



# European Safety and Reliability Association

# Newsletter

<http://www.esrahomepage.org>

October 2010

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## EDITORIAL



*C. Guedes Soares  
ESRA Newsletter Editor  
Instituto Superior Técnico, Lisbon,  
Portugal*

This Newsletter is being issued just after the ESREL2010 Conference and the 2010 ESRA General Assembly. Therefore, we can announce the result of the elections in ESRA, which has brought a new team of Chair, Vice-Chair and Treasurer.

The new Chairman, Enrico Zio, has been ESRA Vice-chair during some years and has the experience to allow him to lead ESRA competently during the coming years. Terje Aven, the Chair of the ESREL 2007 Conference, and Radim Bris, the Chair of the ESREL 2009 Conference, have demonstrated their commitment to ESRA in those initiatives, which certainly gave them experience about one of the main activities of ESRA. I wish them all success in this mandate that is now starting.

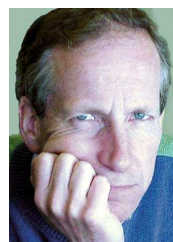
Preparations to the next ESREL Conference are underway and I am happy to see that we are recovering the approach that has been applied since 2006 of having the ESRA Technical Committee Chairs and members very much involved in the Conference organization. The Technical Committees are an important resource of ESRA, not only to help organizing the Technical Programme of the Conference but also to be a support and source of contributions to the ESRA Newsletter.

I cannot overemphasize the need of receiving contributions to the Newsletter from the ESRA Technical Committees and ESRA members so that the periodicity can be increased.

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## FEATURE ARTICLES

### How reliable is Software?



*Sipke van Manen, MSc CE  
Department of Infrastructure,  
Directorate General of Public  
Works and Water Management,  
Ministry of Public Works and  
Water Management,  
The Netherlands*

Software is being used more and more frequently as part of the systems that are provided and maintained by the Dutch Ministry of Transport, Public Works and Water Management, i.e. civil engineering structures for the infrastructure in the Netherlands. Where we used to have relays and hard-wired power switching, we now use programmable logic controllers. Examples are the safety devices in tunnels, the moving parts of sluices, storm surge barriers and moveable bridges, which are now all operated by a digital operating system. Real time traffic management is impossible without software.

In practice it turns out that the reliability and availability of these systems quite heavily depend on the reliability of the software used. Quite a few failures of the system result from software failures: software is definitely susceptible to failure.

In the Netherlands the operation of, e.g. storm surge barriers is specified in terms of probabilistic targets. In order to meet these probabilistic targets (acceptable probabilities of failure), also the probability of failure of the software has to be dealt with and taken into account. Next to the mechanical and electrical components, we will have to allocate a probability of failure to the "component" called software. This is

difficult since the software we apply in our systems is unique.

A very important ingredient that determines the reliability of software is the development process. An international standard, the IEC 61508-3, connects the development process of software with its resulting reliability, expressed in "Safety Integrity Levels" (SIL). That is what we need, but the standard has a few drawbacks. For example, the size of the software does not play a role in the determination. And that seems unlikely. The relation between SIL and the mentioned reliability number - probability of failure - is not substantiated, either.

Because of these drawbacks and because of criticism of some leading ICT experts, the Dutch Ministry of Transport, Public Works and Water Management has taken the initiative to bring together experts in the field of software and reliability to develop a method by which the reliability of software can be quantified. The method is called TOPAAS (Task Oriented Probability of Abnormalities Analysis for Software) and does not only take software development into account, but also the size of the software, the execution environment of the software and the management of the software maintenance.

The method is based on expert opinion. The effect of 15 parameters on the failure probability is estimated by experts and is part of the method. The method must (still) be applied by an ICT expert (preferably the developer of the software) in combination with a reliability (RAMS) expert. As the effect on the existing RAMS analyses can be substantial, the method is currently tested on different systems, each with its own, specific software. The first trials are encouraging. We hope to release the method (and the report) at the end of 2010.

## The Two Largest Industrial Disasters, 25 Year Later



*C.M. Pietersen  
Safety Solutions Consultants (SSC)  
Dutch Hazardous Substances  
Council (AGS)  
Webaddress: [www.safety-sc.com](http://www.safety-sc.com)  
email: [pietersen@safety-sc.com](mailto:pietersen@safety-sc.com)*

At the end of 1984, within two weeks, the two largest disasters up till now with hazardous material occurred. Two disasters with large consequences for the practice of safety management in the process industry.

On 19 November 1984, the LPG disaster in San Juan Ixhuatepec (Mexico City), 500 fatalities, occurred. Two weeks later, 3 December 1984, the Bhopal tragedy (more than 3700 fatalities) occurred. The magnitude of the tragedy in Bhopal caused the

Mexico City disaster to be forgotten soon. The media and the industry focus was on Bhopal.

The two disasters have been investigated by the author, working in TNO at that time. As project leader of both investigations, the author has discussed the disaster with Petróleos Mexicanos (PEMEX) in Mexico City and visited the disaster spot. On invitation of the Indian scientific investigation team (Indian authorities) the Bhopal tragedy have been investigated. It included a visit to the Union Carbide plant in Bhopal.

Now, 25 years later, it is interesting to again remember what actually happened and whether we have sufficiently learned the lessons and improved safety. In a recent book [1], the facts, the investigation and the lessons learned are described. The link is also made with (process) safety in 2010:

- The underlying causes of the failure of safety management. The developments over 25 years are analyzed. The disasters of 1984, compared with more recent incidents, such as an explosion in a furnace (Geleen, the Netherlands, 2003), and the refinery disaster in Texas (USA) in 2005.
- Land use planning policies failed dramatically in Mexico and Bhopal. The existing QRA- policy in Europe for 'safe distances' around plants with hazardous substances will prevent large numbers of victims. However, the underlying causes of Mexico City and Bhopal are still present.
- Contemporary methods for process safety such as HAZOP, LOPA and SIL are described and elaborated through examples. This also applies for the Tripod incident analysis method

### The disasters

#### 19 November 1984, LPG disaster San Juan Ixhuatepec, Mexico City

At around 5.30 hr early Monday morning, a leak occurs at the LPG depot which is located at a distance of about 130 meter from the small village of San Juan Ixhuatepec (see picture below). The LPG vapor cloud drifted to the nearby houses and ignited there. It resulted in a fire in a few houses at the edge of the housing area. The flame front in the vapor cloud travelled back to the LPG depot. What followed was an explosion and damage to the LPG piping, resulting in more LPG release, fires and subsequent BLEVE's (Boiling Liquid Expanding Vapour Explosion) of LPG tanks: 4 spheres of 1600 m<sup>3</sup> each, and 16 horizontal vessels of 180 – 45 m<sup>3</sup>. The BLEVE's were very damaging: up to a distance of about 300 meter de people present in the area did not have a chance to survive.

The investigations resulted in improvement of LPG consequence modeling and lessons about a number of safety aspects for the design and operation of LPG depots. As a consequence, the American Petroleum Institute (API) modified the API standard 2510: Design and construction of LPG installations.



Pictures: (left) the LPG depot before- , situated in San Juan Ixhuatepec; (right) the depot after the disaster.

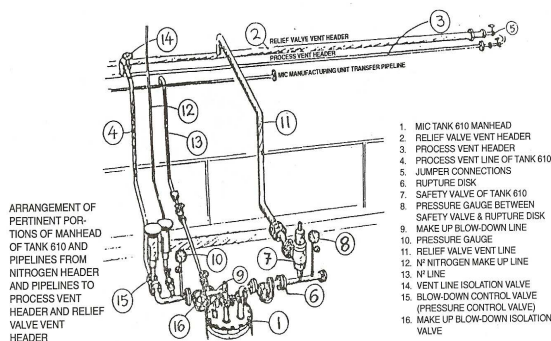
### 3 December 1984. The Bhopal tragedy India

Shortly after midnight, (mainly) MIC vapours escaped from a pipe at about 30 m height. It continued for a number of hours. Here no explosion, no fire, no warning. The people living in the surroundings were inhaling the vapours and almost immediately suffered from the consequences of it: burning throat, eyes and nose. Followed by coughing and vomiting. The long exposure duration caused a very large number of people being killed. No emergency plan was in existence, no emergency warning from the plant (on the contrary), no organized evacuation.

People panicked en rushed into two downwind hospitals, staying in the vapour cloud all the time. The consequences were dramatic.

#### The installation

The Union Carbide India Limited (UCIL) plant at Bhopal produced (from 1969 onwards) carbamate pesticides. The raw material was imported from the USA. In 1975 an own carbaryl production ("Sevin") was started. For that production, Methylisocyanat (MIC) is an intermediate (initially imported). The MIC is distilled to a "Commercial Grade" MIC. The MIC is then stored in (partly) mounded storage tanks. MIC is a highly reactive, unstable, flammable and toxic chemical.



The MIC storage tank topside connections.

#### Water entered the MIC tank

Consensus exists about the direct cause of the runaway reaction in the tank: the fact that water entered the tank. The debate still exists about the quantity of the water and the route of the water to the tank. The report of Union Carbide states that it is clear that the water have been put in on purpose by a disgruntled employee as an act of sabotage. According to Union Carbide a pressure measure instrument was removed from the tank and a water hose was connected. Union Carbide came to convince us about this theory.

However, we studied several possible routes for the water to enter the tank. The most likely one: At some point in the MIC structure, on the evening of the tragedy, a water wash operation was performed for some clogged lines. The work instruction clearly stated that a slip blind need to be placed. This is to physically prevent the water to enter the system. The slip blind was not there. This created a route for the water to the MIC storage tank. Ultimately, it entered through a leaking nitrogen control valve (nr 15, see figure above) into the tank. The water likely being contaminated with rust particles (from non stainless steel lines), caustic (from the VGS) and the lack of cooling of the tank made it possible that a chemical runaway reaction occurred rather fast. It started around 22.00 hour.

At 2,8 bar, the rupture disk ruptured and the safety valve opened. At that moment the large release to the surroundings started.

#### Lessons and today's process safety management

##### • Safety in design and operation

The installation in Mexico City and Bhopal were inherently unsafe with regard to the design and operation. Systematic hazard identification and risk evaluation was lacking.

- *Emergency management*

For both disasters, emergency planning was not performed. Not by the companies and not by the authorities (fire brigade).

- *Land use planning*

Both disasters show a remarkable resemblance in the fact that the (simple) houses were built almost next to the installation. No policies were in place to make sure that minimum distances were adhered to.

### **Safety Management System**

In this paper we focus on the first category: safety in design and operation.

25 Year after these disasters, a lot have changed, also for this category. Already in 1982, the European Directive 'Post Seveso' was issued. The Directive (implemented in law in all member states) requires companies to do everything which is required for optimal safety. This need to be reported to the authorities in a safety report. Later versions of the Directive also include Emergency management and land use planning requirements. Also the requirement for a systematic Safety Management System is included now. The requirement for a Safety Management System (SMS) was a big step forward. It creates a transparent, verifiable approach to Process Safety. In that sense, it is also becoming clear that part of the problems of Mexico and Bhopal still exist today. This is also illustrated by recent independent investigations of disasters as the BP Texas City disaster. The fact that anno 2009, larger incidents are investigated *independently* is a big positive change.

#### *Hazard identification and risk evaluation*

This is an important element of a SMS. It means that HAZOP studies need to be performed and that SIL Classification and - Verification (IEC 61508/ 61511) needs to assure that the risk of the operation has been reduced to an acceptable level.

#### *Organisation, Human factors and Safety Culture*

Most of the larger companies nowadays realize that the safety of the design is not sufficient. The risk is also in how people deal with the design, how they behave and the compliance with internal procedures. This requires leadership and continuous communication of the safety message in safety programs.

#### **Where do we stand?**

- The Chemical and Process Industry have Safety Management System in place as an important framework to prevent accidents. It contains all important elements which we learned from the disasters, accidents, incidents and near misses in the past.
- A positive development is that the authorities tend to switch to more goal oriented approaches instead of prescribing all the safety measures required. This makes the companies more responsible and

accountable for safety and gives space for alternative (safer) solutions.

#### *Remaining worries*

- Disasters and accidents continue to occur. Safety is not easy and requires daily attention of everyone. Counter pressures exist: economy, time pressure on less (experienced) people etc.
- Insufficient monitoring of the safety practice. This aspect is included in a SMS (internal audits, reviews, work floor rounds etc.). In that respect good quality inspection by the regulators are also vital.
- Last but not least: we need to get better in incident investigations in order to find the underlying factors. We also need to become better in remembering the lessons. In that sense: the disasters in Mexico and Bhopal still give us valuable lessons for today's Process Safety.

### **References**

- [1] C.M. Pietersen. *The two largest disasters, 25 year later. ISBN 978-90-78440-33-8 . Published as 'eBook' in March 2010. See web shop at [www.safety-sc.com](http://www.safety-sc.com) .*

## **Incorporation of component ageing into probabilistic safety assessment models**



**Dusko Kancev\*** ("Jozef Stefan" Institute)  
**Marko Cepin** (Faculty of Electrical Engineering, University of Ljubljana, Slovenia)  
**Andrija Volkanovski** ("Jozef Stefan" Institute)

### **Introduction**

Ageing is defined as a continuous process of degradation of systems, structures or components due to normal service conditions that include normal operation and transient conditions, while postulated accident and post-accident conditions are excluded. All materials in a nuclear power plant (NPP) experience ageing degradation to a greater or lesser extent, which may lead to the functional degradation of plant components [1,2]. Therefore, in order to manage the degradation in a proper manner, to assure a continuous safe operation as well as to plan the eventual life-extension of NPPs, it is essential to assess the effects the component ageing has on plant risk. This article briefly presents the analysis of introduction of ageing directly into the probabilistic safety assessment (PSA). The most frequently used methods for modelling of ageing as well as the

methodology for direct incorporation of ageing effects in the PSA models are addressed.

## Methods

The linear, exponential and the Weibull method for modelling of ageing are presented on example of a failure rate as a parameter under investigation. Similarly, the evaluation can be done for other probability parameters other than failure rate, such as the failure probability.

1. The basic mathematical formulation of the linear method is presented in the equation below.

$\lambda(w) = \lambda_0, w \leq w_0$  and  $\lambda(w) = \lambda_0 + \alpha(w - w_0), w > w_0$   
 where  $\lambda_0$  is initial constant failure rate,  $\alpha$  is linear ageing rate and  $w_0$  is the threshold age after which the failure rate increases.

2. The basic mathematical formulation of the exponential method is presented in the equation below.

$\lambda(w) = \lambda_0, w \leq w_0$  and  $\lambda(w) = \lambda_0 \cdot \exp(c(w - w_0)), w > w_0$   
 where  $c$  is exponential scale parameter.

3. The basic mathematical formulation of the Weibull method is presented in the equation below.

$\lambda(w) = \lambda_0, w \leq w_0$  and  $\lambda(w) = \lambda_0 \left[ \frac{w}{w_0} \right]^b, w > w_0$

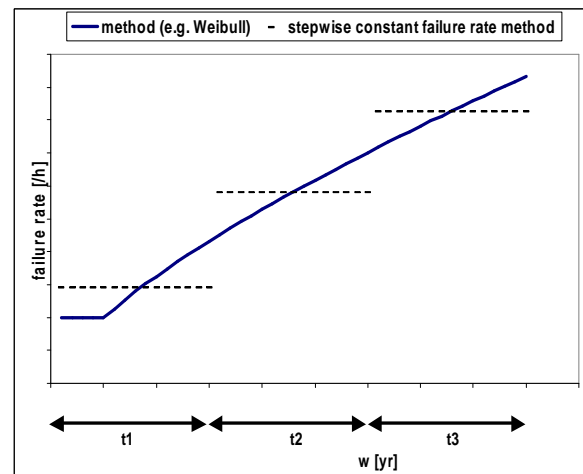
where  $b$  is Weibull shape parameter.

The method of stepwise constant failure rates is used as a method for direct consideration of ageing in PSA. This method includes modification of PSA models in sense that the ageing contribution is added to the initial models, which consequently causes also the modified results when evaluation is performed [3]. Stepwise constant failure rate method assumes the constant failure rates or constant failure probabilities of equipment in the determined time intervals  $\{t_i, t_{i+1}\}$ , and hence these failure rates or failure probabilities are determined as their average through the time of the time interval. The failure rates or failure probabilities change through the selected time intervals according to the selected method for evaluation of failure rates or failure probabilities due to ageing (Figure 1).

## Results and Conclusions

The presented methodology was applied on a system as well as on plant level [4,5]. The same methodology is also applicable to non-nuclear fields, e.g. PSA modelling of an ageing power system [6]. It was concluded that the major problem is the lack of data associated with the ageing effects, which would suit to the detailed models of ageing. The large uncertainties of the ageing parameters as well as the uncertainties associated with the reliability data collection, used for the purpose of this study, have a substantial impact on the quantitative analyses. Also, it is difficult to define the basic elements of the evaluation, which are the components themselves, as

they are mostly made of several parts or subcomponents, which may degrade through time and age differently one from another and which can be partly exchanged, renewed or inspected.



**Figure 1:** Stepwise constant failure rate method

An advantage of the presented methodology is that it can be used in standard probabilistic safety assessment by standard tools for performing probabilistic safety assessment. At the moment, the application of the methods is more theoretical than practical due to lack of real data for the support of the parameters in mathematical formulations.

## References

- [1] IAEA, 1990. "Safety Aspects of Nuclear Power Plant Ageing". IAEA-TECDOC-540, Vienna.
- [2] IAEA, 1992. "Methodology for the Management of Ageing of NPP components important to safety". IAEA-TRS-338, Vienna.
- [3] US NRC, 1992. "Approaches for Age-Dependent PSA with Emphasis on Prioritization and Sensitivity Studies". NUREG/CR-5587, Washington.
- [4] Cepin M., Kancev D., Mavko B., Volkanovski A. "Incorporation of Age-Depended Reliability Parameters and Data Into Probabilistic Safety Assessment models". IJS – DP – 10112, 2009.
- [5] Cepin M, Volkanovski A. "Consideration of ageing within probabilistic safety assessment models and results". Kerntechnik 2009; 74:140-149.
- [6] Kancev D., Cepin M. "Power System Reliability Assessment Incorporating Ageing Based on FTA and AC Power Flow Model". International Conference PSAM 10, 7<sup>th</sup> – 11<sup>th</sup> June, Seattle, USA.

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## PHD DEGREES COMPLETED

### **Aircraft Scheduled Maintenance Programme Development. *Decision Support Methodologies and Tools***

*Alireza Ahmadi*

*Division of Operation and Maintenance Engineering  
Luleå University of Technology, Luleå, SWEDEN*

**Main Supervisor:**

*Prof Uday Kumar, Luleå University of Technology  
Main Examiner/Faculty Opponent: Prof. Ajit Verma,  
IIT, Bombay, India*

Air carriers are constantly striving to achieve high standards of safety and simultaneously to enhance the aircraft's capability to meet market demands at the lowest possible cost. This needs to be supported through an effective maintenance programme. The methodology applied within the aviation sector to determine maintenance tasks is mainly based on the Maintenance Steering Group, in which the analysts consult the experience gained from similar aircraft, and mainly relies on their engineering experience. Even though this approach which leads to conservative decisions, contributes to airworthiness requirements being fulfilled, there is no sufficient evidence for claiming that the maintenance programme derived from this process is optimal or the most effective one, from operator point of view.

The purpose of the research work was to develop decision support methodologies and tools for aircraft scheduled maintenance task analysis. To achieve the purpose of the research, literature studies, case studies, and simulations have been conducted. Empirical data have been collected through document studies, interviews, questionnaires, and observations from the aviation industry. For data analysis Theories and methodologies within risk, dependability and decision making have been combined with the best practices.

One result of the research is the identification of potential areas for improving the use of MSG-3 methodology in aircraft maintenance analysis. The study was based on a constructive review that consists a benchmarking between MSG-3 and other established and documented versions of Reliability-Centred Maintenance (RCM). The study highlights also the differences in approach between MSG-3 and RCM for scheduled maintenance programme development.

Another result is the development of a systematic methodology guided by the application of an Event Tree Analysis (ETA) for the identification and quantification of different operational risks caused by aircraft system failures. Empirical data were extracted through document studies and interviews, guided by the application of an ETA. The analysis was

performed together with experienced practitioners from both an aircraft manufacturer and a number of airlines.

A third result is a proposed methodology, based on a combination of different Multi-Criteria decision making methodologies, for selecting the most effective maintenance strategy. The methodology includes two levels, i.e. the managerial level and the engineering level. The managerial level, experts define the goals and the associated evaluating criteria, and also perform the pairwise comparison to assign the importance of the evaluating criteria. The engineering level experts select a failure mode, define applicable maintenance strategies, and assesses the effectiveness of each alternative strategy after due consideration of the positive and negative consequences of choosing any one of the maintenance alternatives. At this level the analyst performs a multi-criteria ranking of the alternatives using three methodologies, i.e. benefit-cost ratio, TOPSIS and VIKOR. The proposed methodology has been tested through a case study within the aviation context for an aircraft system.

Finally, the fourth result is a proposed Cost Rate Function (CRF) model which can be used to identify the optimum interval and frequencies of Failure Finding Inspection (FFI) and restoration tasks for the aircraft's repairable items which are experiencing aging. A risk constraint optimization is used, based on the average unavailability within the inspection events. Graphical tools also have been introduced for maintenance task interval assignment and selection of the most effective strategy among the FFI, and the combination of FFI and restoration.

These results are related to specific industrial challenges, and are expected to enhance the capability of making effective and efficient decisions during the development of maintenance tasks. The results have been verified through interaction with experienced practitioners within major aviation manufacturers and air operators.

For more details, please contact Dr. Alireza Ahmadi ([alireza.ahmadi@ltu.se](mailto:alireza.ahmadi@ltu.se)) or Prof. Uday Kumar ([uday.kumar@ltu.se](mailto:uday.kumar@ltu.se)).

The thesis can be downloaded from: <http://pure.ltu.se/ws/fbspretrieve/4703084>

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## MSC DEGREE

### **A Master Course on Reliability, Maintenance & Safety at Politecnico di Torino**

*Andrea Carpignano ([andrea.carpignano@polito.it](mailto:andrea.carpignano@polito.it)),  
Politecnico di Torino*

**Claudio Rolandi** ([claudio.rolandi@icimsi.ch](mailto:claudio.rolandi@icimsi.ch)),  
SUPSI

Areas related to the issues of Reliability, Maintenance and Safety represent a critical factor requiring attention in many companies and infrastructures. The figures in charge of managing these issues are linked to two different disciplines: the RAMS Analysis during design and the Maintenance Engineering during operations.

In many advanced countries, there is no specific university degree in this particular area. Companies often face difficulties in trying to identify these professionals on the market and are thus forced to provide training and development programmes for specialists and managers internally.

A Master programme on Reliability Maintenance and Safety has been organised by Politecnico di Torino since 2004, in collaboration with SUPSI (Switzerland), RAMS&E SRL and COREP. The programme is built on long experience from R&D project, industry projects, and teaching. The study is suited for people who like to identify and solve problems, have analytical skills, can work structured and systematically, and enjoy both theoretical and practical problems. Moreover, the Master on Reliability, Maintenance and Safety trains professionals able to intervene in the design and management of industrial plants, transportation systems and infrastructures.

The didactic methodology is strongly orientated to the training on the job and guarantees to the company a concrete feedback highly orientated to a practical application, with the development of immediately working solutions. At the end of a basic and propaedeutic course, the Master proposes two complementary and specialized courses:

- ◆ **RAMS Analyst:** the attendants to the course will learn RAMS tools, by facing both the technical aspects and the impact that these themes can have on contractual issues.
- ◆ **Maintenance Engineer:** the attendants to the course are prepared to monitor the performance and maintenance aspects of industrial plants, both concerning the technical profile and regarding the economic/management aspect.

The Master Programme places the emphasis on the complementary interrelationship between these two disciplines, the first more related to system design and the second mainly involved by system operations, that is often missing in the industrial practice:

- ◆ RAMS Analysts spend a lot of resources in order to optimize system design and catching system criticalities but rarely they are fed by data coming from the field by maintenance;
- ◆ Maintenance Engineers often plan their activity by tradition and does not address the resources

allocation considering the system criticalities highlighted by RAMS studies during design.

This Master Programme tries to fill the gap by putting RAMS Analysts and Maintenance Engineers in the same classroom in order to implement a synergy between design and operations as request by the modern Reliability Centered Maintenance approaches.

Actually, five editions of the Master have been closed, fully sponsored by important firms such as Ahlstrom, Altran, Alenia, Ansaldo, Aventis, Bombardier, ENI, Faiveley, FIAT, Huntsman, Lavazza, Memc, Michelin, Rockwood, Saint Gobain, SKF, Siemens, and other local Companies. There were already trained more than 60 engineers, most of them already operating in the sponsoring companies, the others who were promptly engaged by other companies.

Companies have appreciated this joint training project with the universities, and many of them continue to participate to new editions of the Master with new resources.

Moreover, the created relationships between companies and universities have often led to different modes of co-operation, such as common research and innovation projects.

Companies have appreciated the approach to training and skills acquired by attendees and the operating results of the realised Project Works. The Master has also become a referenced point for specialists who can meet and discuss problems and solutions with colleagues in different companies or different sectors. It is believed that this experience, born in Italy and already proposed in Switzerland and Arab countries, can be profitably exported in other countries.

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## CALENDAR OF SAFETY AND RELIABILITY EVENTS

### 8<sup>th</sup> International Probabilistic Workshop

Szczecin, Poland, 18-19 Nov 2010

**Organization:** Maritime University of Szczecin, Faculty of Navigation & University of Natural Resources and Applied Life Sciences, Vienna, Department of Civil Engineering and Natural Hazards

**Submission:** Submission of abstract: May 2010, Submission of final paper: October 2010

**Conference location:** Maritime University of Szczecin, Poland

**Conference Chairman:** Prof. Lucjan Gućma

**Audience:** The conference is intended for civil and structural engineers and other professionals concerned with structures, systems or facilities that require the assessment of safety, risk and reliability. Participants could therefore be consultants, contractors, suppliers, owners, operators, insurance

experts, authorities and those involved in research and teaching.

**Further information:**

Prof. Lucjan Gućma, Maritime University of Szczecin, Faculty of Navigation, Waly Chrobrego 1-2, 70-500 Szczecin, Poland.

E-mail: l.gucma@am.szczecin.pl

or

PD Dr.-Ing. Dirk Proške, University of Natural Resources and Applied Life Sciences, Vienna, Institute for Mountain Risk Engineering, Peter Jordan-Street 82, 1190 Wien, Austria

E-mail: dirk.proske@boku.ac.at

## ESREL 2011

### European Safety and Reliability Conference,

Troyes, 18-22 September 2011

Safety, reliability and risk management become more and more important in an always more challenging and competitive environment, in every industry and human activity: multidisciplinary approaches to safety & reliability engineering and risk management become more and more necessary and attractive. ESREL 2011 conference will provide a forum for presentation and discussion of scientific works covering theories and methods in the field of risk, safety and reliability, and their application to a wide range of industrial, civil and social sectors and problem areas. ESREL 2011 will also be an opportunity for researchers and practitioners, academics and engineers to meet, exchange ideas and gain insight from each other.

**Important Dates:**

Submission of Abstracts: 15 January 2011

Submission of full-length paper: 31 March 2011

**Website:** [www.esrel2011.com](http://www.esrel2011.com)

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## ESRA INFORMATION

### 1 ESRA Membership

#### 1.1 National Chapters

- French Chapter
- German Chapter
- Italian Chapter
- Polish Chapter
- Portuguese Chapter
- Spanish Chapter
- UK Chapter

#### 1.2 Professional Associations

- The Safety and Reliability Society, UK
- The Danish Society of Risk Assessment, Denmark
- ESRA Germany
- ESReDA
- French Institute for Mastering Risk, France (IMdR-SdF)
- SRE Scandinavia Reliability Engineers

- The Netherlands Society for Risk Analysis and Reliability (NVRB)
- Polish Safety & Reliability Association, Poland
- Asociación Española para la Calidad, Spain

### 1.3 Companies

- ARC Seibersdorf Research GmbH, Austria
- TAMROCK Voest Alpine, Austria
- IDA Kobenhavn, Denmark
- VTT Industrial Systems, Finland
- Bureau Veritas, France
- INRS, France
- Total, France
- Commissariat à l'Energie Atomique, France
- Eurocopter Deutschland GmbH, Germany
- GRS, Germany
- SICURO, Greece
- VEIKI Inst. Electric Power Res. Co., Hungary
- Autostrade, S.p.A, Italy
- D'Appolonia, S.p.A, Italy
- IB Informatica, Italy
- RINA, Italy
- Segretario generale CNIM, Italy
- TECSA, SpA, Italy
- Dovre Safetec Nordic AS, Norway
- PRIO, Norway
- SINTEF Industrial Management, Norway
- Central Mining Institute, Poland
- Adubos de Portugal, Portugal
- Transgás - Gás Natural, Portugal
- Cia. Portuguesa de Produção Electrica, Portugal
- Siemens SA Power, Portugal
- Caminhos de Ferro Portugueses, Portugal
- ESM Res. Inst. Safety & Human Factors, Spain
- IDEKO Technology Centre, Spain
- TECNUN, Spain
- TEKNIKER, Spain
- TNO Defence Research, The Netherlands
- BP International, UK
- HSE - Health & Safety Executive, UK
- Railway Safety, UK
- W.S. Atkins, UK

### 1.4 Educational and Research Institutions

- University of Innsbruck, Austria
- University of Natural Resources & Applied Life Sciences, Austria
- Université Libre de Bruxelles, Belgium
- University of Mining and Geology, Bulgaria
- Czech Technical University in Prague, Czech Republic
- Technical University of Ostrava, Czech Republic
- Technical University of Liberec, Czech Republic
- University of Defence, Czech Republic
- Tallin Technical University, Estonia
- Helsinki University of Technology, Finland
- École de Mines de Nantes, France
- Faculté de Polytechnique de Mons, France
- Université Henri Poincaré (UHP), France
- LAAS, France
- Université de Bordeaux, France
- Université de Technologie de Troyes, France
- Université de Marne-la-Vallée, France
- Fern University, Germany
- Technische Universität Muenchen, Germany
- Technische Universität Wuppertal, Germany
- University of Kassel, Germany
- Nat. Centre Scientific Res. 'Demokritos', Greece



- University of the Aegean, Greece
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- Politecnico di Milano, Italy
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ESRA is a non-profit international organization for the advance and application of safety and reliability technology in all areas of human endeavour. It is an "umbrella" organization with a membership consisting of national societies, industrial organizations and higher education institutions. The common interest is safety and reliability.

For more information about ESRA, visit our web page at <http://www.esrahomepage.org>.

For application for membership of ESRA, please contact the general secretary **Pieter van Gelder**,  
E-mail: [P.van.Gelder@ct.tudelft.nl](mailto:P.van.Gelder@ct.tudelft.nl).

Please submit information to the ESRA Newsletter to any member of the Editorial Board:

**Editor:** **Carlos Guedes Soares** – [guedess@mar.ist.utl.pt](mailto:guedess@mar.ist.utl.pt)  
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### Editorial Board:

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**Lars Bodsberg** – [Lars.Bodsberg@sintef.no](mailto:Lars.Bodsberg@sintef.no)

SINTEF Industrial Management, Norway

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University of Ljubljana, Slovenia

**Paul Ulmeanu** - [paul@cce.fiab.pub.ro](mailto:paul@cce.fiab.pub.ro)

Univ. Politehnica of Bucharest, Romania

**Radim Bris** – [radim.bris@vsb.cz](mailto:radim.bris@vsb.cz)

Technical University of Ostrava, Czech Republic

**Sebastián Martorell** - [smartore@iqn.upv.es](mailto:smartore@iqn.upv.es)

Universidad Politécnica de Valencia, Spain

**Martijn Flinterman** – [martijn.flinterman@rws.nl](mailto:martijn.flinterman@rws.nl)

The Netherlands Soc. for Risk Analysis & Reliability

**Uday Kumar** - [uday.kumar@ltu.se](mailto:uday.kumar@ltu.se)

Luleå University of Technology, Sweden

**Zoe Nivoliantou** – [zoe@ipta.demokritos.gr](mailto:zoe@ipta.demokritos.gr)

Demokritos Institute, Greece

**Zoltan Sadovsky** - [usarzsad@savba.sk](mailto:usarzsad@savba.sk)

USTARCH, SAV, Slovakia