SYSTEM RELIABILITY AND INDUSTRIAL SAFETY LABORATORY (SRISL)

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Overview

The laboratory of System Reliability and Industrial Safety (SRISL) was founded in 1988 with initial objective the development of an integrated capability for the quantitative risk assessment of large nuclear and non-nuclear systems. During the last twenty years the laboratory has contributed to the state-of-the art of system reliability, quantified risk assessment the development of decision support systems with multiple criteria and under uncertainty.

This contribution has been achieved through the participation to over thirty R&D projects partially or totally funded by third party sources including the framework programmes of the European Commission, other international funding organizations, Greek ministries and Greek companies. In these projects SRISL has collaborated with leading European organizations such as the Health and Safety Executive of the UK, the ministry of Environment and the ministry of Labour and Social Works of the Netherlands, the Joint Research Centre of the EC and numerous scientific and research organizations of the EU member states. The SRISL is one of the main consultants to the Greek Government in matters related with the safety of industrial installations having the potential to cause a major accident and subject to the SEVESO European Directive. In this capacity the SRISL has either reassessed or analyzed the safety of almost the totality of the Greek industry subject to the SEVESO directive

Objectives

Research and Development of methodology and associated software tools in the areas of:

- Reliability of large systems with complex stochastic behavior
- Quantitative Risk Assessment of complex technological systems
- Health and Environmental Consequence Assessment of alternative Electrical Power generating systems
- Assessment of human factor for plant safety enhancement
- Natural Hazard assessment
- Quantitative Occupational Risk Assessment

Recently research and development has been focused in the:

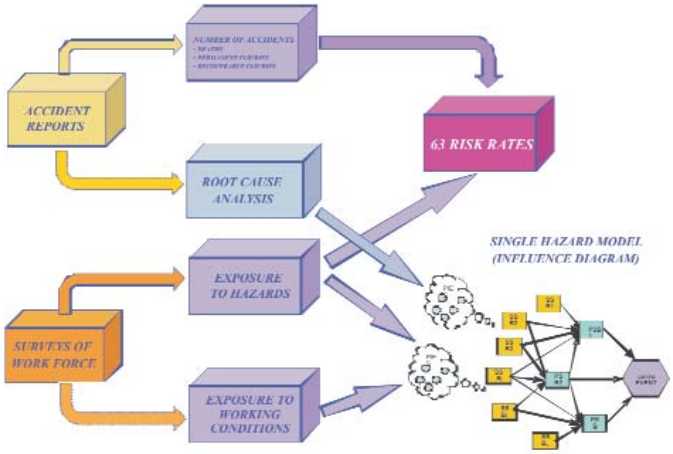
- Development of quantified risk models for occupational risks from accidents and tools for multicriteria optimization of occupational risk management strategies
- Quantification of uncertainties about the models simulating technological systems, physical phenomena and processes.
- Optimization Algorithm development in discrete decision spaces with multiple criteria
- Decision Support System development for risk management as well as emergency response policy selection in major hazard accidents in nuclear and chemical installations.
- Safety enhancement in the process industry through the use of virtual reality tools.
- Development of a simulator to assess the success ratio in operations where multiple teams undertake the mitigation of the consequences of a natural disaster.

R & D Activities

1) Occupational Risk Management

For the last six years (2004-2009) SRISL has been involved in a large research program commissioned by the Dutch Ministry of Social Affairs and Employment aiming at developing a decision support system concerning a choice among various measures or combinations of measures aimed at reducing the risk of employees suffering injury or death as a consequence of job-related incidents. Two major phases of this project can be distinguished: a) the development of a single hazard model: and b) the development of a multiple-hazard model and an optimization tool.

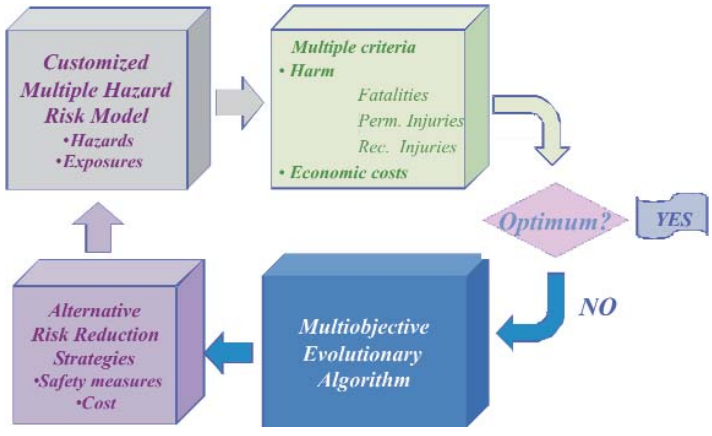
Single hazard model



Sixty three specific hazards (like fall from a scaffold, struck by a moving vehicle, contact with moving parts of a machine) present at various phases of different types of jobs have been identified and a single hazard model has been developed for each one of them. The single-hazard model logically connects the working conditions and the various safety barriers with the occurrence of an accident resulting in death or an injury requiring hospitalization of at least three days. SRISL was responsible for the mathematical aspects of this model and it has put it in the form of an *influence diagram*. SRISL has also developed a software tool that facilitates the development and the quantification of such models in general. The logical structure of the sixty three models has been based on the analysis of more than 10000 accident reports filled by labour inspectors investigating the causes of the accidents. Furthermore, exposure of the workers in the various hazards through the exposure to conditions/activities while performing their jobs has been assessed through extended surveys of the Dutch working population. As a result, the quantification of the sixty three single hazard models (performed by SRISL) provide one of more extensively supported quantification of the corresponding risk rates on a worldwide scale.

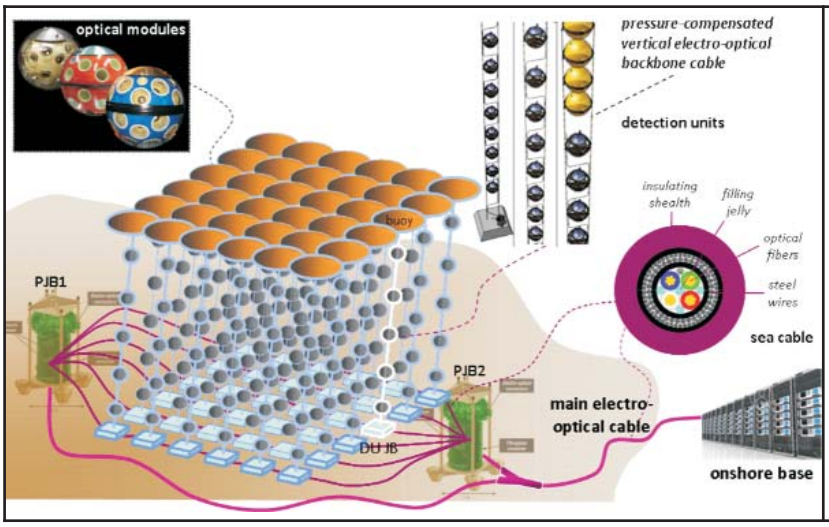
Multiple-hazard model and Decision Support tool

The multiple-hazard model quantifies occupational risk of a worker or a multiple of workers, by taking into account their various tasks, activities and the associated hazards and the corresponding single hazard models. A company, consisting of several workers with different jobs may be also modelled. Various risk measures are then calculated. Risks can be affected through specific measures than can alter working conditions and through them the risk. Each measure is associated with a specific cost. Given a specific "company" and a basket of possible risk reducing measures the question that must be addressed is which is the optimum combination of measures that provides the maximum risk reduction at a given cost, or the a given risk reduction at minimum cost. SRISL has provided the mathematical basis and the software implementation of the multiple-hazard model and an associated multi-attribute optimisation module based on evolutionary algorithm. A single optimisation calculation involves thousands os single-hazard model calculations. In 2009 SRISL developed an algorithm that substantially speeds up the single –hazard model (influence diagram) calculations.



2) *Dependability analysis of a very large volume neutrino telescope*

The SRISL performed the dependability analysis of a very large volume neutrino telescope in the KM3NeT project (EU FP6 KM3NeT Design Study, Contract no. 011937), as part of the work group on «Risk assessment and quality assurance». The KM3NeT is an over M€300 European project involving 40 institutes or university groups from 10 countries, to design, install and operate a deep-sea research infrastructure hosting a neutrino telescope with a volume of at least one cubic kilometer at the bottom of the Mediterranean Sea.



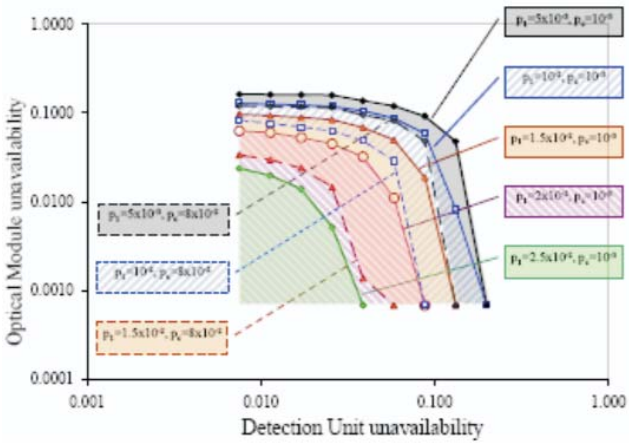
The neutrino detector will consist of several thousand optical sensor modules placed on mechanical structures connecting them in vertical assemblies. The sensors will be inter-connected via watertight and pressure-resistant connectors. Their measured data will travel through an underwater network of specially designed multiplexed passive optical or active electronic equipment and optical fibers to the onshore base.

Challenges in the availability features of this system rise from the extreme deployment, operation and maintenance conditions at depths of 3500 to 5500 meters (depending on the site location).

The final study presented ranges and combinations of possible component unavailability values that satisfied a fixed unavailability requirement for the telescope system. It also developed dependability requirements for major components and/or subsystems consistent with an overall system performance target.

The results depicted the dependence of the system unavailability on the number of optical modules and the alternative deep sea infrastructure configurations for transferring the measured signals.

The dependability analysis performed in the SRISL was a first order steady state approximation and consisted of the following steps:

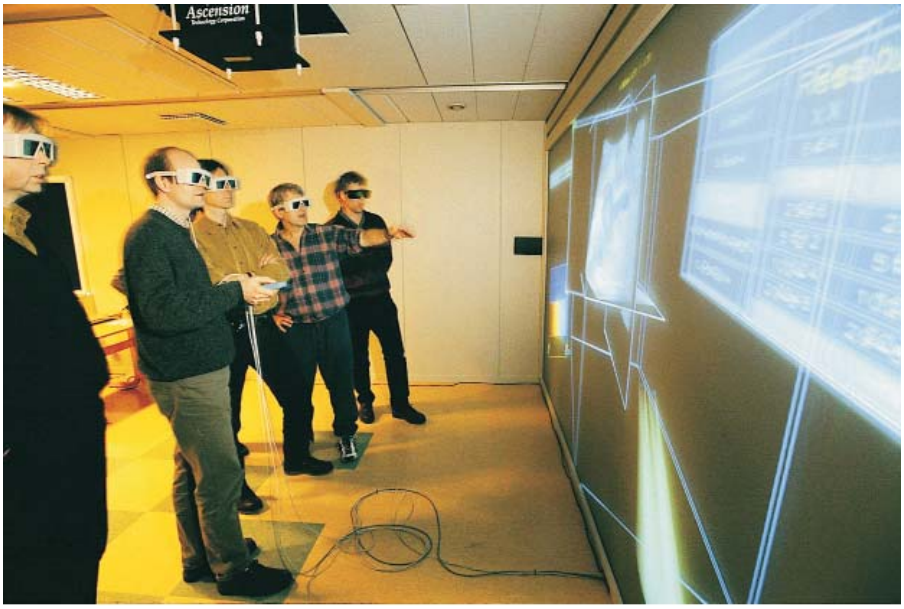


- Treat the neutrino telescope as a complex system; identify the system components and their operational interdependencies, and the required function of the telescope system.
- Develop an appropriate mathematical model to estimate the telescope unavailability based on the unavailabilities of its components and a set of steady state unavailability evaluation correlations depending on possible component repair/test characteristics.
- Obtain results for a variety of alternative detector network configurations, and distances of the detector from the onshore facilities.

This work has been presented as a detailed report on the dependability of the telescope, and will be included in the telescope technical design report which is still in preparatory phase.

3) Virtual Reality and Human Factors (VIRTHUALIS)

SRISL is a main participant to the EU FP6 funded European programme VIRTHUALIS, (2005 to 2010) aiming at the reduction of hazards in production plant and storage sites by addressing end-users' practical safety issues, such as training control room operators, designing proper alarm systems, training teams to cope with emergencies, assessing the impact of plant modifications on operators' reliability, and helping managers to see the impact of their decisions on sharp-end operators' daily work; all this has been achieved through the development of an innovative technology, which has merged Human Factors (HF) knowledge and Virtual Reality (VR) technologies. The innovative character of the VIRTHUALIS technology has mainly be given by the new HF knowledge, such as the Failure Probability Estimator (FPE) tool developed mainly by the SRISL personnel, that provided solutions to cope both with identified safety-critical issues and the "driving license" to profitably exploit VR technologies. The new HF knowledge has been produced ad hoc to cope with two specific case studies, one at a STATOIL gas handling site in Norway and a second at a SONATRACH LPG handling site in Algeria.



The breakthrough offered by the VIRTHUALIS technology relates to the opportunity of moving from static paper-based assessments to dynamic virtual simulations. Safety analyses like HAZOP, FMEA, Fault Tree (FT), Event Tree (ET), Preliminary Hazard Analysis (PHA), Task Analysis (TA), in which critical situations are just imagined by safety analysts, are now moulded in such a way that HF concepts can permeate people's mind through images. In particular this allows safety analysts to easily and quickly understand and integrate HF concepts into safety analyses. Indeed, HF issues are difficult to communicate, to understand and to envision owing to their complex nature. By immerging sharp-end operators, teams, safety analysts, managers into Virtual Environments (VEs) suitably modelled for the specific analysis to perform, it is possible to "almost" experience safety-critical situations amplifying people capabilities and enabling them to suitably exploit HF concepts when performing safety analyses. Existing and new HF knowledge, created to cope with the above mentioned safety cases, have been exploited to enable:

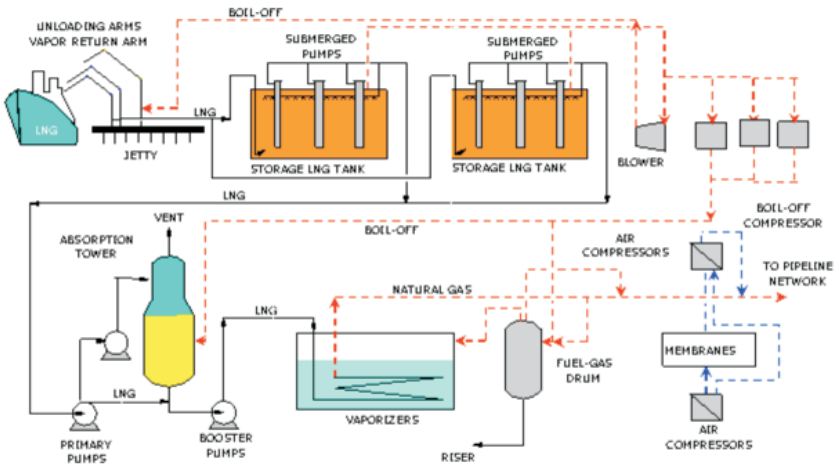
- operator's performance tracking and his/her reliability measuring;
- new design alternatives to be conceived and created;
- informed safety-critical decisions to be made effectively;
- appropriate and effective training programs to be created.

The VIRTHUALIS methodology ultimately enables industry to improve the efficiency of safety production at any of the 7 stages of the production lifecycle, i.e., (1) Exploration & Drilling, (2) Design, (3) Construction, (4) Commissioning, (5) Operation, (6) Maintenance, Repair & Modification, and (7) Decommissioning.

In 2009 the main thrust of the consortium and SRISL effort was put in the finalisation of the second case study in SONATRACH, Algeria

4) Early Recognition, Monitoring, and Integrated Management of Emerging, New Technology Related Risk (iNTeg-Risk)

SRISL participates in Early Recognition, Monitoring, and Integrated Management of Emerging, New Technology Related Risk (iNTeg-Risk) a large scale integrating research project iNTeg-Risk commissioned by the European Union, aimed at improving the management of emerging risks related to "new technologies" in European Industry(2009 -2012). A research consortium of 64 different institutions is united in order to establish a common EU approach to face the challenge of emerging risks from new technologies such as nanotechnology, H2 technology, CO2 underground storage and new materials. This will be achieved by building new management paradigm for emerging risks as a set of principles supported by a common language, agreed tools and methods and Key Performance Indicators, all integrated into a single framework. iNTeg-Risk purpose is to coordinate research and development sub-projects for improving the management of Emerging Risks related to new materials and technologies that will reduce time to-market for the EU lead market technologies and promote safety, security, environmental friendliness and social responsibility as a trademark of the advanced EU technologies. The project will improve early recognition and monitoring of emerging risks, seek to reduce accidents caused by them and decrease reaction times if major accidents involving emerging risks happen. Seventeen individual applications are foreseen in order to include different types of new technologies in respective number of case studies.



SRISL major contribution of SRISL in the iNTeg-Risk project is the establishment and application of the quantified risk assessment methodology to two Liquid Natural Gas regasification facilities, namely an existing on–shore LNG terminal and an offshore under design, consisting of a floating storage and regasification unit (FSRU). The major steps for risk assessment of LNG plants are the assessment of plant Detailed Fault Trees and Event Trees will be constructed and quantified for assessment of frequency of plant damage states. Consequence analysis will be performed by the SOCRATES code and individual risk will be estimated for both LNG terminals damage states and their frequency, the assessment of consequences of LNG release and risk integration. Minor contributions of SRISL in the iNTeg-Risk project will be a) Emerging Risks related to interaction between natural hazards and technologies, with emphasis to the natural hazard of forest fire and b) development of models and methods for plant operators and maintenance staff

In 2009 SRISL has applied the Master Logic Diagram method for hazard identification of LNG terminals establishing the Initiating events for potential accident sequences.

Education

PHD Theses in Progress

E. Georgiadou, "Decision support systems for major industrial accidents", PhD Thesis, National Technical University of Athens, School of Chemical Engineering

E.Kallikazarou PhD Thesis, National Technical University of Athens, School of Chemical Engineering