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A review of RSICC software for medical and health physics

Bernadette L. Kirk[a]

Radiation Safety Information Computational Center, Nuclear Science and Technology Division,
Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831-6171, USA

Abstract. The Radiation Safety Information Computational Center (RSICC) at Oak Ridge National Laboratory has been in the business of software maintenance, testing, and evaluation in the field of radiation transport and has promoted software development in the area of radiation transport for the last forty years. As a result, radiation transport software tools have been very useful in dose estimation and medical applications.

1 Introduction

RSICC's history as a center for the quality control of scientific software goes back to 1963, when it was established as an Information Analysis Center (IAC). It was then called Radiation Shielding Information Center (RSIC). In 1997, RSIC was named Radiation Safety Information Computational Center (RSICC) to better fit its role in computational applications.

RSICC collects, organizes, evaluates and disseminates technical information (software and nuclear data) involving the transport of neutral and charged particle radiation, and shielding and protection from the radiation associated with: nuclear weapons and materials, fission and fusion reactors, outer space applications, accelerators, medical facilities, and nuclear waste management. The Center provides in-depth coverage of radiation transport topics.

The concept of the "live" code package is basic to the RSICC philosophy of serving the user community. When a code is packaged, lines of communication are kept open with the contributor and with users. Proposed corrections by users, after being verified by the original contributor, and additions and modifications are made to the code package as long as the program is of interest. The user is encouraged to, and often does, feed back into the center the results of the conversion and/or modification/extension efforts.

An RSICC software "package" consists of an abstract, source code, sample problem input, sample problem output, documentation, and an executable program. RSICC packages are categorized according to Computer Code Collection (CCC), Peripheral Science Routine (PSR), and Data Library Collection (DLC). Software that tracks particles (neutrons, photons, protons, electrons, etc.) is classified as "CCC". Software that does not directly track particles, but is used as a tool, for example plotting, is classified as "PSR". Nuclear cross section data form the "DLC" collection.

2 Medical and health physics software

The paper is a synopsis of various computer code and nuclear data packages, maintained, tested and distributed by RSICC, used for medical and health physics dosimetry applications. The information is a subset of the total RSICC collection (see the RSICC web site http://rsicc.ornl.gov). The software and data packages are discussed in several categories. The listing is by no means exhaustive.

2.1 Radiation transport, shielding, and supporting codes for radiation therapy

EGS4: Monte Carlo Simulation of the Coupled Transport of Electrons and Photons (CCC-331) [1], is perhaps the most widely used transport code for medical applications. The EGS code system is one of a chain of three codes designed to solve the electromagnetic shower problem by Monte Carlo simulation.

MCNP5/MCNPX: Monte Carlo N-Particle Transport Code System (CCC-730) [2], one of the most widely used general-purpose Monte Carlo transport codes, MCNP5/MCNPX can treat coupled neutron-photon-electron problems. The software comes with an extensive collection of cross-section data.

MRIPP 1.0: Magnetic Resonance Image Phantom Code System to Calibrate *in vivo* Measurement Systems (CCC-655) [3], includes a database of human phantoms that were constructed from magnetic resonance imaging (MRI) scans. A modified voxel version of MCNP4A is used for the Monte Carlo transport.

SABRINA 3.54: Three-Dimensional Geometry Visualization Code System (PSR-242) [4], is used for visualization and verification of MCNP geometries. SABRINA is an interactive, three-dimensional, geometry-modeling code system, primarily for use with MCNP.

DOORS 3.2: One, Two- and Three-Dimensional Discrete Ordinates Neutron/Photon Transport Code System (CCC-650) [5], consists of 3 major codes – TORT, DORT and ANISN. TORT calculates the flux or fluence of particles due to particles incident upon the system from extraneous sources or generated internally as a result of interaction with the system in two- or three-dimensional geometric systems.

PENELOPE: PENetration and Energy LOss of Positrons and Electrons (CCC-682) [6], performs Monte Carlo

[a] Presenting author, e-mail: kirkbl@ornl.gov

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simulation of electron-photon showers in arbitrary materials. PENELOPE generates random electron-photon showers in complex material structures consisting of any number of distinct homogeneous regions (bodies) with different compositions.

ITS 3.0: Integrated TIGER Series of Coupled Electron/Photon Monte Carlo Transport Codes System (CCC-467) [7], permits a state-of-the-art Monte Carlo solution of linear time-integrated coupled electron/photon radiation transport problems with or without the presence of macroscopic electric and magnetic fields of arbitrary spatial dependence.

TART2002: Coupled Neutron-Photon, 3-D, Combinatorial Geometry, Time Dependent, Monte Carlo Transport Code System (CCC-638) [8], is a coupled neutron-photon Monte Carlo transport code designed to use three-dimensional (3-D) combinatorial geometry.

ETRAN: Monte Carlo Code System for Electron and Photon Transport Through Extended Media (CCC-107) [9], computes the transport of electrons and photons through plane-parallel slab targets that have a finite thickness in one dimension and are unbound in the other two dimensions.

QAD-CGGP-A: Point Kernel Code System for Neutron and Gamma-Ray Shielding Calculations Using the GP Build up Factor (CCC-645) [10], is a point-kernel code for calculating fast-neutron and gamma-ray penetration through various shield configurations defined by combinatorial geometry specifications.

CEPXS/ONELD 1.0: One-Dimensional Coupled Electron-Photon Multigroup Discrete Ordinates Code System (CCC-544) [11], generates cross sections to be input to the ONELD code, one-dimensional coupled electron-photon transport code. CEPXS/ONELD has been used for computing source spectra in medical LINAC targets.

SERA-1C0: Simulation Environment for Radiotherapy Applications (CCC-729) [12], was developed for boron-neutron capture therapy (BNCT) patient treatment planning.

2.2 Codes devoted to medical X-ray calculations

BRHGAM: Monte Carlo Estimation of Absorbed Dose from X-Ray Sources in Phantom Man (CCC-350) [13], is a modified version of the ALGAM (Monte Carlo Estimation of Internal Dose from Gamma-Ray Sources in a Phantom Man) code that models an external X-ray source in the energy range 20 to 150 keV.

KUX: Medical X-Ray Shielding Calculation (CCC-515) [14], calculates the thickness of shield required to bring the weekly exposure near an X-ray or mammography room to a specified level, using the NCRP Report No. 49 X-ray shielding methodology.

CALKUX: Code System to Calculate Exposure Transmission of Medical X-Ray Beams through Barrier Materials (CCC-594) [15], performs a variety of calculations related to the transmission of medical diagnostic X-ray beams through common shielding materials.

NCRP49: X-Ray Shield Calculation System (CCC-462) [16], will calculate the primary and/or secondary leakage/scatter barrier requirements (in millimeters of lead) for diagnostic radiographic and/or fluoroscopic X-ray units operating at 50, 70, 100, 125 or 150 kV, using the methodology of NCRP Report No. 49 and the method of Douglas and Archer et al. [17, 18].

XSHLD: Diagnostic X-Ray Shielding Calculation (CCC-495) [19], will calculate the primary and/or secondary leakage/scatter barrier requirements for diagnostic radiographic and/or fluorescent X-ray units operating at 50, 70, 100, and 150 kVp, using the methodology described by McGuire.

2.3 Codes for internal and external dose calculations

GENII-LIN: Multipurpose Health Physics Code System with a New Object-Oriented Interface, Release 2.0 (CCC-728) [20, 21], includes capabilities for calculating radiation dose both for acute and chronic releases, with options for annual dose, committed dose and accumulated dose capabilities for evaluating exposure pathways including direct exposure via water (swimming, boat, fishing), soil (buried and surface sources) and air (semi-infinite cloud and finite cloud model), inhalation pathways and ingestion pathways.

RBD: US Army Radiological Bioassay and Dosimetry Software Package, Version 4.1 (CCC-632) [22], computes the quantity of a radionuclide taken into the body by inhalation, ingestion, or uptake from a wound, based on measurements of the retained activity in the body or its appearance in excreta, i.e., bioassay measurements, for both acute and chronic intakes.

REPC: Estimation of Nuclear Reaction Effects in Proton-Tissue-Dose Calculations (PSR-195) [23], reviews calculational methods for the estimation of dose from external proton exposure of arbitrary convex bodies and presents the necessary information for the estimation of dose in soft tissue.

VARSKIN 3: Computer Code System to Assess Skin Dose from Skin Contamination, Version 3.0.1 (CCC-522) [24], calculates the radiation dose (gamma and beta) to skin from radioactive contamination of skin or protective clothing.

2.4 Data collections and supporting codes useful in nuclear medicine

DECDC 1.0: Nuclear Decay Data Files for Radiation Dosimetry Calculations (DLC-213) [25], contains two groups of data, namely, Publ38 and Non-Publ38. Where, "Publ38" contains 817 radionuclides that are listed in ICRP Publication 38 and for 6 additional isomers; and "Non-Publ38" contains the data files for the radionuclides with half-lives greater than or equal to 10 min that are not listed in Publ38.

NUCDECAY: Nuclear Decay Data for Radiation Dosimetry Calculations for ICRP and MIRD (DLC-172) [26], is a compilation of decay data (energies and intensities of emitted radiations, including beta spectra) to address the needs of occupational, environmental, and medical radiation protection.

NucDecayCalc: Nuclear Decay Data for Radiation Dosimetry Calculations for ICRP (DLC-202) [27], with data identical to the ICRP database of 825 (+13) radionuclides in the NUCDECAY package.

EDISTR: Prepares a Nuclear Decay Data Base for Internal Radiation Dosimetry Calculations (PSR-191) [28]. Using radioactive decay data from the Evaluated Nuclear Structure

Data File (ENSDF), EDISTR computes the mean energies and absolute intensities of all principal radiations associated with the radioactive decay of a nuclide, as well as beta spectra.

2.5 Codes and data collections dealing with the microdosimetry of radiation therapy

ICOM: Code System for Calculating Ion Track Condensed Collision Model (CCC-651) [29], calculates the transport characteristics of ion radiation for application to radiation protection, dosimetry and microdosimetry, and radiation physics of solids.

ALDOSE: Dose Calculation for Alpha Disc Source (CCC-577) [30], calculates the absorbed dose rate, dose-rate equivalent rate, and dose-weighted LET as functions of depth in water irradiated by a uniform alpha disk source.

UMIBIO: Code System to Model Uranium Mills Bioassay Dosimetry (CCC-680) [31], is an internal dosimetry model developed for estimation of the urinary concentration of natural uranium excreted at various times after an inhalation exposure to yellowcake (dried at high and at low temperatures) or ore dust.

3 Medical and health physics application areas of RSICC software include:

- Dosimetry calculations for radiation therapy,
- Treatment planning in radiation oncology,
- Design of photon and secondary neutron shielding for therapy rooms,
- Evaluating and estimating patient and staff radiation dose,
- Electron beam transport and energy deposition,
- Secondary gamma transport and energy deposition,
- Secondary neutron transport and energy deposition,
- Cancer brachytherapy dosimetry,
- Medical imaging applications, including SPECT, PET, and x-ray imaging,
- Accurate physics and geometry models,
- Body composition research,
- Data in variance reductions for radiation oncology,
- Error evaluations for accelerator particle delivery systems,
- Diagnostic imaging,
- Modalities of treatment and exploration of alternatives,
- Licensing and safety analysis for medical radiation facilities,
- Clinical radiation transport,
- Dosimetric consequences,
- Medical diagnostics and therapy,
- Experimental benchmarks in medical physics model and data validation, and
- Determination of medical linear accelerators (LINAC) source spectra, and scattered radiation from LINAC head.

4 Conclusion

In the forty years of its existence, RSICC has established itself as a repository for codes and data libraries in the area of radiation transport supporting research and development in fission and fusion reactors, outer space applications, accelerators, weapons, medical facilities, and nuclear waste management and varied medical applications, especially in radiation therapy modeling.

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