RiskSpectrum
Magazine 2016

▶ # PSAM 13
Welcome to Seoul, Korea

▶ **Risk monitor success stories**
Automatic plant status update
PSA results convince Hungarian regulator

▶ **RiskSpectrum 30 years!**
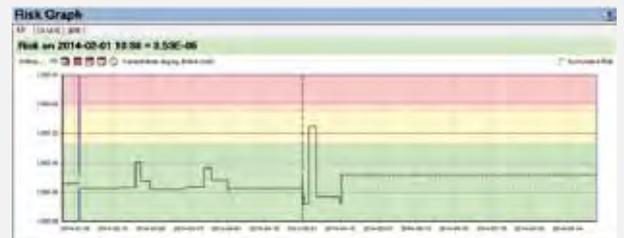**Looking back and moving forward**

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In this issue:

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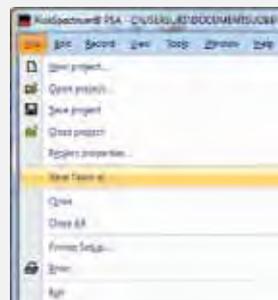
These are dynamic times

Risk analysis processes and methods are constantly evolving – as they should be. It is interesting to follow how focus changes over the years; some approaches stand the test of time and have a significant impact on the way we perform analyses (such as BDD approaches for accuracy), while others end up on the historical garbage heap.

" It is only when we see the results of the risk analysis integrated into the asset management process that we have truly achieved a dynamic use of the results."

I recommend keeping a close eye on two fairly new approaches surely discussed at this PSAM conference: multi-unit analysis and dynamic probabilistic-deterministic analysis. The most interesting aspect of both of these is their potential to fundamentally change the way that analysis is performed. I am not mainly referring to the probabilistic calculation method itself, but rather to how the problems are formulated. (The probabilistic calculations will in all likelihood have to be refined to give better consideration to time as well.)

We should also maintain continual focus on how to maximise the benefit of a risk analysis. We talk about living PSA, but we should be talking about living risk. It is only when we see the results of the risk analysis integrated into the asset management process that we have truly achieved a dynamic use of the results. We are not quite there yet.

RiskSpectrum continues to undergo dynamic development. We have merged with other Lloyd's Register software groups to form the LR Software unit. It is exciting to be part of a big, ambitious team working to improve the way we master risk and uncertainty in complex assets, while protecting life, environment and property.

I am proud to be part of this evolution. These are dynamic times, and I am glad that they are. ■

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Welcome to Seoul and

Bonguensa Temple

Jongmyo Royal Shrine

DR JOON-EON YANG
Integrated Safety
Assessment Division,
Korea Atomic Energy
Research Institute, Daejeon,
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Nuclear safety expert Dr Joon-Eon Yang earned a B.S. in nuclear engineering at Hanyang University in 1984, followed by an M.S. (1986) and Ph.D. (1990) in nuclear engineering at Korea Advanced Institute of Science & Technology (KAIST). Dr Yang has worked for the Korea Atomic Energy Research Institute (KAERI) in Probabilistic Safety Assessment (PSA) and its application areas since 1990, and has been a director of the Integrated Safety Assessment Division since 2007. The author or co-author of over 300 scientific papers on PSA and risk-informed applications, he is also a founder and chair of the Korean PSA Expert Group, which consists of PSA experts from the Korean regulatory body, industry and universities. Dr Yang is a member of the editorial board of the Korean journal *Nuclear Engineering and Technology* as well as of the Nuclear Safety Special Committee of the Korean regulatory body. He holds international positions as well, serving as a member of the Programme Review Group (PRG) and Senior Expert Group on Safety Research Opportunities Post-Fukushima (SAREF) of OECD-NEA, and sitting on the board of directors of the International Association for PSAM (IAPSAM). A former member of the Committee on Safety of Nuclear Installations (CSNI) of OECD-NEA and the Risk and Safety Working Group (RSWG) of the Generation IV International Forum (GIF), Dr Yang has also been involved in many IAEA expert missions in connection with PSA reviews for developing countries.

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PSAM 13

What are your expectations for PSAM13?

In the five years since the Fukushima accident a lot of progress has been made in the PSA area thanks to research and/or work regarding the lessons learned from the accident. PSAM13 is the conference where overall progress in the PSA area after the accident will be summarised and discussed to upgrade the capability of PSA.

What are the most significant events/streams in the PSA community that have happened since PSAM12 in Honolulu in 2014?

After the Fukushima accident many additional systems and/or equipment were installed in operating nuclear power plants based on the lessons learned from the accident. However, the effects of such additional features have not yet been estimated appropriately via PSA. We need to model the additional features in PSA appropriately and derive the insights from PSA results to optimise the use of those features.

What do you think will be the "hot topic" at PSAM13?

Two topics will be the hottest ones: multi-unit risk and extreme external events. Many countries such as Korea, Canada, Japan, etc. have a big interest in these topics. There are many on-going activities on these topics, and it is time to get some meaningful results. We expect such results will be presented at PSAM13.

There are countries now starting nuclear programmes. Are they represented at the PSAM13 conference? What do you think they will bring to the conference?

There will be participants from 38 countries which include many countries now starting nuclear programmes. We expect that they will bring some new PSA-related issues since each country is in a different environment. For instance, some new nuclear power plants are being built in the desert, and this might bring some new issues to the PSA area.

**What would you say are the main differences between PSA in the nuclear industry and in other industries?**

It is difficult to identify the general differences between PSA in the nuclear industry and in other industries since each country is in different environment. In Korea, PSA is not so popular in industries other than the nuclear industry. The most significant issue is the lack of domain-specific reliability data. However, Korean chemical, railway and aerospace industries are interested in PSA and have started to apply PSA in their domains.

If you would recommend one thing to see in Seoul, what would it be?

PSAM13 will be held in Seoul, and Seoul has a lot of interesting places. We recommend seeing the old palaces and/or Insa-Dong if you want to learn about the old Korean culture or the Gangnam area where you can enjoy the modern culture of Korea. ■

Gangnam neighbourhood
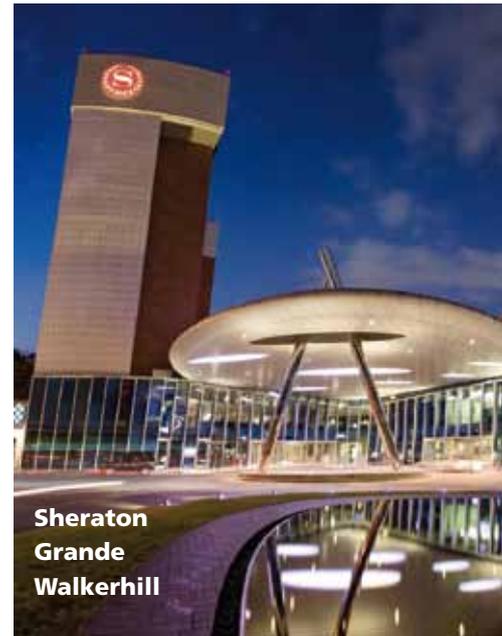
Sheraton Grande Walkerhill

Naksan Park

A guide to Lloyd's Register papers at PSAM 13

In addition to visiting us at the RiskSpectrum stand at PSAM 13, you are also most welcome to come and listen to the papers that we will be presenting.

A-160   SICA – A SOFTWARE COMPLEXITY ANALYSIS METHOD FOR FAILURE PROBABILITY ESTIMATION

This paper proposes a method for measuring the complexity of software. The software complexity is in turn used for estimating software failure probabilities. The challenge is to find a practical and justifiable metric which can be assumed to correlate with reliability.

A-154   EXTREME EVENT ANALYSIS – A BENCHMARKING STUDY

Probabilistic and deterministic safety assessment (PSA/DSA) are normally used to complement one another. However, in a few scenarios, for example when there is a combination of external hazards, the PSA/DSA results may not be sufficient to demonstrate the response of the nuclear power plant under such extreme conditions. Lloyd's Register Consulting, with support from the International Atomic Energy Agency (IAEA), has developed the RiskSpectrum Extreme Event Analyzer (EEA) to systematically analyse both single hazards and combinations of hazards using a deterministic approach together with a PSA model. This paper discusses a benchmarking study that Lloyd's Register has performed together with the Nuclear and Radiation Safety Center (NRSC) and the Armenian Nuclear Power Plant (ANPP).

A-232   VERIFICATION OF RISKSPECTRUM MCS BDD ALGORITHM

This paper summarises the verification of correctness and efficiency of the RiskSpectrum MCS BDD algorithm.
Verification of the algorithm results is based on a combination of small-scale models – where it is possible to calculate the results precisely – and large-scale models – where it is impossible to calculate the results by hand. The large-scale models are used for testing scalability and whether simplification settings (when used) yield reasonable results. The main challenge is to validate expected behaviour with regard to success sequences in large-scale PSA models.

A-340   RISK-INFORMED EVALUATION OF TECHNICAL SPECIFICATIONS FOR LEIBSTADT NPP (KKL)

The KKL Technical Specifications cover LCOs for unavailability of systems and provide AOTs for each unavailability combination along with the surveillance test requirements (STIs). These were developed in the 70s, based mainly on expert judgement on design basis scenarios restricted to transients and LOCAs. A new state-of-the-art PSA evaluation of AOTs and STIs has been performed at KKL based on a newly developed full-scope, all-hazards PSA model. The study applies the ENSI, IAEA and NRC Regulatory Guides on risk-informed decision making.

A281   INTEGRATED HRA DEPENDENCY TREATMENT IN PSA
This paper proposes an innovative integrated HRA dependency treatment process which will improve the current HRA dependency treatment in PSA, with regard to both HRA dependency identification and quantification.

A-069   DEPENDENCIES IN HRA – NPSAG PHASE I PROJECT
Dependencies in human reliability analysis (HRA) may heavily impact the results of probabilistic safety assessment (PSA). This paper presents findings from a project funded by the Nordic PSA Group that studied how HRA dependencies should be accounted for in Level 1 PSA during all plant operating modes. In addition to presenting the results from a literature review, an international survey, plant case studies etc., the situations in which dependencies do need not be considered will also be discussed.

A-103   GUIDANCE IN LEVEL 3 PSA
Funded by the Nordic Nuclear Safety Research group (NKS) and the Nordic PSA Group (NPSAG), a consortium of Swedish and Finnish experts has performed a multi-year study of Level 3 PSA. The objective of the project is to further develop understanding within the Nordic countries in the field of Level 3 PSA, the scope of its application, its limitations, appropriate risk metrics, and the overall need and requirements for Level 3 PSA. This paper describes the project and its results and conclusions.

There are two papers associated with the European project ASAMPSA_E.

A-151   PSA FOR SHUTDOWN STATES, SPENT FUEL POOL AND RECENT R&D RESULTS IN LEVEL 2 PSA
The paper focuses on the aspects of Level 2 PSA that were not addressed in the previous ASAMPSA2 project, i.e. guidance for Level 2 PSA for reactor shutdown states, modelling of spent fuel pools (including dry storages), and recent R&D results in Level 2 PSA.

A-150   HOW TO INTRODUCE HAZARDS IN LEVEL 1 PSA AND ALL POSSIBILITIES OF EVENTS COMBINATIONS
The paper summarizes good practices related to the implementation of external hazards in Level 1 PSA. A work process flowchart including nine steps is introduced that shall ensure that important aspects are taken into account.

A-322   MODELLING THE RELIABILITY OF DIGITAL I&C IN MODERN NUCLEAR POWER PLANTS
The digital I&C system should be included in the PSA, as I&C has the potential to affect overall plant reliability significantly. The use of the PSA model for both DiD evaluation and PSA requires a proper definition and handling of the software system failure modes.
This paper is a continuation of the Nordic R&D project DIGREL related to the definition of software failure modes and calculation of their failure probability.

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RiskSpectrum 30 years

Looking back

PSA

and moving forward

Released in 1986, RELTREE was the first software of its kind designed for standalone PCs. Written for the MS-DOS operating system, it included a fault tree editor and a powerful module for generating minimal cut sets (MCS). When it was launched, RELTREE had to compete with software that ran on mainframe computers. A benchmarking study compared RELTREE running on a PC with a program executed on a Cray – one of the most powerful mainframes in the world at that time. To its credit, RELTREE proved to be just slightly slower in solving the fault tree models.

RELTREE was chosen for use by the Swedish utilities, beating out tough competition from other Swedish, US and German software houses, and we were proud to support the nuclear industry with risk analysis software and services. RELTREE was the predecessor of RiskSpectrum PSA for DOS, which was released in the beginning of the 1990s. RiskSpectrum PSA quickly positioned itself as the industry standard in most civil nuclear power generation countries in Europe. Since then new software products have been released on a regular basis. Today RiskSpectrum PSA is licensed for use at 60 per cent of the world's nuclear power plants.

Software development has proven to be a daunting task, but we are fortunate to have very patient customers who believe in us. This is one of the pillars on which Risk Spectrum's success is built. We recognise that the quality aspect is very important and we take it very seriously. Unfortunately, this extends the development cycle, which in turn tries our licensees' patience.

We will continue to spearhead research and development of this type of software. We are well aware that it will be hard, but we are looking forward to rolling up our sleeves and getting to work. With the continued faith and encouragement of our customers, we know we can do it! ■

30 years

RiskSpectrum release history
1986: RELTREE for DOS
(fault tree editor and analysis engine)
1991: RiskSpectrum PSA for DOS
1998: RiskSpectrum FT for DOS
1998: RiskSpectrum PSA and FT Professional (first Windows version, 16-bit)
2001: RiskSpectrum FMEA
2002: RiskSpectrum RiskWatcher
2007: RiskSpectrum PSA (second Windows version, 32-bit)
2009: RiskSpectrum Doc
2012: RiskSpectrum RiskWatcher BOP (for drilling operations)
2013: RiskSpectrum HRA
2013: RiskSpectrum HazardLite
2016: RiskSpectrum PSA Add-On Package

IMPROVEMENTS and additions to the RiskSpectrum Family

Spring and summer 2016 have been particularly busy for us, with an array of new software releases. The new version of RSAT, which accommodates changes in RiskSpectrum PSA and RiskSpectrum RiskWatcher, has required extensive development and testing. It has now been released along with the much sought-after Add-On Package.

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MCS as input kills two birds with one stone

The possibility of using an MCS list as input to an event tree in RiskSpectrum PSA has ranked very high on our users' wish list. This functionality is now available in version 1.3.2. There are two main reasons why this has been such a popular request:

1. It can take a long time to solve PSA models covering all operating states and internal and external events when linking Level 1 and Level 2 PSA event trees. Instead of linking event trees, you can now use the result (MCS list) from a father event tree as input to a child tree. This will radically reduce the complexity of the model, thereby reducing calculations.

2. Results from the Level 2 PSA are in many cases submitted to the regulator after it has reviewed and approved the Level 1 PSA.

Therefore, the regulator sometimes requires that the Level 2 PSA is based on the results of the Level 1 PSA. Using the MCS results from the Level 1 PSA instead of linking the event trees will ensure that this requirement is fulfilled.

Another advantage of this feature is that you can fine-tune settings for each part of the analysis separately. For instance, it is possible to build the event trees differently with respect to inheritance of boundary condition sets in order to influence success quantification by different success module settings or steer the calculation time for each analysis by cutoff values and limits. These settings are then stored in the results for later review.

Please note that the MCS list used as input to an event tree does not contain information about the not-logic. This means that in some cases analysis results obtained by this feature might differ from the integrated analysis. See the Theory Manual or the paper "Linking of Event Trees via Analysis Results" presented here at PSAM for further details. ■
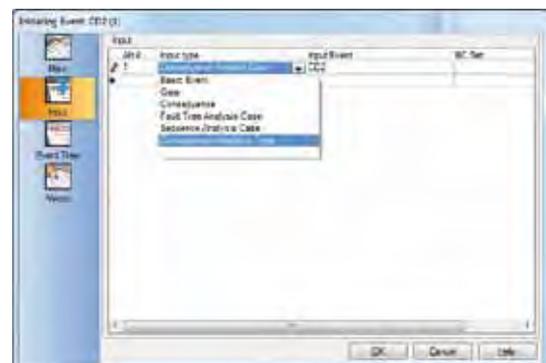
You can define a MCS list as input to an Initiating Event by selecting the Analysis Case it was generated from.

Update for both behind the scenes and on the scene

RiskSpectrum RiskWatcher version 1.37 includes improvements in stability and user experience. The re-use of calculated results has been refined and a related bug has also been fixed. Navigating large event histories has been optimised to improve the user experience. There are also some newly implemented features that are immediately visible when you launch RiskSpectrum RiskWatcher 1.37. One is a vertical line in the risk graph indicating change of plant operating mode. Another is the display of the impact of upcoming events on risk level in the risk graph. This is shown with a coloured line in the risk graph. ◼
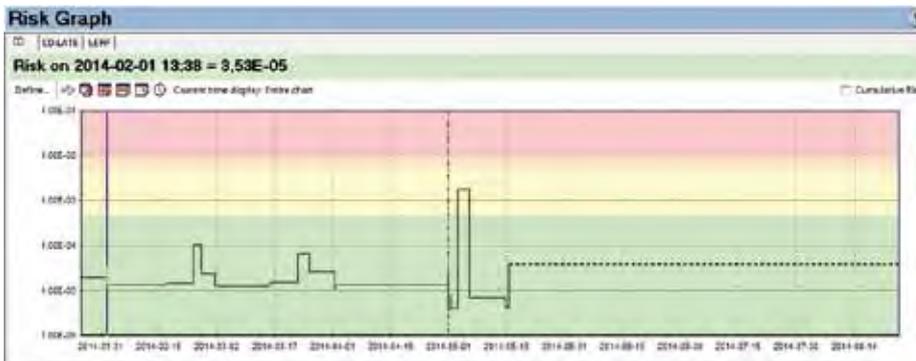
Change of plant operating mode and the impact of upcoming events are displayed in the risk graph in RiskSpectrum RiskWatcher version 1.37.

RiskSpectrum PSA Add-On Package

The first release of the RiskSpectrum PSA Add-On Package includes two applications: ModelCompare and the CutsetTracer. The CutsetTracer is an excellent tool for identifying the sequence from which a particular MCS originates. It allows you to trace how basic event failures propagate to the failure of the top event. In addition, the CutsetTracer provides better insight into how boundary condition sets and calculation settings are applied throughout the sequence. The ModelCompare tool gives you a clear picture of what has been modified, added and deleted relative to another model. ◼

▶

▶ RiskSpectrum ModelCompare

is an Add-On tool to RiskSpectrum PSA that can be used for comparing models. Together with the ability to compare MCS lists in the MCS Editor, the ModelCompare offers a complete toolbox for comparing PSA models logic, record values and results.

The RiskSpectrum ModelCompare (CMP) can be used for comparing record properties and relations between records in the SQL database of RiskSpectrum PSA. The results are presented as records that have been modified, relations that have been removed or added, and fault tree and event tree structures that have been modified. When you select a record in the "Main model", the RickSpectrum CMP displays, in colour codes, whether the record has been added, deleted or modified in the models. It also shows details about the selected record and, whether the record is a fault tree or an event tree, it shows the trees and indicates the changes in them using colour coding. ∎

The ModelCompare software interface is designed to give you detailed information about record properties that have been modified, added or deleted. The same information is also shown graphically in fault trees and event trees.

In my opinion the RiskSpectrum ModelCompare tool will become a fundamental part of the workflow for updating and reviewing RiskSpectrum PSA models. Previously, one could "tag by date" or filter records based on edited dates to see what records had been added or modified after a certain date. This process was susceptible to errors, relied on the assumption that all changes were properly logged by the edited date, and could not account for the records that had been REMOVED! Many, including myself, developed work-arounds (e.g. scripts, spreadsheets) to assist in understanding the changes between RiskSpectrum model versions but these also were also susceptible to numerous assumptions and possible errors. With RiskSpectrum ModelCompare I can finally (and quickly!) assess what has been added, changed or removed between model versions. Furthermore, RiskSpectrum ModelCompare makes comparisons between the actual values and references for each record in the database, which means if something has been modified and reset to its original contents the tool will not needlessly show it as a change, as would be indicated with a search on the edited by date.

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CutsetTracer

The RiskSpectrum CutsetTracer helps you to quickly understand which fault trees and which sequence lead to a particular Minimal Cutset (MCS). The tool is designed to find and display the sequence that a MCS fulfils. The function events that have not failed are colour-coded green, while those that have failed are colour-coded red.

RiskSpectrum PSA provides powerfully flexible and versatile model development through elements such as House Events, Exchange events, and Boundary Condition Sets allowing users to adapt the same core logic to different potential scenarios. This can eliminate unnecessary repetition, reducing potential errors and providing more succinct and organised models. The versatility and flexibility of

RiskSpectrum PSA can, however, make it difficult to trace how the results relate to the model for large and complex analyses. A tool to aid analysts in tracing how the model relates to the results, a cutset tracer, has been on the RiskSpectrum User Group's wish list for many years.

Finding out where the basic events in a MCS originate in the fault tree and event tree logic can be a daunting task even for the most experienced PSA expert. The "Propagate True/False" function in RiskSpectrum PSA can be used for this purpose and will help to find the path of failed events in the fault trees. However, the RiskSpectrum CutsetTracer does much more than that. It displays the sequence, with failed and successful function events, leading to the MCS through all event trees

involved. It also displays the input to the function events, or the sequence initiating event, when you select them. The fault tree logic and events are displayed with exchanges and boundary conditions as they were applied when the MCS was generated. Colour coding of events makes it easy to see how the events in the MCS propagate through the logic structure.

The RiskSpectrum CutsetTracer also shows the boundary conditions, analysis settings and exchanges that were applied in the analysis that generated the MCS. To be able to see, at a glance, the collective boundary conditions that have been applied at a particular point (function event) in the sequence is a fantastic advantage and will make review and understanding of the model much easier. ◾
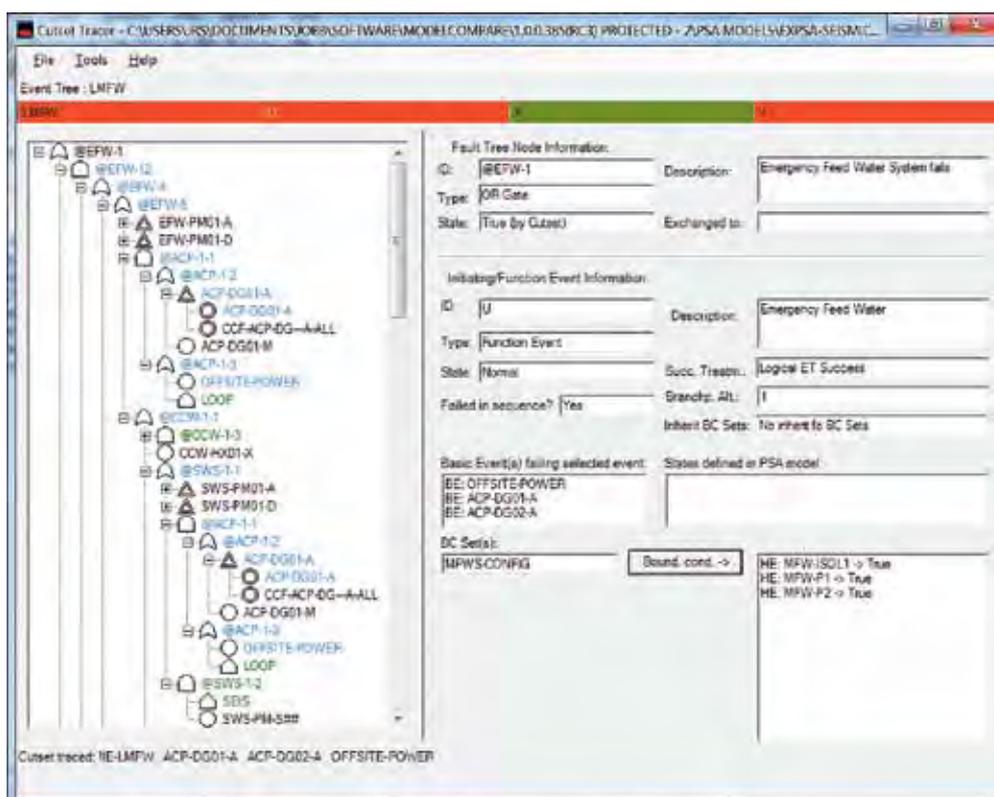
Information about the selected fault tree node and function event is shown on the right side in the CutsetTracer interface. Here you get a quick overview of what settings were used when generating the MCS, whether BC Sets were inherited, and what success treatment was applied. Furthermore, you can see what BC Sets were applied and also a listing of events that were defined as true or false in the model, without using BC Sets.

Fully automated risk monitor implemented in China

RiskSpectrum RiskWatcher Web has been successfully implemented at the Qinshan ll and Tianwan nuclear power plants in China. The web version is designed for PSA applications and is readily accessible to all plant staff. The automatic data capture from the plant information system makes it possible to update and produce new risk calculations in RiskSpectrum RiskWatcher without operator intervention.

The past five years have probably been the busiest for probabilistic safety assessment (PSA) experts in nuclear design and/or engineering companies in China. This is due in part to the fact that in the wake of the Fukushima accident PSA analyses for internal and external events such as seismic PSA were made mandatory by the National Nuclear Safety Administration (NNSA) for all the nuclear power plants (NPP) under construction or recently built in China. A number of PSA application projects have

been launched in the past five years as well.

RiskSpectrum RiskWatcher was implemented at the Qinshan ll and Tianwan NPPs and put into formal use in 2014. Today, with some two years of experience with using RiskSpectrum RiskWatcher, good work processes have been established and positive changes in terms of risk awareness have been observed at the two NPPs. The concept of risk is now widely known and accepted at the plants and plant staff intentionally and

proactively verify the risk level in RiskSpectrum RiskWatcher before changing configuration or initiating other major activities and when any unplanned events occur.

Safety culture is difficult to change

A risk monitor is an important tool for risk-informed application and management. RiskSpectrum RiskWatcher was introduced as part of the PSA application projects at the Qinshan Phase II NPP's four units (650 MW PWR) and the Tianwan NPP's two units (VVER-

1000/V320). Both projects have found that changing the concept of safety and the safety culture is the first challenge that must be overcome when implementing risk monitors and PSA applications in China. Most safety management activities at the NPPs are currently derived from either regulatory requirements/rules or results from deterministic safety analysis. These prescriptive requirements are familiar and well-accepted by plant staff, and they are implemented on a daily basis. Given that China does not have a corresponding regulatory requirement to the US Maintenance Rule, a debate has begun on what a Chinese risk monitor should look like and how it should be used.

Automated interface reduces workload
The use of a risk monitor and PSA applications alters the daily tasks of plant staff as well as how they think about safety and risks. Risk insights from a risk monitor generate more information that personnel have to process and deal with. Who/which department should be responsible for using the risk monitor in their day-to-day activities has been an issue for discussion.

Operation and maintenance departments normally have a high workload at Chinese NPPs. It was therefore required early on in the risk monitor implementation projects at Qinshan ll and Tianwan that any additional work should be kept to a minimum. Therefore, a standalone tool that automatically downloads relevant status signals for equipment from the plant information system and imports them to RiskSpectrum RiskWatcher

was developed. Risk calculations are started automatically after equipment or plant configuration changes and the risk profile is updated. No operator intervention is required for producing new risk calculations when using RiskSpectrum RiskWatcher. Feedback from the NPPs indicates that there is almost no time delay caused by automatic input of plant configuration changes.

Web-based RiskSpectrum RiskWatcher for better deployment
RiskSpectrum RiskWatcher is a mature commercial tool and there are plenty of reference implementations in countries other than China. During the risk monitor development and trial use, knowledge transfer was facilitated via several external and internal training courses on PSA, risk monitors and risk-informed management held for plant staff to increase their knowledge of the concept and the functionality of the tools.

The final delivery of RiskSpectrum RiskWatcher to the Qinshan ll and Tianwan NPPs is a web-based multi-user application with integrated model management functions and an interface to the plants' information systems. It has great advantages compared to other traditional desktop-based risk monitoring tools: it is easier to deploy, maintain and update, and is readily accessible to all NPP staff. This in turn makes it easier to get personnel more involved in risk management activities and increase their awareness of the concept of risk.

Good years for PSA applications
PSA applications have long been

on the agenda in China, also prior to the Fukushima accident. However, it is not possible to assert that the accident had no influence whatsoever on the decision to initiate pilot PSA applications.

The regulatory requirements for PSA for NPPs in China were first included in the nuclear safety regulation HAF102 published in 2004. However, PSA technology had been developed and applied in the Chinese nuclear industry for 20 years before that. In February 2010, the NNSA published the technical policy "Application of PSA in nuclear safety" for guidance on PSA applications, triggering the launch of several PSA application pilot projects. The projects included technical specification optimisations, changes in surveillance test intervals, risk-informed in-service inspection, optimisation of AOT, etc.

More PSA applications expected
Changes are always difficult to implement and NPPs are no exception in this regard. The PSA leaders at the Qinshan ll and Tianwan NPPs understand that there is still a long way to go in promoting PSA applications and establishing risk-informed management systems at their plants. However, they feel more confident today than five years ago that the habits of people and organisations can be changed through continuous effort to drive the use of PSA applications forward. ▪

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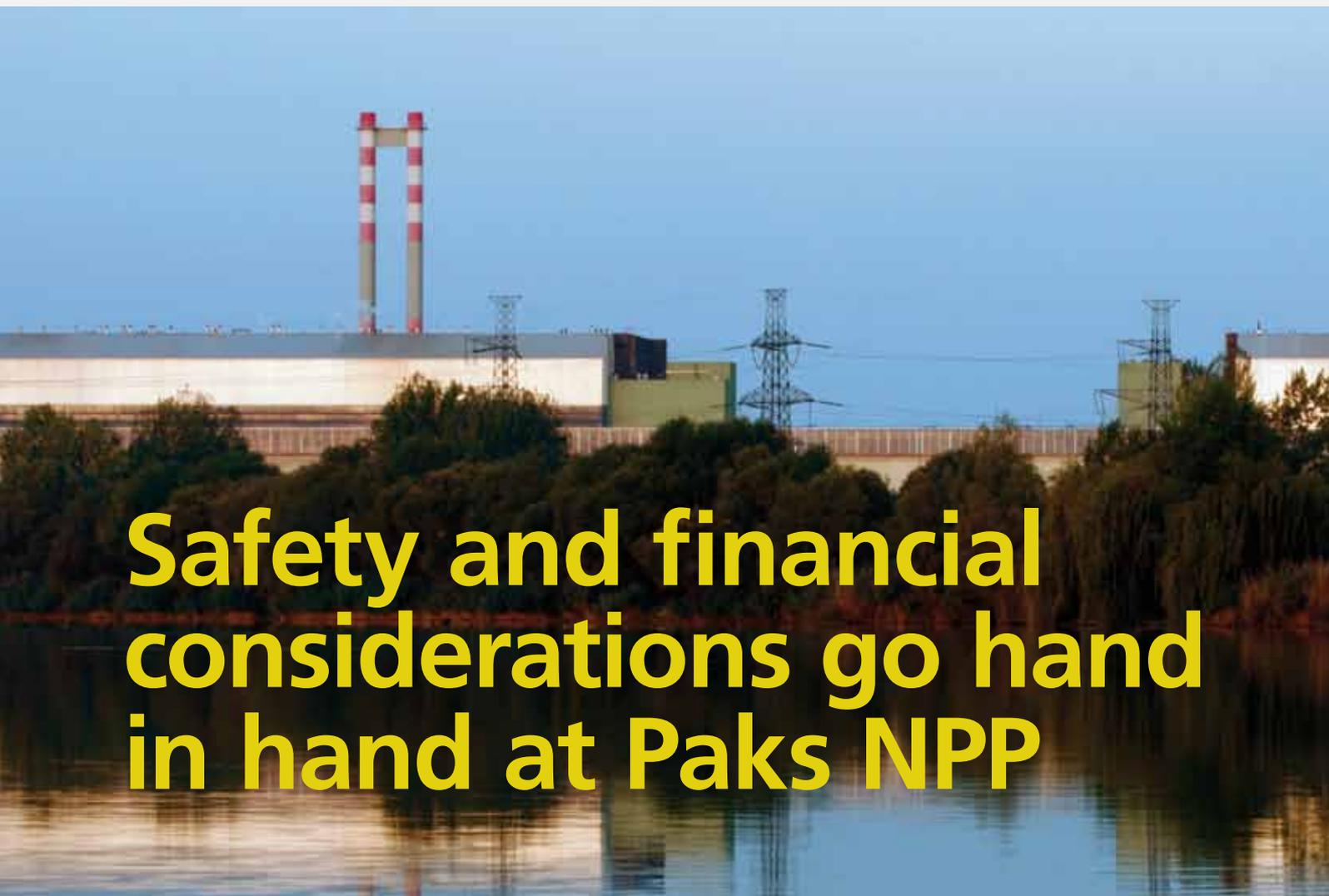
Safety and financial considerations go hand in hand at Paks NPP

Thanks to a systematic and continuous safety assessment programme launched at the beginning of the 1990s, we now have a comprehensive picture of nuclear safety at the Paks Nuclear Power Plant (Paks NPP). Safety enhancement measures based on assessment results have been implemented or are in progress, including technical and administrative measures.

Nowadays, Probabilistic Safety Assessment (PSA or PRA) is playing an increasingly important role alongside "classical" deterministic safety analyses. In addition to the plant-specific PSA model developed and maintained by means of conventional PSA software (RiskSpectrum PSA), the Paks NPP also uses a dynamic risk assessment tool called a risk monitor. When selecting the risk monitor software it was of utmost importance to ensure a correct and smooth transfer of all the necessary information from the existing PSA model into the risk monitor.

This was indispensable for quality assurance as well. Over and above its functional capabilities, efficient model transfer was a key factor in selecting RiskWatcher from Lloyd's Register Consulting for developing a risk monitor for the Paks NPP.

After development, the first risk monitor applications were started in offline mode. The reasons for beginning with offline applications were twofold: firstly, the necessary technical and administrative conditions were not yet in place, and secondly, we wanted to demonstrate the importance of the offline risk monitor application

and show how effectively it could support decision-making during plant operation and maintenance.

Pilot for new maintenance strategy

The first pilot application concerned the review of the plant's maintenance strategy. Particular attention was paid to the possible implementation of online maintenance for safety-related systems and equipment. By processing and incorporating the data recorded in the electronic logs, we were able to produce the risk curves for five years of operation for all four Paks

Figure 1. The risk graphs above show the core camage frequency based on historical events. The red curve represents the risk of "traditional" power operation and outage. The outage begins 2010.03.26 and ends 2010.04.26. The black line shows the risk of a hypothetical case where sequential diesel maintenance (one by one) is performed just before the outage, thereby lowering risk during the outage (because of availability of diesel) compared with the traditional maintenance regime.

units. Together these 20 reactor years formed the basis for a more in-depth investigation of maintenance scheduling. Based on a thorough examination of the risk curves we were able to come up with a proposal for a new maintenance strategy. Modelling the proposed new strategy in the risk monitor allowed us to evaluate the risk performance of the plant in comparison with the use of the earlier strategy. RiskWatcher's cumulative risk calculation option was applied in this comparison, see Figure 1. The implementation of the proposed strategy was only a theoretical possibility, and its practicability and acceptability had to be justified from various points of view. The fulfilment of deterministic safety criteria had to be proven
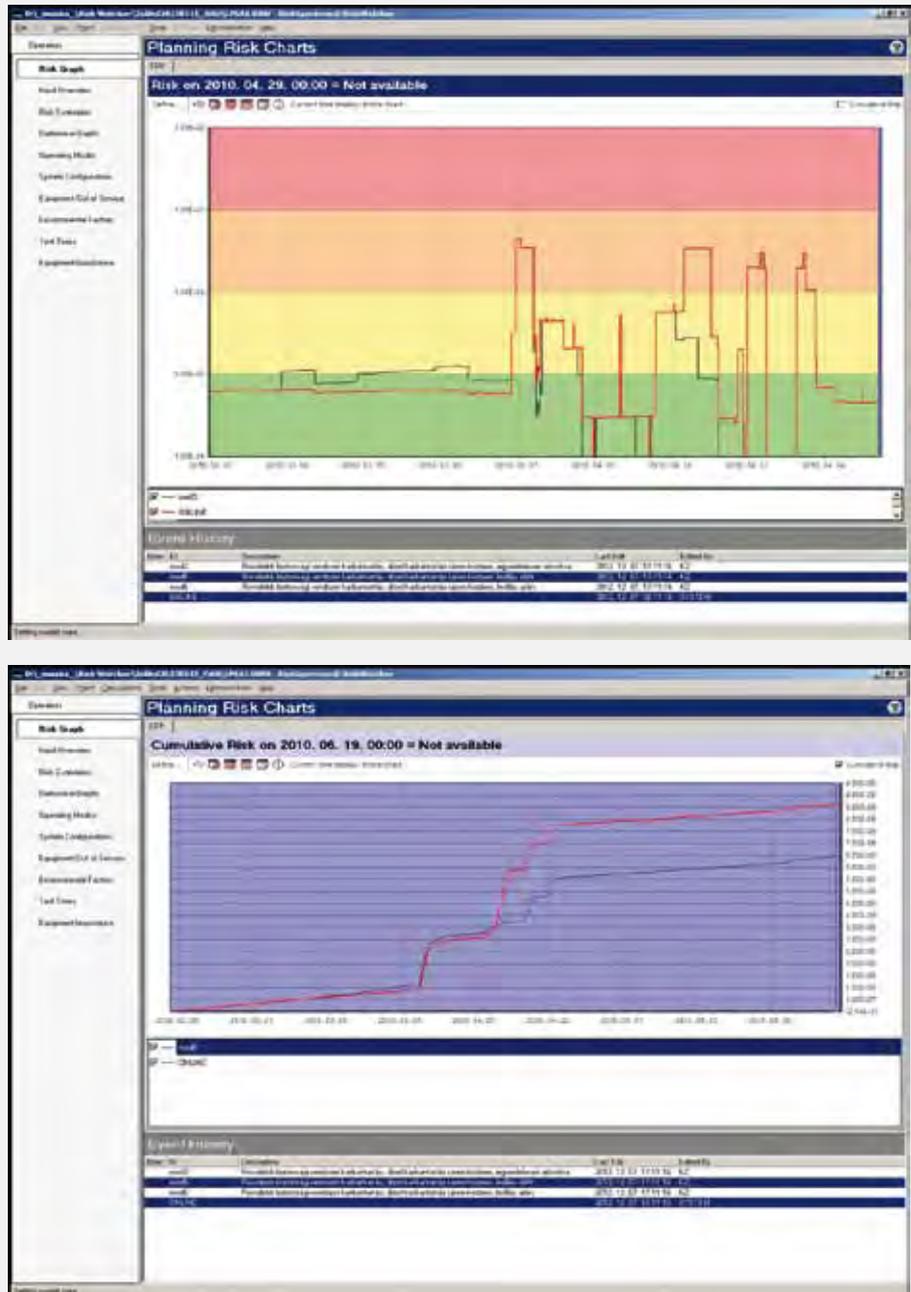
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▶ and other factors involved in a risk-informed decision-making process had to be considered, too. RiskWatcher and the conventional PSA tool (RiskSpectrum PSA) were used extensively to support safety justification by means of probabilistic analyses. Once this was done, experts involved in daily operation and maintenance activities approved the feasibility of programme implementation.

Regulator permits changes to 30-year-old maintenance practice

The introduction of the Paks risk monitor can be considered very successful because at the beginning of 2016 the plant obtained regulatory permission to implement online maintenance for the units with a 12-month fuel cycle. (Comment: The Paks NPP is now in the process of changing to a 15-month fuel cycle.) The regulatory permission document emphasises the fact that it is the first time the regulatory body has permitted changes in the operation and maintenance strategy based mainly on probabilistic arguments. The regulatory permission is significant, not only because it allows a 30-day timeframe for online maintenance but also because it supports better

risk-informed decision-making through the explicit use of risk modelling tools and insights. This is a conceptually new approach for the plant, which must confront the maintenance practice used for the past 30 years. Thanks to the newly established rules, the operating personnel and maintenance planners can shift their way of thinking from the "it is permitted" mode to the "risk credit management" mode. This means that they will be forced to minimise unavailabilities caused by maintenance, which will consequently lead to improved availability of the components performing safety functions and ultimately improve overall safety at the plant. We managed to formulate the rules for the new maintenance strategy by ensuring that the safety improvements are in harmony with the financial interests of the plant. What does this mean in practice? The licensee is motivated to use the permitted 30-day timeframe. In cases of inaccurate planning or extension of maintenance work the licensee will not be able to complete the maintenance within the original timeframe for online maintenance, so the remainder of the work will have to be moved to outage.

• Firstly, this will cause additional risk during outage which – according to the results of supporting analyses – exceeds the risk during power operation.

• Secondly, the additional maintenance burden during outage will result in an extended outage duration causing loss of production.

Thus the safety and financial interests of the licensee are in harmony.

Learning from past events

The application of online risk monitoring at the Paks NPP started in 2016. This enables us to keep track of the operational events that occur at the plant units on a daily basis, to evaluate them, and to report them to the decision-makers as necessary from a risk point of view. Information gathered in this manner can be used for risk evaluation during power operation and outages. These efforts are expected to improve maintenance efficiency and increase plant safety. *The risk monitor is a powerful risk management tool as it can identify the most effective risk reduction interventions and helps with the selection of actions that are tolerable from a risk point of view.* Apart from displaying the actual risk measures, the risk monitor also records the plant events in a representative manner. These archives, similar to a flight recorder or "black box", capture the events so that they can be subsequently analysed in greater detail. This feature enables us to learn from past events in our pursuit to continuously increase safety.

Interface with electronic operator log

Interface software has been developed to support online risk

monitoring that enables semi-automatic transfer of data from the electronic operator logs (E-logs) into the risk monitor. We would like to further develop this tool to shift from a semi-automatic data transfer mode to a fully automatic one. To achieve this, we have to make use of data from other sources such as unit computers in addition to the E-logs.

Decreased outage risk with automatic evaluation of outage planning

At present the most exciting topic on our agenda is risk evaluation to support outage planning. We are currently investigating the sources of input information necessary for this application of the risk monitor. Determining how to obtain the information from the outage planners as quickly as possible and how to upload this information into the risk monitor will be an important challenge to tackle. The better the input information is elaborated the faster we can evaluate risk associated with an outage plan. The final goal is to provide risk feedback from the risk monitor to the planners as quickly as possible. We hope to develop a tool in the near future which can provide online support for outage planning, thereby decreasing outage risk.

Plan for integration in regulatory requirements

Better exploiting the capabilities of the risk monitor for decision-making will inevitably require the presence of an appropriate regulatory environment. We consider the integration of risk monitor applications into the system of regulatory requirements, guidelines and practices to be a very complex task that can be best accomplished step by step.

Relevant risk thresholds improve conception of risk

With the help of visual and numerical representation of the risk monitor calculations personnel can better understand and more easily accept the fact that risk itself cannot be neglected or "switched off"; it is always present. The risk monitor is a very efficient tool for demonstrating the changing nature of risk to personnel, i.e. showing them how risk is affected by their activities. From a risk management point of view it is essential to differentiate between risk levels. Upon the request of the Paks NPP, NUBIKI Nuclear Safety Research Institute Ltd. developed a proposal for risk thresholds (green, yellow, orange and red fields) to be used in the risk monitor together with associated requirements. One of the principles is that the risk level should be in the green field during power operation.

Risk monitor facilitates commitment to nuclear safety

A distinctive advantage of the risk monitor is that its application significantly improves the commitment of the operating personnel and maintenance staff to nuclear safety. Although a "risk-free" state can never be achieved, conscious planning and execution of all safety-related activities can help to further enhance nuclear safety. *At the Paks NPP there is now an understanding that the risk monitor is an important assessment tool that contributes significantly to plant safety.* Over and above the contributions of plant personnel and different technical support organisations, I would like to emphasise the important role played by NUBIKI and its outstanding efforts in the risk monitor development and implementation process. In particular, I would like to thank Mr Zoltan Karsa for his special assistance.

The management of the power plant is committed to the implementation of the risk monitor as part of its strategic planning. Shared use of the risk monitor is also considered a good means of ensuring effective cooperation between the various organisational units of the plant. At present we are still in the pilot phase of implementation. After evaluating the results and experience from pilot applications, the risk monitor will become a compulsory part of everyday operation. ■

BIOGRAPHY TIBOR KISS
After earning his master´s degree in nuclear engineering in Moscow, Tibor Kiss began his career at the Paks NPP, where he still works today. Once he had three years of operational experience under his belt, Mr Kiss was invited to join the newly established Safety Assessment Group. That was over 20 years ago, and he has been a member of this PSA group ever since. Mr Kiss has participated in several domestic and international PSA projects, and is currently responsible for the implementation of the risk monitor at the Paks NPP.

Behold the power of import/export!

In the areas where RiskSpectrum PSA does not provide a built-in solution for operations such as a bulk change to a model or complex filtering, some simple code scripting has enabled me to get my work done efficiently with fewer errors than if I would have made complex multi-step changes manually.

I am quite certain that I am in the majority in saying that I do not enjoy repeating a task over and over again. I am often prone to losing focus and making errors. I am, however, an avid code scripter. (I would not go so far as to call myself a "programmer".) In my several years of experience with PSA, I have found that some operations can be quite difficult or repetitive. Fortunately, RiskSpectrum PSA and some simple utility scripts have turned out to be quite compatible and have allowed me to avoid some of these potentially tedious tasks. The process of scripting and

automating has helped me to develop a structured understanding of exactly what I am trying to perform in my RiskSpectrum PSA projects, and as well as of the models and systems.

The RiskSpectrum software suite continues to grow. With the release of the RiskSpectrum PSA Add-On tools, some of the tasks that I used to perform with the rough tools that I had developed I can now perform with robust and highly functional commercial-level tools. This is not likely to stop me from coding, but it allows me to focus on new and fewer tasks.

There are many ways to interface with RiskSpectrum PSA

The reason why interfacing tools can be used when working with RiskSpectrum PSA is because the software provides a myriad of ways to import and export data. The methods of extracting and importing data to RiskSpectrum PSA models each have their strengths and weaknesses and overlap in places.

The Excel Export/Import dialogue window include settings for defining what to export or import and in the case of import, what method to use.

RiskSpectrum PSA's Excel Import/Export – The Excel Import/Export functionality is easily the most widely used way to interface with a RiskSpectrum PSA model. This is due in part to the ubiquity of MS Excel, but it is also a very powerful way to make large-scale changes to a model or extract significant amounts of information from the model all at once. MS Excel is quite flexible. The Excel Import/Export utility may be found via the menu bar (menu bar > "File" > "Excel Import/Export"), which is only available to the user if all tabs are closed.
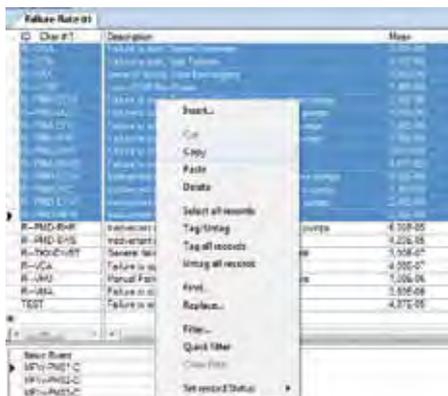
It is easy to use standard Windows commands to copy and paste data from tables.

Copy/paste – The simplest way of extracting information from a RiskSpectrum PSA model is to copy and paste from a record or set of records in RiskSpectrum PSA into a text editor (e.g. Notepad ++, Sublime Text, etc.) or into a spreadsheet program such as MS Excel. This is commonly done to extract analysis case results and place them into a spreadsheet or report table. To copy, highlight selected records (holding "Shift" or "Control" allows for highlighting multiple rows simultaneously) or all records ("Ctrl" + "A") then select "Copy" from the menu bar > "Edit" (alternatively "Ctrl" + "C"). This places tab delimited record data onto the Windows clipboard which can then be pasted into other programs.
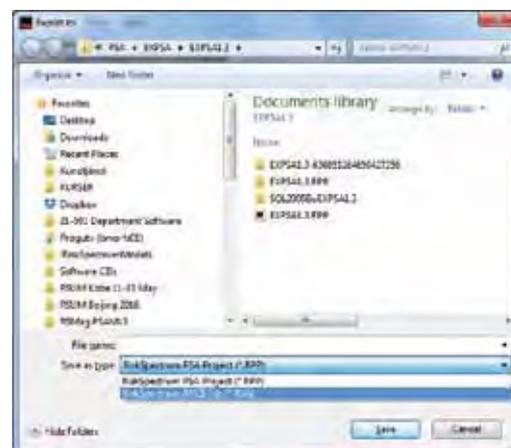
Select Export on the File menu to export the fault tree logic and related data to text files using the .rsa format.
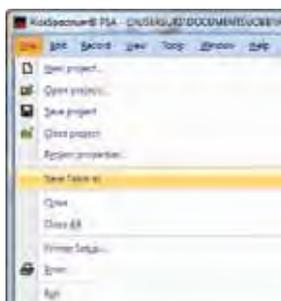
You can save the contents of a table using the command "Save table as…" on the File menu.


Select "Yes" in the dropdown Text result in your analysis case dialogue window to have the program save the results in text files.

Text file output (menu bar/from analysis case/report) – There are many ways to directly output data from RiskSpectrum PSA to text files. One can export the data to a file from the menu bar (menu bar > "File" > "Save table as…"). When running analysis cases, one can set the option "Text File" to "Yes", in which case the results of the enabled analyses will be saved in text format in the *.RPR folder. Finally, one can save RiskSpectrum PSA reports in text format (for more information on saving reports consult RiskSpectrum PSA Help within the program). These rigidly formatted text files allow for easy placement of data into report tables or automation scripts to further assess analysis results.

*.RSA format – A little known but very powerful tool is the import/ export functionality to text files. This was originally provided for ASCII files, but in recent versions of RiskSpectrum PSA the text files allow for Unicode encodings, which can be essential depending on the characters used in record IDs and descriptions. The details and capabilities of RSA files are best discovered through export of a sample model along with trial-and-error while referencing the RSA-manual (entitled "User Manual for RSA Format"). The RSA manual is provided with the RiskSpectrum PSA installation.

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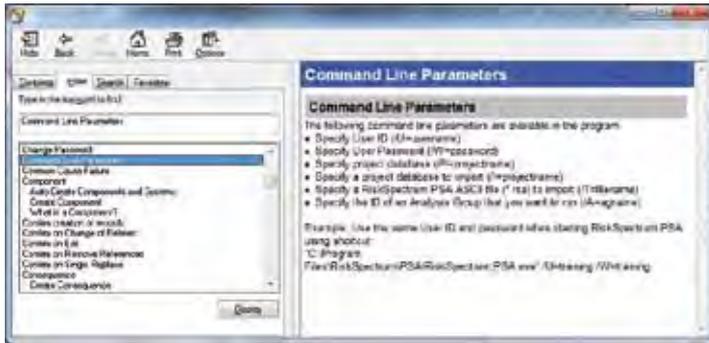
Open the Help file and search for Command Line to get a list of the command line parameters available in RiskSpectrum PSA.

Command line operations – Perhaps even less known, but just as intriguing to those who are interested in automation scripts, is the capability to launch RiskSpectrum PSA and even run analysis cases from the command line. The command line parameters can be used to launch certain models without manually providing user names, for example for a custom shortcut. The command line operations may potentially be used for importing *.RSA text files and running analysis cases in complex sensitivity studies as well.

Uses for data interfacing

Below is a brief overview of the types of interfacing that can be performed with RiskSpectrum PSA merits and hopefully an indication of how these can be useful. As the possibilities are essentially endless, I will provide only a couple of examples where I have found the aforementioned interfacing tools useful.

Plotting – RiskSpectrum PSA provides some general plotting capability, but often the results of interest and best result representation depend on the particular analysis being performed. In such cases it is important to develop an original way to present results. It is very useful to either copy the results into a spreadsheet or extract results from the text file output from an analysis case. With these data, comparisons between importance parameters or differences between the cutsets of different analysis cases can be examined in unique ways.

Comparing – A task I have found myself repeating over and over again is to try to find differences and similarities between two or more lists of basic events. I have performed these comparisons for a variety of reasons such as

comparing which events were added or removed from Model 1.0 to Model 1.1. In Python this is a trivial task with the "set" data type which can return the union, intersection and difference between lists of items by default.

Creating bulk event relations

Often when implementing new capabilities in a model, for example adding attributes or exchange event relations, one must first outline the connection between records and then painstakingly apply them to each group of records. The MS Excel Import/Export utility becomes indispensable for such tasks because one can outline each of these relations or better yet write a program to properly map out relations in a spreadsheet and then bulk import the changes into the model.

Utility programs

RiskSpectrum PSA software is designed to be a general tool. This is reflected in the many different industries around the world that use RiskSpectrum PSA/FTA for varied analyses. The tools to tackle most general issues are already embedded in RiskSpectrum PSA. In certain areas, such as those for which I developed the comparison tools, some additional general

tasks have been identified. Given the steady progress made by the RiskSpectrum software team in recent years with the development of RiskSpectrum PSA and the new RiskSpectrum PSA Add-On Package, the areas where I find myself developing automating scripts to perform a very general task are shrinking. For example, I now use the ModelCompare tool rather than assorted Python scripts to decipher what has been removed between two models.

However, seeing as RiskSpectrum PSA is a general tool there will always be areas where specific applications will be useful for automating something or where a type of analysis will warrant a certain plot output which does not make sense to include within RiskSpectrum PSA. In such cases there will always be a place for MS Excel and Python automation scripts, and RiskSpectrum FTA/PSA provide a myriad of ways for extracting and interfacing with these data. ■

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PSAM 14

When, where, who and why?

- When: 16-21 September 2018

- Where: UCLA Meyer & Renee Luskin Conference Center

- Who:
  - Honorary General Chair: Dr. B. John Garrick
  - General Chair: Dr. David H. Johnson
  - Honorary Technical Chair: to be confirmed
  - Technical Chair: Dr. Enrique Droguett

- Why UCLA?
  - Major Support from B John Garrick Institute for the Risk Sciences
    - A multi-disciplinary international risk center established in Nov. 2014
    - Active centers at the Institute include
      - Medical
      - Resilience Engineering
      - Risk
      - Seismic

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