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The Probabilistic Risk Assessment Tool for Radiological Dispersal Devices

A general description of the tool and recent revision work

Chuanlei Liu and David Waller

Defence Research and Development Canada – Ottawa

Technical Report
DRDC Ottawa TM 2013-126
December 2013

Canada

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Abstract

DRDC Ottawa has been developing and maintaining the Probabalistic Risk Assessment Tool software for the assessment of risk related to radiological dispersal devices since 2002. Major revision work on the tool started in 2009 and has recently been completed.

The revisions introduce several new features such as a new, faster database format, and new graphical user interfaces. These new features required the replacement of older libraries and re-coding of large portions of the software. The changes make the revised tool highly efficient in computation, less dependent on third-party libraries and more manageable for the analysis and presentation of risk results.

The new tabular and graphic displays provide effective means for conveying the assessment results, identifying dominant risk contributors and helping to strengthen risk management practices. Examples of how the tool can be used are given to demonstrate the new features, improved performance and new capabilities.

The revised tool is currently at the alpha version of the development stage so various tests and checks are ongoing.

Résumé

RDDC Ottawa développe et maintient, depuis 2002, un logiciel dévaluation détude probabiliste de la sûreté (PRA, de langlais Probabilistic Risk Assessment), pour lévaluation des risques associés aux dispositifs de dispersion radiologique (RDD, de langlais radiological dispersal devices). Un important travail de révision du logiciel a commencé en 2009 et a récemment été terminé. Ces révisions comportent plusieurs nouvelles fonctionnalités, notamment un nouveau format de base de données, plus rapide, et de nouvelles interfaces graphiques. Ces nouvelles fonctionnalités ont nécessité le remplacement des bibliothèques anciennes, et il a fallu recoder de grandes parties du programme. Avec ces changements, le logiciel révisé est plus efficace en termes de calculs, il dépend moins des bibliothèques tierces et il est plus facile à gérer pour lanalyse et la présentation des résultats de risque. Les nouveaux affichages sous forme de tableaux et de graphiques permettent de présenter efficacement les résultats des évaluations, didentifier les sources principales contribuant au risque et de renforcer les pratiques de gestion du risque. Le rapport présente des exemples dutilisation du logiciel, qui démontrent les nouvelles fonctionnalités, sa performance améliorée et ses nouvelles capacités. Le logiciel révisé est actuellement rendu à la version alpha du stade de développement, de sorte que de nombreux essais et contrôles se poursuivent.

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Executive summary

The Probabilistic Risk Assessment Tool for Radiological Dispersal Devices

Chuanlei Liu, David Waller; DRDC Ottawa TM 2013-126; Defence Research and Development Canada – Ottawa; December 2013.

Background: DRDC Ottawa has been developing and maintaining the Probabilistic Risk Assessment (PRA) Tool to assess the relative risks of Radiological Dispersal Devices (RDDs) since 2002. Several possible ways to improve the tool, in terms of computation efficiency and risk assessment for certain RDD events, have been proposed in previous evaluations of the tool. Those proposals led to the revisions described in this report.

Principal results: The revised tool has adopted several native Java libraries in place of commercial and third-party libraries which were used in the original version. Particularly, the RAF (Random Access File) is used as the new database format, and the libraries used to generate tabular and graphical visualization of the assessment results have been changed for the revised version.

Significance of results: The new version of the tool is more independent due to the use of several native Java libraries. The computation efficiency has been largely improved as a result of applying the new database format. The change of risk visualization libraries makes the tool flexible and manageable in conveying risk results in various customized ways, and it is effective at identifying dominant risk contributors and helping strengthen risk management practices.

Future work: The revised tool is currently at the alpha version of the development stage, which includes debugging, stability and performance checks before its release. Given the relevance of routine updating of the database, a flexible tool to view and edit the database is desirable and will be implemented in the future.

Sommaire

The Probabilistic Risk Assessment Tool for Radiological Dispersal Devices

Chuanlei Liu, David Waller ; DRDC Ottawa TM 2013-126 ; Recherche et développement pour la défense Canada – Ottawa ; décembre 2013.

Contexte : RDDC Ottawa développe et maintient, depuis 2002, un logiciel dévaluation détude probabiliste de la sûreté (PRA, de langlais Probabilistic Risk Assessment), pour lévaluation des risques associés aux dispositifs de dispersion radiologique (RDD, de langlais radiological dispersal devices). Plusieurs améliorations possibles, en termes defficacité de calcul et dévaluation du risque pour certains événements RDD, avaient été proposées lors dévaluations antérieures du logiciel. Ces propositions ont mené aux révisions décrites dans le présent rapport.

Principaux résultats : Dans le logiciel révisé, on a utilisé plusieurs bibliothèques Java natives, au lieu des bibliothèques commerciales et tierces qui étaient utilisées dans la version originale. En particulier, on utilise la bibliothèque RAF (Random Access File) comme nouveau format de base de données, et dans la version révisée, on a également modifié les bibliothèques utilisées pour générer laffichage des résultats des évaluations sous forme de tableaux et de graphiques.

Importance des résultats : La nouvelle version de loutil est plus indépendante, grâce à lutilisation de plusieurs bibliothèques Java natives. Lefficacité de calcul a grandement été améliorée, grâce à lutilisation du nouveau format de base de données. Les changements apportés aux bibliothèques de visualisation du risque rendent loutil plus souple et plus gérable pour la présentation des résultats des analyses de risque, selon différents modes personnalisés. Enfin, loutil est efficace pour identifier les principales sources contribuant au risque, et ainsi contribuer à renforcer les pratiques de gestion du risque.

Travaux futurs : Le logiciel révisé est actuellement rendu à la version alpha du stade de développement, ce qui comprend le débogage, la stabilité et les contrôles de performance, avant sa diffusion. Comme il faudra mettre à jour régulièrement la base de données, il serait souhaitable dajouter un outil souple daffichage et dédition de la base de données, ce qui sera fait ultérieurement.

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1 Introduction

Since 2002, DRDC Ottawa has been developing and maintaining a Java software tool for the Probabilistic Risk Assessment (PRA) of Radiological Dispersal Devices (RDD): the PRA Tool. The objective of the PRA Tool is to provide a systematic and quantitative approach to assess the relative risks of RDD events, as well as other essential, related quantities such as feasibility and consequence. The assessment results can be used to assist planning and taking actions to reduce the risk of potential RDD events.

The first version of the PRA Tool was released in Summer 2006. This included significant effort by defence scientists at DRDC Ottawa to populate a database of RDD parameters for the tool. The database consists of diverse information about the three basic RDD event components: radiological materials (or "practices"), RDD event probabilities [1] and target scenarios [2]. All possible combinations of components in the database make up a total of about 1.3 million RDD events. These categorized components and their associated values represent our current best knowledge of the diversity and severity of RDD events.

In the subsequent evaluation work [3], recommendations for revisions to the tool were made with respect to reducing programming limitations and enhancing performance. Therefore, starting in 2009, a series of revisions of the PRA Tool has been carried out at DRDC Ottawa [4, 5, 6].

This report begins with an introduction to the PRA methodology and the PRA Tool, which is then followed by a description of the revision work as well as the newly introduced features. Before concluding, two examples of using the PRA Tool are given with the purpose of demonstrating the capability and features of the tool.

2 The PRA methodology

PRA is a type of risk assessment which emerged about two decades ago. The PRA employs a structured and logical way to assess and identify risks in complex technological systems [7]. This method is applicable to rare events such as accidental events in nuclear plants, earthquakes or other natural disasters. The PRA method is especially designed for complex systems, where a comprehensive and integrated response of the system is expected. In this case, prior modelling of the system is required.

A well-designed PRA application will provide quantitative and qualitative risk assessment, as well as a list of events, rank-ordered by risk. The ranking allows us to identify the events of greatest concern. Furthermore, a PRA tool is also supposed to have the ability to decompose an event into its identifiable components so that the dominant contributors to the event risk can be identified. These identification features make PRA very useful for risk reduction plans and risk management in general.

3 The PRA Tool

When the PRA method is employed specifically for RDD events, the three basic components in modelling an event are the *radiological practice*, *deployment method* and *target*.

3.1 Event modelling in the PRA Tool

Besides the three basic components described above, the PRA Tool has considered further characteristics that can be used to categorize RDD events. For example, RDD events are also categorized by

- the geographic origin of the RAM,
- the legality of its acquisition,
- its original physical state, and
- whether its state is converted (e.g. from a solid to a liquid).

Further information on the event modelling can be found in [1].

3.2 Risk assessment in the PRA Tool

In order to quantify risk using the PRA Tool, each component in the model has to be assigned a numeric value. These numbers will be used to calculate the two relevant quantities in the risk assessment: feasibility and consequence. Risk is defined as the product of these quantities, as shown in Equation 1.

$$Risk = Feasibility \times Consequence. \tag{1}$$

The *Feasibility* is an overall quantity derived from each individual component's feasibility. The *Consequence* term consists of the economic loss (the disruption loss plus the possible decontamination cost) and the cost connected to the health effects arising from the RDD event (a converted dosimetric factor). The feasibility is a relative variable while the consequence is an absolute one. The relative value of feasibility implies that risks are relative too. The risk results from the PRA Tool provide guidance in risk reduction plans/actions, while the consequence results can be used to estimate the loss in the case of a real RDD event.

3.3 The software scheme of the PRA Tool

The PRA Tool software consists of three functional components: an underlying database, the front-end graphical user interface (GUI) and the back-end risk assessment algorithm. A scheme of the PRA Tool model is given in Figure 1.

The database is composed of several relational tables storing information of basic event feasibility, practice attributes and target scenarios, etc.. The GUI of the tool is the gateway allowing end users, for example intelligence analysts, to select RDD events, assess and analyze the risk results. As Figure 1 shows, the assessment results are presented in tabular and graphical formats. The back-end algorithm is the arithmetic method for computing risk and its related quantities.

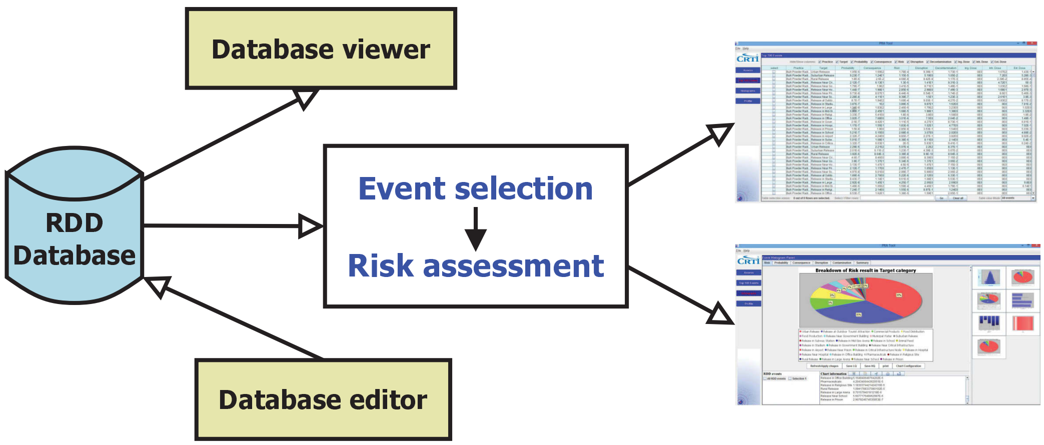

Figure 1: A scheme of the PRA Tool software, which is composed of a RDD database, the event selection GUI, risk assessment algorithm and result display in tables and graphics.

4 Revision of the PRA Tool

Following the recommendations from previous evaluation work [3], the current revision aims to make the tool 1) highly efficient in computation, 2) less dependent on legacy, commercial and third-party libraries, 3) more manageable and meaningful with respect to the way results are represented, and 4) more flexible and configurable in administering the database. During the revision work, the software was almost completely re-programmed, resulting in a new database design, a new *Event Selection* GUI, new tabular and graphical visualization of the assessment results, and a new *Information* interface.

In order to differentiate between the different versions of the PRA Tool developed so far, we will refer to the first version released in 2006 asPRA Tool v1.0, and use PRA Tool v2.0 to refer to the 2009 revision. Finally, we will refer to the current revision (as of March 2013) as PRA Tool v2.1.

4.1 New database design

In PRA Tool v2.0, a new database engine called SQLite [8] was adopted in place of the old legacy database used in PRA Tool v1.0. The replacement was based on the fact that SQLite is lightweight, fast in processing and employs a widely-used format for small and medium database management [4]. However, one of its drawbacks is that it does not support random walking through all the records in the database. The impact of this limitation is outlined in the next paragraph.

Random access in SQLite

In SQLite, accessing a specific record in one individual table requires one first to pass through all the records positioned before that specific record. Additionally, only one task can be performed each time the record is accessed. This could be compared to driving along a one-way street. When you plan to visit a friend living on a one-way street, you have to drive in from the entry side, and only from there, then you pass all the houses prior to your friend's. If your intentions are a) to drop off a post card and b) complain about the inconvenience of the one-way street, you can only drop off the card during this trip. To express your complaints, you have to exit the street, re-enter, pass all the houses before your friend's again, then tell her/him your complaint. This is a very inefficient process.

Random Access File in Java

Given this drawback, it is clear that the SQLite database could be computationally expensive if repeat visits are frequently required. This problem becomes worse as the database becomes larger and more complicated in the relations between tables. In order to overcome this drawback, the Random Access File (RAF) format has been used in the new version.

The RAF format is a native class of Java which has existed since the Java 2 platform. Supported by two additional Java classes, reading from and writing to the RAF database is remarkably more efficient than before. These two classes that support this are the *FileChannel* and *MappedByteBuffer* libraries. The *FileChannel* overcomes the lack of buffering in the original RAF file, while the *MappedByteBuffer* has the ability to map RAF contents into memory so that the file creation/modification/reading becomes extremely fast. More details about these classes can be found in the Java API (Application Programming Interface) [9].

Revisiting the transportation analogy to compare the memory-mapped RAF file to SQLite, a RAF database format is like a helicopter that carries you directly to any location, and multiple tasks can be carried out on each ride.

Benchmark of using the RAF format

Using a 2 GHz CPU, 4 GB RAM Linux laptop, the new database format achieves the following benchmarks:

1. the RDD database can be read in less than one second,
2. the assessment of all 1.3 million events takes 40 seconds, and
3. it takes only two seconds to render all histograms for 1.3 million events.

For comparison, the total processing time for all 1.3 million events was one day with PRA Tool v1.0, and approximately 10 minutes with PRA Tool v2.0.

4.2 New event selection interface

The RDD event selection interface was much improved in PRA Tool v2.0 compared to PRA Tool v1.0. The new look of the *Event Selection* interface was maintained for PRA Tool v2.1and is given in Figure 2.

Only a brief description of the new features is given in this report; please refer to previous work [5] for more details about the new design. The new design of the event selection interface in the PRA Tool v2.0 takes an object-oriented approach. The definition of classes and the application of classes are separated, which makes the code more reusable, and also brings the possibility of including new CBRN threats.

4.3 New tabular display

The previous versions of the tool (PRA Tool v1.0 and PRA Tool v2.0) made use of a commercial product, *ElegantBeans* from *Elegant MicroWeb Technologies Pvt. Ltd*, to hold, display and manipulate RDD results in tabular form. The Java component class *JTable* has been available since Java Standard Edition (J2SE 1.4) in 2008. JTable's features for sorting, filtering and editing have become more mature and stable since then. Therefore, this native Java library has been adopted as a replacement of the old commercial product so that the tool is independent of the licence for *ElegantBeans*. In PRA Tool v2.1, all tables are generated using *JTable*.

The new tabular view of assessment results is shown in Figure 3. The other tables have a similar appearance. As mentioned above, PRA Tool v2.1 comes with common functionality such as sort, hide/show, search/filter and select event. It can also print tables and export them to Excel-compatible files.

Because this functionality was coded and implemented with the low-level functions of *JTable*, the tabular form has the flexibility to be presented in various customized ways.

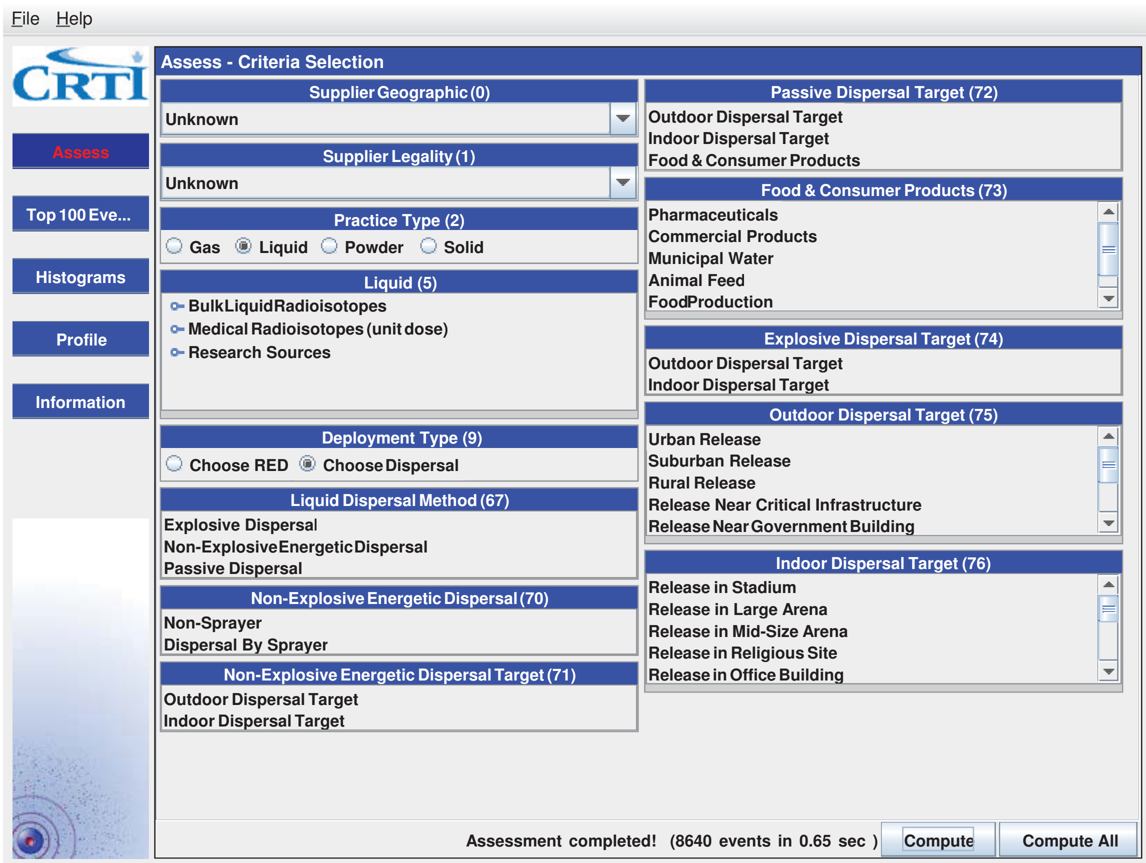

Figure 2: The *Event Selection* interface for PRA Tool v2.1. This panel is designed to automatically generate the subsequent branches or nodes of the possible RDD events after one branch is triggered. The bottom-right "*Compute All*" button will be automatically activated or disabled depending on the size of the allocated memory by the Java virtual machine.

4.4 New graphical visualization

Compared to the previous versions, PRA Tool v2.1 implements many charts and histograms in the *Histogram* GUI to visualize risk assessment results. These charts help to categorize and interpret assessment results. An example of the new *Histogram* GUI is given in Figure 4. In this figure, the top-middle window is used to display any one of the thumbnail snapshots found on the right-side of the GUI. Eight thumbnails are available for viewing; details about each of them are provided in Section 5.1.3. The top-middle window also includes nine tabbed panes which are collapsed together. Each of the first eight tabbed panes is dedicated to exploring a specific quantity, while the last, the "summary" pane, is a one-page summary of the whole assessment. The first tabbed pane is all about RDD risk while the second pane is used to show RDD feasibility, and the third, RDD consequence. The remaining tabs show the components that make up to RDD consequence: disruption

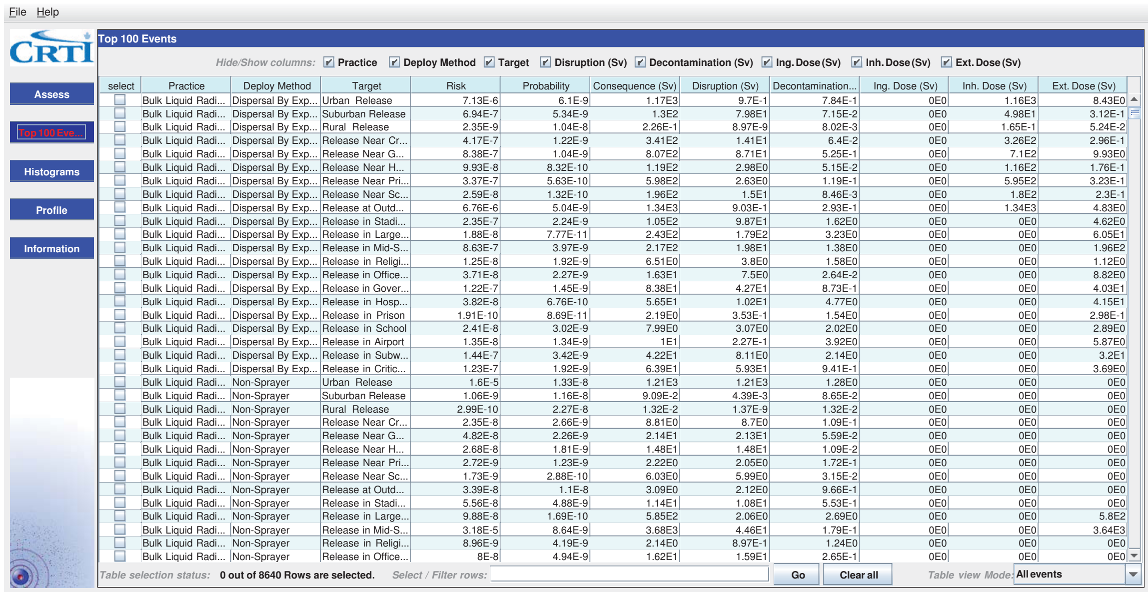

Figure 3: An example of RDD results in tabular view.

loss, decontamination cost and three types of dosimetric estimations.

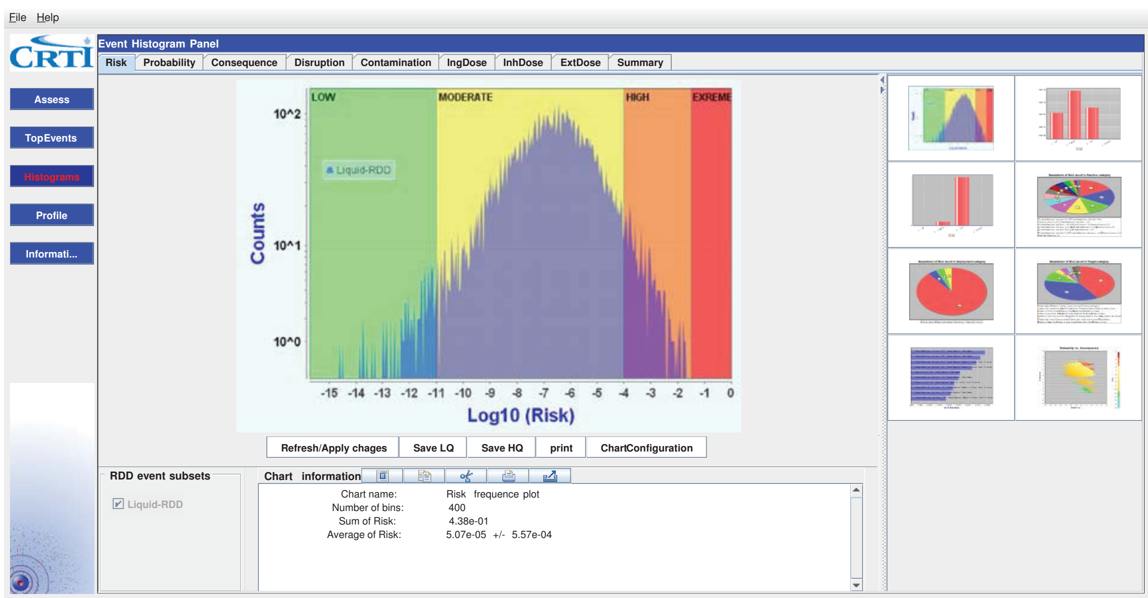

Figure 4: An example of the new graphical visualization of the risk assessment results. This GUI is composed of four sub-windows, which are the top-middle *display* window, the right-side *thumbnail* window, the bottom-left *event subset choice* window and the bottom-middle *chart information* window.

Detailed information on each histogram/chart in view is also displayed in the *Chart information* window which is positioned at the bottom of the GUI. Both charts and detailed information are supplied with several configuration/editing tools.

In addition to viewing the results for all assessed events, the *Histogram* GUI is also capable of displaying any subset of the RDD events if that subset has already been selected and labelled from the *Top Events* GUI. More information about how to select and display subsets of events can be found in the examples in Section 5.

The tables in the *Top Events* GUI provide exhaustive event information, while the charts and histograms in the *Histogram* GUI present aggregated results. For user convenience, a summary panel is available containing the most relevant information for the risk assessment. From the summary panel, the user should be able to obtain quickly the most relevant assessment results, without checking through additional tables or charts. The categorized charts and the concise summary page make the tool more effective than previous versions in identifying dominant risk contributors. A detailed explanation of the summary page can be found in Section 5.

Multiple threading is also configured to shorten the histogram loading time. The multi-threading is especially useful if a large number of events (for example, hundreds of thousands of events) is being analyzed. However, it should be acknowledged that the loading time varies with the number of RDD events, and computer CPU performance. Regardless, a reasonable loading time for histogram display should be on the order of seconds.

4.5 New Information interface

In PRA Tool v2.1, a new GUI was created for displaying system information relevant to the Java environment, and contact information. As seen in Figure 5, real-time memory usage of the PRA Tool is also provided, which contains the free, total and maximum memories. Having sufficient memory is required for optimal performance of the tool. It should be noted that the memory allocation has to be pre-configured before launching the tool; therefore, a good knowledge of the system's physical information is recommended to obtain optimal performance. The tool will also check the virtual memory configurations to determine whether or not all 1.3 million RDD events exceed the Java allocated memory.

4.5.1 Monitoring the memory usage

When a long run (or a large volume of RDD events) is being processed, knowledge of the live memory usage of the Java virtual machine might be useful. This would be especially useful to check and capture if/when there are issues such as memory leakage or shortage. An *Information* GUI has been developed and implemented in order to do this. From this GUI, one can start or stop the memory monitoring anytime. An example of a monitoring process can be found in Figure 5.

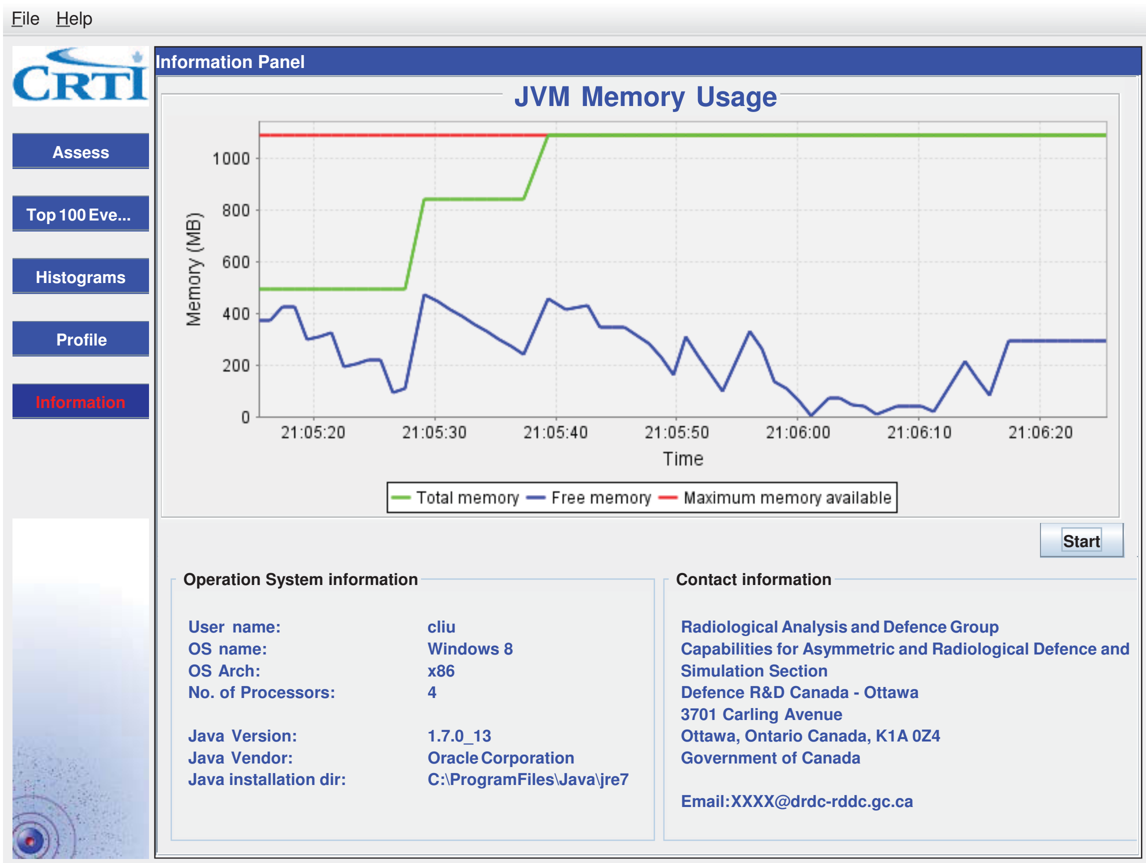

Figure 5: An example of the *Information* GUI of the tool. The memory usage can be monitored or stopped anytime by clicking the "start/stop" button.

5 Examples PRA Tool usage

In this section, we will demonstrate step-by-step how to apply the tool to address and resolve real life concerns. The PRA Tool was designed to assist in finding answers to three general questions related to the RDD threats:

- For a given type of RDD event, which specific RDD events have the highest risks?
- What are the dominant contributors to the highest risk events?
- For a specific RDD event of concern, what are the consequences?

With these questions in mind, two examples are given below:

- determine the highest risk events given a specific type of RDD;
- obtain a consequence assessment for a specific RDD event.

Note: all the numbers used in these examples were generated randomly so that this report contains no classified information.

In the former case, we will use the tool to evaluate risks, consequences and feasibilities of a particular category of RDDs. A ranked event list in tabular form helps to identify the RDD events with highest risk. The various categorized charts will provide information about which component dominates the contribution to risk and other related quantities. The second example explains the assessment of the consequences for a specific RDD event. In this case, the feasibility/probability of the event is not considered.

5.1 Example 1: Risk assessment for a particular category of RDDs

Let us take the *Liquid Dispersal* events as the RDD category of interest. The procedure to carry out an assessment is given below.

5.1.1 Start with event selection

As the *Event Selection* panel is brought up, a click on the *Liquid* button selects the practice type in question, as shown in Figure 6. A subsequent step is to go to the *Deployment Type* check box, and select the *Choose Dispersal* option. Please note that the practice and dispersal types are mandatory categories that must be specified. Other categories may be chosen if desired, but the tool is now ready to run the assessment by clicking the “Compute” button at the bottom-right position of the panel.

A brief message will appear by the “Compute” button to show the processing status. This message shows the number of RDD events assessed and the processing time.

5.1.2 View assessment results from the Top Event GUI

A tabular view of the assessment result will be automatically updated and shown in the *Top Events* GUI panel after the assessment completes. In fact, even during the assessment process, the table continually refreshes itself with new contents. An example of the assessment result in tabular form is shown in Figure 7.

Sort/filter table
In order to identify the highest risk RDD or top 100 RDD set, a risk-ranked RDD list is obtained. As an example, we assume the top 100 *Non-Sprayer* events are of special interest. In this case, the following are the steps to take to look at this specific subset of events.

1. Type in “non-sprayer” in the filter/search box at the bottom of the panel, and click “Go” to proceed.

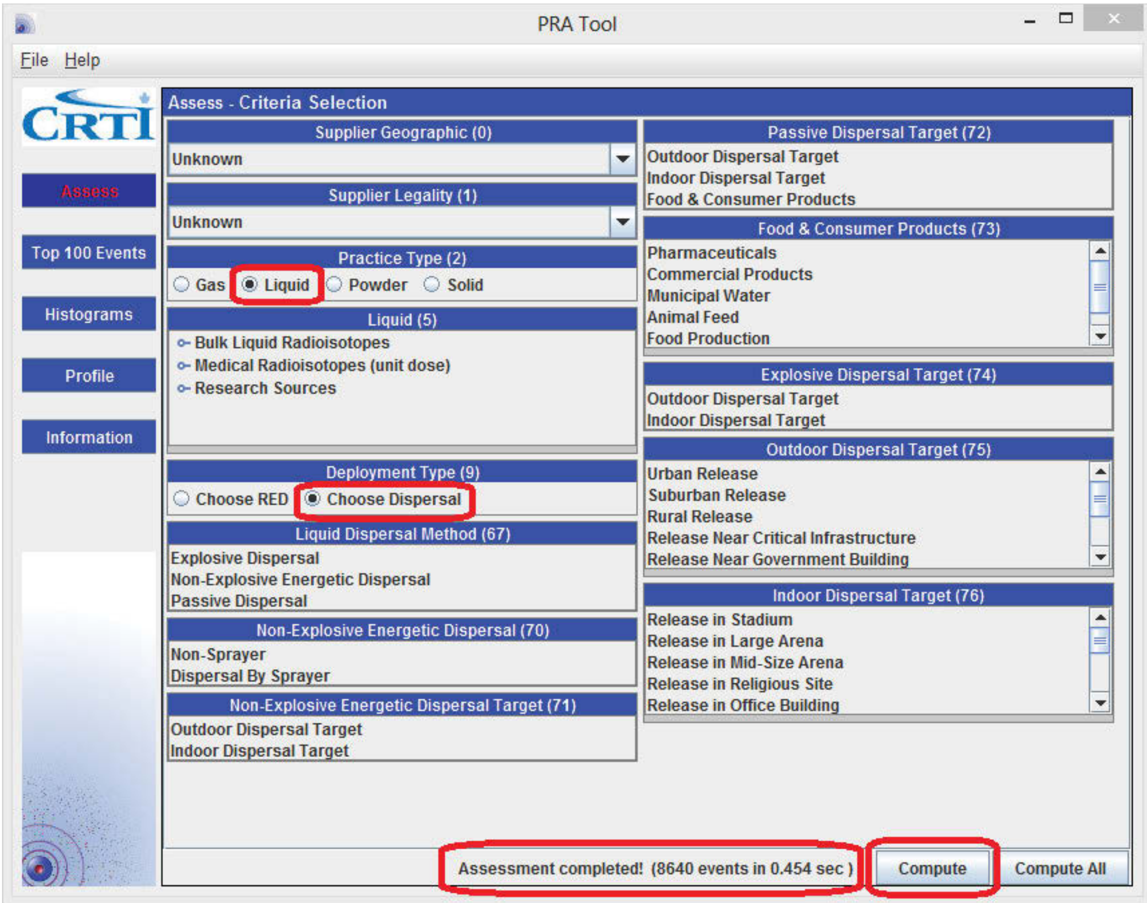

Figure 6: Select *Liquid Dispersal* events and launch an assessment. The highlighted buttons with red squares are the items to choose for this type of event selection. Whenever the selection is ready, a click on the "Compute" button at the bottom launches the assessment. The processing status is also shown by the "Compute" button when the assessment ends.

2. Select "Top 100 Risk" in the *Table View Mode* selection menu.

   OR

   Sort all "non-sprayer" events in Risk by clicking the header of the Risk column, and then select the top 100 events.

After these steps, a list of the top 100 *Non-Sprayer* events is filtered out. The list can be saved into an Excel-like file or printed out from the pop-up menu with a right mouse click on the table.

Label RDDs for later check

At a later stage, one might be interested in further investigating this specific subset of RDDs. For example, a user might want to perform a check on the chart and histogram

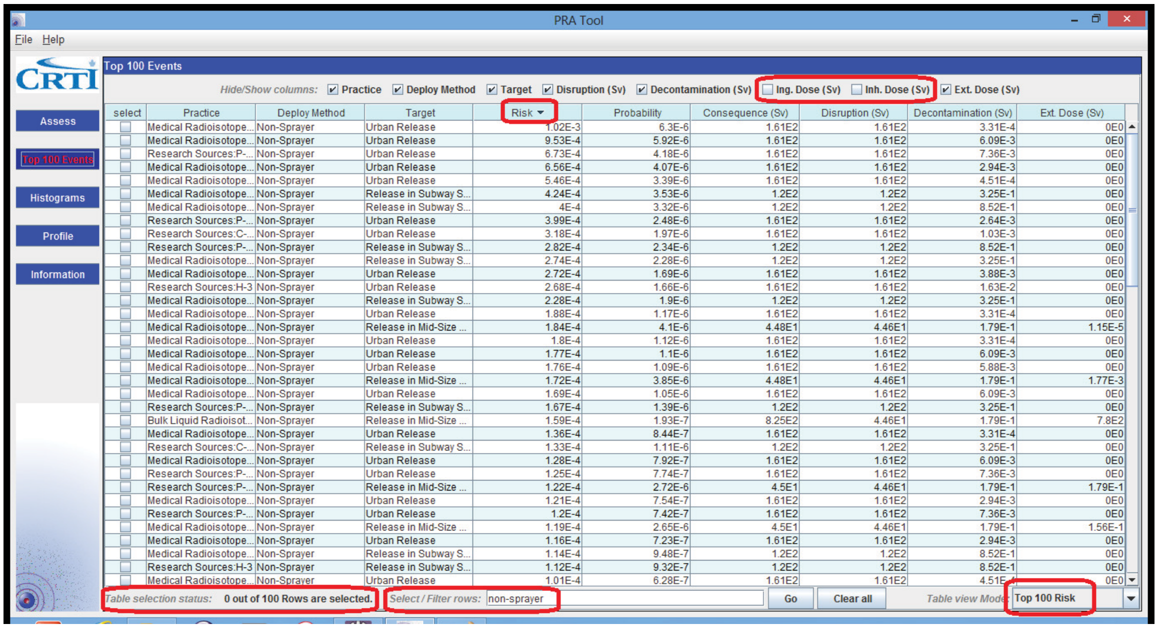

Figure 7: A tabular view of the assessment results for *Liquid Dispersal* RDD events. The tools to manage the table data are highlighted by red squares. Additional tools like select rows, print and export data can be found with a right-click of the computer mouse.

results of these filtered events. In this case, we can follow a couple of additional steps to label this RDD set and perform subsequent analysis.

1. To select all 100 filtered events, right click on any of the rows, and left click "Select all rows" in the pop-up menu.
2. Right click the selection again, and click on "label selection/check histograms", as shown in Figure 8
3. A pop-up window requesting the label information will appear, as shown in Figure 9.
4. Type in meaniful text, like "Non-sprayer top 100", in the message box, and click "OK" to confirm the label.

After these steps, a check box labelled by "Non-sprayer top 100" will appear in all the tabbed panes of the *Histogram* GUI.

Short summary

Sorting and filtering the table allows us to check any specific quantities for any specific RDDs. Therefore, the higher ranked RDDs in the "Liquid Dispersal" type RDDs can be easily found and labelled for later investigation.

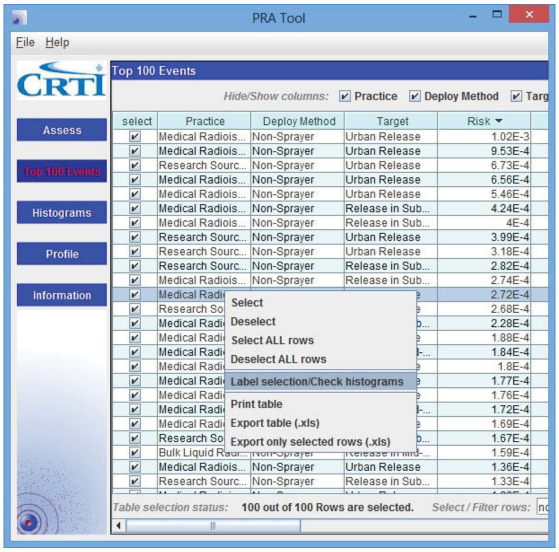

Figure 8: Label a subset of events for subsequent analysis.

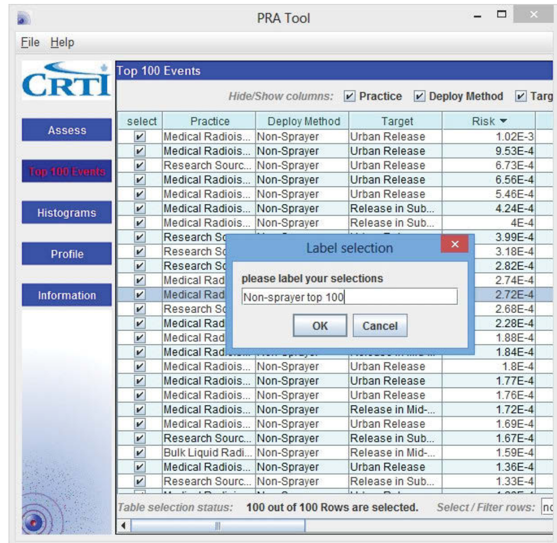

Figure 9: Pop-up window for labelling text input.

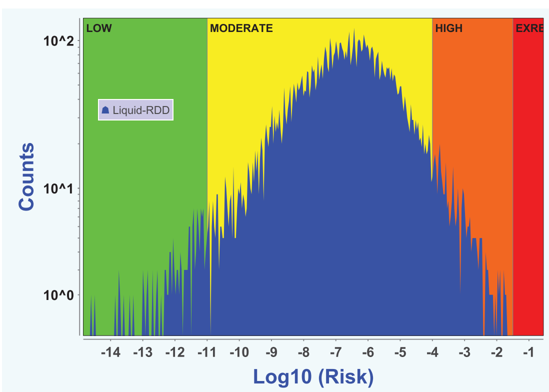

Figure 10: The risk frequency distribution for all *Liquid Dispersal* RDD events. The risk severity bands, denoted by different colours, sit in the background as a reference metric to qualify the level of risk.

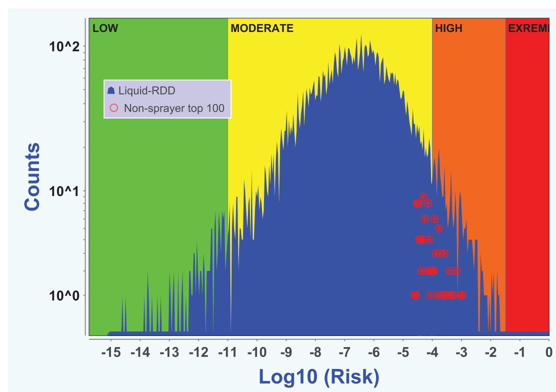

Figure 11: The risk frequency distribution for subset *Non-sprayer top 100* events, together with the risk frequency distribution of all *Liquid Dispersal* events as a reference.

5.1.3 View assessment results from the Histogram GUI

In addition to the RDD list described in the *Top Events* GUI, many informative charts and histograms are presented in the *Histogram* GUI to visualize and interpret the assessment results (see Figure 4). The thumbnail figures which are accessible from the right panel of the *Histogram* GUI are described in the remainder of this sub-section.

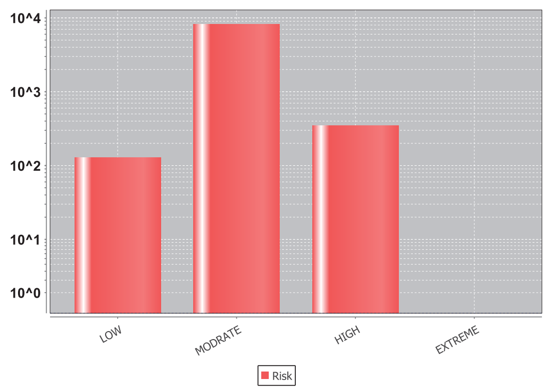

Figure 12: The number RDD events at different risk levels.

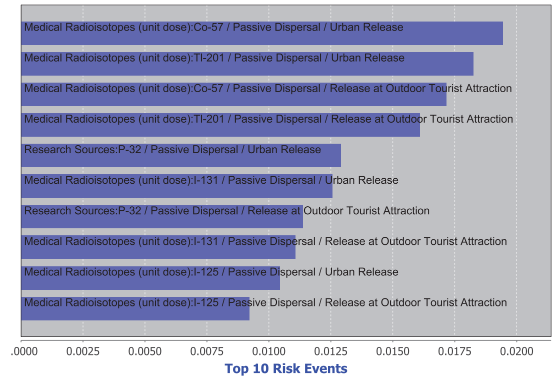

Figure 13: The 10 highest risk events for all Liquid Dispersal events.

Risk pane

The risk pane is explained here; if one is interested in investigating further, for example in order to understand how the probability or/and consequence depend on the other quantities, exploring the remaining panes is recommended.

Figure 10 shows the risk frequency distribution for all *Liquid Dispersal* events which were considered in the initial assessment. Recall, this is one of the eight thumbnails available on the right of the *Histogram* GUI (as seen in Figure 4). The statistics related to this figure, for example the total and average risk values, are presented in the *Chart information* window below the histogram. Note the RDD risk in this plot is not on a linear scale, but a logarithmic scale. The reason for choosing a logarithmic scale is to separate RDD events which have very low risks. Because of this, we are able to separate the small-risk event population so as to reduce the occurrence of a high frequency spike at low risks.

The four coloured bands in the background of the plot are used to indicate the level of risk. The risk severity criteria are somewhat arbitrary but can be adjusted if desired. Please note that the criteria are the same for all RDDs, therefore the risk level provides a standard metric to represent and compare RDD risk severity.

The risk level for a set of RDDs is defined to be the highest level of risk found in the frequency plot or in the counter plot in Figure 12. For this specific example, the highest risk RDD event is found in the *High* risk level, therefore we can say that the risk level for the *Liquid Dispersal* events is assessed to be relatively high.

Risk pane for the pre-selected subset of RDDs

As explained in Section 5.1.2, a subset of RDD events can be selected and the associated charts can be investigated. In this example, the “Non-sprayer top 100” RDDs have been pre-selected.

The change accompanying this selection is the presence of a checkbox in the “RDD subset” window at the left-bottom of the *Histogram* GUI. By selecting this box, a frequency plot like Figure 11 is created in which the “Non-sprayer top 100” RDDs are highlighted as red circles. Having the overall risk frequency as the reference in this figure, it is easy to tell how a subset like the one in this example compares to the whole population of RDD events.

Except for the frequency plot, the rest of the charts function in a similar way, regardless of the choice of the RDDs (all RDDs or a specific subset of RDDs). Therefore, hereafter, no intention is made to separate the choice of RDDs in the following part of the demonstration.

Top 10 RDDs
As shown in Figure 13, the top 10 events are displayed with their risks. This figure is one of the thumbnails that is generated automatically for the Risk pane. Here, the three RDD components (practice, deployment method and target) have been used to characterize the RDD events. This figure provides a straightforward way to tell which RDD has the highest risk and how their risks compare to each other.

Identify the dominant components to risk
One major goal of the PRA is to identify the RDD components which contribute most to the event risk. For this purpose, the categorized charts are created and available to analyze and interpret the assessment results. The risk categorization is done according to the three RDD components: practice, deployment method and targets.

As seen in Figures 14-15, the risk values for each sub-component are summed up and plotted as sections in these plots. From the percentage numbers shown in the plot (or the same numbers given in the *Chart information* window), the relatively high risk practice/target categories can be distinguished. Such plots provide key information to respond to questions like “What kind of liquid material would put us at a highest risk?” and “Which target is at the highest risk if a liquid radiological material is used for a RDD attack?”. As a result, we get a sense of how to allocate resources to prepare for potential RDD events, as described in Section 5.1.5.

Similarly, the relative risk for different deployment methods is given in Figure 16. Information derived from this figure can be used to address questions like “Which dispersal method poses the highest risk?”.

Risk curve
The dependence of the risk on feasibility and consequence can be visually interpreted by a two dimensional histogram as shown in Figure 17. In this plot, the colour bands denoting the level of risk are the same as those used in the bands in Figure 10.

Other panes
Similar sets of plots are provided for the other important quantities, such as probability, consequence, disruption, decontamination, dose, etc. Generally, these plots are very informative so will provide further information for users who wish to understand better the

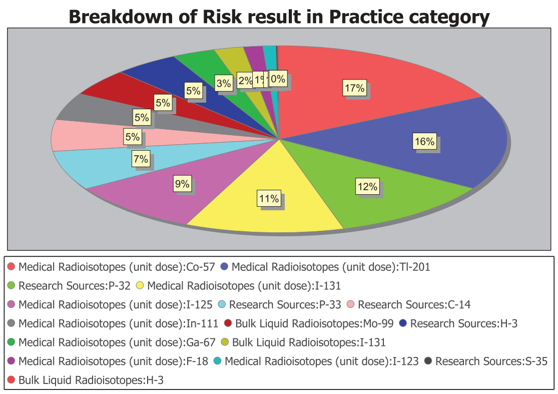

Figure 14: The risk compositions for different practice types for all *Liquid Dispersal* events.

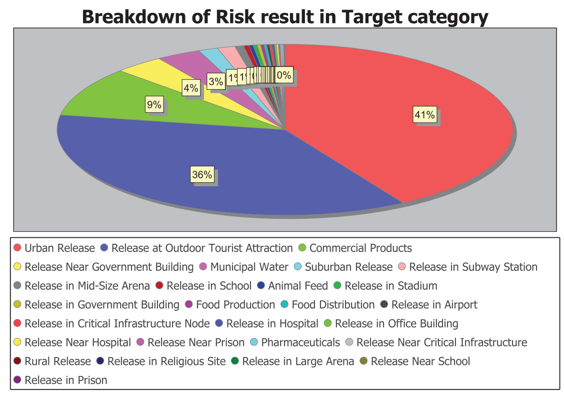

Figure 15: The risk compositions for different target types for all *Liquid Dispersal* events.

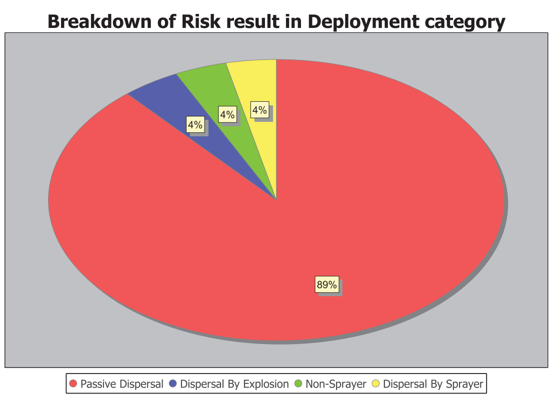

Figure 16: The risk results for different deployment categories for for all Liquid Dispersal events.

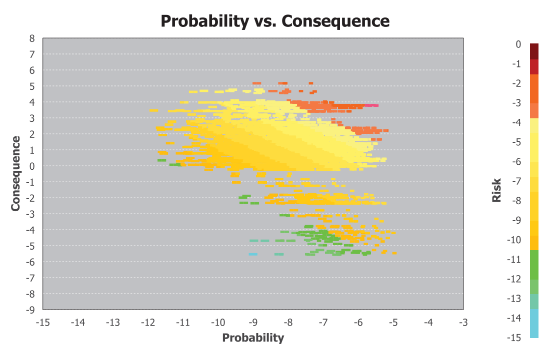

Figure 17: The risk distribution as a function of feasibility and consequence.

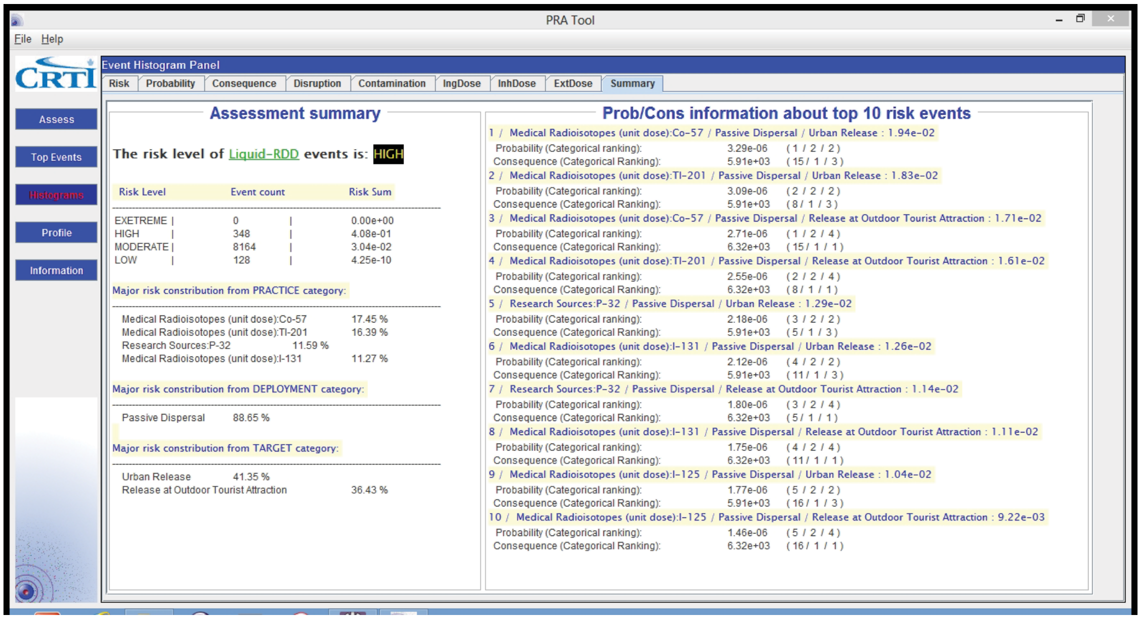

Figure 18: An example of the assessment summary page in the *Histogram* GUI. The left part shows the risk results in both quantitative and qualitative form. The right part shows detailed risk, feasibility and consequence information about the top 10 events.

individual contributions to the overall risks posed by different RDD events.

5.1.4 Check histogram summary pane

For convenience, most of the important information is summarized in the *Summary* pane. Here, you will find the overall quantitative and qualitative assessment results.

An example of the assessment summary page is given in Figure 18. The left part of the page summarizes the risk results: the risk level is shown at the very beginning and what follows is the number of RDD events and the summed risk for each of the risk levels. The bottom part shows the significant categorical risks in terms of practice type, deployment method and target. Note that only categories whose accumulated risk value is $\geq 50\%$ of the total risk are presented.

The right part of the page shows a breakdown of risk for both feasibility and consequence for the top 10 events. This information is helpful to understand the factors contributing to high risk, through either a high probability or a large consequence.

5.1.5 The possible risk management options

As suggested by Figures 14-16 and the summary page, the dominant cause of RDD risk, in terms of practice, deployment means and target scenarios, can be clearly determined.

Such information is especially helpful for decision makers to understand risk management options and plan actions to prevent, reduce or eliminate potential risks.

Practice-oriented options
Based on the assessment results, one might want to initiate a dialogue between the PRA Tool users and these potentially affected/associated groups. For example those who possess certain practice materials (for example, hospitals or research institutes) could be contacted. One could inform them about the risk levels, together with the reasons/causes which might be related to their availability, activity, or another factor.

Target-oriented options
Similar action can also be taken once the target-oriented information from Figure 15 has been inferred. In this case, public security stakeholders might be contacted about the higher risk locations. By enhancing surveillance or taking other measures, the risk can be reduced or, most favourably, eliminated.

5.2 Example 2: Consequence assessment for a RDD event

As described previously, the risk is a product of feasibility and consequence. Therefore, the risk assessment takes the relative probability of success into account. However, if a RDD event has already taken place in reality, the PRA Tool could be used to estimate the consequence of that event.

The consequence evaluated by the PRA Tool is an absolute term, and it is ideally able to estimate economic loss and health effects. In order to make the assessment as accurate as possible, one typically needs to modify those parameters which represent the scenarios of the RDD in the tool. Therefore, a flexible way to configure the database is highly desirable. Regardless, in the absence of other tools, the consequence currently assessed by the tool can be used as a rough estimate in case of a real or imminent RDD event.

In order to do the consequence assessment, a user must know (a) the type and (b) the quantity of RAM that is used, (c) its method of dispersal, and (d) the target of the dispersal. The PRA Tool event that is most similar can then be used to estimate the consequences of the event. The breakdown of the consequences are also available in either tabular or graphical format.

6 Discussions and future plans

The new version of the PRA Toolis now close to completion; however, thorough testing, debugging and additional optimization work remains to be done. There are a few other modifications/improvements which also may be made before the tool ready for all users.

6.1 Lower the memory usage

The performance of the tool varies depending on the platform, operating system and Java running environment. Based on the current estimation, at least 1 GB of memory needs to be allocated to the Java virtual machine if one wants to run all RDDs. According to the typical Java configuration, 1 GB memory for Java requires at least 4 GB of physical memory for the machine.

If the memory demands become critical for some older computers and operating systems, then there is a need to reduce the memory usage without reducing functionality. One of the possible ways is to ignore the *Supplier* categories during the assessment process, but apply the corresponding factors afterward when displaying tables or figures. In this way, we expect an improvement by a factor of six in the processing time and a corresponding reduction in the total memory usage. This will be explored further in future versions of the tool.

6.2 Improve the database configurability

The discussion so far has been from the user's point of view; however, since regular updates to the database are expected, either to add new CBRN threats or update RDD attributes, the tool developers desire a flexible and effective tool for configuring the database.

One of the targeted improvements in the future is to find a way to represent the health effects in a more realistic way. Instead of using a set of fixed discrete numbers for dose calculations, one might wish to incorporate a stochastic element into the calculations.

6.3 Help information in the menu

For software like this one, it is always desirable to have a useful help imenu for users; for example, a feature to provide users with a recommended procedure for assessing and interpreting results. This type of helpful information should form part of the completed PRA Tool.

7 Conclusions

After a series of revisions, the new PRA Tool has had several improvements in performance and functionality. The revised tool is more efficient in computation, less dependent on other libraries and more manageable for presenting results. The new tabular and graphical displays for assessment results make the tool more convenient for identifying high risk RDD events and the cause of their high risks.

The revised tool is still undergoing debugging and stability and performance tests before wide distribution.

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DRDC Ottawa has been developing and maintaining the Probabalistic Risk Assessment Tool software for the assessment of risk related to radiological dispersal devices since 2002. Major revision work on the tool started in 2009 and has recently been completed.

The revisions introduce several new features such as a new, faster database format, and new graphical user interfaces. These new features required the replacement of older libraries and re-coding of large portions of the software. The changes make the revised tool highly efficient in computation, less dependent on third-party libraries and more manageable for the analysis and presentation of risk results.

The new tabular and graphic displays provide effective means for conveying the assessment results, identifying dominant risk contributors and helping to strengthen risk management practices. Examples of how the tool can be used are given to demonstrate the new features, improved performance and new capabilities.

The revised tool is currently at the alpha version of the development stage so various tests and checks are ongoing.

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