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CARI Documentation: User's Guide

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Final Report

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LIST OF ABBREVIATIONS

CARI	Civil Aviation Research Institute
CAMI	Civil Aerospace Medical Institute
CPU	Central processing unit
CR	Cosmic radiation
GCR	Galactic cosmic radiation
GLE	Ground level event
GFZ	German Research Center for Geosciences
GPU	Graphics processor unit
ICAO	International Civil Aviation Organization
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation Units and Measurements
ISO	International Standards Organization
<i>MCNPX</i>	<i>Monte Carlo N-Particle eXtended</i>
<i>NASA</i>	<i>National Aeronautics and Space Administration</i>
<i>NCRP</i>	<i>National Council on Radiation Protection and Measurement</i>
<i>NOAA</i>	<i>National Oceanic and Atmospheric Administration</i>
NRC	Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Administration
ORNL	Oak Ridge National Laboratory
SCR	Solar cosmic radiation
SPE	Solar proton event
TGF	Terrestrial gamma-ray flash

EXECUTIVE SUMMARY

This report is a guide to the use and maintenance the CARI-7 programs (CARI-7 and CARI-7A). Primary cosmic radiation from both the Sun and interstellar space enters Earth's atmosphere in varying amounts, As a result, aircrews and passengers are exposed to ionizing radiation in amounts that depend on severable variables. Outside of Earth's atmosphere, cosmic radiation is modulated by solar activity and Earth's magnetic field. Once the radiation enters Earth's atmosphere, it interacts with Earth's atmosphere in the same manner regardless of its point of origin (solar or galactic). CARI (Civil Aeromedical Research Institute [this is the acronym for a previous name of what is now known as the Civil Aerospace Medical Institute, or CAMI]) software for calculation of doses of ionizing radiation in the atmosphere from cosmic radiation has been in development at CAMI the since the late 1980s. While CARI-7 handles the data in the way most consistent with the Monte Carlo simulations, CARI-7A offers added options for users in the handling of these data.

CARI Documentation: User's Guide

INTRODUCTION

CARI (Civil Aviation Research Institute [this is the acronym for a previous name of what is now the Civil Aerospace Medical Institute, or CAMI]) software for calculation of doses of ionizing radiation in the atmosphere from cosmic radiation (CR) has been in development at CAMI since the late 1980s. The sixth generation family of CARI programs (CARI-6, -6M, -6P, -6PM, and 6W, hereafter referred to collectively as CARI-6) is well proven at aviation altitudes and has been used for many years for aircrew dosimetry in many countries. However, in the uppermost atmosphere, CARI-7 is more accurate than earlier versions because of its superior nuclear breakup modelling. In CARI-6 all primary nuclei were broken apart before transport through the atmosphere, while in CARI-7 the primary nuclei and intermediate mass fragments were tracked in the nuclear cascade. Also CARI-6 variants were usually limited to a single output, International Commission on Radiological Protection (ICRP) effective dose based on their 1990 recommendations (ICRP, 1991), and did not have the most up-to-date geomagnetic data.

There are two publically available versions of CARI-7, -7 and -7A (Copeland, 2014; 2017a). Following the first release of CARI-7 in 2014, user feedback indicated the number of options was an unwanted burden for users who simply wanted to upgrade from CARI-6. Development was thus divided into two branches, -7 and -7A. For CARI-7A most of the developer options remained included as user choices, while for CARI-7 the option set was reduced to what was operationally useful: many options were set to what was deemed the most reasonable choice for users in order to minimize transition problems when they upgraded from CARI-6 to CARI-7.

To calculate a cosmic radiation related quantity such as dose rate at any point in the atmosphere for any date and time, two questions must be answered: (a) what cosmic radiations are entering at the top of the atmosphere for any given day and time, and (b) what dose rate results from the answer to the first question for that day and time for the location in the atmosphere under consideration. In CARI-7 these problems are solved independently. In the first three CARI-7 documentation reports, the methods used to arrive at the incident cosmic radiation spectrum entering Earth's atmosphere, cosmic radiation transport in the atmosphere, and particle fluence-to-dose conversion are discussed (Copeland 2019; 2021a; 2021b). The primary descriptions of the development and validation of the programs through October 2016 are in Copeland (2014) and Copeland (2017a), with more recent developments in Atwell and Copeland (2019) and Matthias et al. (2018)

CARI-7 calculates the dose (or any of several other quantities) from galactic cosmic radiation received by an adult on a nonstop aircraft flight on any date from January 1958 to the present. It can also calculate the effective dose rate from galactic cosmic radiation (GCR) at any specific location in the atmosphere at altitudes up to 100 km for these dates.

The program takes into account the effects of solar activity, as well as the geomagnetic field on galactic cosmic radiation levels for the date selected by the user. Simultaneous irradiation from solar particle events is not taken into account directly by the program, but Forbush decreases are taken into account unless data indicate an exceptionally large solar proton event (SPE) called often called a Ground Level Event (GLE) is ongoing, and geomagnetic cutoffs are adjusted for Kp index if data are available.

Doses and dose rates are integrated from databases of cosmic ray showers calculated by MCNPX 2.7.0. The shower intensities are derived from the primary cosmic ray (GCR) input spectrum. CARI-7A allows the user to select the CR spectrum from multiple preinstalled GCR models and Solar Proton Event models, or to use a user defined spectrum.

This report, the fourth in the CARI-7 documentation series, explains how to use the program.

DESCRIPTION

Introduction

There are two ways to run the program: it can be called within a user-provided script or via a set of internal menus. The mode of operation and several other user definable settings are read from the CARI.INI file during start-up. This file and the other interface and data files are text files for easy user checking and (if needed) editing.

Through the remainder of this document, since CARI-7 options are a subset of CARI-7A options, options available only in CARI-7A will be italicized in the text.

System Requirements and Installation

Compiled versions are provided for Intel processors running 64-bit Windows and Linux. The program and associated files are available as self-extracting ZIP files and use about 120 MB of disk space and about 80 MB of RAM. Follow the links from the CAMI Radiobiology Research Website at:

www.faa.gov/data_research/research/med_humanfacs/aeromedical/radiobiology/

After installation, file space demands will not increase much with use, unless debugging output is requested by the user through the INI file. No special installation is needed beyond unpacking the ZIP archive.

The program is processor intensive and not compiled for multi-core use, so when multitasking on older, single core systems, limiting CPU access to something less than 100 percent may significantly improve performance of other running programs. Running multiple copies does not become an issue on multi-core processor devices, as long as at least one core is kept free for other tasks (Also, there is currently no GPU enabled version.).

A text editor is needed to view and edit the data and control files in all versions. To use the Linux version, adjust the VIEWER and OS variables in the CARI.INI file (see below) and then call the Linux executable instead of the Win64 executable in the main folder.

A list of files needed by the program is in Appendix A.

User Interfaces

As with previous versions of CARI, the basic internal user interface is menu driven. Once the program is started, users select choices from numbered lists, starting at the Main Menu. If menu-less operation is designated in CARI.INI (i.e., MENUS = NO!, see below) then CARI will use DEFAULT.INP and other user indicated files.

Control files

Several files are used to control the operation of the program. Foremost among these is CARI.INI, which is used to pass most of the run-time internal variables that affect user-interactions with the program. DEFAULT.INP is important for menu-less operation. VEHICLE.DAT provides optional shielding

information to CARI-7A. FROM_USER.DAT is used to pass user-designated parameter values to the program without rewriting the historical databases.

CARI.INI

This file contains the user settings that define how the program interacts with the user. The first several lines are variables and their values, then there is a set of comments (A sample of this file is provided as Appendix B). The order of active variables before END does not matter, but the format is critical. Everything after the END line is treated as a comment and is not read. The variables are listed and explained in Table 1: DIAGNOSE, VIEWER, OUTPUT, OS, DISPLAY, MENUS, SUPERPOS, GCR_MODEL, NVCR, VEHICLE, and CARI7RPT. The format for the active lines is VARIABLE (10 characters), "=" (2 characters), VALUE (up to 12 characters). CARI.INI can be edited with any text editor or accessed through the Main Menu (option <6>) followed by option <1> on the Output Menu (changes will require a program restart to have effect. Variables not found in the file will use default values.

Table 1. Variables in file CARI.INI and their uses.

Variable	Use
CARI7RPT	Toggles an additional level of reporting by writing to CARI-7.RPT. Choices are 'YES' or 'NO!' (Default is 'NO!'). The CARI-7.RPT file has essentially the same format and new data will be appended to it just as CARI-6.RPT was for CARI-6 users. This allows the automated storing in a single file of several runs of the same flight plans using different dates (e.g., for route dose studies) and can ease transition to CARI-7 from CARI-6. Since this file will continuously grow if this switch is 'YES', caution in regards to readability is suggested.
DIAGNOSE	Diagnose sets internal diagnostic printing for routines not under manual control in the source code. It can be 'YES' or 'NO!' (Default is 'NO!'). Use 'YES' to generate much more detailed output in files in subfolder DIAGNOSE. Run times will be increased significantly. Because of the large size of the output files this is best used with short sets of calculations.
DISPLAY	Display selects the user interface: DOS (command prompt shell) or GUI (not yet available). (Default is 'DOS')
GCR_MODEL	<p><i>GCR_MODEL sets the model to use as the input primary cosmic radiation spectrum. and affects menu-less use for flight analysis only. It has no influence on location file data analysis. Choices are: 1=ISO, 2=BON11, 3=BON14*, 4=ISO-HP**, 5=LaRC February 1956 solar proton event cumulative spectrum, 6=LaRC September 1989 solar proton event cumulative spectrum, 7=user supplied spectrum (Default is 4, and is always used in CARI-7).</i></p> <p><i>For the two solar proton event spectra (5 and 6), please note that both solar event models are total event fluence spectra.</i></p> <p><i>To input a custom spectrum, put the spectrum data in the file GCR_MODELS\MY_MODEL.OUT.</i></p> <p><i>The custom spectrum must have the same format as the BO11_GCR.OUT.</i></p> <p><i>Expected units are: nuclei/(m²-sr-s-gev) for z=1 to z=26 (H through Fe) ions.</i></p> <p><i>*The BO14 spectrum needs a calling script appropriate to the OS and shell. 'Runbon14.bat' is supplied for Windows OSes. Also, the Linux executable may not be compatible with any particular version of Linux. Contact the gcr model developers to request source code or alternative executables for this model.</i></p> <p><i>**The second ISO spectrum (#4) is the ISO local interstellar spectrum modulated using the CARI-6 heliocentric potential at 1 AU.</i></p>

Variable	Use
MENUS	<p>Toggles use of internal menus. Choices are 'YES', 'FEW', or 'NO!' (Default is 'NO!')</p> <p>Starting the program with this option = 'NO!' will result in an attempt to analyze the contents of the file named at line 5 in file DEFAULT.INP. If the file is a .BIG or .DEG flight data file and the date = '0000/00/00', then dates in the named flight data file will be used, but other run options will be controlled by the DEFAULT.INP and CARI.INI contents. For location data files the date and options in DEFAULT.INP are ignored, the program always uses the data in the named file. Filenames are limited to less than 30 characters. Normal output files are produced:</p> <ul style="list-style-type: none"> • for *.BIG results will be in *.out • for *.DEG a summary will be in *.SUM and a longer report in *.DAT • for a location file (suggest *.loc, or *.txt) the output will be in *.ANS (the name of the location data file can have any 3-character extension except 'DEG or BIG). <p>Starting the program with this option = 'FEW' will provide menus with a reduced set of options, more like CARI-6 and CARI-6M, e.g., total effective dose using ICRP Pub. 103 (2007 guidance) is the assumed desired calculation.</p>
NVCR	<p>Choose combinations of isotropic or angularly resolved treatments of showers and cutoff rigidities.</p> <p>0 = 'none', model uses altitude adjusted apparent cutoff rigidity calculated from the effective vertical cutoff rigidity for all angles of approach and assumes flux is isotropically incident (and is always used in CARI-7 and default).</p> <p>1 = <i>'locally-adjusted cutoffs', the celestial sphere surrounding the vehicle and unblocked by the earth (i.e., above the horizon) is divided into 900 sectors which are assigned nonvertical cutoff rigidities calculated from the effective vertical cutoff rigidity based on latitude, longitude, zenith, azimuth, date, and altitude. The fraction of the shower entering each sector of sky is attenuated using the calculated cutoff rigidity (i.e., the local cutoff rigidity in the direction of the craft is used for incident gcr flux entering that sector).</i></p> <p>2 = <i>'zenith-dependent transport', model uses a slant function to treat showers as beams with zenith dependent depth. Apparent vertical cutoff rigidities are used for all angles of approach.***</i></p> <p>3 = <i>'transport and cutoffs', uses both option 1 and 2 together.***</i></p> <p>4 = <i>'none', model uses an altitude adjusted effective vertical cutoff rigidity for all angles of approach and flux is handled as isotropically incident.</i></p> <p><i>***A note of caution: the angularly resolved cutoffs are accurately calculated, but the shower secondary fluences were calculated using an isotropically incident source and thus do not lend themselves well to angularly resolved treatments (everything has already been averaged over angle in the tallies). Using angularly resolved results that treat the shower data in this way will be more approximate than using the completely isotropic treatment.</i></p>
SUPERPOS	<p><i>This toggles the superposition approximation in CARI-7A. Choices are 'YES' or 'NO!'. ('NO!' is the default and is always used in CARI-7) and uses shower data for all ions (protons through iron) in calculations. 'YES' forces the calculations to use the superposition approximation. In this approximation all primary nuclei with more than one nucleon are approximated as Z free protons and N-Z free neutrons of the same energy per nucleon after geomagnetic rigidity cutoff filtering, (e.g. C-12 enters the atmosphere as 6 free protons and 6 free neutrons). The switch only applies to flight analysis during menu-less use. It has no influence on location file data analysis where it is selected by the user on a case-by-case basis.</i></p>

Variable	Use
OS	Selects the operating system: Windows or other (i.e., Linux). This changes the path subfolder designation character in system calls, as well as any OS file manipulation commands not available to the compiler. Windows and Linux paths to files and commands are encoded. Some tweaking of source code may be needed for others. The default value of this is 'WIN', anything else uses the Linux paths.
OUTPUT	Selects the output destination: FILE (default), SCREEN, or BOTH. This option is currently inactive in CARI-7 and CARI-7A. Results are always written to a file.
VEHICLE	<i>Toggles using a local shield defined by the user. Choices are 'YES' or 'NO!'(default) The usual industry practice is to assume no shielding of occupants by the vehicle. To use aluminum, polyethylene, and dry air thicknesses defined in file 'VEHICLE.DAT' set this to 'YES'.</i>
VIEWER	Designates which command is used to open files called for editing/viewing external files at runtime (e.g., gedit, write, etc., write is the default). The name is limited to 12 characters and should be a command line program that opens files using the "command filename" syntax. For linux/unix systems '.' is not needed since OS related changes will handle that switch, but the program name could be case sensitive.

DEFAULT.INP

If menu-less operation is indicated by CARI.INI, then this file is used to provide CARI-7 with information that the user would normally provide the program: the name of the file with the flight profiles or locations; an alternative flight date and flight hour, if any; and the kind of tally to generate. The first five lines are used.

1. Line 1, if not "0000/00/00," is the date to use instead of the date in the flight profile file.
2. Line 2, if not "0," is an integer hour (UT+1) for the start of the flights.
3. Line 3 is an integer indicating the secondary particle of interest to tally (e.g., neutrons or total).
4. Line 4 is an integer indicating the dose or other endpoint to tally (e.g., H*(10)).
5. Line 5 is the name of the file with the flight dose or location data the user wants analyzed.

The first four lines are used when analyzing flights. As explained in more detail immediately below, the first two lines allow the user to override the date information in the flight profiles and request a specific starting hour for the flight. The next two lines (3 and 4) tell CARI what output tally the user wants. And the fifth line provides the name of the file with the flight or location information. Everything after the fifth line is ignored and can be used as a comment. A sample of this file is provided as Appendix C. In our experience on some systems, a space is required before the middle three entries (lines 2-4).

The first line is a 10 character string for DATE: yyyy/mm/dd.

- 0000/00/00 to use dates from the file indicated by line 5.
- For a monthly average use dd = 00.

Include the zeros for months and days (i.e., use 1998/04/01, do not use 1998/4/1).

The second line is an integer designating the hour in UT: for daily average use HOUR = 0. This variable is ignored if dd = 00. A non-zero value is useful for modeling instrument exposures at specific dates and times, since it will force the inclusion of any historical Forbush effects and geomagnetic storm effects indicated in the databases in the calculations, but it does slow down calculations and for long term crewmember dosimetry the added precision is not meaningful.

The third line is an integer for designating the secondary particle to tally:

0 = Total from all particles (there is an exception: see below)

- 1 = Neutrons
- 2 = Photons
- 3 = Electrons
- 4 = Positive
- 5 = Negative muons
- 6 = Positive muons
- 7 = Protons
- 8 = Negative pions
- 9 = Positive pions
- 10 = Deuterons
- 11 = Tritons
- 12 = Helions
- 13 = Alpha particles
- 14 = Lithium
- 15 = Beryllium
- 16 = Boron
- 17 = Carbon
- 18 = Nitrogen
- 19 = Oxygen
- 20 = Fluorine
- 21 = Neon
- 22 = Sodium
- 23 = Magnesium
- 24 = Aluminum
- 25 = Silicon
- 26 = Phosphorus
- 27 = Sulphur
- 28 = Chlorine
- 29 = Argon
- 30 = Potassium
- 31 = Calcium
- 32 = Scandium
- 33 = Titanium
- 34 = Vanadium
- 35 = Chromium
- 36 = Manganese
- 37 = Iron

The fourth line is another integer, it indicates the dose or other endpoint to tally

- 1 = secondary particle fluence (if particle requested is the total, then output is total ion fluence, which excludes neutrons and photons)
- 2 = microSv, ICRP Pub. 103 effective dose
- 3 = microSv, ICRP Pub. 60 effective dose
- 4 = microSv, ICRU ambient dose equivalent, $H^*(10)$ (Warning: results of this tally are approximate to the degree that heavy ion flux is significant and effective dose from these particles differs from $H^*(10)$)
- 5 = microGy, Average whole-body absorbed dose
- 6 = microGy, Dose in 0.5 mm Si
- 7 = microGy, Dose in 0.3 mm Si
- 8 = Counts, Response rate NM64 neutron monitor BF-3 tube (Warning: results of this tally are NOT VALID if HZE and alpha flux is significant, i.e., at altitude above 60000 feet.)

The fifth and final line is the name of the file to process. This can be a *.DEG or *.BIG or other. Name length must be less than 30 characters with no spaces and a 3-letter extension (e.g. EXAMPLE.BIG or MYPLACES.DAT):

- If the extension is DEG then the program will process the file as a waypoint defined flight file (same as CARI-6M). Outputs will be in *.SUM (short form) and *.DAT (long form);
- If the extension is BIG then the program will process the file as a geodesic route flight archive file (same as CARI-6). Output will be in *.OUT;
- Otherwise the program processes the file as a locations definition file (my convention is to use the LOC extension, but this extension is not required), and output will be in *.ANS.

The first 4 lines are ignored if the file on line 5 is a LOC style file and not BIG or DEG (flight data).

VEHICLE.DAT

If its use is indicated in the CARI.INI file, then this file is used to provide shielding information to CARI-7A. Only three materials are allowed and only the first four lines are read.

1. *Line 1 is Al alloy thickness in units of $g \cdot cm^2$*
2. *Line 2 is HDPE (polyethylene, i.e., CH_2) thickness in units of $g \cdot cm^2$*
3. *Line 3 is dry air thickness in units of $g \cdot cm^2$, used for testing.*
4. *Line 4 indicates the end of the data.*

The net effect is the weighted average of the three shields. The expected input for each line is a real number. Everything below the end-of-data indicator line is ignored and can be used for comments. A sample of this file is provided as Appendix D.

FROMUSER.DAT

This file is used to provide information that the program would usually read from a database: Kp index, effective vertical cutoff rigidity, and Forbush scale factor. It is thus most useful for hypothetical studies of the influence of these parameters. Use of this file can also reduce run time by eliminating searches when precise matching of historical data is not needed or if the data are known by the user. A negative value is used to indicate CARI should search the database, a positive indicates a user-designated value. Only the first three lines are read. The lines are comma delimited:

1. Line 1 is a real (FP) number for user supplied Kp and a comment;
2. Line 2 is a real (FP) number user supplied effective vertical cutoff rigidity and a comment;
3. Line 3 is a real (FP) number user supplied Forbush scaling factor and a comment.

A space is recommended before the number on each line to assure proper reading across platforms. Everything below the third line is comment. A sample of this file is provided as Appendix E.

Using the Menus

If the user chooses not to run CARI as a command (e.g., within a shell script) controlled entirely externally by changing the contents of the four files (CARI.INI, DEFAULT.INP, VEHICLE.DAT, and FROMUSER.DAT), the user can interact by means of internal menus. To run using internal menus set the CARI.INI variable MENUS to 'YES'.

After preloading some data files, the program will start at the MAIN MENU (Figure 1). The first choice is to view the HELP file. Selecting this option will open the file HELP.TXT using the default editor named in CARI.INI. The text file contains an abridged version of the documentation.

```
CARI-7A (ACADEMIC USE)      Civil Aerospace Medical Institute
February 14, 2018 (4.0.1)   Federal Aviation Administration

                               MAIN MENU

<1>  HELP file (Read me).
<2>  Galactic radiation received on flights.
<3>  View, add, or change airport information.
<4>  Radiation level at user-specified
      altitude and geographic coordinates.
<5>  Update heliocentric potential, ISO sunspot
      number, or Forbush effect data.
<6>  Change output settings. View old results.
<7>  Exit program.

Type 1, 2, 3, 4, 5, 6, or 7 and press <ENTER> .
```

Figure 1. The Main Menu

The second option moves the user to the Flight Menu (Figure 2).

```
CARI-7A (ACADEMIC USE)      Civil Aerospace Medical Institute
February 14, 2018 (4.0.1)   Federal Aviation Administration

                               FLIGHT MENU

Indicate which kind of flight data you are using.

<1>  Flight path(s) nearly geodesic (i.e., great
      circle) route(s) between selected airports
      (*.BIG files, same as CARI-6, -6P, and -6W).
<2>  Flight path(s) defined by many waypoints
      (*.DEG files, same as CARI-6M and -6PM).
<3>  Return to Main Menu.
<4>  Exit program.

Type 1, 2, 3, or 4 and press <ENTER> .
```

Figure 2. The Flight Menu

To perform calculations based on flight profile information, the user selects <1> or <2>, depending on the kind of flight profiles the user has created, geodesic routes between airports or waypoint based flights.

Calculating flight doses

There are 2 kinds of flight profiles the program can analyze. Flights that follow approximately geodesic (great circle) routes between airports are stored collectively in archives called *.BIG files. Flights that follow waypoint defined flight paths are stored individually in *.DEG files. Selecting item <2> on the Main Menu brings up the option of analyzing a BIG or DEG file. Versions of these files for previous versions of CARI are compatible with CARI-7A.

Flights can also be analyzed from the command line by designating the name of the flight data file in DEFAULT.INP. Writing a script to do this is probably the easiest way to use the program if there are many DEG files to analyze, or if a set of updated flight or location databases is often re-analyzed.

Flights following geodesic routes

Selecting option <1> from the Flight Menu will list of all of the available BIG files in the current directory. BIG files are just ordinary text files containing flight information needed by CARI to do an analysis. The file EXAMPLE.BIG is provided as an example to use as a template (Appendix F). The program expects the filename to follow the traditional 8.3 format, so give it name with 8 characters or less, e.g. EXAMPLE1.BIG. Dozens of BIG files are allowed, and there is no built-in limit to the number of flights that can be described in a file. CARI-6 users have run files with thousands of flights.

Up to 16 BIG files can be listed on a single page at any one time. They will be listed in alphabetical order. If there are many unused files, consider moving the unused files from the working folder to reduce clutter.

The format of each profile in these files has the same template:

1. Flight ID of 1 to 20 characters
2. Flight date (MM/YYYY)
3. ICAO code of origin airport
4. ICAO code of destination airport
5. Number of en route altitudes (limit is 20)
6. Minutes climbing to 1st en route altitude
7. 1st en route altitude: feet (limit 320000) minutes
8. 2nd en route altitude: feet minutes (if needed)
9. 3rd en route altitude: feet minutes (if needed)
10. Etc. (other en route altitudes)
11. Minutes descending to destination airport
12. End of profile indicator

Altitudes are in feet and there must be at least one cruise altitude of at least 1 minute. Total flight time is limited to 2000 minutes. After the first en route altitude, time at an en route altitude is expected to include minutes climbing or descending from the previous en route altitude. Flights reaching altitudes above 300000 feet are not permitted. A flight not following an approximately geodesic route, or not cruising at a nearly constant speed for most of the flight should use the more specific, waypoint based modeling method *or, for altitudes above 100 km, use individual locations* as the basis of the analysis.

Flight doses can be calculated for the dates entered with the flight profiles or for other dates. To use other dates or to calculate a dose for a more specific time than a monthly average, entered the new date (and time) through the file DEFAULT.INP or at run time.

Flights along a user-specified path

Selecting option <2> from the Flight Menu will list of all of the available DEG files in the current directory. DEG files are text files containing the user-specified waypoints that define the flight. CARI uses a geodesic route, constant speed, and a constant rate of climb or descent between each waypoint pair. The file EXAMPLE.DEG is provided as an example to use as a template (Appendix G). The first line is the flight date and name, the second line is headers to aid the reader, and all following lines are waypoints.

In each waypoint data line the data are comma separated:

- Column 1 is integer degrees latitude
- Column 2 is real minutes latitude
- Column 3 is N or S designator (equator can be either)
- Column 4 is integer degrees longitude
- Column 5 is real minutes longitude
- Column 6 is E or W designator (prime meridian can be either)
- Column 7 is integer altitude in feet
- Column 8 is integer time in minutes from start of flight

Flight doses can be calculated for the dates entered with the flight profiles or for other dates. To calculate a dose for a more specific time than a monthly average, it must be entered through the file DEFAULT.INP or at run time.

For a flight requiring a time resolution of less than one minute between waypoints for accurate results or with an altitude exceeding 300000 feet, such as a sounding rocket flight or other suborbital flight, a properly weighted integration of dose rates from individual location data (See “Dose rates at specific locations” below) is the recommended means of calculating a flight dose.

Airport data

Options related to airport information are available from the Main Menu through option <3>. Airport data are stored in \AIRPORTS. The file AIRPORTS.DAT has most of the data. NEWPORTS.DAT is used to store user-created airports. CODES is a list of 3-letter codes and matching ICAO codes. The other files are sorted versions of the data and are rebuilt as needed by CARI.

Searching airport data

The program databases include information on over 5000 airports worldwide. The International Civil Aviation Organization (ICAO) airport codes (typically 4 characters, e.g., KOKC for Will Rogers International in Oklahoma City) are used by the program to designate origin airports and destination airports in BIG files and can be used to indicate geographic coordinates (but not altitudes) in location (LOC) files.

The code for an airport may be found by choosing item <3> on the Main Menu. This will bring up the Airport Menu (Figure 3). A search can be performed using city name, airport name, or ICAO code.

```
CARI-7A (ACADEMIC USE)      Civil Aerospace Medical Institute
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                                AIRPORT MENU

<1> Find an airport by airport name.
<2> Find airport by city.
<3> Find airport by code.
<4> Add new airport or replace existing airport.
<5> Associate a non-ICAO code with an airport.
<6> Return to Main Menu.
<7> Exit program.

Type 1, 2, 3, 4, 5, 6, or 7 and press <ENTER> .
```

Figure 3. The Airport Menu

When searching by name, use the first few characters and try alternate spellings. To find codes for airports in Washington, DC, for example, examine all city entries beginning with Washington. Note that for cities with several airports, not all entries may appear on the first screen.

Adding or editing airport data

For airports not in the databases or to make corrections, the geographic coordinates (degrees and minutes), elevation (feet), and airport code for the new entry may be entered into the file NEWPORTS.DAT either with a text editor or by choosing item <4> on the AIRPORT MENU (item <3> on the MAIN MENU). If the new airport will become a permanent change, copy the new data line from NEWPORTS.DAT to AIRPORTS.DAT.

The format is an 89 character string containing:

- CITY NAME(30 Characters),
- ICAO CODE (4-6 characters),
- AIRPORT NAME(30 Characters),
- LATITUDE (6 Characters +0) DDMMSS0,
- N?S character (0 for North),
- LONGITUDE (7 Characters +0) DDDMMSS0,
- E?W character (0 for West),
- AIRPORT RUNWAY ALTITUDE IN FEET (5 Characters +0),

e.g.,

ADELAIDE, AUSTRALIA YPAD ADELAIDE INTL 3456420}13831540}000200

Users of CARI-6 and earlier version can import their personal airport data from older versions of CARI, since the data format is the same. Copy the lines from the older files to either AIRPORTS.DAT (recommended) or NEWPORTS.DAT.

If multiple airports have the same ICAO code but different location data, CARI will use the data for the first airport found in PORT.NDX. PORT.NDX is a combination of the airport databases sorted on the airport name.

The sorted files are rebuilt when the program is started and whenever a new airport might have been added through the internal menus.

Dose rates at specific locations

Options related to calculations of dose rates and other quantities at user-specified locations are accessed through Main Menu item <4>. To calculate for a single location, choose item <1> from the LOCATION MENU and make selections as requested by CARI.

Selecting item <1> to calculate the dose rate for a single location and set of conditions does not alter any files and the results are only printed to screen, not saved. To keep it, make a note or do a screen dump to file.

```
CARI-7A (ACADEMIC USE)      Civil Aerospace Medical Institute
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                                LOCATION MENU

<1> Calculate the dose rate at a single location.
<2> Calculate dose rates for locations in a
    locations file (*.LOC).
<3> Open/Edit a location file (*.LOC).
    (uses the default text editor)
<4> Open a dose rate archive file (*.ANS).
<5> Open the HELP file.
<6> Return to Main Menu.
<7> Exit program.

Type 1, 2, 3, 4, 5, 6, or 7 and press <ENTER> .
```

Figure 4. Screen shot of Locations Menu

To calculate the dose at a single point, with output to screen only, selecting item <1>. Selecting item <2> displays a list of existing files with the extension .LOC. Once chosen, CARI starts analysis of the selected location data file. Results of calculations are stored in files ending with the .ANS extension (e.g., results for MY.LOC will be placed in MY.ANS). LOC files can be edited by selecting item <3> from the Location Menu. Lines are comma delimited and each line of data is limited to 66 characters. Adding more characters will introduce junk lines to the output file and may result in unread data at the end of the line and erroneous calculations. The format of the used lines in the file is:

START-----

data line 1

data line 2

etc.

STOP-----

Everything above the first line beginning with "START-" is considered a comment, as is everything below the first line beginning with "STOP--". Comments within the active data can be designated by starting the line with a "C" or "!" and will be included in the output. However, only the first 60 characters of a comment line will be included in the resulting ANS file output. See the sample files in Appendix H or for more details.

To view results select item <4>. The ANS is rewritten each time when using item <2>, so to keep the results it is best to either rename the LOC file or to copy the ANS file elsewhere before re-use (e.g., with different shielding in VEHICLE.DAT).

Choosing item <5> from the opens the help file.

Collections of locations can also be analyzed from the command line by designating the name of the location data file on line 5 of in DEFAULT.INP.

Solar modulations

Maintenance of Badhwar-O'Neill GCR model solar activity related files must be done externally. For the ISO models option <5> from the Main Menu can be used to view or update solar modulation. Forbush effect data can also be accessed through this menu. The Solar Modulation Menu (Figure 5) provides access to these files using the editor indicated in CARL.INI.

```
CARI-7A (ACADEMIC USE)      Civil Aerospace Medical Institute
February 14, 2018 (4.0.1)    Federal Aviation Administration

      SOLAR MODULATION MENU

<1> View/modify heliocentric potential data.
<2> View/modify sunspot number data for ISO.
<3> View/modify Forbush effect data.
<4> Return to Main Menu.
<5> Exit program.

Type 1, 2, 3, 4, or 5 and press <ENTER> .
```

Figure 5. The Solar Modulation Menu

Viewing Output Files

The final secondary menu accessible from the Main Menu (option <6>) is the Output Menu (Figure 6). From this menu all the recognized output files in the working folder can be accessed. Users can also edit CARI.INI and DEFAULT.INP from this menu. Changes to CARI.INI require a restart of CARI to have effect.

```
CARI-7A (ACADEMIC USE)      Civil Aerospace Medical Institute
February 14, 2018 (4.0.1)   Federal Aviation Administration

                                OUTPUT MENU

<1> Review/Edit the default settings in CARI.INI.
<2> Review/Edit defaults specified for shell
    script use (i.e., batch mode) in DEFAULT.DAT.
<3> Review a city-pair flight dose (OUT) archive.
<4> Review a waypoint flight dose (SUM) archive.
<5> Review a location dose rate (ANS) archive.
<6> Return to Main Menu.
<7> Exit program.

Type 1, 2, 3, 4, 5, 6, or 7 and press <ENTER> .
```

Figure 6. The Output Menu.

Avoiding the Menus

A major advantage of CARI-7 over its predecessors is its increase in flexibility of use from scripts. DEFAULT.INP and CARI.INI are the primary control files when the program is used in this way. CARI.INI variable MENUS must be 'NO!' to use the program this way. Information the user provides from DEFAULT.INP is used to provide the information usually obtained from the user by the menus.

Options for All Calculations

Regardless of which of the calculations (flight dose or location dose rates) is to be performed, several choices must be made by the user. These include the following:

- *Primary particle spectrum;*
- Secondary particle to tally (e.g., neutrons or total);
- Kind of tally (e.g., particle flux or effective dose);
- Specificity of the date and time (e.g., monthly average or a specific hour)
- *Whether or not to use the superposition approximation.*

Primary spectra

In CARI-7A, the seven primary spectra choices currently available for calculations are (see Copeland, 2021a for descriptions):

1. *ISO 2004 GCR*

2. *Badhwar and O'Neill 2011 GCR*
3. *Badhwar and O'Neill 2014 GCR*
4. *ISO 2004 GCR model LIS--solar modulation by heliocentric potential*
5. *Feb. 1956 SPE event-cumulative proton spectrum*
6. *Sep. 1989 SPE event-cumulative proton spectrum*
7. *A user supplied spectrum in file MY_MODEL.OUT*

If an SPE spectrum (5 OR 6) is selected, note that results are normalized for total event fluence.

To input a custom spectrum using option <7>, the custom spectrum must be in the file \GCR_MODELS\MY_MODEL.OUT and have the same format as BO11_GCR.OUT. Expected units are: nuclei·(m²·sr·s·GeV)⁻¹ for Z=1 to Z=26 (H - Fe) ions. Trivially small numbers (e.g., 1.00E-33) should be used instead of zeros for spectra without some particles.

The Badhwar and O'Neill 2014 GCR entry, option <3>, is integrated only for Windows versions. To try to use this spectrum from Linux or MacOS write a script on an executable equivalent to runbon14.bat that can be called from the CARI-7A folder with './runBON2014'. Also, the supplied executable may not be compatible with some systems.

Modulation of galactic cosmic radiation

The GCR data are modified based on up to 3 factors: long-term solar activity (accounted for using model-specific methods), short-term variations in solar activity from the monthly average such as Forbush decreases accounted for using hourly neutron monitor count rate data, and geomagnetic storm effects accounted for using the Kp index.

Ionizing radiation increases from solar proton events are not included but can be calculated using MY_MODEL.OUT. Be careful since this file is assumed to have GCR flux units.

The effects of geomagnetic storms and Forbush decreases on primary GCR flux are usually ignored. However, for comparison with instrument measurements, using the specific day and hour of the measurement is best practice. This invokes the Forbush and geomagnetic storm based adjustment subroutines, which are not needed for monthly average calculations. Using these routines significantly increases run times. Forbush effects and geomagnetic storm effects on primary GCR flux are handled independently of GCR model chosen.

ISO GCR Model

Wolf sunspot number

The dynamics of the large-scale GCR modulation by the solar wind in the International Standards Organization (ISO) GCR model (ISO, 2004) is characterized by the effective modulation potential of the heliosphere calculated from the Wolf sunspot number and solar magnetic field orientation. The latest sunspot numbers are available from the World Data Center for the Sunspot Index, Royal Observatory of Belgium, Monthly Report on the International Sunspot Number, online catalogue of the sunspot index at:

www.sidc.be

The file SN_m_tot_V20.csv is an exact replica of SN_m_tot_V2.0.csv from SIDC. It contains all the needed data. It is updated by downloading 'SN_m_tot_V2.0.csv' and renaming it to 'SN_m_tot_V20.csv', replacing the older version.

Format is: YYYY;MM;DATE_in_decimal; SSN; SD; other stuff not used in the ISO model. The numbers from the file are converted to Wolf numbers within CARI-7A.

Heliocentric potential

For continuity with previous versions of CARI, the ISO model local interstellar spectrum (LIS) modulated by the heliocentric potential method using heliocentric potentials for CARI-6, calculated from neutron monitor count rates is the GCR model used by CARI-7. CARI-7A can also use this model instead of the Wolf sunspot and magnetic field orientation driven method described in the ISO report (ISO, 2004). On longer time scales, this modulation method still produces a slowly varying GCR spectrum at Earth orbit, but this type of modulation is more dynamic at shorter timescales than the Wolf number driven modulation described in the ISO report and thus does a better job of reproducing ground level neutron monitor counting rates.

Recent heliocentric potentials are available from the FAA Web site. Search for "FAA Radiobiology heliocentric" and follow the links. The current address as of May 2019 is:

http://www.faa.gov/data_research/research/med_humanfacs/aeromedical/radiobiology/heliocentric/

There is a lag of about one month in availability of heliocentric potential data on our Web site. To estimate flight doses during the current month or a future month, use the most recent heliocentric potential available (The program will default to this choice if a potential does not exist for the entered date. NOTE: This approximation is increasingly less accurate for dates more than 2 months removed from the month of interest, particularly during solar maximum.).

The data are kept in the folder \SOLARMOD. Heliocentric potentials with corresponding dates are stored in a permanent database (MV-DATES.L99) and in a user-modifiable database (MORDATES.2K). New data can be placed in either SOLARMOD\MV-DATES.L99 or MORDATES.2K, but MV-DATES.L99 is searched much faster and updated monthly. If the same date is found in both files, data in MOREDATES.2K takes precedence over data in MV-DATES.L99.

BADHWAR-O'NEILL 2011 (BO'11) and 2014 (BO'14) GCR models

For CARI-7A, the stand alone BO11 GCR model source code provided by Patrick O'Neill was minimally modified to allow its incorporation (O'Neill et al., 2013). Only executables were supplied to CAMI for the 2014 update (O'Neill et al., 2015), so its integration into CARI is less complete.

The 2011 revised version of the 2010 GCR model of Badhwar and O'Neill was developed to provide an accurate galactic cosmic ray (GCR) energy spectrum that can be used by engineers in single-event effect (SEE) rate prediction codes and by radiation health physicists for astronaut exposures on deep space missions. The GCR model is designed for free space, i.e., beyond the Earth's magnetosphere. The model uses the spherically symmetric Fokker-Planck equation that accounts for cosmic ray propagation in the heliosphere due to diffusion, convection, and adiabatic deceleration. The boundary condition is the constant energy spectrum [called the Local Interstellar Spectrum (LIS)] for each GCR element at the outer edge of the heliosphere (assumed to be at 100 AU). The Fokker-Planck equation modulates the LIS to a given radius from the Sun, assuming steady-state heliosphere conditions.

Like the ISO model, the BO11 model uses the correlation with sunspot number (International Sunspot Number or ISS in this case) to determine the level of solar modulation to a monthly level, to allow users to take advantage of the predictive capability in the correlation. To enable increased accuracy (and finer time

resolution), spacecraft data are used to calibrate the sunspot number for periods where they overlap, IMP-8 from 1974 to 1997 and ACE after 1997.

The file that most needs to be kept up-to-date is MONTHLY.TXT

CARI-7A looks for model data in various files in the \GCR_MODELS directory. The BO'11 and 'BO'14 models have their own databases which should be kept up to date for best results if using these models for recent dates.

BO'11 data files are:

- *ISSFILE = 'GCR_MODELS\MONTHLY.TXT '!* A Wolf number file from NOAA-SWPC that they no longer update. Newer data use SIDC numbers*0.6
- *GCR_MODELS\ISSVST.DAT*
- *GCR_MODELS\ISSDELAY.DAT*
- *GCR_MODELS\ISSTMNX.DAT*
- *GCR_MODELS\ISSWMNX.DAT*
- *GCR_MODELS\ISSZONE.DAT*
- *GCR_MODELS\FRBEHELI.DAT*
- *GCR_MODELS\DSSDTISS.DAT*

BO'14 data files are to update are:

- *iss-sidc.dat*
- *solar_cycle_date.dat*
- *ssn_minmax.dat*.

More information on upkeep of these models can be found in their specific documentation.

Forbush Effects

Hourly deviations in GCR from the monthly average such as Forbush decreases are kept in the file \FORBUSH\FORBUSH.DAT. The format is based on the IZMIRAN (Russian Academy of Sciences) neutron monitor data format, with the last column added as the hourly count rate relative to the monthly average. If no day or day and hour is specified, there will be no effect on results. Also, if data are not found for the user entered specific day or day and hour there is no effect. Hourly resolution from the historical table increases calculation time. FROMUSER.DAT can be used to specify a specific value regardless of the date used in the calculations.

Geomagnetic Storms

Short term variations in geomagnetic shielding are accounted for using the planetary K geomagnetic index (Kp index). The data are stored in \KP_INDEX\KP_INDEX.TXT. The file has one header line and then daily data, with each Kp datum representing 3 hours.

```
“YYYYMMDD Kp[8]          Sum ap[8]          Ap”  
“19580101 6 6+5+4 3+4-5+4 38  80 94 56 27 18 22 56 27 48  ”
```

Current and recent geomagnetic index data are available from NOAA's Space Weather Prediction Center.

ftp://ftp.swpc.noaa.gov/pub/indices/old_indices/

New data can also be found at also from the German Research Center for Geosciences (GFZ), the current official archiving institution for the index.

<https://www.gfz-potsdam.de/en/kp-index/>

Depending on the source file format, some reformatting may be needed. Typically the century must be added to the date, and data can have slightly alternate forms, e.g., “60, 6+, and 6-“ are sometimes “6 , 63, and 67.” As with the Forbush data, if data are not present, CARI results will be for geomagnetically quiet conditions, and FROMUSER.DAT can be used to specify a specific value regardless of the date used in the calculations.

Tally Options

There are 38 particle tally choices in CARI-7: neutrons, photons, electrons (β^-), positrons (β^+), positive muons, negative muons , positive pions, negative pions, protons, deuterons, tritons, helions, alpha particles, atomic nuclei from lithium through iron ($Z=3$ to $Z=26$), and the total. These are also listed individually in Appendix C.

There are eight tally options applicable to each particle. These are:

- Whole-body averaged absorbed dose;
- Effective dose from ICRP Publication 60 (1990) recommendations;
- Effective dose from ICRP Publication 103 (2007) recommendations;
- Ambient dose equivalent, $H^*(10)$;
- Particle flux;
- Absorbed dose in a 0.5 mm thick silicon chip;
- Absorbed dose in a 0.3 mm thick silicon chip;
- NM-64 neutron monitor tube counts.

Particle flux

Particle flux reported by CARI is summed over the entire energy spectrum. Any individual particle can be requested or a total. If a total from all particles is requested, the total ion particle flux (which is not the same as the local ionization) is reported. Neutrons and photons are not included in the total.

Whole-body average absorbed dose

The fluence-to-whole-body-average-absorbed-dose coefficients provide a means for comparing effective dose to similar quantities such as effective dose equivalent and older standard doses used to control exposures such as those still used by the Nuclear Regulatory Commission (see 10 CFR part 20) and Occupational Safety and Health Administration (see OSHA Standard 1910.1096-ionizing radiation), through the use of appropriate factors.

Ambient dose equivalent, $H^*(10)$

Ambient dose equivalent is defined by the ICRU and ICRP (ICRP, 1997) as the dose equivalent measured within a 30-cm diameter sphere of tissue equivalent material (called the ICRU sphere) irradiated by a plane parallel beam. Since effective dose cannot be measured, but ambient dose equivalent can be measured by properly calibrated instruments, it is sometimes used as a measurement surrogate for effective dose in aviation. Ambient dose equivalents at various depths (d , in mm) along the axis of the sphere opposing the incident radiation beam depth are denoted by $H^*(d)$. Thus, $H^*(10)$ is the ambient dose equivalent at a depth of 10 mm. Like effective dose, it is also measured in units of joule per kilogram with the special name

sievert (Sv). The calculations of coefficients proceed along the same lines as those for effective dose coefficients, except that the anthropomorphic phantoms needed to calculate effective dose are replaced by the ICRU sphere and the radiation source is a beam of parallel moving particles.

Effective dose

The ICRP introduced effective dose as a radiation protection quantity in its 1990 recommendations. (ICRP, 1991). In its 2007 recommendations the ICRP continued to recommend effective dose as a radiation protection quantity for general application, including aviation at high altitudes (ICRP, 2007). The 2007 revisions included a slightly different set of tissue weighting factors and radiation weighting factors for calculation of effective dose, and a standard phantom was adopted (ICRP, 2009). Tables of coefficients based on the updated standards were published in Publication 116 (ICRP, 2010).

For CR dosimetry, the most important changes involved neutron and proton radiation weighting factors. Both were generally reduced in the newer recommendations. The proton contribution to effective dose was reduced by 60 percent (radiation weighting factor reduced from 5 to 2), while the factors for the lowest and highest energy neutrons were also reduced (from 5 to 2.5). The most important change to tissue weighting factors made in the 2007 recommendations was an increase in the breast tissue weighting factor. Because of the shallow depth of this tissue, weakly penetrating particles are able to more significantly affect the dose under the newer recommendations. As a result, coefficient values rise faster at low energies. At higher particle energies organ depth is less important and coefficients from the two sets of tissue weighting factors return to being essentially the same. The net effect is reduced dose rates when using the newer recommendations (Table 2).

Table 2. Effective doses using 1990 and 2007 recommendations of the ICRP and ambient dose equivalent, $H^*(10)$, calculated with CARI-7 rel. 4.0.2 at 10.7 km (35000 ft.).

IGRF 2000 vertical magnetic rigidity cutoff at 20 km / GV	Date	Effective dose rate, 1990 ICRP recommendations / $\mu\text{Sv}\cdot\text{h}^{-1}$	Effective dose rate, 2007 ICRP recommendations / $\mu\text{Sv}\cdot\text{h}^{-1}$	Ambient dose equivalent, $H^*(10)$ / $\mu\text{Sv}\cdot\text{h}^{-1}$
0	2002/01	5.33	4.11	4.68
0	1998/01	7.39	5.68	6.57
17	2002/01	1.81	1.44	1.54
17	1998/01	1.91	1.52	1.63

Absorbed dose in silicon and NM-64 neutron monitor tube response

Coefficients for absorbed dose in 150 mm by 150 mm by 0.3 mm thickness silicon, 0.5 mm thickness silicon, and neutron monitor response used by CARI-7 were originally developed elsewhere (Matthiä et al., 2014; Matthiä, 2018). The coefficient set for dose in 0.5 mm silicon did not contain coefficients for heavy (Li-Fe) ion, triton, helion, or deuteron data. For these particles 0.3 mm data were used as surrogate data.

The coefficient set for NM-64 neutron monitor tube response contains no data for particles other than alphas, protons, muons, electrons, pions, and neutrons (these are the particles that are expected to contribute to the signal). This feature must be used with extreme care at locations where other particles should also be contributing significantly. Results should be normalized to the monitor being simulated.

Vehicle Related Shielding

By default, shielding is not accounted for by CARI-7 or CARI-7A. However, for situations where the aircraft or spacecraft is a significant fraction of the shielding for its occupants (spaceflight and extremely high

altitude aircraft), shielding can be included in the calculations. This is currently done in an approximate manner, with three shielding materials currently allowed: dry air, aluminum alloy, and polyethylene. The net effect is the thickness weighted average of the effectiveness of the three materials relative to dry air.

Transport Options

Superposition approximation

The form of the superposition approximation available in CARI-7A treats CR nuclei with more than one nucleon as multiple free nucleons for atmospheric transport, with the energy per nucleon and rigidity taken from the originating nucleus. For example, an alpha particle (helium nucleus) is treated as two free protons and two free neutrons. The superposition approximation was once commonly used in the transport calculations built into aircrew dosimetry programs. It both greatly simplified the physics models needed for the calculations and, if a Monte Carlo approach was used, vastly reduced the needed number of calculations. The fact that dosimetry programs like CARI-6, which are based on transport models incorporating this approximation, work with good accuracy in the lower and middle atmosphere (where modern commercial and business aviation takes place) is proof that the approach was very successful for these regions. It is less successful in the upper atmosphere, where significant numbers of CR heavy ions are present. Until they break up, these ions lose energy due to ionization much faster than their nucleonic constituents (ionization is proportional to the square of the charge). Thus, one can reasonably expect varying amounts of underestimation of very high altitude dose rates when using superposition. Figure 7 shows the effect of superposition on various dose rates.

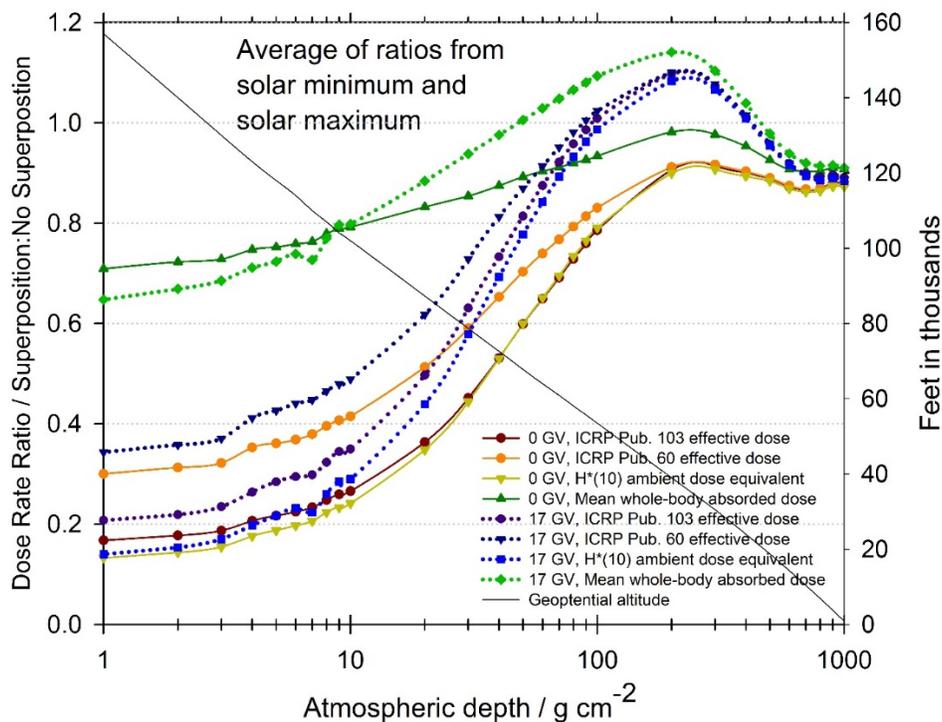


Figure 7. Ratios of dose rates calculated using the superposition approximation to those calculated without using the superposition approximation. Ratios shown are averages from solar minimum and solar maximum dose rates, calculated using the Badhwar-O’Niell 2011 GCR model in the polar latitude region (0 GV cutoff rigidity) and equatorial latitude (~17 GV cutoff rigidity) using CARI-7A rel. 4.0.2.

CARI-7 does not use this approximation. While superposition remains an option in CARI-7A, not using the approximation gives CARI-7 an important advantage over its predecessors when used to calculate doses and dose rates to occupants of aircraft flying at high altitudes or in spacecraft.

Angularly resolved transport

Angular resolution in the calculations is controlled through the NVCR variable in CARI.INI. For CARI-7, the most reasonable choice is selected for the user (see Table 1). For atmospheric transport, this means that radiation showers are assumed to be built from isotropically incident fluences of radiation entering the atmosphere at an altitude of 100 km, apparent cutoff rigidities are used, the fluence data are handled in a manner most similar to original MCNPX simulation design

In addition to allowing use of the superposition approximation, CARI-7A also allows the user to approximate angularly resolved transport, i.e., handle the data as if transport results were the result of vertical beams at the same tally shell depths (this can be a good approximation at very-large depths, where secondaries from non-vertical primary particles do not contribute much to totals). This can be applied with or without the use zenith and azimuth dependent non-vertical cutoff rigidities. The method of shower-result integration reconstructs the total dose from contributions from various slant depths, interesting if non-vertical cutoff rigidities are also used directly, rather than an effective or apparent cutoff rigidity (see Copeland 2019). When beam-like transport and/or angularly resolved cutoff rigidities are requested by the user, the sky is subdivided into 900 sections (the number needed to numerically stabilize the results) above the horizon, characterized by azimuth (18 subdivisions) and zenith (50 subdivisions).

Each section's contribution from each primary ion spectrum to the total is considered. With regard to geomagnetic passage into each sector a pass-band function of primary particle rigidity is used: each band of a primary ion spectrum with a lower rigidity above the cutoff for that sector is fully allowed; each band of a primary ion spectrum with an upper rigidity below the cutoff for that sector is fully rejected; each band of a primary ion spectrum with an upper rigidity above the cutoff for that sector, but a lower rigidity below the cutoff for that sector is only allowed to contribute based on the fluence of that primary ion spectrum within the band with rigidity above the cutoff.

CONCLUDING REMARKS

This report describes the operation of CARI-7 and CARI-7A for calculations of flight doses, dose rates, and some other quantities of interest resulting from cosmic radiation in the vicinity of Earth's atmosphere. CARI-7 and CARI-7A were developed with model flexibility in mind. CARI-7 uses what are considered to be the most reasonable choices for normal aviation dosimetry, while CARI-7A includes additional options allowing the user to explore the sensitivities of results to model choices and is more readily applied to less common uses like spaceflight, where the vehicle provides the primary shielding of occupants from cosmic radiation. All of the transport, geomagnetic and spectra options influence dose rates in the atmosphere to various degrees, and work continues to both verify results and improve usefulness of the programs (e.g., Copeland and Atwell, 2018; Matthias et al., 2018; Atwell et al, 2019).

Air and space travelers are constantly exposed to GCR. Only galactic cosmic radiation is considered in CARI-7, while modeling solar cosmic radiation exposure is also possible with CARI-7A. Depending on the specific environment and time of exposure, other man-made and natural sources can result in higher doses over short time spans. Man-made sources sometimes encountered in aviation include: radioactive cargo (e.g., medical isotope shipments), fallout from nuclear weapons testing, and releases of radioactivity

into the atmosphere from nuclear reactors (such as can result from an operational accident or natural disaster). Other natural sources that hypothetically could lead to large doses include, terrestrial gamma-ray flashes (TGFs) and trapped particles from Earth's radiation belts (a serious potential hazard for space vehicle crews). Exposure to these sources is either low and controlled (e.g., radioactive isotope shipments) or extremely unpredictable (e.g., TGFs).

Contact Information

User feedback is always welcome. Questions, suggestions, and comments should be sent to:

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APPENDICES

Appendix A: Files needed by the program

The files listed here are needed by the program for full functionality. Other files may be created by the user.

Folder	Files
<local working folder>	CARI-7.EXE ^A (CARI-7A), CARI.INI, DEFAULT.INP, FROMUSER.DAT, HELP.TXT, <i>runbon14.bat</i> , VEHICLE.DAT, /AIRPORTS, /ATMOSPHERE, /CUTOFFS, /DIAGNOSE, /FORBUSH, /GCR_MODELS, /KP_INDEX, /SHOWERS, /SOLARMOD, /SUNSPOTS (other files are created at run-time or by the user)
AIRPORTS	AIRPORTS.DAT, CODES, NEWPORTS.DAT (other files are created at run-time)
ATMOSPHERE	FT-GM.DAT
CUTOFFS	DGRF1990.1X1, IGRF1980.1X1, IGRF1995.1X1, IGRF2000.1X1, IGRF2010.1X1, WGRC1965.1X1
DIAGNOSE	(all files created at run-time)
FORBUSH	FORBUSH.DAT
GCR_MODELS	<i>BO11_GCR.OUT, BO14_GCR.OUT, DSSDTISS.DAT, Feb56SPE.OUT, FLX.DAT, FRBEHELI.DAT, IMACEOX.G, ISSDELAY.DAT, ISSDELAY.G, ISSMNT.DAT, ISSVST.DAT, ISSWMNX.DAT, ISO_GCR.OUT, ISO_GCR.OWV, ISO_GCR2.OUT, last_gcr_time.txt, LIS_BO11.DAT, LISTMP.DAT, MONTHLY.TXT, PHIFRISS.DAT, Sep89SPE.OUT, /BO14_Inx, /BO14_W64, /BON_14UC</i>
GCR_MODELS/BO14_Inx, GCR_MODELS/BO14_W64, and GCR_MODELS/BON_14UC/ BON_2104UserCopy/MAC_OSX10.10 ^B	<i>BON2014 (BON2014.exe for WIN64), /IN, /IN/daterange.dat, /IN/iss_sidc.dat,/IN/lis_bon14.dat, /IN/solar_cycle_date.dat, /IN/ssn_minmax.dat, /OUT, /OUT/allflux.dat, /OUT/avephi.dat, /OUT/FRBEHELI.DAT, /OUT/ISSDELAY.DAT, /OUT/ISSVST.DAT, /OUT/LISTMP.DAT, /OUT/running_month_phi.dat</i>
KP_INDEX	KP_INDEX.TXT
SHOWERS	Alshower.dat, Arshower.dat, B_shower.dat, Beshower.dat, C_shower.dat, Cashower.dat, Clshower.dat, Crshower.dat, F_shower.dat, Feshower.dat, H_shower.dat, Heshower.dat, K_shower.dat, Lishower.dat, Mgshower.dat, Mnshower.dat, N_shower.dat, Nashower.dat, Neshower.dat, nushower.dat, O_shower.dat, P_shower.dat, S_shower.dat, Scshower.dat, Sishower.dat, Tishower.dat, V_Alshower.dat
SOLARMOD	MORDATES.2K, MV-DATES.L99
SUNSPOTS	SN_m_tot_V20.csv
<p>^A The executable can have any name. “/” indicates a subfolder for any OS.</p> <p>^B The folder contents are shown here to aid the user in attempting to use this model. Since it must be called from a script or external program with the expected name, the folders could be placed anywhere in the file structure.</p>	

Appendix B: CARI.INI Sample File Contents

CARI.INI is the primary external file use to control CARI-7.

```

DIAGNOSE = NO!           !DEFAULT DIAGNOSTIC OUTPUT SETTING
VIEWER    = WRITE       !DEFAULT FILE VIEWER FOR OUTPUT
OUTPUT    = FILE        !DEFAULT DESTINATION OF OUTPUT
OS        = WIN         !CURRENT OS, CHOOSE WIN OR UNIX
DISPLAY   = DOS         !HOW TO DISPLAY MENUS: DOS OR GUI (GUI NOT YET CODED!)
MENUS     = YES         !YES INDICATES USING ALL INTERNAL MENUS
SUPERPOS  = NO!        !DEFAULT IS 'NO!', 'YES' WILL TURN ON FOR FLIGHT DOSES WITH MENUS='NO!'
GCR_MODEL = 4           !1-7, SPECTRUM USED FOR FLIGHT DOSES
NVCR      = 0           !0-4, ISO OR ANGULARLY RESOLVED TRANSPORT: 0=RECOMMENDED, OTHER OPTIONS SEE BELOW
VEHICLE   = NO!        !DEFAULT IS NO! CHANGE TO YES TO USE VEHICLE DATA FROM VEHICLE.DAT
CARI7RPT  = YES        !TOGGLES WRITING FILE CARI-7.RPT DURING *.BIG FLIGHT PROFILE PROCESSING
END       = END

```

MENU-LESS OPERATION IS PRIMARILY CONTROLLED FROM "DEFAULT.INP" (see NOTES below).

SEE ALSO NOTES IN FILE "FROMUSER.DAT"

SEE ALSO NOTES IN FILE "VEHICLE.DAT"

NOTES:

0. DO NOT CHANGE THE FORMAT OF THIS FILE ABOVE "END"!!! EACH LINE IS A10,A2,A12 THROUGH END.
1. VIEWER EXPECTED COMMAND FORM IS 'VIEWER FILE_TO_OPEN', FOR LINUX/UNIX SYSTEMS './' IS NOT NEEDED SINCE OS RELATED CHANGES WILL HANDLE THAT SWITCH, BUT THE PROGRAM NAME COULD BE CASE SENSITIVE! ALSO, SELECTION IN VIEWER DESIGNATES WHICH PROGRAM IS CALLED FOR EDITING/VIEWING EXTERNAL FILES AT RUNTIME.
2. ONLY FILE WORKS RIGHT NOW, OUTPUT DIRECTLY TO THE SCREEN AND TO BOTH ARE NOT YET CODED!
3. DIAGNOSE SETS INTERNAL DIAGNOSTIC PRINTING FOR ROUTINES NOT UNDER MANUAL CONTROL IN THE SOURCE CODE, SET TO 'YES' FOR MASSIVE OUTPUT IN FILES 'DIAGNOSE\CARI7CHK.DAT','DIAGNOSE\DIAGDAP.DAT',ETC. RUN TIMES WILL BE INCREASED SIGNIFICANTLY.

4. SELECTS THE OPERATING SYSTEM: WINDOWS/DOS OR OTHER (I.E., LINUX/UNIX). THIS CHANGES PATH IN SYSTEM CALLS, AS WELL AS ANY OS FILE MANIPULATION COMMANDS NOT AVAILABLE TO THE STD COMPILER. WINDOWS AND LINUX PATHS TO FILES AND COMMANDS ARE ENCODED. SOME TWEAKING OF SOURCE CODE MAY BE NEEDED FOR OTHER OSes.
5. DISPLAY SELECTS THE USER INTERFACE: DOS (COMMAND PROMPT SHELL) OR GUI (NOT YET AVAILABLE)
6. TOGGLES INTERNAL MENUS. STARTING THE PROGRAM WITH THIS OPTION = 'NO!' WILL RESULT IN AN ATTEMPT TO ANALYZE THE CONTENTS OF THE FILE NAMED AT LINE 5 IN DEFAULT.INP. IF THE FILE IS A .BIG OR .DEG FLIGHT DATA FILE AND THE DATE = '0000/00/00', THEN DATES IN THE NAMED FLIGHT DATA FILE WILL BE USED, BUT OTHER RUN OPTIONS WILL BE CONTROLLED BY THE DEFAULT.INP AND CARI.INI CONTENTS. FOR LOCATION DATA FILES THE DATE AND OPTIONS IN DEFAULT.INP ARE IGNORED, THE PROGRAM ALWAYS USES THE DATA IN THE NAMED FILE. FILENAMES ARE LIMITED TO LESS THAN 30 CHARACTERS. NORMAL OUTPUT FILES ARE PRODUCED:
 - FOR *.BIG OUTPUT WILL BE IN *.OUT
 - FOR *.DEG A SUMMARY WILL BE IN *.SUM AND A LONGER REPORT IN *.DAT
 - FOR A LOCATION FILE (SUGGEST *.LOC, OR *.TXT) THE OUTPUT WILL BE IN *.ANS (THE NAME OF THE LOCATION DATA FILE CAN HAVE ANY 3-CHAR EXTENSION EXCEPT 'DEG' OR 'BIG').

'FEW' WILL PROVIDE MENUS WITH A REDUCED SET OF OPTIONS, MORE LIKE CARI-6/6M. IT CHOOSES TOTAL EFFECTIVE DOSE FROM ICRP PUB 103.
7. SUPERPOS TOGGLES THE SUPERPOSITION APPROXIMATION FOR 'NO MENUS' USE FLIGHT ANALYSIS ONLY! IT HAS NO INFLUENCE ON LOCATION FILE DATA ANALYSIS. 'NO' (RECOMMENDED AND DEFAULT) USES SHOWER DATA FOR ALL IONS (PROTONS THROUGH IRON) IN CALCULATIONS. 'YES' FORCES THE CALCULATIONS TO USE THE SUPERPOSITION APPROXIMATION. IN THIS APPROXIMATION ALL PRIMARY NUCLEI WITH MORE THAN ONE NUCLEON ARE APPROXIMATED AS Z FREE PROTONS AND N-Z FREE NEUTRONS OF THE SAME ENERGY PER NUCLEON AFTER GEOMAGNETIC RIGIDITY CUTOFF FILTERING, (E.G. C-12 ENTERS THE ATMOSPHERE AS 6 FREE PROTONS AND 6 FREE NEUTRONS).
8. GCR_MODEL AFFECTS 'NO MENUS' USE FOR FLIGHT ANALYSIS ONLY. IT HAS NO INFLUENCE ON LOCATION FILE DATA ANALYSIS. 1=ISO, 2=BO11, 3=BO14*, 4=ISO(v2)**, 5=LaRCFeb56SPE, 6=LaRCSep89SPE, 7=USER SUPPLIED
IT SETS THE MODEL TO USE AS THE INPUT PRIMARY CR SPECTRUM. FOR THE TWO SPE SPECTRA (5 AND 6), PLEASE NOTE THAT THE TWO SOLAR EVENT MODELS ARE TOTAL EVENT FLUENCE SPECTRA.

TO INPUT A CUSTOM SPECTRUM, SET GCR_MODEL = 7 AND PUT THE SPECTRUM DATA IN THE FILE GCR_MODELS\MY_MODEL.OUT.
IT MUST HAVE THE SAME FORMAT AS THE BO11_GCR.OUT FILE.

EXPECTED UNITS ARE: nuclei/(m²-sr-s-GeV) FOR Z=1 to Z=26 (H THROUGH Fe) IONS.

*THE BO14 SPECTRUM NEEDS A CALLING SCRIPT APPROPRIATE TO THE OS AND SHELL. 'RUNBON14.BAT' IS SUPPLIED FOR WINDOWS OS. ALSO, THE LINUX EXECUTABLE MAY NOT BE COMPATIBLE WITH ANY PARTICULAR VERSION OF LINUX. CONTACT THE GCR MODEL DEVELOPERS TO REQUEST SOURCE CODE OR ALTERNATIVE EXECUTABLES FOR THIS MODEL.

**THE SECOND ISO SPECTRUM (4) IS THE ISO LIS MODULATED USING CARI-6 HELIOCENTRIC POTENTIAL AT 1 AU.

9. CHOOSE ISOTROPIC OR ANGULARLY RESOLVED TREATMENTS OF SHOWERS AND CUTOFF RIGIDITIES.

0 = 'None', MODEL USES ALTITUDE ADJUSTED APPARENT CUTOFF RIGIDITY CALCULATED FROM THE EFFECTIVE VERTICAL CUTOFF RIGIDITY FOR ALL ANGLES OF APPROACH AND ASSUMES FLUX IS ISOTROPICALLY INCIDENT (RECOMMENDED AND DEFAULT).

1 = 'Locally-Adjusted Cutoffs', THE CELESTIAL SPHERE SURROUNDING THE VEHICLE AND UNBLOCKED BY THE EARTH (I.E., ABOVE THE HORIZON) IS DIVIDED INTO 900 SECTORS WHICH ARE ASSIGNED NONVERTICAL CUTOFF RIGIDITIES CALCULATED FROM SHEA&SMART EQUATIONS BASED ON LAT, LON, ZENITH, AZIMUTH, DATE, AND ALTITUDE. THE FRACTION OF THE SHOWER ENTERING EACH SECTOR OF SKY IS ATTENUATED USING THE CALCULATED CUTOFF RIGIDITY. (I.E., THE LOCAL CUTOFF RIGIDITY IN THE DIRECTION OF THE CRAFT IS USED FOR INCIDENT GCR FLUX ENTERING THAT SECTOR).

2 = 'Zenith-Dependent Transport', MODEL USES A SLANT FUNCTION TO TREAT ISO SHOWERS AS BEAMS WITH ZENITH DEPENDENT DEPTH. EFFECTIVE VERTICAL CUTOFF RIGIDITIES ARE USED FOR ALL ANGLES OF APPROACH.***

3 = 'Transport and Cutoffs', RUN USING BOTH OPTION 1 AND 2.***

4 = 'None', MODEL USES ALTITUDE ADJUSTED EFFECTIVE VERTICAL CUTOFF RIGIDITY FOR ALL ANGLES OF APPROACH AND FLUX IS HANDLED AS ISOTROPICALLY INCIDENT

***NOTE OF CAUTION: THE ANGULARLY RESOLVED CUTOFFS ARE ACCURATELY CALCULATED, BUT THE SHOWER SECONDARY FLUENCES WERE CALCULATED USING AN ISOTROPICALLY INCIDENT SOURCE AND THUS DO NOT LEND THEMSELVES WELL TO ANGULARLY RESOLVED TREATMENTS (EVERYTHING HAS ALREADY BEEN AVERAGED OVER ANGLE IN THE TALLIES). ANGULARLY RESOLVED RESULTS WILL BE MORE APPROXIMATE IN THAT SENSE THAN FOR THE COMPLETELY ISOTROPIC TREATMENT.

10. VEHICLE TOGGLES USING OPTIONAL SHIELD DEFINITION DEFINED BY THE USER. THE USUAL (DEFAULT) PRACTICE IS TO ASSUME NO

SHIELDING OF OCCUPANTS BY THE VEHICLE. TO USE ALUMINUM AND POLYETHYLENE THICKNESSES DEFINED IN FILE 'VEHICLE.DAT'
SET THIS TO 'YES'.

11. THE CARI-7.RPT FILE HAS ESSENTIALLY THE SAME FORMAT AND NEW DATA WILL BE APPENDED TO IT JUST AS CARI-6.RPT WAS FOR CARI-6 USERS. THIS ALLOWS THE AUTOMATED STORING IN A SINGLE FILE OF SEVERAL RUNS OF THE SAME FLIGHT PLANS USING DIFFERENT DATES (E.G., FOR ROUTE DOSE STUDIES) AND EASES TRANSITION TO CARI-7 FROM CARI-6. SINCE THIS FILE WILL CONTINUOUSLY GROW IF THIS SWITCH IS 'YES', CAUTION IN REGARDS TO READABILITY IS SUGGESTED.

Appendix C. DEFAULT.INP sample file contents

This file designates the data file to read for scripts and allows designation of some parameter changes from the source file. In DEFAULT.INP only the first five lines are read. Comments or alternative data lines may be placed after these lines.

```
0000/00/00  
0  
0  
2  
places20190520.loc  
icrulocs.dat
```

ONLY THE FIRST 5 LINES ARE READ. COMMENTS MAY BE PLACED AFTER LINE 5

Appendix D. VEHICLE.DAT sample file contents

The file VEHICLE.DAT allows the user to define structural shielding to incorporate into the calculations.

0.
0.
0.

END OF DATA

To use this file there must be a line in the variable list in CARI.INI that reads

VEHICLE = YES

Reading this file must be indicated in CARI.INI or it will be ignored (NO! is the default).

NOTE: This file allows the user to define structural shielding for the vehicle

1st line is Al alloy thickness in units of g/cm^2

2nd line is HDPE (polyethylene, i.e., CH₂) thickness in units of g/cm^2

3rd line is dry air thickness in units of g/cm^2 , used for testing.

The net effect is the thickness weighted average of the three shields.

Appendix E. FROMUSER.DAT sample file contents

This file overrides values of certain parameters, enabling use of values other than historical values read from the databases.

```
-1, 'Kp index'  
-1.0000, 'Vertical Cutoff Rigidity'  
-1.0000, 'Forbush scale factor'
```

Use of this file can considerably reduce run time by eliminating searches.

A negative value to indicate searching the databases, positive indicates user decided value.

FOR THIS VERSION, CARI-7A v4.00, ONLY THE FIRST 3 LINES ARE READ.

Expected line formats are:

Real, A8

Real, A24

Real, A20

A space is recommended before the number on each line to assure proper reading across platforms.

TO CHANGE OTHER OPTIONS SUCH AS THE INCIDENT CR (GCR or SPE) MODEL AND TRANSPORT OPTIONS
CHANGE THE CONTENTS OF THE FILE 'CARI.INI' (MAIN MENU OPTION 6, THEN OPTION 1).

ANY COMMENTS MAY BE PLACED HERE.

Appendix F. Flight profiles: Geodesic routes sample files

Geodesic route information is read from files called .BIG files. Thousands of flights are allowed in a single file. Output from analysis of *.BIG is written to *.OUT.

Contents of EXAMPLE.BIG

FL-9.EZ

03/1995

KJFK

TJSJ

2

29

33000 48

37000 87

17

Contents of EXAMPLE.OUT

FLIGHTS FROM EXAMPLE.BIG

PARTICLE 38 DOSEKIND 2

GCR MODEL 4 SUPERPOSITION 0 YMD 0000/00/00

FL-9.EZ KJFK TJSJ 9.2562E+00 microSv, ICRP Pub. 103 EFFECTIVE DOSE

TOTAL

REACHED END OF BIG FILE

Appendix G. Waypoint-based flights: *.DEG and *.sample file

When a .DEG file is used for flight dose calculations two output files are generated. The shorter file summarizes the user choices and the resulting dose. The longer file is a table of dose rates and total doses throughout the flight, ending with the same summary report found in the shorter file.

Contents of EXAMPLE.DEG

```
01/2002, FL-27
DEG MIN N/S DEG MIN E/W FEET TIME (MIN)
4, 58.76, N, 97, 0.27, W, 667, 0
3, 30.29, N, 85, 32.60, W, 33000, 6
2, 17.01, N, 84, 15.59, W, 33000, 15
1, 17.01, S, 84, 15.59, W, 37000, 18
2, 24.25, S, 3, 28.7, W, 37000, 21
3, 28.30, S, 0, 27.2, W, 80, 25
```

Contents of EXAMPLE.SUM; short form output from analysis of EXAMPLE.DEG

```
FLIGHT FROM EXAMPLE.DEG
GCR MODEL 4 TRANSPORT AND CUTOFFS: 0 SUPERPOSITION: 0
DATE: 2002/01/00 HOUR: 0
5.0595E-01 TOTAL microSv, ICRP Pub. 103 EFFECTIVE DOSE
```

Contents of EXAMPLE.DAT; long form output from analysis of EXAMPLE.DEG

LAT (N)	LON (E)	DEPTH	STEP	DOSE RATE	TOTAL DOSE
4.8633	263.9523	913.733	1	4.0013E-02	6.6688E-04
4.6272	265.8650	745.696	2	8.8518E-02	2.1422E-03
4.3859	267.7763	603.604	3	1.9242E-01	5.3492E-03
4.1398	269.6864	484.281	4	4.0916E-01	1.2168E-02
3.8890	271.5954	384.813	5	7.7215E-01	2.5038E-02
3.6339	273.5032	302.575	6	1.2792E+00	4.6358E-02
3.4370	274.5280	267.166	7	1.5712E+00	7.2545E-02
3.3014	274.6708	267.166	8	1.5699E+00	9.8709E-02
3.1657	274.8135	267.166	9	1.5686E+00	1.2485E-01
3.0300	274.9561	267.166	10	1.5673E+00	1.5097E-01
2.8944	275.0988	267.166	11	1.5662E+00	1.7708E-01

2.7586	275.2413	267.166	12	1.5652E+00	2.0316E-01
2.6229	275.3839	267.166	13	1.5642E+00	2.2923E-01
2.4872	275.5264	267.166	14	1.5633E+00	2.5529E-01
2.3514	275.6689	267.166	15	1.5624E+00	2.8133E-01
1.6890	275.7402	258.946	16	1.6307E+00	3.0851E-01
0.5000	275.7402	243.121	17	1.7688E+00	3.3799E-01
-0.6890	275.7402	228.084	18	1.9073E+00	3.6978E-01
-1.7689	289.1926	220.891	19	1.9786E+00	4.0275E-01
-2.4251	316.1156	220.891	20	1.9487E+00	4.3523E-01
-2.5525	343.0536	220.891	21	1.9578E+00	4.6786E-01
-2.5380	356.8995	274.944	22	1.4451E+00	4.9195E-01
-2.8054	357.6554	415.311	23	6.1240E-01	5.0215E-01
-3.0723	358.4116	608.793	24	1.8035E-01	5.0516E-01
-3.3387	359.1682	869.552	25	4.7393E-02	5.0595E-01

GCR MODEL 4 TRANSPORT AND CUTOFFS: 0 SUPERPOSITION: 0
DATE: 2002/01/00 HOUR: 0
5.0595E-01 TOTAL microSv, ICRP Pub. 103 EFFECTIVE DOSE

Appendix H. Multiple locations: EXAMPLES.LOC and EXAMPLES.ANS sample files

A .LOC file is a list of locations. They need not be related in any way, but it can be useful to add comments. Data analysis will start at the first line that is not a comment line after the line that begins with the first uncommented "START-," and end at the last line before the first uncommented "STOP--." Comment lines can be indicated by including a "C" as the first character or placing them before the START line at beginning of the active section or after the STOP line that indicates the end of the active section of the file.

```
C FORMATS (66 character limit)
C 1. BY EXPLICIT LOCATION
C N/S, LATITUDE, E/E, LONGITUDE, G/F/K, DEPTH, DATE, HR, D, P, GCR, SP
C N, XX.XXXXX, E, XXX.XXXX, F, XXXX.XXXX YYYY/MM/DD, HXX, DX, PXX, CX, SX
C----- OR -----
C 2. USE AN AIRPORT ICAO CODE
C A, CODE, G/F, ALTITUDE, DATE, HOUR, DOSE, PARTICLE, GCR, SP
C A, AAAAA, F, XXXX.XXXX, YYYY/MM/DD, H0 to H24, DX, PXX, CX, SX
C----- OR -----
C 3. ADD A COMMENT
C EVERY LINE ABOVE THE FIRST INSTANCE OF START OR BELOW THE FIRST STOP IS A COMMENT
C BETWEEN START AND STOP, BEGIN A COMMENT LINE WITH A 'C '
C LIMIT DATA LINES TO 66 CHARACTERS
C
C           G/F/K
C Input altitude units: atmospheric depth 'G' (g/sq.cm),
C                       feet 'F', or
C                       kilometers, K
C
C           H##
C <0> average
C <1-24> hour of the day in UT+1
C
C           DOSE (D#)
C <1> Particle Flux (Any rad but TOTAL, i.e., no P0)
C     (TOTAL for P0 is total ion flux)
C <2> ICRP PUB 103 EFFECTIVE DOSE
C <3> ICRP PUB 60 EFFECTIVE DOSE
C <4> ICRU H*(10) AMBIENT DOSE EQUIVALENT
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C      <5> WHOLE BODY ABSORBED DOSE
C
C      RADIATION (P#)
C      <0> TOTAL      <10> DEUTERONS  <20>F      <30>K
C      <1> NEUTRONS   <11> TRITONS    <21>Ne     <31>Ca
C      <2> PHOTONS    <12> HELIONS    <22>Na     <32>Sc
C      <3> ELECTRONS  <13> ALPHAS     <23>Mg     <33>Ti
C      <4> POSITRONS  <14> Li         <24>Al     <34>V
C      <5> NEG. MUONS <15> Be         <25>Si     <35>Cr
C      <6> POS. MUONS <16> B          <26>P     <36>Mn
C      <7> PROTONS    <17> C          <27>S     <37>Fe
C      <8> POS. PIONS <18> N         <28>Cl
C      <9> NEG. PIONS <19> O         <29>Ar

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C      GCR SPECTRUM (C#)
C      <4> 2004 ISO/Nymmik GCR Local Interstellar Spectrum
C      modulated using adjusted CARI-6 heliocentric
C      potential (Other models available in CARI-7A.)

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C      SUPERPOSITION (S#)
C      <0> Off (Transport nuclei using LAQGSM and CEM nuclei-nuclei
C      collision models in MCNPX 2.7.0) (SUPERPOSITION is
C      always 'off' for CARI-7)

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START-----
C, ICRU Rep 84 quick comparison points
C, ICRU SOL MIN
N, 85.0000, E, 5.00, F, 31000.0 , 1998/01/00, H0, D4, P0, C4, S0
N, 85.0000, E, 5.00, F, 35000.0 , 1998/01/00, H0, D4, P0, C4, S0
N, 85.0000, E, 5.00, F, 39000.0 , 1998/01/00, H0, D4, P0, C4, S0
N, 15.0000, E, 75.0, F, 31000.0 , 1998/01/00, H0, D4, P0, C4, S0
N, 15.0000, E, 75.0, F, 35000.0 , 1998/01/00, H0, D4, P0, C4, S0
N, 15.0000, E, 75.0, F, 39000.0 , 1998/01/00, H0, D4, P0, C4, S0
C, ICRU SOL MAX
N, 85.0000, E, 5.00, F, 31000.0 , 2002/01/00, H0, D4, P0, C4, S0
N, 85.0000, E, 5.00, F, 35000.0 , 2002/01/00, H0, D4, P0, C4, S0
N, 85.0000, E, 5.00, F, 39000.0 , 2002/01/00, H0, D4, P0, C4, S0

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N, 15.0000, E, 75.0, F, 31000.0 , 2002/01/00, H0, D4, P0, C4, S0
 N, 15.0000, E, 75.0, F, 35000.0 , 2002/01/00, H0, D4, P0, C4, S0
 N, 15.0000, E, 75.0, F, 39000.0 , 2002/01/00, H0, D4, P0, C4, S0
 C, Altitude profile high latitude QUICK TEST, ICRU Sol Min
 N, 85.0000, E, 5.0000, G, 1000. , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 900.0 , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 700.0 , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 500.0 , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 300.0 , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 200.0 , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 125.0 , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 100.0 , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 77.0 , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 50.0 , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 30.0 , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 20.0 , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 15.0 , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 10.0 , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 5.0 , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 2.0 , 1998/01/00, H0, D2, P0, C4, S0
 N, 85.0000, E, 5.0000, G, 1.0 , 1998/01/00, H0, D2, P0, C4, S0
 C, Altitude profile low latitude QUICK TEST, ICRU Sol Max
 N, 15.0000, E, 75.0000, G, 1000. , 2002/01/00, H0, D2, P0, C4, S0
 N, 15.0000, E, 75.0000, G, 900.0 , 2002/01/00, H0, D2, P0, C4, S0
 N, 15.0000, E, 75.0000, G, 700.0 , 2002/01/00, H0, D2, P0, C4, S0
 N, 15.0000, E, 75.0000, G, 500.0 , 2002/01/00, H0, D2, P0, C4, S0
 N, 15.0000, E, 75.0000, G, 300.0 , 2002/01/00, H0, D2, P0, C4, S0
 N, 15.0000, E, 75.0000, G, 200.0 , 2002/01/00, H0, D2, P0, C4, S0
 N, 15.0000, E, 75.0000, G, 125.0 , 2002/01/00, H0, D2, P0, C4, S0
 N, 15.0000, E, 75.0000, G, 100.0 , 2002/01/00, H0, D2, P0, C4, S0
 N, 15.0000, E, 75.0000, G, 77.0 , 2002/01/00, H0, D2, P0, C4, S0
 N, 15.0000, E, 75.0000, G, 50.0 , 2002/01/00, H0, D2, P0, C4, S0
 N, 15.0000, E, 75.0000, G, 30.0 , 2002/01/00, H0, D2, P0, C4, S0
 N, 15.0000, E, 75.0000, G, 20.0 , 2002/01/00, H0, D2, P0, C4, S0
 N, 15.0000, E, 75.0000, G, 15.0 , 2002/01/00, H0, D2, P0, C4, S0
 N, 15.0000, E, 75.0000, G, 10.0 , 2002/01/00, H0, D2, P0, C4, S0
 N, 15.0000, E, 75.0000, G, 5.0 , 2002/01/00, H0, D2, P0, C4, S0

N, 15.0000, E, 75.0000, G, 2.0 , 2002/01/00, H0, D2, P0, C4, S0
 N, 15.0000, E, 75.0000, G, 1.0 , 2002/01/00, H0, D2, P0, C4, S0
 C Neutron flux profile near solar min, mid latitude
 N, 46.0000, E, 60.0000, G, 1 , 1998/03/00, H0, D1, P1, C4, S0
 N, 46.0000, E, 60.0000, G, 2 , 1998/03/00, H0, D1, P1, C4, S0
 N, 46.0000, E, 60.0000, G, 4 , 1998/03/00, H0, D1, P1, C4, S0
 N, 46.0000, E, 60.0000, G, 7 , 1998/03/00, H0, D1, P1, C4, S0
 N, 46.0000, E, 60.0000, G, 15 , 1998/03/00, H0, D1, P1, C4, S0
 N, 46.0000, E, 60.0000, G, 30 , 1998/03/00, H0, D1, P1, C4, S0
 N, 46.0000, E, 60.0000, G, 50 , 1998/03/00, H0, D1, P1, C4, S0
 N, 46.0000, E, 60.0000, G, 77 , 1998/03/00, H0, D1, P1, C4, S0
 N, 46.0000, E, 60.0000, G, 125 , 1998/03/00, H0, D1, P1, C4, S0
 N, 46.0000, E, 60.0000, G, 200 , 1998/03/00, H0, D1, P1, C4, S0
 N, 46.0000, E, 60.0000, G, 300 , 1998/03/00, H0, D1, P1, C4, S0
 N, 46.0000, E, 60.0000, G, 500 , 1998/03/00, H0, D1, P1, C4, S0
 N, 46.0000, E, 60.0000, G, 1000 , 1998/03/00, H0, D1, P1, C4, S0
 C, AIR-2 NEUTRON FLUX MEASUREMENTS
 N, 53.9, W, 117.2, G, 56.0, 1997/06/13, H0, D1, P1, C4, S0
 N, 18.5, W, 127.2, G, 53.5, 1997/06/11, H0, D1, P1, C4, S0
 N, 55.6, W, 120.6, G, 101.0, 1997/06/13, H0, D1, P1, C4, S0
 N, 37.6, W, 122.3, G, 201.0, 1997/06/11, H0, D1, P1, C4, S0
 C A Balloon flight over Ft. Churchill
 A, PAEI , F, 30000, 1965/08/03, H0, D4, P0, C4, S0
 A, PAEI , F, 35000, 1965/08/03, H0, D4, P0, C4, S0
 A, PAEI , F, 40000, 1965/08/03, H0, D4, P0, C4, S0
 A, PAEI , F, 45000, 1965/08/03, H0, D4, P0, C4, S0
 A, PAEI , F, 50000, 1965/08/03, H0, D4, P0, C4, S0
 A, PAEI , F, 55000, 1965/08/03, H0, D4, P0, C4, S0
 A, PAEI , F, 60000, 1965/08/03, H0, D4, P0, C4, S0
 A, PAEI , F, 65000, 1965/08/03, H0, D4, P0, C4, S0
 A, PAEI , F, 70000, 1965/08/03, H0, D4, P0, C4, S0
 A, PAEI , F, 80000, 1965/08/03, H0, D4, P0, C4, S0
 A, PAEI , F, 90000, 1965/08/03, H0, D4, P0, C4, S0
 A, PAEI , F, 100000, 1965/08/03, H0, D4, P0, C4, S0
 A, PAEI , F, 100000, 1965/08/03, H0, D4, P0, C4, S0
 A, PAEI , F, 110000, 1965/08/03, H0, D4, P0, C4, S0
 A, PAEI , F, 120000, 1965/08/03, H0, D4, P0, C4, S0

A, PAEI , F, 130000, 1965/08/03, H0, D4, P0, C4, S0
A, PAEI , F, 140000, 1965/08/03, H0, D4, P0, C4, S0
A, PAEI , F, 30000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 35000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 40000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 45000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 50000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 55000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 60000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 65000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 70000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 80000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 90000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 100000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 100000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 110000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 120000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 130000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 140000, 1965/08/03, H0, D5, P0, C4, S0
A, PAEI , F, 30000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 35000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 40000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 45000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 50000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 55000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 60000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 65000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 70000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 80000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 90000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 100000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 100000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 110000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 120000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 130000, 1965/08/03, H0, D1, P1, C4, S0
A, PAEI , F, 140000, 1965/08/03, H0, D1, P1, C4, S0

STOP-----

Both CARI-7 and CARI-7A use the same format for location input, but output form is slightly simpler for CARI-7, since uncertainty (column SIGMA) is not reported. The .ANS files are written in the standard comma delimited data format. Results for the above locations would be in EXAMPLES.ANS (the small font used below was needed to get each line of output, which varies with requested calculation, onto a single line of text). Note that only comment lines within the START-to-STOP section of the .LOC file are repeated within the .ANS file, and only the first 60 characters of long comment lines will be printed.

LAT,	LON,	ALTITUDE,	DATE,	HR,	VCR(GV),	PARTICLE,	DOSE RATE,	SIGMA,	UNIT,	QUANTITY
C, ICRU Rep 84 quick comparison points										
C, ICRU SOL MIN										
85.00000,	5.00000,	31000.0000,	F,1998/01/00,	0,	0.00,	TOTAL	,	4.7168E+00,	2.9486E-01,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)
85.00000,	5.00000,	35000.0000,	F,1998/01/00,	0,	0.00,	TOTAL	,	6.5284E+00,	4.0836E-01,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)
85.00000,	5.00000,	39000.0000,	F,1998/01/00,	0,	0.00,	TOTAL	,	8.5084E+00,	5.3531E-01,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)
15.00000,	75.00000,	31000.0000,	F,1998/01/00,	0,	17.06,	TOTAL	,	1.2386E+00,	7.9670E-02,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)
15.00000,	75.00000,	35000.0000,	F,1998/01/00,	0,	17.05,	TOTAL	,	1.6137E+00,	1.0124E-01,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)
15.00000,	75.00000,	39000.0000,	F,1998/01/00,	0,	17.05,	TOTAL	,	1.9532E+00,	1.2161E-01,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)
C, ICRU SOL MAX										
85.00000,	5.00000,	31000.0000,	F,2002/01/00,	0,	0.00,	TOTAL	,	3.4341E+00,	2.0349E-01,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)
85.00000,	5.00000,	35000.0000,	F,2002/01/00,	0,	0.00,	TOTAL	,	4.6819E+00,	2.7564E-01,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)
85.00000,	5.00000,	39000.0000,	F,2002/01/00,	0,	0.00,	TOTAL	,	6.0083E+00,	3.5337E-01,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)
15.00000,	75.00000,	31000.0000,	F,2002/01/00,	0,	17.07,	TOTAL	,	1.1771E+00,	7.3223E-02,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)
15.00000,	75.00000,	35000.0000,	F,2002/01/00,	0,	17.06,	TOTAL	,	1.5352E+00,	9.3002E-02,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)
15.00000,	75.00000,	39000.0000,	F,2002/01/00,	0,	17.05,	TOTAL	,	1.8580E+00,	1.1163E-01,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)
C, Altitude profile high latitude QUICK TEST, ICRU Sol Min										
85.00000,	5.00000,	1000.0000,	G,1998/01/00,	0,	0.00,	TOTAL	,	3.9747E-02,	2.4845E-03,	microSv/hr, ICRP Pub. 103 EFFECTIVE DOSE
85.00000,	5.00000,	900.0000,	G,1998/01/00,	0,	0.00,	TOTAL	,	6.8596E-02,	4.2481E-03,	microSv/hr, ICRP Pub. 103 EFFECTIVE DOSE
85.00000,	5.00000,	700.0000,	G,1998/01/00,	0,	0.00,	TOTAL	,	2.3447E-01,	1.4636E-02,	microSv/hr, ICRP Pub. 103 EFFECTIVE DOSE
85.00000,	5.00000,	500.0000,	G,1998/01/00,	0,	0.00,	TOTAL	,	9.3018E-01,	5.8945E-02,	microSv/hr, ICRP Pub. 103 EFFECTIVE DOSE
85.00000,	5.00000,	300.0000,	G,1998/01/00,	0,	0.00,	TOTAL	,	3.8272E+00,	2.3612E-01,	microSv/hr, ICRP Pub. 103 EFFECTIVE DOSE
85.00000,	5.00000,	200.0000,	G,1998/01/00,	0,	0.00,	TOTAL	,	7.4620E+00,	4.6099E-01,	microSv/hr, ICRP Pub. 103 EFFECTIVE DOSE

85.00000,	5.00000,	125.0000,G,1998/01/00,	0,	0.00,TOTAL	,	1.2156E+01,	7.5008E-01,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
85.00000,	5.00000,	100.0000,G,1998/01/00,	0,	0.00,TOTAL	,	1.4847E+01,	8.8888E-01,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
85.00000,	5.00000,	77.0000,G,1998/01/00,	0,	0.00,TOTAL	,	1.8197E+01,	1.0606E+00,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
85.00000,	5.00000,	50.0000,G,1998/01/00,	0,	0.00,TOTAL	,	2.3763E+01,	1.3246E+00,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
85.00000,	5.00000,	30.0000,G,1998/01/00,	0,	0.00,TOTAL	,	3.1664E+01,	1.6280E+00,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
85.00000,	5.00000,	20.0000,G,1998/01/00,	0,	0.00,TOTAL	,	3.9137E+01,	1.8936E+00,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
85.00000,	5.00000,	15.0000,G,1998/01/00,	0,	0.00,TOTAL	,	4.3557E+01,	2.0418E+00,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
85.00000,	5.00000,	10.0000,G,1998/01/00,	0,	0.00,TOTAL	,	5.1771E+01,	2.3361E+00,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
85.00000,	5.00000,	5.0000,G,1998/01/00,	0,	0.00,TOTAL	,	6.1769E+01,	2.6334E+00,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
85.00000,	5.00000,	2.0000,G,1998/01/00,	0,	0.00,TOTAL	,	7.5680E+01,	3.0459E+00,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
85.00000,	5.00000,	1.0000,G,1998/01/00,	0,	0.00,TOTAL	,	8.0324E+01,	3.1784E+00,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE

C, Altitude profile low latitude QUICK TEST, ICRU Sol Max

15.00000,	75.00000,	1000.0000,G,2002/01/00,	0,	17.12,TOTAL	,	2.1928E-02,	1.7105E-03,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
15.00000,	75.00000,	900.0000,G,2002/01/00,	0,	17.11,TOTAL	,	3.6744E-02,	2.8421E-03,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
15.00000,	75.00000,	700.0000,G,2002/01/00,	0,	17.10,TOTAL	,	9.1931E-02,	7.0363E-03,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
15.00000,	75.00000,	500.0000,G,2002/01/00,	0,	17.09,TOTAL	,	2.9474E-01,	2.1056E-02,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
15.00000,	75.00000,	300.0000,G,2002/01/00,	0,	17.07,TOTAL	,	1.0409E+00,	6.4231E-02,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
15.00000,	75.00000,	200.0000,G,2002/01/00,	0,	17.05,TOTAL	,	1.7828E+00,	1.0458E-01,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
15.00000,	75.00000,	125.0000,G,2002/01/00,	0,	17.04,TOTAL	,	2.3267E+00,	1.3844E-01,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
15.00000,	75.00000,	100.0000,G,2002/01/00,	0,	17.03,TOTAL	,	2.4424E+00,	1.4699E-01,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
15.00000,	75.00000,	77.0000,G,2002/01/00,	0,	17.02,TOTAL	,	2.5362E+00,	1.5374E-01,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
15.00000,	75.00000,	50.0000,G,2002/01/00,	0,	17.00,TOTAL	,	2.6552E+00,	1.5974E-01,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
15.00000,	75.00000,	30.0000,G,2002/01/00,	0,	16.99,TOTAL	,	2.9119E+00,	1.6933E-01,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
15.00000,	75.00000,	20.0000,G,2002/01/00,	0,	16.97,TOTAL	,	3.1727E+00,	1.8349E-01,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
15.00000,	75.00000,	15.0000,G,2002/01/00,	0,	16.96,TOTAL	,	3.2166E+00,	1.9123E-01,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
15.00000,	75.00000,	10.0000,G,2002/01/00,	0,	16.95,TOTAL	,	3.6726E+00,	2.1034E-01,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
15.00000,	75.00000,	5.0000,G,2002/01/00,	0,	16.92,TOTAL	,	3.9078E+00,	2.2348E-01,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE
15.00000,	75.00000,	2.0000,G,2002/01/00,	0,	16.89,TOTAL	,	4.4854E+00,	2.5644E-01,	microSv/hr,	ICRP Pub. 103 EFFECTIVE DOSE

15.00000,	75.00000,	1.0000,G,2002/01/00,	0,	16.86,TOTAL	,	4.7055E+00,	2.6514E-01,	microSv/hr, ICRP Pub. 103 EFFECTIVE DOSE
C Neutron flux profile near solar min, mid latitude								
46.00000,	60.00000,	1.0000,G,1998/03/00,	0,	5.09,NEUTRONS	,	1.0223E+00,	9.4414E-02,	particles/sq.cm/sec, SECONDARY FLUX
46.00000,	60.00000,	2.0000,G,1998/03/00,	0,	5.10,NEUTRONS	,	1.0129E+00,	9.3450E-02,	particles/sq.cm/sec, SECONDARY FLUX
46.00000,	60.00000,	4.0000,G,1998/03/00,	0,	5.11,NEUTRONS	,	1.4507E+00,	1.3383E-01,	particles/sq.cm/sec, SECONDARY FLUX
46.00000,	60.00000,	7.0000,G,1998/03/00,	0,	5.12,NEUTRONS	,	1.7456E+00,	1.6064E-01,	particles/sq.cm/sec, SECONDARY FLUX
46.00000,	60.00000,	15.0000,G,1998/03/00,	0,	5.13,NEUTRONS	,	2.4158E+00,	2.2099E-01,	particles/sq.cm/sec, SECONDARY FLUX
46.00000,	60.00000,	30.0000,G,1998/03/00,	0,	5.13,NEUTRONS	,	3.3387E+00,	3.0265E-01,	particles/sq.cm/sec, SECONDARY FLUX
46.00000,	60.00000,	50.0000,G,1998/03/00,	0,	5.14,NEUTRONS	,	4.0883E+00,	3.6688E-01,	particles/sq.cm/sec, SECONDARY FLUX
46.00000,	60.00000,	77.0000,G,1998/03/00,	0,	5.14,NEUTRONS	,	4.5104E+00,	4.0028E-01,	particles/sq.cm/sec, SECONDARY FLUX
46.00000,	60.00000,	125.0000,G,1998/03/00,	0,	5.15,NEUTRONS	,	4.3873E+00,	3.8359E-01,	particles/sq.cm/sec, SECONDARY FLUX
46.00000,	60.00000,	200.0000,G,1998/03/00,	0,	5.15,NEUTRONS	,	3.4475E+00,	2.9695E-01,	particles/sq.cm/sec, SECONDARY FLUX
46.00000,	60.00000,	300.0000,G,1998/03/00,	0,	5.16,NEUTRONS	,	2.1553E+00,	1.8327E-01,	particles/sq.cm/sec, SECONDARY FLUX
46.00000,	60.00000,	500.0000,G,1998/03/00,	0,	5.16,NEUTRONS	,	6.7367E-01,	5.6179E-02,	particles/sq.cm/sec, SECONDARY FLUX
46.00000,	60.00000,	1000.0000,G,1998/03/00,	0,	5.17,NEUTRONS	,	2.5069E-02,	1.9965E-03,	particles/sq.cm/sec, SECONDARY FLUX
C, AIR-2 NEUTRON FLUX MEASUREMENTS								
53.90000,-117.20000,	56.0000,G,1997/06/13,	0,	0.85,NEUTRONS	,	1.1043E+01,	8.1129E-01,	particles/sq.cm/sec, SECONDARY FLUX	
18.50000,-127.20000,	53.5000,G,1997/06/11,	0,	11.83,NEUTRONS	,	1.3068E+00,	1.2655E-01,	particles/sq.cm/sec, SECONDARY FLUX	
55.60000,-120.60000,	101.0000,G,1997/06/13,	0,	0.76,NEUTRONS	,	1.0666E+01,	7.7331E-01,	particles/sq.cm/sec, SECONDARY FLUX	
37.60000,-122.30000,	201.0000,G,1997/06/11,	0,	4.50,NEUTRONS	,	3.8134E+00,	3.2048E-01,	particles/sq.cm/sec, SECONDARY FLUX	
C A Balloon flight over Ft. Churchill								
64.66500,-147.09667,	30000.0000,F,1965/08/03,	0,	0.51,TOTAL	,	4.3441E+00,	2.7220E-01,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)	
64.66500,-147.09667,	35000.0000,F,1965/08/03,	0,	0.51,TOTAL	,	6.6170E+00,	4.1331E-01,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)	
64.66500,-147.09667,	40000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	9.1537E+00,	5.7565E-01,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)	
64.66500,-147.09667,	45000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	1.1747E+01,	7.4127E-01,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)	
64.66500,-147.09667,	50000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	1.4401E+01,	8.9765E-01,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)	
64.66500,-147.09667,	55000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	1.7278E+01,	1.0508E+00,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)	
64.66500,-147.09667,	60000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	2.0283E+01,	1.1974E+00,	microSv/hr, ICRU AMBIENT DOSE EQ. H(*10)	

64.66500,-147.09667,	65000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	2.3115E+01,	1.3294E+00,	microSv/hr,	ICRU AMBIENT DOSE EQ. H(*10)
64.66500,-147.09667,	70000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	2.6047E+01,	1.4485E+00,	microSv/hr,	ICRU AMBIENT DOSE EQ. H(*10)
64.66500,-147.09667,	80000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	3.3431E+01,	1.7069E+00,	microSv/hr,	ICRU AMBIENT DOSE EQ. H(*10)
64.66500,-147.09667,	90000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	4.1001E+01,	1.9516E+00,	microSv/hr,	ICRU AMBIENT DOSE EQ. H(*10)
64.66500,-147.09667,	100000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	4.9378E+01,	2.2551E+00,	microSv/hr,	ICRU AMBIENT DOSE EQ. H(*10)
64.66500,-147.09667,	100000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	4.9378E+01,	2.2551E+00,	microSv/hr,	ICRU AMBIENT DOSE EQ. H(*10)
64.66500,-147.09667,	110000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	5.6351E+01,	2.4731E+00,	microSv/hr,	ICRU AMBIENT DOSE EQ. H(*10)
64.66500,-147.09667,	120000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	6.1590E+01,	2.6194E+00,	microSv/hr,	ICRU AMBIENT DOSE EQ. H(*10)
64.66500,-147.09667,	130000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	7.0761E+01,	2.9559E+00,	microSv/hr,	ICRU AMBIENT DOSE EQ. H(*10)
64.66500,-147.09667,	140000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	7.4010E+01,	3.0170E+00,	microSv/hr,	ICRU AMBIENT DOSE EQ. H(*10)
64.66500,-147.09667,	30000.0000,F,1965/08/03,	0,	0.51,TOTAL	,	1.5009E+00,	8.5446E-02,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	35000.0000,F,1965/08/03,	0,	0.51,TOTAL	,	2.3713E+00,	1.3355E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	40000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	3.3329E+00,	1.8996E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	45000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	4.2602E+00,	2.4831E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	50000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	5.1363E+00,	3.0442E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	55000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	5.9653E+00,	3.5764E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	60000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	6.6673E+00,	4.0619E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	65000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	7.1974E+00,	4.4567E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	70000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	7.5641E+00,	4.7470E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	80000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	8.2307E+00,	5.2076E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	90000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	8.6665E+00,	5.3940E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	100000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	9.2950E+00,	5.6948E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	100000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	9.2950E+00,	5.6948E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	110000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	9.4678E+00,	5.7189E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	120000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	9.7753E+00,	5.7965E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	130000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	1.0256E+01,	5.9222E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	140000.0000,F,1965/08/03,	0,	0.50,TOTAL	,	1.0455E+01,	5.9836E-01,	microGy/hr,	AVE WHOLE-BODY ABSORBED DOSE
64.66500,-147.09667,	30000.0000,F,1965/08/03,	0,	0.51,NEUTRONS	,	3.6227E+00,	2.5400E-01,	particles/sq.cm/sec,	SECONDARY FLUX

64.66500,-147.09667,	35000.0000,F,1965/08/03,	0,	0.51,NEUTRONS	,	5.3163E+00,	3.7453E-01,	particles/sq.cm/sec,	SECONDARY FLUX
64.66500,-147.09667,	40000.0000,F,1965/08/03,	0,	0.50,NEUTRONS	,	7.1117E+00,	5.0365E-01,	particles/sq.cm/sec,	SECONDARY FLUX
64.66500,-147.09667,	45000.0000,F,1965/08/03,	0,	0.50,NEUTRONS	,	8.7551E+00,	6.2348E-01,	particles/sq.cm/sec,	SECONDARY FLUX
64.66500,-147.09667,	50000.0000,F,1965/08/03,	0,	0.50,NEUTRONS	,	1.0051E+01,	7.1985E-01,	particles/sq.cm/sec,	SECONDARY FLUX
64.66500,-147.09667,	55000.0000,F,1965/08/03,	0,	0.50,NEUTRONS	,	1.0880E+01,	7.8333E-01,	particles/sq.cm/sec,	SECONDARY FLUX
64.66500,-147.09667,	60000.0000,F,1965/08/03,	0,	0.50,NEUTRONS	,	1.1228E+01,	8.0999E-01,	particles/sq.cm/sec,	SECONDARY FLUX
64.66500,-147.09667,	65000.0000,F,1965/08/03,	0,	0.50,NEUTRONS	,	1.1091E+01,	8.0334E-01,	particles/sq.cm/sec,	SECONDARY FLUX
64.66500,-147.09667,	70000.0000,F,1965/08/03,	0,	0.50,NEUTRONS	,	1.0685E+01,	7.7899E-01,	particles/sq.cm/sec,	SECONDARY FLUX
64.66500,-147.09667,	80000.0000,F,1965/08/03,	0,	0.50,NEUTRONS	,	9.1831E+00,	6.7305E-01,	particles/sq.cm/sec,	SECONDARY FLUX
64.66500,-147.09667,	90000.0000,F,1965/08/03,	0,	0.50,NEUTRONS	,	7.6011E+00,	5.5893E-01,	particles/sq.cm/sec,	SECONDARY FLUX
64.66500,-147.09667,	100000.0000,F,1965/08/03,	0,	0.50,NEUTRONS	,	6.1672E+00,	4.5465E-01,	particles/sq.cm/sec,	SECONDARY FLUX
64.66500,-147.09667,	100000.0000,F,1965/08/03,	0,	0.50,NEUTRONS	,	6.1672E+00,	4.5465E-01,	particles/sq.cm/sec,	SECONDARY FLUX
64.66500,-147.09667,	110000.0000,F,1965/08/03,	0,	0.50,NEUTRONS	,	5.2551E+00,	3.8867E-01,	particles/sq.cm/sec,	SECONDARY FLUX
64.66500,-147.09667,	120000.0000,F,1965/08/03,	0,	0.50,NEUTRONS	,	4.6424E+00,	3.4430E-01,	particles/sq.cm/sec,	SECONDARY FLUX
64.66500,-147.09667,	130000.0000,F,1965/08/03,	0,	0.50,NEUTRONS	,	3.7039E+00,	2.7511E-01,	particles/sq.cm/sec,	SECONDARY FLUX
64.66500,-147.09667,	140000.0000,F,1965/08/03,	0,	0.50,NEUTRONS	,	3.0098E+00,	2.2377E-01,	particles/sq.cm/sec,	SECONDARY FLUX