NRC-RADTRAN 1.0
Quick Start User's Guide

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October 2020

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1. INTRODUCTION

NRC-RADTRAN 1.0 consists of RADTRAN 6.02.1 in combination with a new Graphical User Interface (GUI). RADTRAN is a text-based program for radioactive material transportation risk and consequence assessment. RADTRAN combines user inputs with physical and radiological data from its internal libraries, and calculates radiological risks and consequences arising from transportation of radioactive material. The detailed functionality of RADTRAN and the format of the RADTRAN text input file are provided in the RADTRAN 6 Technical Manual [1]. RADTRAN was developed at Sandia National Laboratories (SNL) and a version is now maintained by the U.S. Nuclear Regulatory Commission (NRC). It is made available at the NRC RAMP website with a free user registration.

Other graphical interfaces for RADTRAN have been used in the past (most recently RadCat), but are no longer maintained or publicly distributed. However, the RADTRAN 6/RadCat 6 User Guide [2] remains useful as a reference for RADTRAN 6.02. Not all of the issues discussed there are revisited in this quick start guide.

The RADTRAN 6/RadCat 6 User Guide and the RADTRAN 6 Technical Manual are provided in the Documentation folder with this quick start guide.

Users should take care to document the sources of any parameters used in an analysis. Additional guidance for analyzing transport risk may be found in NUREG-2125, "Spent Fuel Transportation Risk Assessment" [3].

NRC-RADTRAN is designed to facilitate use of RADTRAN with routing code output files that describe a transport route and related information such as population density and speed for each segment. Currently the code is compatible with WebTRAGIS, a transportation routing analysis geographic information system (GIS) service provided by Oak Ridge National Laboratory (ORNL). Importing and interpreting these files is described in the **WEBTRAGIS INTEGRATION** section below.

The remainder of this user's guide primarily discusses the various elements of the graphical user interface (GUI) and how they affect RADTRAN analysis. The NRC-RADTRAN GUI is divided into two main tabs, the *Input File Editor* on the left and the *Output Display* on the right, plus a toolbar at the top. Figure 1 shows the main window, with the *Input File Editor* tab selected.

Figure 1   NRC-RADTRAN interface

2. FILE TOOLBAR

The toolbar at the top of the screen allows basic file operations (see Figure 2). The user can create a new input file or open an existing file, save an input file, undo and redo modifications to the input file, check the file for errors, and run RADTRAN. The toolbar also allows the user to toggle visibility of the help display.
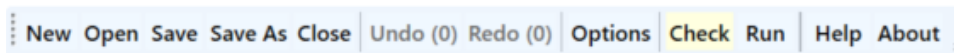
Figure 2   File toolbar

2.1 Opening and Saving Input Files

RADTRAN input files are created, opened, and saved using the buttons on the toolbar. Keyboard shortcuts are also available (e.g., **Ctrl+S** for save and **Ctrl+O** for open). The default file extension is *.input, but files with other extensions may be opened by selecting the "all files" option in the open file dialog, as long as they follow the correct RADTRAN input file format. When an existing input file is opened, in order to prevent accidentally overwriting it, the user will be asked whether to create a copy or edit the original file. This prompt may be turned off on the Options tab, in which case the original file will be opened for editing.

Opening and saving files will be recorded in the log file log.txt, along with certain other events.

NRC-RADTRAN does not support opening multiple input files in the same window, but multiple NRC-RADTRAN windows can be opened (by running the program from the start menu or another shortcut) in order to edit multiple files simultaneously.

NRC-RADTRAN will allow saving a file with errors in it that make it an invalid file, such as link fields that have not been set. In rare cases, if an invalid file is written, NRC-RADTRAN may be unable to re-open it. Such files would have to be corrected using a text editor before they can be opened again. For this reason, it is recommended that the user resolve any errors (indicated by a red Check button) before saving or closing an input file.

If an existing RADTRAN text input file is opened in NRC-RADTRAN and then saved without making any changes, the file will be written using the NRC-RADTRAN format. It will be functionally equivalent to the original, but the order of inputs, spacing, number formatting, and comments may all change.

2.2 Check Button

The Check button in the toolbar indicates whether any errors or warnings have been detected for the current input file. If there are errors in the file, the button will turn red. If there are warnings but no errors, the button will turn yellow. Clicking it shows a window with a list of errors and warnings. The **Errors and Warnings** window may be left open while editing the input file and will update itself in response to modifications.

Many warnings refer to input settings that may cause unexpected RADTRAN results; these may be safely ignored as long as the user understands their effects. They will not prevent saving the input file or running RADTRAN. Unlike warnings, errors will generally prevent RADTRAN from completing its execution and (as noted above) may occasionally cause information to be lost when saving or may prevent re-opening the input file.

Not all input combinations that cause RADTRAN execution to fail will be detected by the Check function. Undetected errors will be reported after running RADTRAN (see Section 6 on **RUNNING AN ANALYSIS**).

2.3 Undo/Redo

Any user action that modifies the open input file will cause NRC-RADTRAN to make a copy, in order for the user to revert back to the older versions as needed. The number of modifications currently available to undo and redo are shown in the button text, and the buttons are disabled when none are available. The maximum number of saved reversions is 99. All reversions are deleted if the input file is closed.

2.4 Options

The Options button opens an options tab that allows the user to set various file and display options. The interface/display options include disabling tooltips, toggling double-click help navigation, changing the font size, and showing/hiding some legacy input controls such as Handling inputs that are not normally needed. File options make it possible to pick auxiliary input files (i.e., ingestion, isotope, standard, and defaults files), and choose whether to save copies of these in the calculation folder; choose whether to have separate calculation folders for every RADTRAN run; and save the temporary output files that RADTRAN produces. Option settings are saved in the settings.txt file in the user's NRCRADTRAN folder.

2.5 Help Button

The Help button toggles the integrated help viewer, which displays this Quick Start User's Guide on the right side of the input file editor. Double-clicking on a tab or label in the input file editor will navigate the integrated help viewer to the appropriate page of the quick start guide. To resize the help viewer, you can click and drag its left edge. Moving the mouse over the **help viewer** will bring up a pane that shows the table of contents, and clicking an item in that table will navigate to its page in the Quick Start User's Guide.

2.6 About Button

The **About** button provides some basic information about NRC-RADTRAN, including version number, copyright information, and bug reporting (i.e., send emails to NRCRADTRAN_Help.Resource@nrc.gov). It also includes links to documentation.

3.   INPUT FILE EDITOR

The input file editor (the leftmost tab on the tab bar at the top of the window) displays and modifies the open RADTRAN input file, which describes the radioactive material transport scenario. RADTRAN also uses several auxiliary text input files (data libraries and default settings); these cannot be viewed or edited in the graphical user interface, but alternate auxiliary files may be selected under **Options** (see Section 6 on **RUNNING AN ANALYSIS** for more information).

The input file editor displays some general inputs and summary information at the top.

Below the general inputs there is a tabbed input region with nine tabs along the left side, corresponding to different categories of information needed for RADTRAN analysis (Figure 3). Each of these is discussed in its own section below.
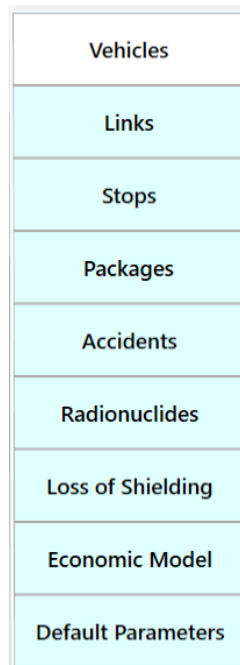

Figure 3   Input category tabs

3.1   General Inputs/Summary Area

The general inputs area is found at the top of the input file tab, and is shown in Figure 4.

Figure 4   General inputs/summary area

3.1.1 Case Title

The case title is optional in RADTRAN 6.02.1 (the current version in NRC-RADTRAN). It can be up to 74 characters and may contain spaces. If there is no case open, typing in the title box will create a new input file.

3.1.2 Analysis Type

RADTRAN can perform two separate and independent types of risk calculations. The incident-free analysis calculates dose from intact vehicles/packages, where the radiation dose is the dose from the external surface of the vehicle. The accident analysis accounts for cask failure and dispersion of radionuclides, where the radiation dose is from the radionuclides released to the environment in the accident.

Selecting incident-free analysis will disable the Accident, Radionuclide, Loss of Shielding, and Economic tabs, since they affect only the accident output from RADTRAN. Similarly, selecting accidental release analysis will disable the Stops and Handling tabs.

Vehicle input is required for calculation of both incident-free and accident doses. Package input is optional for incident-free calculations, and is required for calculating accident consequences. Link input is used for both types of analysis but is not mandatory (doses for stops and handling can be calculated without defining any links).

3.1.3 Consequence Format

This option (FORM in the text input) controls how RADTRAN output reports consequences. The options are to report the dose (keyword **UNIT**) in Roentgen Equivalent Man (REM) or Sievert, or to report the number of Latent Cancer Fatalities (LCF) (NON-UNIT). Predicted latent cancer fatalities are calculated by multiplying the dose by a constant factor (0.06 LCF/person-Sv or 0.0006 LCF/person-rem) using the conservative linear, no threshold (LNT) model. The constant factor can be modified in the Default Parameters section. Because the calculation method for latent cancer fatalities is not well-supported, this option is by default made visible only for input files that use the latent cancer fatalities format; it can be enabled for other input files via the Options menu.

3.1.4 Output Units

This option (**OUTPUT**) chooses whether to output in SI units for radioactivity and dose (Becquerel and Sievert) or historical units (Curie and REM). This option does not affect the units used for input values (see the SI_INPUT option in Section 3.11, **Default Parameters**, for discussion of input units).

3.1.5 Output Size

There are three levels of output available in RADTRAN 6.02. All three levels provide an input echo (RADTRAN outputs a copy of the text input file, excluding any portions it was unable to parse). In addition,

- Short output (Level 1) prints incident-free, accident, and non-radiological risk tables.
- Intermediate output (Level 2) adds early effects values, ground contamination tables, intermediate tables, and total expected population dose tables.
- Full output (Level 3) adds consequence tables and sensitivity analysis.

Older versions of RADTRAN used four output levels. If an input file for an older version is opened with NRC-RADTRAN and has output level 4 selected, it will be changed to level 3 and the user will be notified by a message box.

3.1.6   Comments

This field displays comments added by the user that do not affect RADTRAN execution. In the RADTRAN text input file, any line preceded by && is a comment. When NRC-RADTRAN opens an input, it combines all comment lines, no matter where they are in the file, into a single comment block which is displayed in this text box. When the file is saved, all those lines are written as comments near the top of the text file (below the title) rather than distributed throughout the file.

In addition, NRC-RADTRAN writes some automated comments into the input file to make it easier to decipher. These begin with "*&" instead of "&&", and are ignored when opening the file (they do not appear in the comments field).

3.1.7   Input File Summary Box

The case summary box in the upper right-hand corner provides an overview of which (and how many) elements are included in the open input file, including packages, vehicles, links, stops, accident severities, and release groups. It also provides basic information about any route that has been imported from WebTRAGIS.

3.2   Vehicles Tab

The Vehicles tab allows the user to create vehicles, delete existing vehicles, and modify the individual vehicle inputs in the vehicle table. At least one vehicle must be defined for RADTRAN to calculate incident-free or accident doses.

3.2.1   Vehicles Table

Each row in the Vehicles Table corresponds to the entries following the **VEHICLE** keyword in the text input file. On the left is a button for deleting the vehicle, followed by the input fields described below:

-- Vehicle Name

Each vehicle must have a unique name no more than 10 characters in length (the name itself may be longer, but RADTRAN will ignore the extra, so the first 10 characters must be not be identical to the first 10 characters of any other vehicle name). It may not contain spaces. RADTRAN converts names to uppercase, so two names that are identical except for capitalization are not allowed.

-- Transportation Mode

Select between Highway, Rail, and Waterway. This determines which links the vehicle can travel on. Highway vehicles can be used for both Primary Highway and Secondary Road link types.

-- Exclusive Use

An exclusive-use package is one that must be shipped without other freight or cargo present in the same vehicle or ship hold (RADTRAN 6 Technical Manual [1], p. 89). See the technical manual for information about when exclusive use is required.

-- Size (Critical Dimension)

This value should be the largest dimension of the portion of the vehicle carrying radioactive materials. If there is only one package on the vehicle, the critical dimension should be the same as that of the package, such as the length for a cylindrical package (assuming its length is greater than its diameter) or the longest

diagonal of a rectangular package. Despite the name, it is unrelated to nuclear criticality. Dimensions larger than about 9 m should not be used (see RADTRAN 6 Technical Manual [1], p. 18).

-- Dose Rate at 1 m (Transport Index)

The dose rate 1 m from the surface is used, along with the critical dimension, to calculate dose rates at other distances.

According to 49 CFR 173.403,

> *Transport index (TI) means the dimensionless number (rounded up to the next tenth) placed on the label of a package, to designate the degree of control to be exercised by the carrier during transportation. The transport index is determined by multiplying the maximum radiation level in millisieverts (mSv) per hour at 1 m (3.3 ft) from the external surface of the package by 100 (equivalent to the maximum radiation level in millirem per hour at 1 m (3.3 ft)).*

If the vehicle has only one package then the dose rate values for the package and vehicle should be the same.

-- Gamma Fraction/Neutron Fraction

These inputs specify the partitioning of the total external package dose into gamma radiation and neutron radiation. They must sum to 1. Since the dose rate is entered in mSv/hr or mrem/hr, the relative biological effectiveness of neutron and gamma radiation is already accounted for. The vehicle gamma and neutron fractions should generally be the same as those for the package assigned to it.

-- Crew Size

The number of crew members traveling in the vehicle.

-- Crew Distance

The average distance from the crew to the nearest surface of the radioactive cargo (about 2-3 m for large trailer rigs, possibly longer for heavy haul trucks). A train crew is generally at least 150 m from the radioactive cargo (see RADTRAN/RadCat 6 User Guide [2], p. 27).

-- Width Facing Crew

Also referred to as the Crew View, this is the largest dimension of the cargo that faces toward the crew (such as the diameter of a cylindrical cask).

-- Crew shielding factor

This is the fraction of radiation to which the crew is exposed (inverse of the shielding fraction) so 1.0 corresponds to no shielding, and 0.0 corresponds to total shielding. If RADTRAN is run without regulatory constraints, the crew shielding factor, if the crew distance from the package is 3 meters, is 0.38 (RADTRAN 6/RadCat 6 User Guide [2], p. 27). If the Regulatory Check option is enabled on the Default Parameters tab, the crew dose will automatically be no greater than 2 mrem/hr.

-- Number of Shipments

The doses/risks are calculated for one shipment, and then multiplied by the number of shipments entered in this field.

3.3   Links Tab

The Links tab provides information about the route traveled by the vehicle. The route is divided into links, which are defined in the Links table. RADTRAN calculates doses for each link individually and then adds them up to get the total dose for the route.

-- Link Title

The Links section has an optional Title field which appears in the text input file above the link, stop, handling, and LOS stop definitions.

The input fields defining each link are described below. The Links tab also allows the user to import information about the route from the **WebTRAGIS** routing software; this feature is described in the **WEBTRAGIS INTEGRATION** section.

3.3.1   Links Table

As with the **Vehicles Table**, each link in the Links Table has a delete button at the left end of the row.

-- Link Name

As with Vehicles, each link name should be unique, not case sensitive, and no longer than 12 characters.

-- Vehicle

Each link must be associated with a Vehicle defined on the Vehicles tab. The vehicle's Transportation Mode should match the link Transportation Mode.

-- Transportation Mode

Link mode (referred to in some of the documentation as link type) can be Primary Highway, Secondary Road, or Non-Road/Other (the option list also includes an Unknown option, but selecting it will cause a RADTRAN error). Both Highway and Secondary Road link types require a Highway vehicle. **NonRoad** link types work with either a Rail or Waterway vehicle.

-- Length

The distance traveled on this link.

-- Speed

The average speed of travel for this link.

-- Adjacent Vehicle Occupants

The average number of people in other vehicles on this link.

-- Population Density

The population density in the area immediately surrounding the link.

-- Traffic Rate

The number of vehicles traveling on this route per hour.

-- Accident Rate

The probability of a vehicle accident per kilometer of travel.

-- Fatality Rate (Deaths per Accident)

This is the average number of (non-radiological) fatalities resulting from a vehicle accident. It is only used for calculating non-radiological risks.

-- Population Type

Links can be rural, suburban, or urban. This affects the Residential Shielding factor. It also determines whether dose to pedestrians on sidewalks will be calculated (only for urban links).

-- Farm Fraction

The fraction of area surrounding the route that is in agricultural use. This option is relevant only to rural links (if entered for a suburban/urban link, it is ignored) and is used for the ingestion dose model.

3.4 Stops Tab

The Stops tab allows the user to define instances when the vehicle stops during travel. RADTRAN calculates doses to the population surrounding the stop as part of the incident-free analysis.

-- Name

As with Vehicles and Links, each stop name should be unique, not case sensitive, and no longer than 12 characters.

-- Vehicle

Each stop must be associated with a Vehicle defined on the Vehicles tab. That Vehicle's external dose rate is used to calculate the dose to people near the stop.

-- Inner Radius and Outer Radius

The inner radius and outer radius specify the bounds of the area in which doses are calculated. If the same distance is entered for both, however, then all nearby people are assumed to be at the same distance from the vehicle, and the population field is used to specify the number of people (rather than the density).

-- Population Density / Population

This field can have two different meanings, depending on whether the inner radius and outer radius are set to equal values (as noted above).

-- Shielding Factor

The shielding factor is a multiplier used for the stop dose calculation. Zero corresponds to total shielding (no dose) and one corresponds to no shielding.

-- Duration

The duration of the stop, in hours.

3.5 Handling Tab

Handling inputs are considered deprecated, but are available as a legacy option which can be enabled in the Options menu (this option will be enabled when a file containing a **Handling** block is opened). For most purposes, doses to package handlers are better calculated using the Stop inputs. Handling event inputs include number of handlers, distance from the package, and duration of exposure. To achieve the same effect using a Stop, set the Inner Radius and Outer Radius to the same distance; this will cause RADTRAN to interpret the Population box for that stop as the total number of people at that distance, instead of as a population density. Handling doses are calculated using the dose rate of the package(s) assigned to the vehicle, and ignore the dose rate specified for the vehicle.

3.6 Packages Tab

The Packages tab allows the user to create packages, delete existing packages, and modify the individual package inputs used for incident-free analysis. If accident analysis is selected and at least one package and vehicle have been defined, the Packages tab also permits the user to add packages to vehicles using the Vehicle Packages grid. To use a package for accident analysis, it must be created and added to a vehicle on this tab, and have radionuclide inventories added to it on the Radionuclides tab.

3.6.1 Individual Package Inputs

When a new package is created, a row of input fields appears, corresponding to the entries following the PACKAGE keyword in the text input file. These inputs determine the incident-free dose for **Handling Tab** events, which are considered deprecated. Therefore, package definitions are not needed for most incident-free analyses. On the left is a button for deleting the package, followed by the input fields described below:

-- Package Name

Each package must have a unique name no more than 12 characters in length (the name itself may be longer, but RADTRAN will ignore the extra, so the first 12 characters must be not be identical to the first 12 characters of any other package name). It may not contain spaces. RADTRAN converts names to uppercase, so two names that are identical except for capitalization are not allowed.

-- Critical Dimension

This value should be the largest dimension of the package, such as the length for a cylindrical package (assuming its length is greater than its diameter) or the longest diagonal of a rectangular package. Package dimensions larger than about 9 m should not be used (see RADTRAN 6 Technical Manual [1], p. 18).

-- Dose rate at 1 m (Transport Index)

The dose rate 1 m from the surface is used, along with the critical dimension, to calculate dose rates at other distances. Its definition is given in 49 CFR 173.403.

-- Gamma Fraction/Neutron Fraction

These inputs specify the partitioning of the total external package dose into gamma radiation and neutron radiation. They must sum to 1. Since the dose rate is entered in mSv/hr or mrem/hr, the relative biological effectiveness of neutron and gamma radiation is already accounted for.

3.6.2   Vehicle Packages

The Vehicle Packages grid (Figure 5) contains a row for each vehicle and a column for each package. The number in each box specifies how many of package for that column are carried by the vehicle in that row. A blank box is the same as entering zero. Each non-empty box will create a package line in the text input file below the vehicle definition.

Figure 5   Vehicle packages grid

3.7   Accidents Tab

Analysis of accidental release risks requires the user to provide information about the probability of damage to the package, the release fraction of each type of radioactive material, and other factors that affect dispersion and health consequences.

3.7.1   Accident Severities

Accident severity levels categorize the extent to which the package is damaged in a vehicle accident. The Severity Probabilities tab allows the user to create severity levels and specify the conditional probability of each severity level, given that a vehicle accident occurs. These conditional probabilities are also referred to in some of the RADTRAN documentation as "severity fractions". One severity level typically corresponds to vehicle accidents that do not affect the integrity of the package; the others correspond to different degrees of damage resulting in releases of radioactive material (which are described in detail in the Release Groups section). Severity probabilities may be specified separately for different transportation modes and location types (rural/suburban/urban). In some cases, the desired probabilities may be the same for all groups; the "**Use one set of probabilities**" checkbox automatically synchronizes the tables so that edits to the first group will apply to the others as well. Currently, it is not possible to paste values into the Severity Probabilities tables—the probabilities must be typed individually.

3.7.2   Release Groups

This section defines physical/chemical groups of materials that share similar dispersion behavior. Up to 15 release groups may be created; typical examples are particulates, volatiles, and crud. Group names must be unique and are not case sensitive.

Each group must have a release fraction, aerosol fraction, and respirable fraction for each accident severity level. The release fraction determines what fraction of the materials in that group escapes the package containment. The aerosol fraction determines what fraction of the released material aerosolizes, and the respirable fraction is the fraction of the aerosolized material that consists of particles small enough to enter the lung alveoli.

Each group also requires a deposition velocity, which depends on the size, density, and shape of the particles released. Gases should have a deposition velocity of zero. A value of 0.01 m/s is often used for aerosol particles. Velocities greater than 0.1 m/s are not recommended.

It is not possible to add or remove severity levels from the Release Groups tab; severity levels must be created on the Severity Probabilities tab before editing the release group inputs. Currently, it is also not possible to paste values into the Release Groups tables—the fractions must be typed individually.

3.7.3   Weather

Weather is a critical factor in dispersion of radionuclides after their release. There are three options for specifying the weather: national average, Pasquill fractions, and user-defined.

-- National Average

National Average weather is the simplest, and requires no further input. It is also the only option that allows specifying individual population densities for each isopleth.

-- Pasquill Fractions

The **Pasquill** option requires the user to choose a set of fractions that correspond to the six Pasquill Stability Classes (class A through class F) which identify the degree of turbulence in the air. The fractions must add up to one. The Pasquill option cannot be used in combination with the economic model.

-- User-Defined Weather

The User-Defined weather option permits more detailed specification of the release parameters and weather conditions. The input fields are described in detail in the RADTRAN 6/RadCat 6 User Guide [2], and the descriptions are not repeated here.

3.7.4   Isopleths (Dispersion Areas)

Isopleths are concentric rings surrounding the release point, in which accident doses are calculated. There must be at least two, but no more than 18. The number of Isopleths can be changed on this tab using the Add and Remove buttons.

In some cases, it may be beneficial to edit the sizes and distances of the isopleths individually. This can be accomplished by clicking the "Edit isopleth information" checkbox. Otherwise, RADTRAN will use default values for the area, centerline, and dilution factor of each isotope. If entered manually, the area of each isopleth must be greater than that of the previous isopleth.

It is also possible to assign a population density to each isopleth individually, but only if the National Average weather option is used. Normally, all isopleths use the same population density (taken from the Link where the accident occurs).

3.8   Radionuclides Tab

3.8.1   Package Isotopes

Analysis of an accidental release requires adding radioactive isotope inventories to a package. This section shows a table of isotopes for each package that has been created on the Packages tab.

Isotopes may be added and deleted here; when adding an isotope, it must be selected from the drop-down list, which contains both default and user-defined isotopes. To search for an isotope in the list, start typing its name.

Each isotope must also be assigned to a physical/chemical release group that was created on the Accidents tab, and its radioactive inventory must be specified in Curies.

3.8.2   User-Defined Radionuclides

This section allows users to add new radioactive materials to the list of isotopes available for adding to Packages. Ingestion doses are not calculated for user-defined radionuclides. See the RADTRAN 6/RadCat 6 User Guide [2] for more information about the radionuclide inputs.

3.9   Loss of Shielding Tab

Lead shielding is sometimes used for highly radioactive cargo (typically spent nuclear fuel casks). During a vehicle accident, the lead shielding may shift position (slump, in RADTRAN terminology) or melt, exposing some or all of the package. Steel or depleted uranium shielding, by contrast, is considered unlikely to be damaged in a vehicle accident (see RADTRAN 6 Technical Manual [1], p. 77).

Dose for a loss of lead shielding event is calculated in almost the same way as a **Stop**, but with an increased gamma dose rate corresponding to the fraction of shielding lost (slump fraction). It requires creating at least one link, and entering a conditional loss of shielding probability for the appropriate link location (rural/suburban/urban); the link's accident rate and the conditional probability are applied to the dose from each loss of shielding stop to get a loss of shielding total risk value.

3.10   Economic Model Tab

The economic model calculates the estimated costs of evacuating and decontaminating an area affected by a release of radioactive material. It is not used for incident-free analysis. To enable the economic model, check the "Use Economic Model" box and select the appropriate severity category from the drop-down menu (if left blank, the first severity level will be used by default). All other economic model inputs are optional—the default values are listed in the RADTRAN 6/RadCat 6 User Guide [2].

The economic model is described in more detail in SAND2007-7120, "An Economic Model for RADTRAN" [5].

3.11   Default Parameters Tab

This tab includes a large number of inputs, all of which are optional. Most of these belong to the MODSTD block of the RADTRAN text input file. For these, the user may choose whether to include them by checking the checkbox to the left of the option. Four of the options on this tab (**IUOPT, ITRAIN, REGCHECK, and IACC**) are part of the FLAGS block in the text input file, and two are stand-alone options (SI_INPUT and TRANSFER). These are discussed individually below.

3.11.1   SI Input Option

Selecting the **SI Input** option sets keyword **SI_INPUT** to 1 in the text input file. This causes RADTRAN to interpret its inputs using SI radiation units (Sv/Bq) rather than historical radiation units (Ci/Rem). It also changes the units of a few other inputs, such as resin density (in the Economics tab) and heat release rate (in the User-Defined Weather section).The units displayed next to each input field will change to match their new interpretation, but the values are NOT converted. Therefore, users are advised to use caution with this

option, and check all previously entered inputs before running RADTRAN to confirm the correct interpretation.

3.11.2 Residential Shielding

Residential shielding is controlled by both the flag **IUOPT** (which has options **Total, Default, and None**) and by the individual **Rural/Suburban/Urban** shielding factors **RR/RS/RU**, which are part of the MODSTD block. If both are included, the individual shielding factors override the **IUOPT** flag. This will generate a warning in the graphical interface, since there is no need to include both **IUOPT and RR/RS/RU**.

3.11.3 Rail Option

This option (keyword **ITRAIN** in the text input file) is applicable only if there is at least one rail vehicle. It allows the user to choose between common carrier and dedicated freight.

3.11.4 Regulatory Check Option

If the regulatory check option is selected (keyword **REGCHECK** is set to 1 in the text input file), then any package or vehicle with a dose rate exceeding the regulatory limit will be overridden and the regulatory limit will be substituted for the user-input value. The regulatory limit for external dose is 10 mrem/hr at 2 m. The limit for truck and rail crew dose is 2 mrem/hr.

3.11.5 MODSTD Inputs

The remaining fields on the **Default Parameters** tab belong to the **MODSTD** block of the text input file. Their meanings are summarized in the tooltips that appear when the mouse hovers over each textbox. More detailed descriptions are available in the RADTRAN 6/RadCat 6 User Guide [2].

-- DISTOFF/DISTON

This block specifies distances used for off-link and on-link dose calculations. **DISTOFF** is a set of three distances, in meters, used in off-link dose calculations for each of freeway, city street, secondary road, rail, and waterway. The three distances are: (1) the minimum perpendicular distance over which the off-link dose calculation will be integrated; (2) the distance to the far edge of the pedestrian-walkway, for instances in which dose to pedestrians beside the link is calculated (see variable **RPD** in the RADTRAN 6/RadCat 6 User Guide [2] for discussion of pedestrian density); and (3) the maximum perpendicular distance over which the off-link dose calculation will be integrated.

DISTON includes up to six values: the distance to a vehicle going the opposite direction, for each of freeway, city street, secondary road, rail, and waterway; and the distance to a vehicle going the same direction, which applies only to roads.

The default values, which are supplied for each link type, are from NUREG-0170 [6].

-- Transfer Coefficients

Transfer parameters may be provided for gamma and/or neutron radiation. These are the polynomial coefficients used to calculate attenuation in air for the incident-free model (Equation 12 on page 20 of the RADTRAN 6 Technical Manual [1]).

3.11.6 <u>Dispersion Option</u>

The dispersion flag (IACC) allows the user to choose between Gaussian dispersion of radionuclides (the preferred model) and no dispersion. The RADTRAN 6/RadCat 6 User Guide indicates that the latter value is no longer used in RADTRAN (page 83 of Reference [2]).

4.   WEBTRAGIS INTEGRATION

NRC-RADTRAN can import a route created by the WebTRAGIS transportation routing analysis GIS service provided by Oak Ridge National Laboratory (ORNL). WebTRAGIS calculates routes by road, rail, and waterway between points in the contiguous United States (Alaska and Hawaii are not included). Running WebTRAGIS creates several output files; the one required by NRC-RADTRAN has file extension .kml and contains XML-formatted information about each segment of the route, including transportation mode, state, time to traverse the segment, and distance and population density in each of the rural, suburban, and urban portions of the segment. More information about using WebTRAGIS can be found in the WebTRAGIS User's Manual [4].

Future versions of NRC-RADTRAN may allow importing KML files from Google Earth or other sources, in addition to WebTRAGIS.

4.1   Import Instructions

To import a WebTRAGIS route, click the "Import from "**WebTRAGIS**" button on the **Links** tab beneath the Links table, then navigate to the desired .kml file. Upon opening the file, NRC-RADTRAN will create corresponding links and add them to the Links table (existing links are not affected). Up to three links are created per state traversed in the route (one rural, one suburban, and one urban). In addition, a map of the US will be shown below the Links table, with the route drawn on it in red (this map is approximate, so the route may sometimes appear to be on the wrong side of borders or coastlines). Below the map, NRC-RADTRAN will show a table of the detailed route segment information from the WebTRAGIS file; this information is for reference only and is not needed by RADTRAN.

It is possible to import multiple WebTRAGIS files sequentially, for instance if a route requires multiple modes of transportation (since WebTRAGIS allows only one transport mode per route). Simply press the import button again and select another file. Only the most recently imported route will be displayed on the map.

When the NRC-RADTRAN input file is saved, the WebTRAGIS data may optionally be included as comment lines so that the map display will load into NRC-RADTRAN again if the input file is re-opened. This feature may be disabled by clicking the checkbox "Embed WebTRAGIS Route in RADTRAN Input File" above the map.

4.2   Methodology

When links are created from WebTRAGIS route information, some assumptions have to be made to complete the link definition and to simplify the route. Simplifications are necessary because WebTRAGIS often outputs hundreds or thousands of route segments, while RADTRAN currently allows a maximum of 60 links. NRC-RADTRAN creates one rural, one suburban, and one urban link per state as needed (links that would have zero length are not included). The length, speed, and population density of each of these links is approximated from WebTRAGIS information as described below.

WebTRAGIS outputs are in English units (miles and mph), and NRC-RADTRAN automatically converts these, to kilometers, and km/h, when importing from the route file.

-- Vehicle

The WebTRAGIS file describes the route as highway, rail, or water. If a Vehicle with the correct transportation mode has been defined in the **Vehicles** table, the newly created links will use that Vehicle. If more than one Vehicle is defined, the user should verify that the correct one is selected in the imported links.

-- Speed

NRC-RADTRAN calculates the speed for each WebTRAGIS route segment by dividing the segment distance by the duration. Speed is assumed to be constant within a segment (that is, the same speed is used for the rural, suburban, and urban portions). The duration of the rural, suburban, and urban portions of each segment are each calculated from distance and speed. Then, taking just the rural portions of all the segments in one state, the distances are added together to get total rural distance, the durations are added to get total rural duration, and dividing the distance by the duration gives the average rural speed for that state. The same process is repeated for suburban and rural portions.

-- Population Density

Population density for a link is calculated from a time-weighted average of all the rural, suburban, or urban route portions in the corresponding state. For a rural link, for example, the product of population density and duration is calculated for the rural portion of each segment in that state; these are summed; and the sum is divided by the sum of the durations of the rural portions.

-- Traffic, Accident Rate, and Fatality Rate

These Link fields are left at zero, since WebTRAGIS does not provide any relevant information. It may be possible to use average values for each state as described in the RADTRAN 6/RadCat 6 User Guide [2].

-- Farm Fraction

When creating a rural link, the Farm Fraction is initialized to 0.5. This value is arbitrary, and for a realistic accident analysis it should be replaced with more accurate information where available.

5.   RUNNING AN ANALYSIS

To run a RADTRAN analysis on the current input file, press the **Run** button in the file toolbar. Prior to running RADTRAN, the user is encouraged to resolve any errors displayed when the **Check Button** is pressed, as these will generally prevent RADTRAN from completing its run. It is not necessary to save the input file before running a RADTRAN analysis; running the analysis writes a new version of the open file into the calculation folder (described below) and does not affect the original.

Launching a calculation will be recorded in the log file log.txt, along with certain other events.

5.1   Auxiliary Input Files

Four auxiliary input files are required for a RADTRAN analysis to run (RT6_Isotope.INFILE, RT6_INGESTION.BIN, RT6_Defaults.INFILE, and RT6_Standard.INFILE). Default versions of these files are provided along with the RADTRAN 6.02.1 executable. Custom versions of these files can be specified by file path in the **Options** tab.

5.2   Case/Calculation Folders

When a RADTRAN analysis is run on an input file, NRC-RADTRAN creates a case folder to hold the inputs and outputs, which is given the same name as the input file. The case folder path is the user's home directory (e.g. C:\Users\ExampleUser) followed by \NRCRADTRAN\Calculations\Name_of_input_file.input\. Since the case folder is named after just the filename of the open input file (rather than its full path), it is possible for two input files with the same name to share a case directory. This will not generally cause any problem. Inputs files that are run before they are saved will use the default case folder name **RADTRAN.INPUT**.

Inside the case folder, each input/output file is named according to the date and time it was run (e.g. 2020_05_05_09_30_15). Depending on the options selected, the case folder may contain:

- A copy of the open input file at the time the Run button was pressed, named **RADTRAN[date].INPUT**
- Text output file **RADTRAN[date].OUTPUT**, which is the source of the displays shown in the output tab
- Auxiliary output files, if the "**Save auxiliary output files**" option is selected (RT6_Accident.Outfile, RT6_IncidentFree.Outfile, RT6_Isopleth.Outfile, RT6_MonteCarlo.Outfile, and sometimes **IngestionData.Outfile**)
- The text of RADTRAN's console output, if there is any
- The auxiliary input files, if the option "**Make copies of the auxiliary input files**" is selected. This is generally not necessary if the default auxiliary files are used.

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6.   OUTPUT DISPLAY

The Output tab is populated after running RADTRAN. The output display is divided into two main portions, the input echo/edit and the output.

6.1   Input Echo and Input Edit

On the left is a box displaying the input echo and input edit. The input echo is just a copy of the input file as read by RADTRAN (that is, in all uppercase, and excluding any portions RADTRAN was unable to process). If RADTRAN encountered an error processing the input file, the error message will be displayed at the bottom of the input echo box.

The input edit is included only if **Output Size** is set to level 3. It appears below the input echo, and provides detailed information about how RADTRAN interpreted the input file.

6.2   RADTRAN Output

The box on the right side of the screen displays the RADTRAN output (everything following the input edit). It includes (depending on the analysis option and output size) incident-free, accident, and non-radiological risk tables; early effects values; ground contamination tables; intermediate tables; total expected population dose tables; consequence tables; and sensitivity analyses.

It provides the option to display the output either as text (easiest to read) or in a spreadsheet form, which makes it easy to select and paste tables from the output into Excel or another spreadsheet for further analysis. There is also a button for saving this spreadsheet output as a **CSV** file (**output[date].csv**) in the case folder.

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7. FUTURE WORK

There are a number of possible improvements and additional features that may be incorporated into NRC-RADTRAN in the future. These include:

1. **Google Earth routing:** Like WebTRAGIS, Google Earth creates .kml route files that fully specify the path between two locations. It can be used to generate routes anywhere in the world and is accessible to non-governmental users. However, the information provided in the route file is not the same as WebTRAGIS (e.g., it does not include population density); therefore, integrating it as an alternative in the NRC-RADTRAN GUI will require incorporating information from additional databases.

2. **Further output processing:** Currently, NRC-RADTRAN splits the text output file into two sections. The first contains the input echo and input edit, and the second contains the output. Minor additional processing of the output is performed for the spreadsheet view, where output lines are divided into cells. In the future, it may be desirable to further subdivide both the text view and the spreadsheet view so that each output block is displayed in a separate customized text block or datagrid (or can be added/removed on the main grid), to make it easier to navigate through large output files and find the most pertinent results. Parts of the output can be displayed in a tree view, which groups output blocks displaying the same information for different links/vehicles/etc.

3. **Output plotting:** Some portions of RADTRAN output may be easier to understand if plotted; for instance, dose risk by link (or dose risk per mile) could be plotted on a bar graph to make it more clear which portions of the route are most consequential.

4. **Recent files list:** A list of recently opened files could be saved to make it easier to find them again. Additionally, an option may be added to open the most recent file when the program starts.

5. **Separate Link information for incident-free and accident:** Currently all the information about a link is displayed in a row of the links table. Some of this information is needed only for accident calculations and can be ignored in incident-free analysis; these inputs could be moved to a separate table, or the columns could be disabled (grayed out) when incident-free analysis is selected.

6. **Help display:** The help display is currently located in a pane on the right side of the main window. Future versions may offer the ability to pop-out this display into a separate window so that it can be positioned wherever it is convenient for the user.

7. **Make Package input format consistent with other tabs:** The Vehicles, Links, and Stops tabs use datagrids to enter inputs, whereas the Packages tab uses individual text boxes; these may be changed over to a datagrid for the sake of consistency.

8. **Log files:** File actions (open/save) are already saved to a log file. Metadata from running RADTRAN could be saved as well to improve reproducibility. A tab for viewing the log file could also be added to the interface. Certain error dialogs can be replaced with messages in the log file.

9. **Open existing output files:** Currently, a RADTRAN output file can only be opened in the GUI when it is newly created by running RADTRAN. In some cases, users may wish to open a previously-created output file, especially if the additional output processing discussed in item 9 is available..

10. **Make sure undo/redo only contains meaningful file changes:** In some cases, navigating to a cell in a datagrid and then away without modifying anything, can register as a change to the file and add an entry to the reversion stack. Future versions can attempt to remove this limitation.

11. **File editing history:** Currently, the file history (undo/redo) is deleted when NRC-RADTRAN exits or when a different input file is opened. In the future, an option may be added for saving the reversion stack so that undo/redo information is available when the file is reopened.

12. **Direct printing:** An option to send the output to a printer may be added, to save the intermediate step of opening output files in a text editor.

13. **Automatic backups:** A backup copy of the input file can be saved after every edit, rather than just at the user's request or when running RADTRAN.

14. **Text input tab:** The text version of the input file is currently only displayed in the input echo after running RADTRAN. It may be desirable in some cases to be able to view the generated text file in a separate tab of the GUI while editing the input file.

8. REFERENCES

1. R. Weiner, K. Sieglinde Neuhauser, T. Heames, B. O'Donnell, M. Dennis, "RADTRAN 6 Technical Manual," SAND2014-0780, January 2014. (RAMP website link).

2. R. Weiner, D. Hinojosa, T. Heames, C. Ottinger Farnum, E. Kalinina, "RADTRAN 6/RadCat 6 User Guide," SAND2013-8095, September 2013. (RAMP website link).

3. "Spent Fuel Transportation Risk Assessment," U.S. Nuclear Regulatory Commission, NUREG-2125, January 2014. (RAMP website link).

4. S. Peterson, "WebTRAGIS: Transportation Routing Analysis Geographic System User's Guide," ORNL/TM-2018/856, May 2018. (RAMP website link).

5. D. Osborn, R. Weiner, J. Penisten, T. Heames, "An Economic Model for RADTRAN," SAND2007-7120, October 2007.

6. "Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes," U.S. Nuclear Regulatory Commission, NUREG-0170, December 1977. (NRC website link).

Copies of References 1, 2, 4, and 5 listed above are included with NRC-RADTRAN in the same Documentation folder that contains this Quick Start Guide. The **Documentation** folder path is the user's **Home Directory** (e.g. C:\Users\ExampleUser) followed by **\NRCRADTRAN\Documentation**. They can also be accessed from the About window.

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