 1a. List of NEADB and RSICC programs and data in alphabetical order

Name

<blank>	*Programs available*
(**)	*Programs known but not publicly available*
(***)	*Additions/updates since the SATIF5 meeting*

Identification

CCC-,PSR-,DLC-M00	*: original packaging by RSICC*
RIST	*: located at the Research Organization for Information Science and Technology*
NESC	*: original packaging by NESC (now ESTSC)*
USCD	*: originated in US/Canada, packaged by NEA DB*
NEA, IAEA	*: original packaging by NEA DB*
<blank>	*: acquisition sought*

Name	Identification	Function
ABAREX	PSR-248	optical statistical model to calculate energy averaged neutron induced reaction cross-sections
ACTIV-87	IAEA1275	library with fast neutron activation x-sections
AIRSCAT	CCC-0341	dose rate from gamma air scattering, single scat. approx.
ALBEDO	NEA 1353	gamma, neutron attenuation in air ducts
ALDOSE	CCC-0577	calculates absorbed dose and dose equivalent rates as function of depth in water irradiated by alpha source
ALICE91	PSR-0146	precompound/compound nuclear decay model
ALPHN	CCC-0612	calculates the (alpha, n) production rate in a mixture receiving alpha particles from emitting actinides
AMALTHEE	NEA 0675	emission spectra for n, p, d, h3, he3, alpha reaction
ANISN	CCC-0650	1-D Sn, n, gamma transport in slab, cylinder, sphere
ANITA2000 ***	NEA 1638	code system to calculate isotope inventories from neutron irradiation for fusion applications
ASOP	CCC-0126	1-D Sn shield calculation (new version for AIX and Linux)
ASTAR	IAEA1282	calculates stopping power and range for alphas
ASTROS	CCC-0073	primary/secondary proton dose in sphere/slab tissue
AUJP	IAEA0906	optical potential parameters search by chi**2 method
BALTORO	NEA 0675	n, gamma transport perturbation from MORSE, ANISN calculation
BASACF	IAEA0953	integral neutron adjustment and dosimetry
BERMUDA	NEA 0949	1-D, 2-D, 3-D n, gamma transport for shielding
BETA-2B	CCC-0117	MC time-dependent bremsstrahlung, electron transport
BETA-S3.1	CCC-657	calculates beta decay source terms and energy spectra
BOT3P 1.0***	NEA 1627	code system for 2D and 3D mesh generation and graphical display of geometry and results for the DOORS deterministic transport codes
BREESE	PSR-0143	distribution function for MORSE from albedo data
BREMRAD	CCC-0031	external/internal bremsstrahlung
BRHGAM	CCC-0350	MC absorbed dose from x-rays in phantom
CADE	NEA 1020	multiple particle emission x-sections by Weisskopf-Ewing
CALOR95	CCC-0610	MC system for design, analysis of calorimeter system
CAMERA	CCC-0240	radiation transport and computerised man model
CARP-82	PSR-0131	multigroup albedo data using DOT angular flux results
CASCADE	CCC-0176	high-energy electron-photon transport in matter
CASIM	NESC0742	MC high energy cascades in complex shields
CCRMN	PSR-355	computation of reactions of a medium-heavy nucleus with six light particles
CEM95	IAEA1247	MC calculation of nuclear reactions (cascade exciton model)
CENDL	IAEA1256	chinese evaluated nuclear data library (neutron, proton, deuteron, triton, He3 and He4)
CEPXS/ONELD	CCC-0544	1-D coupled electron photon multi-group transport
CFUP1	IAEA1266	n, charged-particle reaction of fissile nuclei E < 33 MeV
CHARGE-2/C	CCC-0070	electron, p, heavy particle flux/dose behind shield
CHEMENGL	NEA-1561	chemical and physical properties of elements
CHENDF 6.1***	PSR-333	Codes for Handling ENDF/B-V and ENDF/B-VI Data
CHUCK	USCD1021	n, charged particle x-sections, coupled channel model
CMUP2	IAEA1265	reaction x-sections for n, p, d, t, he3, he4, E < 50 MeV
COLLI-PTB	NEA 1126	MC n fluence spectra for 3-D collimator system
COMNUC3B	PSR-0302	compound nucleus interaction in n reactions
COVFILES	DLC-0091	library of neutron x-sections covariance data, useful to estimate radiation damage or heating
DANTSYS	CCC-0547	1-D, 2-D, 3-D Sn neutron, photon transport
DASH	CCC-0366	void tracing Sn - MC coupling with fluxes from DOT
DCTDOS	CCC-0520	n, gamma penetration in composite duct system
DCHAINSP2000**	RIST	High-Energy Particle-Induced Radioactivity Calculation Code
DDCS	IAEA1290	neutron, proton, deuteron, triton, He3, and alpha induced reactions of medium heavy nuclei up to 50 MeV
DECDC 1.0***	NEA 1644	Nuclear Decay Data Files for Radiation Dosimetry Calculations
DISDOS	CCC-0170	dose from external photons in phantom
DOORS3.2	CCC-0650	Discrete ordinates system for deep penetration neutron and gamma transport
DORT	CCC-0543	1-D 2-D Sn n, photon transport with deep penetration
DOSDAT-2	DLC-0079	gamma, electron dose factors data lib. for body organs
DOSEDAT-DOE	DLC-0144	dose rate factors for external photon, electron exposure

Table 1a. List of programs and data in alphabetical order (*continued*)

Name	Identification	Function
DUST	CCC-0453	albedo MC simulation of n streaming inducts
DWBA98	NEA 1209	distorted wave born approximation nuclear model
DWUCK-4	NESC9872	distorted wave born approximation nuclear model
E-DEP-1	CCC-0275	heavy ion energy deposition
EADL	DLC-0179	library of atomic subshell and relaxation data
EAF99	NEA-1609	cross section library for neutron induced activation materials
EASY-97	NEA-1564	european neutron activation system
ECIS-95	NEA 0850	Schroedinger/Dirac nuclear model with experimental fit
ECPL-86	DLC-0106	evaluated charged particle cross-sections
EDMULT	NEA 0969	electron depth dose in multi-layer slab absorbers
EEDL	DLC-179	electron interaction x-section from 10 eV to 100 GeV
EGS4	CCC-0331	MC electron photon shower simulation
ELBA	CCC-0119	bremsstrahlung dose from electron flux on Al shield
ELPHIC-PC	IAEA1223	statistical model MC simulation of heavy ion reaction
ELPHO	CCC-0301	MC muon, electron, positron generation from pions
ELTRAN	CCC-0155	MC 1-D electron transport
EMPIRE-MSC	IAEA1169	multi-step compound nucleus/pre-equilibrium x-sections
EMPIRE-II v 2.13***	IAEA1169	statistical model code system for nuclear reaction calculations, version 2.13
ENLOSS	PSR-0047	energy loss of charged particles
ENDLIB-97	DLC-0179	coupled electron & photon transport library (in LLL ENDL format)
EPDL-97	DLC-0179	photon interaction x-sections library (10 eV to 100 GeV)
EPICSHOW-96.1	IAEA1285	interactive viewing of the electron-photon interaction (10 eV < E < 1 GeV)
ERINNI	NEA 0815	multiple cascades emission spectra by optical model
ESTAR	IAEA1282	calculates stopping power and range for electrons
ETRAN	CCC-0107	MC electron, gamma transport with secondary radiation
EVA		codes performing the nuclear evaporation processes (working on the output from ISABEL)
EVALPLOT	IAEA0852	plots x-sections in ENDF/B format, angular and energy distributions
EVAP_F **		modified version of the Dresner evaporation code
EXIFONGAMMA	IAEA1211	n, alpha, proton, gamma emission spectra model
FALSTF	CCC-0351	n, gamma flux detector response outside cylindrical shields
FEM-RZ	NEA 0566	2-D multi-group n transport in r-z geometry
FGR-DOSE	DLC-0167	library of dose coefficients for intake and exposure to radionuclides
FLEP	DLC-0022	neutron, proton non-elastic x-sections and spectra E < 400 MeV
FLUKA	CCC-0207	MC high energy extranuclear hadron cascades
FOTELP/EM	CCC-0581	MC photons, electrons and positron transport
FOTELP/2KG***	IAEA 1388/01	photons, electrons and positrons transport in 3D by Monte Carlo techniques
FRITIOF **		hadronic cascades in high-energy heavy ion collisions
FSMN	IAEA1264	fission spectra by compound-nucleus optical model
FSXLIB-J3R2	NEA 1424	JENDL-3 Evaluated Nuclear Data File, fusion neutronics
G33-GP	CCC-0494	multi-group gamma scattering using gp build-up-factor
GAMMONE	NEA 0268	MC gamma penetration from various geometrical sources
GBANISN	CCC-0628	1-D neutron & gamma fluxes with group band fluxes
GCASCAD	IAEA1362	gamma production cross-sections from statistical model
GEANT-CERN		
GGG-GP	CCC-0564	multi-group gamma-ray scattering - build-up factors
GMA	PSR-367	generalised least squares evaluation of related cross-sections
GNASH-FKK	PSR-0125	multi-step direct and compound and Hauser Feshbach models
GNASH-LANL	PSR-0125	pre-equilibrium/statistical x-sections, emission spectra
GRACE-1	NESC0045	multi-group gamma attenuation, dose in slab
GRAPE	NEA 1043	precompound/compound nuclear reaction models
GRPANL	PSR-0321	germanium gamma and alpha detector spectra unfolding
GUI2QAD 3D***	CCC-697/01	point kernel code system for neutron and gamma-ray shielding calculations in complex geometry, including a graphical user interface
HELLO	DLC-0058	47 n, 21 gamma group coupled x-sections from VITAMIN-C library
HERMES-KFA	NEA 1265	MC high-energy radiation transport
HERMES96b	NEA 1265	MC high-energy radiation transport
HETC NMTC	CCC-0178	MC high energy nucleon meson cascade transport
HETC-KFA	CCC-0496	MC high energy nucleon-meson cascades
HETC95 **		MC high energy nucleon-meson cascades and transport
HFMOD	IAEA1317	elastic and inelastic x-section calculation by Hauser-Feshbach and Moldauer
HFTT	IAEA0954	n x-sections by compound-nucleus evaporation model
HIC-1	CCC-0249	MC heavy ion reactions at E>50 MeV/nucleon
HIJET **		hadronic cascades in high-energy Heavy Ion Collisions
HILO86	DLC-0119	66 n, 22 gamma group x-section lib. for ANISN-ORNL, DORT, MORSE-CGA
HILO86R	DLC-0187	66 n, 22 gamma group x-section, up to 400 MeV (neutron) and 20 MeV (gamma)
HIMAC***	M00000	differential neutron yields in energy and angle produced by high-energy Ar, C, Fe, He, Ne, Nb, Si, on thick Al, C, Cu, Nb, and Pb
HOMO	IAEA1253	program for mixing/converting libraries in ANISN format

Table 1a. List of programs and data in alphabetical order (*continued*)

Name	Identification	Function
HUGO-VI	DLC-0146	photon interaction evaluated data library ENDF-6 format
IAEF-2001***	NEA 1656/01	Intermediate Energy Activation File IEAF-2001
ICOM	CCC-651	calculate transport characteristics of ion radiation
IDC	CCC-0384	ICRP dosimetric calculational system
IHEAS-BENCH	NEA 1468	high-energy accelerator shielding benchmarks
IMPACTS	ESTS0005	radiological assessment code
INFLTB	PSR-0313	dosimetric mass energy transfer and absorption coefficients
INTEL-BERMUDA**	RIST	radiation shielding calculation for rusion reactor, accelerator and reprocessing facility
ISABEL	NEA 1413	intra-nuclear cascade model allowing hydrogen and helium ions and antiprotons as projectiles
ISAJET **		hadronic cascades in high-energy Heavy Ion Collisions
ISO-PC	CCC-0636	kernel integration code system for general purpose isotope shielding
ITS-3.0	CCC-0467	MC system of coupled electron photon transport, photon, neutron dose in electron accelerator
K009	CCC-0062	charged particle penetration – phantom quantum mechanical multi-step direct model
LA100	DLC-0168	evaluated data library for n, p up to 100 MeV, ENDF-6 format
LAHET 2.8 ***	CCC-696	code system for high energy particle transport calculations
LAHIMAC	DLC-0128	neutron, gamma x-sections - response functions, E<800MeV
LEP	DLC-0001	results from intra-nuclear cascade and evaporation
LIMES	NEA 1337	intermediate mass fragments in heavy ion nuclear reactions
LPPC	CCC-0051	proton penetration, slab
LPSC	CCC-0064	p, n flux, spectra behind slab shield from p irradiation
LRSPC	CCC-0050	range and stopping power calculator for ions
MAGIK	CCC-0359	MC for computing induced residual activation dose rates
MAGNA	NEA 0163	dose rates from gamma source in slab or cylindrical shell shields
MARLOWE15a***	PSR-0137/06	atomic displacement cascades in solids
MARMER	NEA 1307	point-kernel shielding, ORIGEN-S nuclide inventories
MATXS10	DLC-0176	library with 30n-12gamma energy groups for particle transport codes
MATXS11	DLC-0177	library with 80n-24gamma energy groups for particle transport codes
MCB***	NEA 1656	A continuous energy Monte Carlo burnup simulation code
MCNP-4B2	CCC-0660	MC 3-D time-dependent coupled n, photon, electron transport
MCNP-4C2***	CCC-0701/00	MC 3-D time-dependent coupled n, photon, electron transport
MCNPDATA***	DLC-0200	x-section data library for the MCNP-4C2 transport code
MCNP-VISED 4C2***	PSR-500/00	visual editor for MCNP 4C2 input
MCNPXDATA***	DLC-205/01	x-section data library for the MCNPX 2.1.5
MCNPXS	DLC-0189	x-section data for MCNP4B2
MCNPX 2.1.5***	CCC-705/00	The LAHET/MCNP Code merger
MECC-7***	CCC-0156/01	medium energy intra-nuclear cascade model
MENDL-2P***	IAEA 1376	proton cross-sections for 504 nuclei with atomic number from 13 to 84 at the energies up to 200 MeV
MENSLIB	DLC-0084	neutron 60 group x-sections, E<60MeV
MERCURE-4	NEA 0351	MC 3-D gamma heating/gamma dose rate, fast flux
MEVDP	CCC-0157	radiation transport in computerised anatomical man
MICAP	PSR-0261	MC ionisation chamber responses
MIRDOSE3.1	CCC-0528	calculate internal dose estimates by the MIRD technique
MORSE-CGA	CCC-0474	MC n, gamma multi-group transport
MRIPP 1.0	CCC-0655	magnetic resonance image phantom for in vivo measurements
MSM-SOURCE	PSR-0369	estimate stopping characteristics of proton transmissions
MUONLM	NEA 1475	calorimeter Interaction of muons
MUP-2	IAEA0907	fast n reaction x-sections of medium-heavy nuclei
MUTIL	NEA-1451	calculates the asymmetry factor of the Mott scattering of electrons and positrons by point nuclei
NDEM**		generates a gamma-ray source from the de-excitation of residual nuclei
NESKA	NEA 1422	electron, positron scattering from point nuclei
NFCLIST	ESTS0352	radionuclide decay data tabulations (240 radionuclides)
NJOY-94.61	PSR-0171	n, p, photon evaluated data processing system
NJOY97.0	PSR-355	n, p, photon evaluated data processing system
NJOY99.0	PSR-0480	data processing system of evaluated nuclear data files ENDF format
NMTC/JAERI	NEA 0974	MC high-energy p, n, pion reactions
NMTC/JAERI-97***	NEA-0974	high-energy neutron, proton, pion reaction Monte Carlo simulation
NMF-90	IAEA1279	database for neutron spectra unfolding
NUCDECAY	DLC-0172	nuclear decay data for radiation dosimetry calculations
NucDecayCalc	DLC-0202	nuclear decay data for radiation dosimetry and retrieval program
NUCHART	IAEA1320	nuclear properties and decay data chart
NUCLEUS		nuclear spallation simulation and primary products
NUCLEUS-CHART	NEA-1492	interactive chart of nuclides
OPTMOD	IAEA1316	elastic & total x-section, polarisation calculations using the optical model
OSCAR **	RIST	Calculation of yields of nuclear reaction products for particle accelerator
PACE2 **		codes performing the nuclear evaporation processes (working on the output from ISABEL)
PALLAS-2DY	NEA 0702	2-D n ,gamma transport for fixed source
PCROSS	IAEA1220	pre-equilibrium emission spectra in neutron reaction
PCNUDAT32.2.8	USCD1205	nuclear properties database & retrieval system

Table 1a. List of programs and data in alphabetical order (*continued*)

Name	Identification	Function
PEGAS	IAEA1261	unified model of particle and gamma emission reactions
PENELOPE 2001***	NEA 1525	Monte Carlo code for electron-photon transport
PEQAG-2	IAEA1185	pre-equilibrium model nucleon, gamma spectra, x-sections
PEREGRINE **		used to model dose to humans from radiation therapy
PHENOM/BCS-COLL	IAEA1327	nuclear level density of excited nuclei
PHOTX	DLC-0136	photon interaction x-section library for 100 elements
PICA	CCC-0160	MC nuclear cascade reactions by the collision of photons (30 < E < 400 MeV) with nuclei
PIPE	NEA 0416	1-D gamma transport for slab, spherical shields
PLACID	CCC-0381	MC gamma streaming in cylindrical duct shields
PNESD	IAEA1235	elastic x-sections of 3 MeV to 1000 MeV p on natural isotopes
POINT2000 ***	DLC-212	temperature-dependent, linearly interpolable, tabulated cross section library based on ENDF/B-VI, Release 7
POTAUS	IAEA1249	H through U ion ranges, stopping power for various materials
PREANG	NEA 0809	nuclear model particle spectra, angular distribution
PRECO-2000***	PSR-0226/01	pre-equilibrium, direct reaction double differential x-sections
PREM	NEA 0888	nucleon emission pre-equilibrium energy spectra, x-sections
PREPRO-96	CCC-351	pre-processing code system for data in ENDF/B format
PSTAR	IAEA1282	calculates stopping power and range for protons
PTRAN	CCC-0618	MC proton transport for 50 to 250 MeV
PUTZ	CCC-0595	point-kernel 3-D gamma shielding
QAD-CGGP-A	CCC-0645	fast neutron and gamma ray penetration in shields
QMD		intra-nuclear cascade and classical molecular dynamics
GUI2QAD 3D***	CCC-697/01	Point Kernel Code System for Neutron and Gamma-Ray Shielding Calculations in Complex Geometry, Including a Graphical User Interface
RADCOMPT	PSR-0348	sample analysis for alpha and beta dual channel detect
RADDECAY	DLC-0134	decay data library for radiological assessment
RADHEAT-V3	NEA 0467	transport, heat, radiation damage x-sections in reactor, shield
RAID	CCC-0083	gamma, n scattering into cylindrical or multi-bend duct
RAF	IAEA1350	neutron and proton radiative capture differential and integrated cross-section
REAC	CCC-0443	activation and transmutation
REAC-2	NESC9554	nuclide activation, transmutation
REAC*3	CCC-0443	isotope activation & transmutation in fusion reactors
REBEL-3	IAEA0846	MC radiation dose to human organs
RECOIL/B	DLC-0055	heavy charged particle recoil spectra lib. for radiation damage
REMIT	ESTS0579	Radiation Exposure Monitoring and Inf. Transmittal system
REPC	PSR-0195	dose from protons in tissue
RESRAD5.82	CCC-0552	calculation of residual radioactive material guidelines, site specific radiation doses and risks
SAM-CE	CCC-0187	MC time-dependent 3-d n ,gamma transport in complex geometry
SAMMY M6B***	PSR158/07	code system for multilevel r-matrix fits to neutron and charged-particle cross-section data using Bayes' equations
SAMSY	IAEA0837	N, gamma dose rates, heat source for multi-layer shields
SAND-II	PSR-0345	determines neutron energy spectra using multiple experimental activation detector data
SANDYL	CCC-0361	MC 3-d time-dependent gamma electron cascade transport
SCAP-82	CCC-0418	scattering, albedo, point-kernel anal. in complex geometry
SCAT-2B***	NEA-0829	spherical optical model for light particles and heavy ions
SCINFUL	PSR-0267	MC response of scintillation neutron detector (incident neutron energies from 0.1 to 75 MeV)
SEECAL	CCC-0620	age-dependent effective energies for 54 and 32 target regions in the human body (825 radionuclides)
SFERXS	NEA 1239	photon absorption, coherent, incoherent x-sections for shielding
SHIELD***	CCC-667	universal code for exclusive simulation of hadron cascades in complex macroscopic targets
SIGMA-A	DLC-0139	photon interaction and absorption data 1 KeV-100 MeV
SINBAD97	DLC-191	Shielding INtegral Benchmark Archive DataBase
SINBAD2000		Shielding INtegral Benchmark Archive DataBase
SITHA **	IAEA1179	SImulation Transport HAdron, calculates hadron transport
SKYIII-PC	CCC-0289	PC version of program SKYSHINE-III
SKYPORT	DLC-0093	importance of n, photon skyshine dose from accelerators
SKYSHINE-KSU***	CCC-0646/03	computation of gamma skyshine doses by different methods
SNLRML	DLC-0178	dosimetry library compendium
SNL/SAND-II	PSR-0345	enhanced version of SAND-II
SOURCE **		description of the proton transmission and generation of n source
SOURCESA4	CCC-661	(α,n), spontaneous fission and (β,n) delayed neutron sources and spectra due to decay in homog. media
SPACETRAN	CCC-0120	radiation leakage from cylinder with ANISN flux
SPAR	CCC-0228	stopping power and ranges from muons, pions, protons ions
SPARES	CCC-0148	space radiation environment and shielding evaluation
SPEC	IAEA1332	computation of neutron and charged particle reactions using optical and evaporation models
SPCHAIN **		calculates accumulation and decay of nuclides
SPECTER-ANL	PSR-0263	n damage for material irradiation
SRIM-2000	NEA 0919	stopping power and ranges of ions (10 ev-2 GeV/amu)
SRNA-2KG***	IAEA 1382/01	proton transport using 3d by monte carlo techniques
STAC-8		transmitted, absorbed power/spectrum – synchrotron radiation

Table 1a. List of programs and data in alphabetical order (*continued*)

Name	Identification	Function
STAPRE-H95	IAEA0971	evaporation, pre-equilibrium model reaction x-sections
STAPREF***	NEA-0461	nuclear reactions cross-sections by evaporation model, gamma-cascades
STARCODES	PSR-0330	stopping power, ranges for electrons, protons, alpha
STOPOW	IAEA0970	stopping power of fast ions in matter
STR92	ESTS1041	energy deposition in accelerator ring components
STRAGL	CCC-0201	energy loss straggling of heavy charged particles
SWIMS	ESTS0682	angular dispersion of ion beams at small-angle incoherent multiple scattering by gaseous or solid media
TART2000***	CCC-638/01	3D MC transport program for neutrons and photons
TDTORT***	CCC-709/00	Time-Dependent, Three-Dimensional, Discrete Ordinates, Neutron Transport Code System
TNG1	PSR-0298	N multi-step statistical model
TORT	CCC-0543	3-D Sn n, photon transport with deep penetration
TPASGAM	DLC-0088	library with gamma-ray decay data for 1438 radionuclides
TRANSX2.15	PSR-0317	code to produce neutron, photon transport tables for discrete ordinates and diffusion codes
TRAPP	CCC-0205	proton and alpha transport, reaction products neglected
TRIPOLI-3		MC time-dependent 3-D N, gamma transport
TRIPOS	CCC-0537	MC ion transport
TWODANT-SYS	CCC-0547	1-D,2-D multi-group Sn n, photon transport
UNGER	DLC-0164	effective dose equivalent data for selected isotopes
UNIFY	IAEA1177	fast n x-sections, spectrum calculation for structural materials
UNSPEC	ESTS0827	X-ray spectrum unfolding using an iterative technique
VEGAS **		intra-nuclear cascade code (from which ISABEL is derived)
VIRGIN	IAEA0932	uncollided neutron flux and neutron reactions due through a neutron beam through any thickness of material
VITAMIN-E	DLC-0113	x-section data library with 174n-38gamma energy groups
VITAMIN-B6	DLC-0184	x-section data library with 199n-42gamma energy groups from ENDF/B-VI Release 3
XCOM	DLC-0174	photon cross-sections from 1 KeV to 100 GeV
ZOTT99***	IAEA1371	data evaluation using partitioned least squares

Table 2a. Evaluated and processed data (cross-sections, co-variance, dose conversion, ranges, stopping powers)

Name	Identification	Function
ACTIV-87	IAEA1275	library with fast neutron activation x-sections
CENDL	IAEA1256	chinese evaluated nuclear data library (neutron, proton, deuteron, triton, He3 and He4)
CHENDF 6.1***	PSR-333	codes for handling ENDF/B-V and ENDF/B-VI data
COVFILES	DLC-0091	library of neutron x-sections covariance data, useful to estimate radiation damage or heating
DECDC 1.0***	NEA 1644	nuclear decay data files for radiation dosimetry calculations
DOSDAT-2	DLC-0079	gamma, electron dose factors data lib. for body organs
DOSEDAT-DOE	DLC-0144	dose rate factors for external photon, electron exposure
EADL	USCD1192	library of atomic sub-shell and relaxation data
EAF99	NEA-1609	cross section library for neutron induced activation materials
EASY-97	NEA-1564	european neutron activation system
ECPL-86	DLC-0106	evaluated charged particle cross-sections
EEDL	USCD1193	electron interaction x-section from 10 eV to 100 GeV
ENDLIB-94	DLC-0179	coupled electron & photon transport library (in LLL ENDL format)
ENDLIB-97	DLC-0179	coupled electron & photon transport library (in LLL ENDL format)
EPDL-VI/MOD	USCD1187	photon interaction x-sections library (10 eV to 100 GeV)
FGR-DOSE	DLC-0167	library of dose coefficients for intake and exposure to radionuclides
FLEP	DLC-0022	neutron, proton non-elastic x-sections and spectra E < 400 MeV
FSXLIB-J3R2	NEA 1424	JENDL-3 Evaluated Nuclear Data File, fusion neutronics
HILO86	DLC-0119	66 N, 22 gamma group x-section lib. for ANISN-ORNL, DORT, MORSE-CGA
HILO86R	DLC-0187	66 N, 22 gamma group x-sections, up to 400 MeV (neutron) and 20 MeV (gamma)
HIMAC***	M00000	differential neutron yields in energy and angle produced by high-energy Ar, C, Fe, He, Ne, Nb, Si, on thick Al, C, Cu, Nb, and Pb
HELLO	DLC-0058	47 n, 21 gamma group coupled x-section from VITAMIN-C library
HUGO-VI	DLC-0146	photon interaction evaluated data library ENDF-6 format
IAEF-2001***	NEA 1656/01	Intermediate Energy Activation File IEAF-2001
IDC	CCC-0384	ICRP dosimetric calculational system
IHEAS-BENCH	NEA 1468	high-energy accelerator shielding benchmarks
JENDL-3.2	NEA-1470	cross sections data library and plots for neutrons up to 70 MeV
JENDL/D-99	NEA-1624	dosimetry cross-section data library and plots for neutrons
LA100	DLC-0168	evaluated data library for n, p up to 100 MeV, ENDF-6 format
LAHIMACK	DLC-0128	multi-group neutron and gamma x-sections up to 800 MeV
LEP	DLC-0001	results from intra-nuclear cascade and evaporation
LRSPC	CCC-0050	range and stopping power calculator
MATXS10	DLC-0176	library with 30 n-12 gamma energy groups for particle transport codes
MATXS11	DLC-0177	library with 30 n-12 gamma energy groups
MCNPDATA***	DLC-0200	x-section data library for the MCNP-4C2 transport code
MCNPXS	DLC-0189	x-section data for MCNP-4B2
MCNPXDATA***	DLC-205/01	x-section data library for the MCNPX 2.1.5
MENDL-2P***	IAEA 1376	proton cross-sections for 504 nuclei with atomic number from 13 to 84 at the energies up to 200 MeV
MENSLIB	DLC-0084	neutron 60 group x-sections, E<60MeV
NJOY97.0	PSR-355	n, p, photon evaluated data processing system
NJOY99.0	PSR-480	data processing system of evaluated nuclear data files ENDF format
NMF-90	IAEA1279	database for neutron spectra unfolding
NUCDECAY	DLC-0172	nuclear decay data for radiation dosimetry calculations
NucDecayCalc	DLC-0202	nuclear decay data for radiation dosimetry and retrieval program
NUCHART	IAEA1320	nuclear properties and decay data chart
PCNUDAT32.2.8	USCD1205	nuclear properties database & retrieval system
PHOTX	DLC-0136	photon interaction x-section library for 100 elements
PNESD	IAEA1235	elastic x-sections of 3 MeV to 1000 MeV p on natural isotopes
POINT97	DLC-0192	combination of resonance parameters and/or tabulated energy dependent evaluated cross-sections
POINT2000 ***	DLC-212	temperature-dependent, linearly interpolable, tabulated cross-section library based on ENDF/B-VI, Release 7
RADDECAY	DLC-0134	decay data library for radiological assessment
RECOIL/B	DLC-0055	heavy charged particle recoil spectra lib. for radiation damage
SAMMY M6B***	PSR158/07	code system for multilevel r-matrix fits to neutron and charged-particle cross-section data using Bayes' equations
SFERXS	NEA 1239	photon absorption, coherent, incoherent x-sections for shielding
SIGMA-A	DLC-0139	photon interaction and absorption data 1 KeV-100 MeV
SINBAD2000	DLC-191/02	shielding integral benchmark archive database
SINBAD2002***	DLC-191/03	shielding integral benchmark archive database
SKYIII-PC	CCC-0289	PC version of program SKYSHINE-III
SKYPORT	DLC-0093	importance of n, photon skyshine dose from accelerator
SKYSHINE-KSU***	CCC-0646/03	computation of gamma skyshine doses by different methods
SNLRML	DLC-0178	dosimetry library compendium
SPAR	CCC-0228	stopping power and ranges from muons, pions, protons, ions
SRIM-2000	NEA 0919	stopping power and ranges of ions (10 eV-2 GeV/amu) in matter
STARCODES	PSR-0330	stopping power, ranges for electrons, protons, alpha
STOPOW	IAEA0970	stopping power of fast ions in matter
TPASGAM	DLC-0088	library with gamma-ray decay data for 1438 radionuclides
UNGER	DLC-0164	effective dose equivalent data for selected isotopes

VITAMIN-E	DLC-0113	x-section data library with 174 n-38 gamma energy groups
VITAMIN-B6	DLC-0184	x-section data library with 199 n-42 gamma energy groups derived from ENDF/B-VI Release 3
XCOM	DLC-0174	photon cross-sections from 1 KeV to 100 GeV

Table 3a. Generating Cross Sections – Spectra from nuclear models (for E > 20 MeV)

Name	Identification	Function
ALICE91	PSR-0146	precompound/compound nuclear decay model
AMALTHEE	NEA 0675	emission spectra for n, p, d, h3, he3, alpha reaction
ASOP	CCC-0126	1-D Sn shield calculation
AUJP	IAEA0906	optical potential parameters search by chi**2 method
CADE	NEA 1020	multiple particle emission x-sections by Weisskopf-Ewing
CCRMN	IAEA1347	computation of reactions of a medium-heavy nucleus with six light particles
CEM95	IAEA1247	MC calculation of nuclear reactions (Cascade Exciton Model)
CFUP1	IAEA1266	n, charged-particle reaction of fissile nuclei E < 33 MeV
CHUCK	USCD1021	n, charged particle x-sections, coupled channel model
CMUP2	IAEA1265	reaction x-sections for n ,p, d, t, he3, he4, E < 50 MeV
COMNUC3B	PSR-0302	compound nucleus interaction in n reactions
DWBA82	NEA 1209	distorted wave born approximation nuclear model
DWUCK-4	NESC9872	distorted wave born approximation nuclear model
ECIS-95	NEA 0850	Schroedinger/Dirac nuclear model with experimental fit
ELPHIC-PC	IAEA1223	statistical model MC simulation of heavy ion reaction
EMPIRE-MSC	IAEA1169	multi-step compound nucleus/pre-equilibrium x-sections
EMPIRE-II	IAEA1169	comprehensive nuclear model code, nucleons, ions induced cross-sections
EMPIRE-II v 2.13***	IAEA1169	statistical model code system for nuclear reaction calculations, Version 2.13
ERINNI	NEA 0815	multiple cascades emission spectra by optical model
EVA		codes performing the nuclear evaporation processes
EVAP_F**		modified version of the Dresdner evaporation code
EXIFONGAMMA	IAEA1211	n, alpha, proton, gamma emission spectra model
FRITIOF **		MC high-energy heavy ion collisions
GCASCAD	IAEA1362	gamma production cross-sections from statistical model
GNASH-FKK	PSR-0125	multi-step direct and compound and Hauser-Feshbach models
GNASH-LANL	PSR-0125	pre-equilibrium/statistical x-sections, emission spectra
GRAPE	NEA 1043	precompound/compound nuclear reaction models
HETC NMTC	CCC-0178	MC high energy nucleon meson cascade transport
HETC-KFA	CCC-0496	MC high energy nucleon-meson cascades
HETC95 **		MC high energy nucleon-meson cascades and transport
HFMOD	IAEA1317	elastic and inelastic x-section calculation by Hauser-Feshbach and Moldauer
HFTT	IAEA0954	n x-section by compound-nucleus evaporation model
HIJET **		MC high-energy heavy ion collisions
ISABEL	NEA 1413	intra-nuclear cascade model allowing hydrogen and helium ions and antiprotons as projectiles
ISAJET **		MC high-energy heavy ion collisions
KAPSIES		quantum mechanical multi-step direct model
LIMES	NEA 1337	intermediate mass fragments in heavy ion nuclear reactions
MARLOWE15a***	PSR-0137	atomic displacement cascades in solids
MECC-7***	CCC-0156/01	medium energy intra-nuclear cascade model
MUP-2	IAEA0907	fast n reaction x-section of medium-heavy nuclei
MUTIL	NEA 1451	calculates the asymmetry factor of the Mott scattering of electrons and positrons by point nuclei
NDEM**		generates a gamma-ray source from the de-excitation of residual nuclei
NJOY-94.61	PSR-0171	n, p, photon evaluated data processing system
NJOY97.0	PSR-355	n, p, photon evaluated data processing system
NJOY99.0	PSR-0480	data processing system of evaluated nuclear data files ENDF format
NMTC/JAERI-97***	NEA 0974	MC high-energy p, n, pion reactions
NUCLEUS		nuclear spallation simulation and primary products
OPTMOD	IAEA1316	elastic & total x-section, polarisation calculations using the optical model
PACE2 **		codes performing the nuclear evaporation processes
PCROSS	IAEA1220	pre-equilibrium emission spectra in neutron reaction
PEGAS	IAEA1261	unified model of particle and gamma emission reactions
PEQAG-2	IAEA1185	pre-equilibrium model nucleon, gamma spectra, x-section
PHENOM/BCS-COLL	IAEA1327	nuclear level density of excited nuclei
PREANG	NEA 0809	nuclear model particle spectra, angular distribution
PRECO-D2	PSR-0226	pre-equilibrium, direct reaction double differential x-section
PRECO-2000***	PSR-0226/01	pre-equilibrium, direct reaction double differential x-sections
PREM	NEA 0888	nucleon emission pre-equilibrium energy spectra, x-section
QMD		intra-nuclear cascade and classical molecular dynamics
RAF	IAEA1350	neutron and proton radiative capture differential and integrated cross-section
REAC	CCC-0443	activation and transmutation
REAC-2	NESC9554	nuclide activation, transmutation
REAC*3	CCC-0443	isotope activation & transmutation in fusion reactors
SCAT-2B***	NEA-0829	spherical optical model for light particles and heavy ions
SOURCES4A	CCC-661	determine (α,n), spontaneous fission and (β,n) delayed
SPEC	IAEA1332	computation of neutron and charged particle reactions using optical and evaporation models
STAPRE-H95	IAEA0971	evaporation, pre-equilibrium model reaction x-sections
STAPREF***	NEA-0461	nuclear reactions cross-sections by evaporation model, gamma-cascades
TNG1	PSR-0298	N multi-step statistical model

UNIFY	IAEA1177	fast n x-section, spectrum calculation for structural materials

Table 4a. Monte Carlo (MC) and deterministic radiation transport (neutron/photon)

Name	Identification	Function
ALBEDO	NEA 1353	gamma, neutron attenuation in air ducts
ANISN	CCC-0254	1-D Sn, n, gamma transport in slab, cylinder, sphere
ASOP	CCC-0126	1-D Sn shield calculation
BALTORO	NEA 0675	n, gamma transport perturbation from MORSE, ANISN calculation
BASACF	IAEA0953	integral neutron adjustment and dosimetry
BERMUDA	NEA 0949	1-D,2-D,3-D n gamma transport for shielding
BREESE	PSR-0143	distribution function for MORSE from albedo data
CARP-82	PSR-0131	multigroup albedo data using DOT angular flux results
COLLI-PTB	NEA 1126	MC n fluence spectra for 3-D collimator system
DANTSYS	CCC-0547	1-D, 2-D, 3-D Sn neutron, photon transport
DASH	CCC-0366	void tracing Sn - MC COUPLING with fluxes from DOT
DCTDOS	CCC-0520	n, gamma penetration in composite duct system
DOORS3.2	CCC-0650	discrete ordinates system for deep penetration neutron and gamma transport
DORT	CCC-0543	1-D 2-D Sn n, photon transport with deep penetration
DOMINO	PSR-0064	coupling of Sn DOT with MC MORSE
DOT	CCC-0276	2-D Sn n, photon transport with deep penetration
DUST	CCC-0453	albedo MC simulation of n streaming inducts
FALSTF	CCC-0351	n, gamma flux detector response outside cylindrical shields
FEM-RZ	NEA 0566	FEM 2-D multi-group n transport in r-z geometry
GBANISN	CCC-0628	1-D neutron & gamma fluxes with group band fluxes
GEANT-CERN		MC hadron shower simulation
LAHET 2.8 ***	CCC-696	Code System for High Energy Particle Transport Calculations
MAGIK	CCC-0359	MC induced residual activation dose rates
MCB***	NEA ????	A continuous energy Monte Carlo burnup simulation code
MCNP-4A	CCC-0200	MC 3-D time-dependent coupled n, photon, electron transport
MCNP-4B	CCC-0660	MC 3-D time-dependent coupled n, photon, electron transport
MCNP-4B2	CCC-0660	MC 3-D time-dependent coupled n, photon, electron transport
MCNP-4C2***	CCC-0701/00	MC 3-D time-dependent coupled n, photon, electron transport
MCNPX 2.1.5***	CCC-705/00	The LAHET/MCNP Code merger
MICAP	PSR-0261	MC ionisation chamber responses
MORSE-CGA	CCC-0474	MC n, gamma multi-group transport
PALLAS-2DY	NEA 0702	2-D n ,gamma transport for fixed source
RADHEAT-V3	NEA 0467	transport, heat, radiation damage x-sections in reactor, shield
QAD-CGGP-A	CCC-0645	fast neutron and gamma ray penetration in shields
RAID	CCC-0083	gamma, n scattering into cylindrical or multi-bend duct
SAMSY	IAEA0837	n, gamma dose rates, heat source for multi-layer shields
SAM-CE	CCC-0187	MC time-dependent 3-d n ,gamma transport in complex geometry
SCINFUL	PSR-0267	MC response of scintillation neutron detector (incident neutron energies from 0.1 to 75 MeV)
SCAP-82	CCC-0418	scattering, albedo, point-kernel anal. in complex geometry
SNL/SAND-II	PSR-0345	enhanced version of SAND-II
SPACETRAN	CCC-0120	radiation leakage from cylinder with ANISN flux
SPECTER-ANL	PSR-0263	n damage for material irradiation
STAPREF***	NEA-0461	nuclear reactions cross-sections by evaporation model, gamma-cascades
STARCODE S	PSR-0330	stopping power, ranges for electrons, protons, alpha
TART2000***	CCC-638/01	3D MC transport program for neutrons and photons
TDTORT***	CCC-709/00	time-dependent, three-dimensional, discrete ordinates, neutron transport code system
TORT	CCC-0543	3-D Sn n, photon transport with deep penetration
TRANSX	PSR-0317	code to produce neutron, photon transport tables for discrete ordinates and diffusion codes
TRIPOLI-2	NEA 0874	MC time-dependent 3-D n, gamma transport
TWODANT-SYS	CCC-0547	1-D,2-D multi-group Sn n, photon transport
VIRGIN	IAEA0932	uncollided neutron flux and neutron reactions due through a neutron beam through any thickness of material

Table 5a. Monte Carlo (MC) and deterministic radiation transport (photon)

Name	Identification	Function
AIRSCAT	CCC-0341	dose rate from gamma air scattering, single scat. approx.
GAMMONE	NEA 0268	MC gamma penetration from various geometrical sources
MERCURE-4	NEA 0351	MC 3-D gamma heating/gamma dose rate, fast flux
PLACID	CCC-0381	MC gamma streaming in cylindrical duct shields
BRHGAM	CCC-0350	MC absorbed dose from x-rays in phantom
BREMRAD	CCC-0031	external/internal bremsstrahlung
GRPANL	PSR-0321	germanium gamma and alpha detector spectra unfolding
G33-GP	CCC-0494	multi-group gamma scattering using gp build-up-factor
ISO-PC	CCC-0636	kernel integration code system for general purpose isotope shielding
MAGNA	NEA 0163	dose rates from gamma source in slab or cylindrical shell shields
MARMER	NEA 1307	point-kernel shielding, ORIGEN-S nuclide inventories
PELSHIE	IAEA0855	dose rates from gamma source, point-kernel method
PIPE	NEA 0416	1-D gamma transport for slab, spherical shields
PUTZ	CCC-0595	point-kernel 3-d gamma shielding
SKYSHINE-KSU***	CCC-0646/03	computation of gamma skyshine doses by different methods
STAC-8		transmitted, absorbed power/spectrum – synchrotron radiation
UNSPEC	ESTS0827	x-ray spectrum unfolding using an iterative technique

Table 6a. Monte Carlo (MC) and deterministic radiation transport (electron/photon)

Name	Identification	Function
BETA-2B	CCC-0117	MC time-dependent bremsstrahlung, electron transport
BETA-S3.1	CCC-0657	calculates beta decay source terms and energy spectra
CASCADE	CCC-0176	high energy electron-photon transport in matter
CEPXS ONELD	CCC-0544	1-D coupled electron photon multi-group transport
DOSDAT-2	DLC-0079	gamma, electron dose factors data lib. for body organs
EDMULT	NEA 0969	electron depth dose in multi-layer slab absorbers
EGS4	CCC-0331	MC electron photon shower simulation
ELBA	CCC-0119	bremsstrahlung dose from electron flux on Al shield
EPICSHOW-96.1	IAEA1285	interactive viewing of the electron-photon interaction (10 eV < E < 1 GeV)
ESTAR	IAEA1282	calculates stopping power and range for electrons
ETRAN	CCC-0107	MC electron, gamma transport with secondary radiation
ELTRAN	CCC-0155	MC 1-D electron transport
FOTELP	CCC-0581	MC photons, electrons and positron transport
FOTELP/EM	CCC-0581	MC photons, electrons and positron transport
FOTELP/2KG***	IAEA 1388/01	Photons, electrons and positrons transport in 3D by Monte Carlo techniques
INFLTB	PSR-0313	dosimetric mass energy transfer and absorption coefficients
ITS-3.0	CCC-0467	MC tiger system of coupled electron photon transport
MCNP-4A	CCC-0200	MC 3-D time-dependent coupled n, photon, electron transport
MCNP-4B	CCC-0660	MC 3-D time-dependent coupled n, photon, electron transport
MCNP-4C2***	CCC-0701	MC 3-D time-dependent coupled n, photon, electron transport
PENELOPE 2001***	NEA 1525	Monte Carlo code for electron-photon transport
SANDYL	CCC-0361	MC 3-D time-dependent gamma electron cascade transport

Table 7a. Monte Carlo (MC) and deterministic radiation transport (proton)

Name	Identification	Function
ASTROS	CCC-0073	primary/secondary proton dose in sphere/slab tissue
LPPC	CCC-0051	proton penetration, slab
PSTAR	IAEA1282	calculates stopping power and range for protons
PTRAN	CCC-0618	MC proton transport for 50 to 250 MeV
SOURCE **		description of the proton transmission and generation of n source
SRNA-2KG***	IAEA 1382/01	proton transport using 3d by Monte Carlo techniques
TRAPP	CCC-0205	proton and alpha transport, reaction products neglected

Table 8a. Monte Carlo (MC) and deterministic radiation transport (alpha)

Name	Identification	Function
ALDOSE	CCC-0577	absorbed dose and dose equivalent rates as function of depth in water irradiated by alpha source
ALPHN	CCC-0612	(alpha,n) production rate in a mixture from alpha emitting actinides
ASTAR	IAEA1282	calculates stopping power and range for alphas
GRPANL	PSR-0321	germanium gamma and alpha detector spectra unfolding
RADCOMPT	PSR-0348	sample analysis for alpha and beta dual channel detectors

Table 9a. Monte Carlo (MC) and deterministic radiation transport (nucleons/hadrons/cascades)

Name	Identification	Function
CALOR95		MC system for design, analysis of calorimeter system
CASIM	NESC0742	MC high energy cascades in complex shields
FLUKA	CCC-0207	MC high energy extranuclear hadron cascades
GEANT-CERN		MC hadron shower simulation
HERMES-KFA	NEA 1265	MC high-energy radiation transport
HERMES96b		idem
HETCNMTC-97	CCC-0178	MC high energy nucleon meson cascade transport
HETC-KFA	CCC-0496	MC high energy nucleon-meson cascade transport
LAHET 2.8 ***	CCC-696	code system for high energy particle transport calculations
LPSC	CCC-0064	p, n flux, spectra behind slab shield from p irradiation
NMTC/JAERI97***	NEA 0974	MC high-energy p, n, pion reactions
SITHA **	IAEA1179	simulation transport hadron, used to calculate hadron transport
SHIELD ***	IAEA1287	hadron cascades in complex macroscopic targets

Table 10a. Monte Carlo (MC) and deterministic radiation transport (heavy ions)

Name	Identification	Function
E-DEP-1	CCC-0275	heavy ion energy deposition
ELPHIC-PC	IAEA1223	statistical model MC simulation of heavy ion reaction
HIC-1	CCC-0249	MC heavy ion reactions at E > 50 MeV/nucleon
STRAGL	CCC-0201	energy loss straggling of heavy charged particles
SWIMS	ESTS0682	angular dispersion of ion beams at small-angle incoherent multiple scattering by gaseous or solid media
TRIPOS	CCC-0537	MC ion transport

Table 11a. Monte Carlo (MC) and deterministic radiation transport (muons)

Name	Identification	Function
MUONLM	NEA 1475	calorimeter interaction of muons

Table 12a. Monte Carlo (MC) and deterministic radiation transport (other cascades)

Name	Identification	Function
CHARGE-2/C	CCC-0070	electron, p, heavy particle flux/dose behind shield
DDCS	IAEA1290	neutron, proton, deuteron, triton, He3, and alpha induced reactions of medium heavy nuclei in the energy range up to 50 MeV
ELPHO	CCC-0301	MC muon, electron, positron generation from pions
IMPACTS-BRC	ESTS0005	radiological assessment code
JENKINS		photon, neutron dose in electron accelerator
PICA	CCC-0160	MC nuclear cascade reactions by the collision of photons (30 < E < 400 MeV) with nuclei
SPARES	CCC-0148	space radiation environment and shielding evaluation

Table 13a. Monte Carlo (MC) and deterministic radiation transport (anthropomorphic phantom modelling)

Name	Identification	Function
BRHGAM	CCC-0350	MC absorbed dose from x-rays in phantom
CAMERA	CCC-0240	radiation transport and computerised man model
DISDOS	CCC-0170	dose from external photons in phantom
K009	CCC-0062	charged particle penetration – phantom
MEVDP	CCC-0157	radiation transport in computerised anatomical man
MIRDOSE3.1	CCC-0528	calculate internal dose estimates by the MIRD technique
MRIPP 1.0	CCC-0655	magnetic resonance image phantom for *in vivo* measurements
PENELOPE 2001***	NEA 1525	Monte Carlo code for electron-photon transport
PEREGRINE **		used to model dose to humans from radiation therapy
REBEL-3	IAEA0846	MC radiation dose to human organs
REPC	PSR-0195	dose from protons in tissue
SEECAL	CCC-0620	computes age-dependent effective energies for 54 and 32 target regions in the human body (825 radionuclides)

Table 14a. Benchmark data relative to Reactor Shields* sets included in the SINBAD database

Name	Description
ASPIS-FE	Winfrith Iron Benchmark Experiment (ASPIS)
ASPIS-FE88	Winfrith Iron 88 Benchmark Experiment (ASPIS)
ASPIS-GRAPHITE	Winfrith Graphite Benchmark Experiment (ASPIS)
IPPE- BTiH	**IPPE Fast n/γ through BTiH Prism**
Winfrith H2O	Winfrith Water Benchmark Experiment
Winfrith PCA-REPLICA	Winfrith Water/Iron Benchmark Experiment
Winfrith NESDIP-2	Radial Shield of a PWR
Winfrith NESDIP-3	Radial Shield w/Cavity and Backing Shield of a PWR
Winfrith Water/Steel	**Winfrith Neutron-Gamma Ray Transport through Water/Steel Arrays (ASPIS)**
EURACOS-FE	Ispra Iron Benchmark Experiment (EURACOS)
EURACOS-NA	Ispra Sodium Benchmark Experiment (EURACOS)
HARMONIE-NA	Cadarache Sodium Benchmark Experiment (HARMONIE)
HB Robinson II	**HB Robinson-2, Cycle 9 (US NRC PV Benchmark)**
JANUS-I	Fast Reactor w/Mild Steel, SS, and Concrete -Phase I
JANUS-VIII	Fast Reactor w/ Mild Steel, SS, Sodium, Polyethylene, Lead
KFK-FE	Karlsruhe Iron Sphere Benchmark Experiment
PROTEUS-FE	Wuerenlingen Iron Benchmark Experiment
PCA-PV	Pool Critical Assembly - Pressure Vessel Experiment (PCA
SDT1	Iron Broomstick Benchmark Experiment (TSF-ORNL)
SDT2	Oxygen Broomstick Benchmark Experiment (TSF-ORNL)
SDT3	Nitrogen Broomstick Benchmark Experiment (TSF-ORNL)
SDT4	Sodium Broomstick Benchmark Experiment (TSF-ORNL)
SDT5	Stainless Steel Broomstick Benchmark Experiment (TSF-ORNL)
SDT 11	ORNL Neutron Transport in Iron and SS
SDT 12	ORNL Neutron Transport in Thick Sodium
SB2	Gamma Production Cross-Sections from Thermal Neutrons
SB3	Gamma Production Cross-Sections from Fast Neutron in 14 elements and SS
JASPER Axial Shield	Fast Reactor w/SS, B4C
JASPER Radial Shield	Fast Reactor w/SS, Graphite, B4C, and Sodium
JASPER Int. Heat Exch.	Fast Reactor w/Sodium, Spent Fuel, and B4C
Illinois Iron Sphere	Univ. of Illinois Iron Sphere

Table 15a. Benchmark data sets relative to Fusion Shielding and Accelerator Shielding included in the SINBAD database

Name	Description
FNS- Graphite	**FNS Graphite Cylindrical Assembly**
FNS-Vanadium	**FNS Vanadium block**
OKTAVIAN-Fe	Osaka Iron Sphere Benchmark Experiment
OKTAVIAN-Ni	Osaka Nickel Benchmark Experiment
OKTAVIAN-Al	Osaka Leakage Neutron and Gamma Spectra from Aluminum Sphere Pile
OKTAVIAN-Si	**Osaka Silicon Sphere Experiment**
TUD Iron Slab	TU Dresden Iron Slab
TUD FNG Bulk Shield	TU Dresden FNG Bulk Shield
SB5	ORNL 14-MeV Neutron Stainless-Steel/Borated Polyethylene Slab Experiment
ENEA Bulk SS	FNG SS Bulk Shield Benchmark Experiment (Frascati)
ENEA Blanket	FNG ITER Blanket (VV+First Wall+Shield+TF Coil) (Frascati)
Accelerators:*	
U. of Tokyo INS	Intermediate Energy Neutrons and Gamma-rays on Shielding Materials – 52 MeV and 65 MeV Protons **MCNPX Benchmark Calculation Number 4 Rev. 0.0.1Penetration Through Shielding Materials of Secondary Neutrons and Photons Generated by 52-MeV Protons**
Osaka U. AVF	Penetration of Secondary Neutrons and Photons through Concrete, Fe, Pb, and C **MCNPX Benchmark Calculation Number 2 Rev. 0.0.1 Transmission Through Shielding Materials of Neutron and Photons Generated by 65-MeV Protons**
Osaka U. AVF	**MCNPX Benchmark Experiment Number 3 Rev. 0.0.1 (75 MeV protons) Transmission of Medium Energy Neutrons Through Concrete Shields (1991)**
TIARA	**TIARA 40 and 65 MeV Neutron Transmission Through Iron, Concrete and Polyethylene**
U. of Tokyo, INS	**MCNPX Benchmark Experiment Number 5 Rev. 0.0.1 Neutron Production from Thick Targets of Carbon, Iron, Copper, and Lead by 30- and 52-MeV Protons(1982)**
Swiss SINR	**MCNPX Benchmark Experiment Number 1 Rev. 0.0.1 -High Energy Neutron Spectra Generated by 590-MeV Protons on a Thick Lead Target (1979)**

*Bold indicates new SINBAD additions since the SATIF-5 meeting, July 2000.

-Appendix 2 -

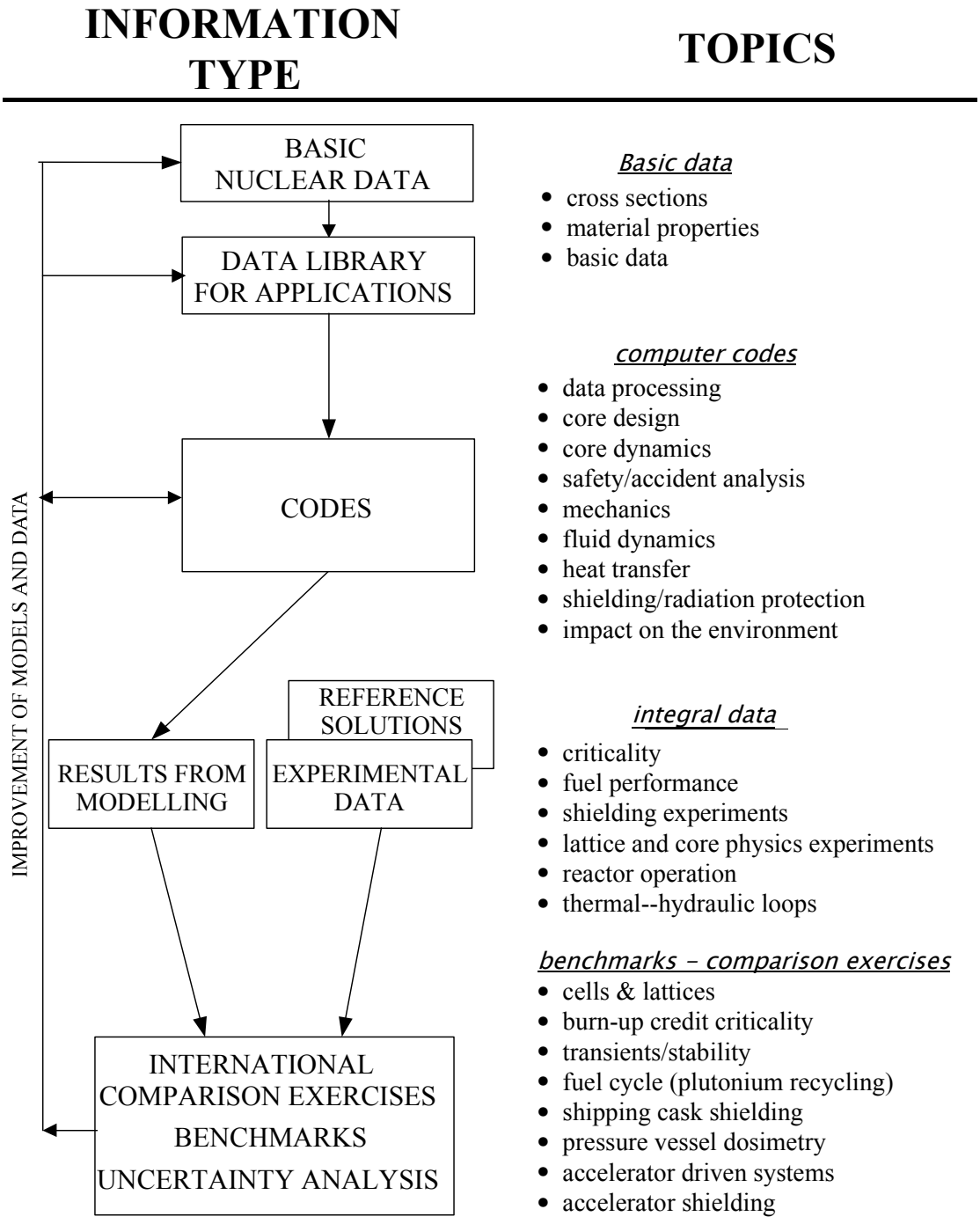

Figure 1b: Procedures, Data and Computer Codes for Model Validation and Improvement (Sartori, [7])