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STATUS OF THE MORSE MULTIGROUP MONTE CARLO RADIATION TRANSPORT CODE

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ABSTRACT

There are two versions of the MORSE multigroup Monte Carlo radiation transport computer code system at Oak Ridge National Laboratory. MORSE-CGA is the most well-known and has undergone extensive use for many years. MORSE-SGC was originally developed in about 1980 in order to restructure the cross-section handling and thereby save storage. However, with the advent of new computer systems having much larger storage capacity, that aspect of SGC has become unnecessary. Both versions use data from multigroup cross-section libraries, although in somewhat different formats. MORSE-SGC is the version of MORSE that is part of the SCALE system, but it can also be run stand-alone. Both CGA and SGC use the Multiple ARray System (MARS) geometry package.

In the last six months the main focus of the work on these two versions has been on making them operational on workstations, in particular, the IBM RISC 6000 family. A new version of SCALE for workstations is being released to the Radiation Shielding Information Center (RSIC). MORSE-CGA, Version 2.0, is also being released to RSIC. Both SGC and CGA have undergone other revisions recently. This paper reports on the current status of the MORSE code system.

HISTORY OF MORSE DEVELOPMENT

There are two versions of the MORSE[1-3] Monte Carlo radiation transport computer code system at Oak Ridge National Laboratory: MORSE-CGA and MORSE-SGC. Both will be discussed in this presentation. MORSE-CGA is the most well-known version, and it has undergone extensive use for many years. Known simply as MORSE, originally it was developed in the 1968 time frame in response to the need for a Monte Carlo code with multigroup cross sections. This need came about partially because the discrete-ordinates codes ANISN[4] and DOT[5] used multigroup data, and a similar three-dimensional (3-D) code would allow direct comparison of results between these codes without having to determine whether cross-section differences were causing discrepancies. The original version of this multipurpose neutron and gamma-ray transport code used the O5R-type of geometry packages, such as general geometry, spherical geometry, cylindrical geometry, and slab geometry. MORSE solves neutron, gamma-ray, or coupled neutron-gamma-ray problems in both forward and adjoint modes. PICTURE, which makes two-dimensional (2-D) printer plots of the geometry mockups, was the only peripheral code available with this version. The MORSEC cross-section package and the SAMBO analysis package were installed in 1971. At about the same time, a collision density analysis package was made available to MORSE users.[6]

In 1973, the O5R geometry package was replaced with the combinational geometry package, and the code was renamed MORSE-CG. In 1975, this version was documented in the report, ORNL-4972. The combinational geometry package was based on one previously developed by MAGI and was originally installed in the UNIVAC version of MORSE by Dr. Edward Straker of the Huntsville SAIC office.[7] This new geometry package made modeling complex geometries much easier.

MORSE was being used primarily for radiation transport in reactors until 1973 when calculations of radiation exposure to crews of military vehicles were needed. At that time a Vehicle Code System[8] (VCS) made up of DOT, VISA, MORSE, and DRC (a detector response code) was developed and packaged. This code, which was documented in ORNL/TM-4648 in 1974, underwent major revisions to become MORSE Adjoint SHielding (MASH) code which was published as ORNL/TM-11778.[9] This system used MORSE in the adjoint mode to solve problems where an event occurs at a long distance from a vehicle which may have various orientations relative to the event. That is to say, a collision tape produced by adjoint MORSE may be coupled with several DOT flux results by running DRC specifying different orientations.

Early in the development of the MORSE code system, it became obvious that there was a need for the capability to couple a 2-D discrete-ordinates calculation to a MORSE Monte Carlo calculation. This allows users to solve the simpler part of a geometric structure in two dimensions with a code like DOT (DORT) and then produce a source distribution or a scoring function for use in MORSE. The code that processes the 2-D fluxes from the DOT runs to form probability tables for source or estimation selection is called the Discrete Ordinates to Monte Carlo INterface Operation (DOMINO-II).[10] Since the DOT family of codes has been revised and renamed to DORT, DOMINO needs to be altered to process the newer flux tapes and to run on newer computer architectures such as workstations. This is currently in the planning stages.

The ability to run an albedo calculation with MORSE was made available with the development of CARP (1978)[11] and BREESE-II (1979).[12] CARP processes DOT angular flux tapes to produce albedo data that are used as input for BREESE-II which calculates cumulative distribution functions and writes an albedo tape used by MORSE. In 1991 a University of Tennessee graduate student modified the MORSE albedo option.[13] New albedo data were generated using the three-dimensional (3-D) discrete-ordinates code, TORT,[14] in order to remove the limitations on the data generated by the 2-D discrete- ordinates codes (DOT). These limitations involved the absence of a direction and a distance variable. Use of TORT allowed the inclusion of these two additional parameters. Several additional options were added to the MORSE/BREESE package, including the capability of running an albedo problem in the adjoint mode. This work resulted in a computer code package, MORSE/STORM, which serves merely as a "proof of principle." Results for the chosen sample problem were good, but the code would require additional work for more general application. One major concern is that the volume of data could be too large for practical use.

In 1983, ORNL 4972/R1 was published. It included a section of advice on running MORSE and a description of some new options. In 1985, a set of nine sample problems, including the two original sample problems, was released and published in ORNL 4972/R2. Also, in 1985, a report detailing how to apply MORSE to various problems was published.[15]

MORSE-SGC, which was published in 1981, had as its primary purpose the restructuring of the cross-section handling to save storage, but the next generation of large core computers nullified this need. The MARS[16] geometry package was originally developed for SGC; but because the SGC developers left ORNL while the code was not thoroughly checked out, and because of various problems that arose when users attempted to apply it, a decision was made to add the MARS geometry module to MORSE-CG, which was thoroughly checked out as a result of years of widespread use. Another factor was the desire to update and verify MARS. This development effort, which began in 1982, resulted in MORSE-CGA. MORSE-CGA has therefore been in use at ORNL since the early 1980s, and has been applied to extremely complicated geometries such as shipping casks and buildings.

In the last six months, the focus of the work on CGA and SGC has been on getting them operational on workstations. Version 2.0 of MORSE-CGA, which will run on several mainframes as well as on personal computers and IBM workstations, and a SCALE 4.1 version of MORSE-SGC have recently been released, and a workstation version of SCALE 4.1 for IBM RISC 6000 family will be available very soon.

FEATURES ASSOCIATED WITH MORSE SYSTEM

MORSE has many options and modes of operation. Some of the features associated with the MORSE system of computer codes are as follows:

- Applicable to both multiplying and non-multiplying media.
- Can operate in a fixed source or a k_{eff} eigenvalue mode.
- Operable in both forward and adjoint modes.
- Uses cross-section and/or albedo data in CGA.
- Treats regular and delta (fictitious) scattering.
- Can be coupled with discrete-ordinates codes (source and/or response mode coupling).
- Has available a general combinatorial geometry.
- Contains a multiple array nesting feature for finite or infinite geometry lattices.
- Has a 2-D geometry picture drawing capability.
- Includes many standard variance reduction techniques.
- Uses ANISN library multigroup cross- section and anisotropic scattering formats, including upscatter for any number of thermal energy groups.
- Can treat Klein Nishina, pair production, and photoelectric reactions for gamma-ray next-event estimation.
- CGA uses a history file for post-processing of results.
- Has a "user friendly" framework of routines and other aids which alleviate much of the effort necessary for user-written routines.
- Has a large library of "standard" user routines which may be used directly or serve as models for further modification.

- Is supported by a plethora of related literature and documentation describing the code, multigroup and general theory, programming details, debugging aids, error messages, sample problems, applications, interpretation of results, and other capabilities and limitations.

SIMILARITIES AND DIFFERENCES IN CGA AND SGC

Both CGA and SGC use data from multigroup cross-section libraries although in somewhat different formats. CGA uses an ANISN-type library whereas SGC uses an AMPX[17] working library. In either case the cross sections may be premixed (in earlier MORSE runs or, in the CGA case, by XCHEKR runs) and read from file IXTAPE. One difference in the two codes is that SGC contains no provision for running a neutron-gamma problem with a truncated number of neutron groups (e.g., CGA, when using a 22-group-neutron/18-group-gamma coupled cross-section set, could run 13 neutron groups and 17 gamma groups, but SGC must run all 22 neutron groups). The other major difference as far as cross sections are concerned is that CGA always has all cross-section data in core whereas SGC can have "n" groups in core at a time. Because of the availability of large amounts of core in the current generation of computers, it is unusual for SGC to fragment the groups.

Geometrically speaking, the two versions are identical—MARS is the geometry package in both. The MARS system allows the user to describe many rectangular cells of arbitrary content, called "universes." These universes can be arbitrarily combined to describe arrays. Arrays may contain sub-arrays, universes, and vacancies. Arrays may also be rotated.

One recent improvement to MARS was the implementation of a fix-up for fatal geometry errors which allows orderly termination of a problem for n-1 batches when such an error occurs in the nth batch. The change was initiated because of the occasional occurrence of geometry round-off errors that cause termination after significant amounts of CPU time have been expended. A new subroutine, RCOVER, was added to normalize results. Results printed for the "extra arrays of length ND" will include events that occurred in the current batch. There is no simple way to change this; and since these results are seldom, if ever, used, modification was not justified. Final tabulations of random walk statistics are not printed in this case because they would include the partial batch.

Another difference in SGC and CGA is that CGA requires user-written routines to describe the source and estimation techniques while SGC contains a set of default routines for these functions. Due to the long-time, widespread use of MORSE-CGA, many standard user routines exist and are distributed with the code; and they may be used directly or modified as needed. The user is responsible for altering subroutine BANKR in CGA to call the appropriate estimation routines (for example, RELCOL). Over the years of SGC use, occasions have arisen where its source and estimation routines have also required user intervention; therefore, this is no longer a clear-cut difference, although SGC allows the user to specify on input which routines to call rather than having him alter a set of call statements.

Both codes are now in FORTRAN-77. They are executable on many different computers. A master file for MORSE-CGA is operated on by a preprocessor named CFLAG that configures it for the computer requested by the user's input. MORSE-SGC is handled in a similar way by the preprocessor code COMMENT. CGA will run on IBM mainframes with MVS, on CRAY mainframes with UNICOS or CTSS (where available), on VAX VMS, on personal computers under Silicon Valley FORTRAN or MICROSOFT FORTRAN, and on the (UNIX- based) IBM RISC 6000 family. SGC has not been run on any personal computers but will run on IBM mainframes, CRAYs and IBM RISC workstations. Although MORSE-SGC is part of the SCALE system, it can also be run stand-alone; and it is part of the SAS3[18] and SAS4[19] sequences in SCALE. CGA has been converted to use all free-form FIDO-type input; SGC also uses a free-form FIDO-type input but allows some additional options. If the user executes the SAS3 or SAS4 sequence, the MORSE-SGC input utilizes a keyword input which allows the user to specify only the parameters that require change and utilizes default values for the others. A track-length estimator is now a standard estimator in CGA.

CONFIGURATION CONTROL

In the past there have been several versions of MORSE-CGA and MORSE-SGC that were set up as quality assured, or QA'd, systems. Efforts are currently underway to place both CGA and SGC under configuration control. There is a SCALE configuration control document, and many of the SCALE modules used for nuclear criticality safety are already handled in this way. Last year a verification was done for MORSE-SGC on a CRAY unicos system for the New Production Reactor (NPR) program, and a document was published describing that work.[20] A new effort is beginning related to software used for nuclear safety calculations at the plants operated by Martin Marietta Energy Systems, Inc.

SAMPLE PROBLEMS

MORSE-CGA has a set of nine sample problems that illustrate neutron only, gamma only, combined neutron-gamma, adjoint mode, multiplying systems (k-effective calculations), several types of estimators, PICTURE, and XCHEKR. In 1992 four of these problems were adapted to MORSE-SGC and used to help verify the Unicos version of SGC. MORSE-SGC now has seven sample problems. Results of the sample problems are distributed with the code.

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