Safety for Sustainable European Industry Growth

European Technology Platform Industrial Safety
www.industrialsafety-tp.org

Strategic Research Agenda
Detailed Version


Title:
STRATEGIC RESEARCH AGENDA, Detailed version.

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Presented at:
ETPIS General Assembly on 7th February 2006 in Brussels.  
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PREAMBLE

This document is the first detailed version of the Strategic Research Agenda of the European Technology Platform on Industrial Safety (ETPIS).

The Strategic Research Agenda has been elaborated thanks to an open and transparent consultation process which started on 27 January 2005 with the first draft edition. Then, three other draft versions were made publicly available in order to collect comments and contributions from the community concerned by industrial safety.

| DRAFT VERSION 1 | 27/01/2005 | First edition, drafted after the open ETPIS workshop 'To share the vision on industrial safety' organised in Brussels on 20 October 2004 where the Focus Groups were created. |
| DRAFT VERSION 2 | 22/03/2005 | Second edition enriched with the contribution received by the members of the Focus Groups |
| DRAFT VERSION 3 | 24/06/2005 | Third edition with reorganisation of the content of each FG, and introduction of the prioritisation in the FGs |
| DRAFT VERSION 4 | 07/11/2005 | Fourth edition with introduction of FG Structural Safety and an Executive Summary (this version was discussed during the open Seminar 'Sharing knowledge and vision in industrial safety' organised in Milan on 1&2 December 2005) |

The Strategic Research Agenda of ETPIS will be updated regularly according to the evolving context and by taking into account the results of research and a specific review of stakeholder concerns and needs. Therefore, every second year the SRA will be reviewed and a new version will be edited after an open workshop gathering the members of ETPIS and the community of interest.

The Strategic Research Agenda is a tool for co-ordinating the RTD effort in industrial safety at European, national and regional level to prepare research programmes. The objective is to develop synergies between public and private sectors at European, national and regional level to optimise the resources allocated to research in industrial safety. The SRA constitutes therefore the RTD roadmap for industrial safety improvement. The national technology platforms on industrial safety will provide contribution in resources and work and this will be co-ordinated by the ETPIS.
Executive Summary

Introduction

It is expected that improving the level of industrial safety will sustain and foster the competitiveness of the European industry. In particular, improved control of industrial risks will contribute to the sustainable growth of the European industry. There is also a benefit to be expected from the development of a co-ordinated effort in safety-related research across industry sectors. As it stand today, the effort in Research & Development often remains fragmented, at both national and European levels, and no coherent attempt is made to transfer success from one industry to another or the benefits of research in one sector to another.

The ETPIS recognises that only an integrated approach to industrial production, risk assessment and management will help introduce improved and integrated safety standards across the European industry, along with occupational practice that matches the objectives of industrial safety. Such integration includes: man-machine interactions, organisational and cultural factors, influence of safety culture, etc. The ETPIS also recognises that it is through education and training that can be established a context wherein managers, technology developers and designers can create production adapted safety systems, while operators at facility level also know how to operate and maintain them in a safe and efficient way.

The methods relied upon by ETPIS partners include: modelling the risk, as well as reliability and availability of the systems throughout their lifetime. Purpose here is to be able to study the impact of new maintenance and repair schemes on system safety, life cycle costs, reliability, serviceability and quality. Another major problem facing many industrial products, structures and industrial facilities at large is the technical need, or economic pressure, to extend the lifetime of industrial systems and structures. It is therefore critical to ensure that this extension will not degrade the level of safety in industrial activities. This problem is being dealt with in different industries that usually rely on the same main theoretical background but often develop different strategies and approaches. Thus, methods for the assessment of existing structures and equipment (reliability; ageing; etc.) are also addressed by ETPIS. This is also the case of approaches and criteria relied upon to extend, in a safe way, the lifetime of products and industrial systems. Purpose is that this practice of extending lifetime of systems and products is done based on properly identified and accepted levels of risk, reliability and availability.

For safety to be maintained throughout the operational life, safety management systems are required. These deal with physical systems, processes and people; these systems are based on measures including: risk elimination, prevention, control and mitigation, emergency response and recovery. All these features shall be used in different combinations, depending on the nature of hazards, precursors, accidental scenarios (e.g.: from benign incident to worst-case) and potential loss.

The ETPIS is closely co-operating with the industry-specific platforms, such as MANUFACTURE, ECTP, Sustainable Chemistry, transport related TPs... so as to turn the methods and technologies developed within the Platform Industrial Safety into practical, accessible and easy-to-apply principles and tools. This will require an industry-specific approach. The commitment of ETPIS is expected to help industry practitioners to identify and
prevent potential risks, understand and improve safety culture, and understand what other factors have an influence on safety.

**RTD Strategy**
The analysis of the broader situation, regarding industry and safety interactions and issues, led the ETPIS members to propose a RTD strategy that focuses on 6 major challenges. These have been identified wherever there is a clear need to develop basic knowledge in safety sciences.

**Developing new risk assessment and risk management methods addressing the complexity of industrial systems**
Basic knowledge, methods and technologies need to be developed in:
- Understanding hazardous phenomena to develop safety solutions, equipment and technologies
- Development and validation of methods and tools to improve risk assessment and management
- Impact of natural and man-made hazards on plant safety
- Harmonisation in risk assessment
- Risk management and governance (new forms of participative governance)
- Multicriteria analysis and decision support tools
- Systemic methods to address the complexity of the industrial systems
- Uncertainties in risk assessment and management
- Reliability and safety of network systems
- Methods for dynamic reliability assessment
- Risk metrics and dynamic risk metering

**Improving methods and technologies to reduce risks at work and to prevent major accidents**
Basic knowledge, methods and technologies need to be developed in:
- Technologies for inherently safer design and to reduce risks at source;
  - Technologies to reduce emissions of hazardous substances and aerosols
  - Novel and effective methods for reducing risks related to noise and vibration
  - Novel and effective methods for reducing risks related to electromagnetic hazards and optical radiations (non-laser and laser radiations)
  - Technologies and methods for inherently safer design of industrial plants and installations to reduce major-accident hazards
- Technologies for reducing risks by collective protective systems and devices;
- Protection systems and smart sensors for machines, production and transportation processes
- Software tools for detecting dangerous situations in industrial systems
- Systems and devices protecting against noise and vibration
- Collective protection devices against electromagnetic hazards and optical radiations
- Novel and advanced technology in lighting the workplaces
- Application of information technologies in safety-related systems
- New materials, technologies and test methods for personal protective equipment (PPE);
- Test methods and safety requirements for PPE applied against new specific hazards
- Innovative materials & individual systems for the personal protection of health and life
- Ergonomics innovations for PPE used in work and everyday life conditions
Structural safety
Basic knowledge, methods and technologies need to be developed in:
• Structural reliability based design
• Structural Health Monitoring (SHM) and risk-informed inspection
• Structural Safety of Aged & Repaired Structures and life extension
• Fitness-for-Service (FFS) of structures
• Integrity of Multi-Material (Hybrid) structures
• Structural safety against natural hazards and accidental loads

Understanding the impact of human and organisational factors in risk control
Basic knowledge, methods and technologies need to be developed in:
• Human and Organisational Factors in Managerial Safety Factors in Organisational and Managerial Safety
• Human-Centred Design
• Integrated Risk Assessment and Management Methods & Techniques
• Human Performance & Technology Usability
• Human Factors in Emergencies and Crisis Management
• Safety and Quality: Could they be merged, do they really match?

Understanding emerging risks
Basic knowledge, methods and technologies need to be developed in:
• Future Legislation, codes, standards, and their influence on industry
• New/emerging technologies
• Methodology for identification and assessment of new and emerging risks
• Networks, industrial parks and other interdependencies
• Natural hazards triggering threat to industrial safety
• Attacks on and against industrial installations (security aspects in safety of industrial plants - CBRN Risks)
• Old/aged plants and integration of risk management in to the life cycle of industrial plants

Improving knowledge transfer to industry and in particular SMEs, education and training activities
Basic knowledge, methods and technologies need to be developed in:
• Maintain Competence
• Open Platforms and modular systems for education and training
• Simulation – Using virtual reality

Improving safety of nanotechnologies and use of nanomaterials
Basic knowledge, methods and technologies need to be developed in:
• Technical issues
• Societal issues
• Enabling technology development
Organisation of the RTD strategy

The analysis of the broader situation, regarding industry and safety interactions and issues, led the ETPIS members to propose a RTD strategy that focuses on several major challenges. These have been identified wherever there is a clear need to develop basic knowledge in safety sciences.

After the workshop on 20th October 2004 in Brussels, 4 Focus Groups (FG) were created to gather scientists and stakeholders concerned by the same research area. Then the structure has evolved to correspond to the RTD strategy.

Now the structure consists in 5 FGs and 2 Hubs:
- Risk Assessment and Management
- Advanced risk reduction technologies
- Structural Safety
- Human and organisational factors
- Emerging risks
- Hub Education and training
- Hub NanoSafe
This structure has been confirmed by the ETPIS members at the two days seminar in Milan, 1-2\textsuperscript{nd} December 2005. The present document was then further developed by taking account of the views of the ETPIS members and subsequent discussions at the ETPIS Management Board meetings in Paris, 11-12\textsuperscript{th} January 2006.

**What is a HUB?**

It is known that most of the safety related industrial challenges are not confined to a single industrial sector and usually they are complex in nature. Therefore, the solution may need to take into account of the knowledge and expertise of several Focus Groups as listed above. Furthermore, to enable the mobilisation of the critical mass to solve interdisciplinary problems and attract the interested sectors, the ETPIS has decided to create the concept of research HUBs. A research HUB is a topic-based group of stakeholders aiming at both exchanging knowledge and starting projects, once they have defined a research agenda that is specific to their topic of interest.

This paragraph introduces the choice of the focus group topics.

Two research hubs are created in the ETP on Industrial Safety:

- **NANOSAFETY**: it addresses safety-related issues in the field of nano-technologies and nano-materials
- **EDUCATION AND TRAINING, TRANSFER TO INDUSTRY**: it aims at developing new technologies and methods to improve the knowledge transfer to industry, and to the engineers and scientist working in the field of safety.
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1. INTRODUCTION

1.1 RATIONALE

1.1.1 Safety for European quality of life and competitiveness

The European Union has been defining a number of objectives for the future of RTD activities, which require a variety of concerted actions. The Lisbon summit (2000) established the objective for Europe to become the most dynamic and most competitive knowledge-based economy by 2010, while in the Gothenburg summit (2001) emphasis was put on sustainable development, involving aspects of environment, health, economy and employment.

The achievement of these objectives for the European economy and way of living requires that industry as a whole modernises itself, improving its efficiency, quality and safety. It also requires improvement in the efficiency, quality and safety of transport systems, as mobility is a requirement for the industrial development and also for the well-being of citizens. It is becoming more evident that the industrial and the transport networks in Europe are transnational and increasingly more dependent on each other. Efficiency of industrial production is intimately related with the delivery of materials and products in a timely manner and this can only be viable with adequate logistic and transport infrastructures.

Safety is essential for the human well-being but also to ensure the efficiency and competitiveness of the industrial and transport systems as a whole. Any disruption in the chain of production and transport has adverse consequences on the affected industries and transport systems, which happens across country borders, as national economies are increasingly interlinked. It is therefore essential that in all European countries there is a consistent approach to Safety and that this approach is also maintained consistently across the various industries and transportation facilities. This is not the present situation but should be a long-term objective that should mobilise efforts among all parties involved, from Governments to industry, and from technology developers to the public at large.

1.1.2 An evolving context

The performance of the European industry in many sectors is competing with other countries which are growing quickly thanks to structural and economic advantages. Since Europe is a largely mature market which is not expanding rapidly, investment for expansion is taking place in other regions where there are market and sometimes economic advantages. Investment in Europe is ‘plateau-ing’ and new production capacity is built in Asia or in South America. This position creates a challenge to maintain competitiveness and a fair socio-economic level in EU.

Part of the challenge is in meeting public expectations in safety and environmental protection while reigning competitive. New emerging technologies are providing and requiring new design, operation and assessment routes which needs long-term considerations to maintain industrial safety. Furthermore, as European industrial installations are becoming older and technical expertise follows new investment and older experts are retiring, making education and training for industry a special issue.
The market is evolving towards specialised production and complex manufacturing processes (speciality chemistry, aeronautics, services...) which require enhanced knowledge, adaptability and flexibility. If the required technological disciplines and hard science education do not attract enough people, it will be impossible to stimulate innovation.

1.1.3 Need for changes in industrial safety policies

Policies addressing industrial systems, and in particular safety, must evolve from prescriptive policies to objective policies, because the key players able to implement the solutions are the industries themselves and it is no longer possible to prescribe solutions when the systems are so specific and so complex. There is a need to harmonise the policies and ensure a consistent implementation throughout Europe, and in particular as the Union enlarges.

The public expects to take part in decision-making process related to safety and environmental protection which also involves issues such as ageing and emerging infrastructures and systems in Europe. There is always a residual risk related to human activities. It is important that industry and public authorities decision making process are as transparent as possible and it is fundamental that it is comprehensible by the public. For that latter reason, there is a need to develop an open and ethical industrial risk (or safety) culture and explain risks and benefits that our society gain from industry.

The solutions to be developed to minimise both accidents and pollution must be integrated ones while maintaining the integrity of operation of industrial systems. The new systems that will be designed must take into account at conception safety and environmental performance as major opportunities and requirements. Inherently safe and clean concepts should be permeate industry at all levels of the life-cycle of the manufactured products.

1.2 Scope of the European Technology in Industrial Safety

Safety of the Society derives from properly addressing risks to the public, industrial risks and occupational risks, the nature of which changes with the target population to which it relates. Public risks are related to governmental decisions on major topics such as major diseases (e.g. AIDS and cancer), genetically modified products, climate change and natural hazards to name a few. Industrial risks are related to the risk that the industrial activity brings to employees and the public in general, including transportation which is considered here as part of the industrial activity. In industrial risks, risks related to the introduction of new technologies (e.g. nanotechnology, hydrogen storage etc.) and design routes need particular attention as the new hazards need to be properly identified and managed. Safety in this context results from Governmental regulations, technical codes and standards that generally define minimum acceptable safety levels (and sometimes enforce these levels) and from the various industrial actors that organise their activity in order to achieve the level of safety they consider compatible with their aims and responsibilities. Finally, occupational risks concern the accidents that occur within the industrial and related activities and thus they affect a smaller percentage of population at risk. They also depend on the policies and aims of the various industrial sectors and Governmental regulations.

The scope of the Industrial Safety Technology Platform provides an integrated approach to the safety related aspects of advanced design, production, operation processes and fitness-for-service assessment of industrial products and systems, dealing with technical and human, organisational and cultural aspects, as well as the actual systems and processes used for managing safety. The main emphasis is on the development of preventive
technologies, damage assessment routes using risk-based methods for the optimal design of products, production facilities, industrial systems, activities and ageing and new advanced structures from the point of view of delivering recommendations in the form of “Best Practice Documents”. These can be basis for development of CEN Norms by the respective Technical Committees for improved safety levels at acceptable costs.

1.3 THE VISION AND THE WAY TO ACHIEVE IT

1.3.1 Background and Present Situation

According to European Statistics\(^1\), in EU-15, in 2001 there were 7.6 million accidents at work. 4.9 million of these resulted in more than 3 days of absence from work and 4,900 fatalities occurred. This means that one worker became a victim of an industrial accident every 5 seconds and one worker died every two hours. All industry sectors are concerned: manufacturing, energy, transport, construction, agro-industry, process industry.

The MARS database\(^2\) records that, approximately 30 Major Accidents happen each year within the industry sectors covered by the Seveso 2 Directive. These accidents are not major contributors to the overall statistics but have a major impact on industry and society. The major accident, which occurred at Toulouse on 21st September 2001, killed 21 people on the site, 9 people off-site and injured 2,242 people. 27,000 homes and 1,300 companies suffered significant damage. 5,000 people needed treatment for acute stress. The economic cost exceeded €1 500 million.

Incidents and accidents disrupt the process of sustainable industrial development, directly through the remedial and prevention activity and indirectly through restrictions placed on the whole industry as a result of these failures.

Additionally, introduction of new technologies brings new safety challenges which need to be addressed before they impose added risks.

Performance statistics for different sectors indicate that some industries are apparently much safer than others. The difference between the best performers and the average for all industry is often dramatic and cannot always be explained by the inherent hazards of the specific features of the primary structural components and workplace or work activity. There are underlying reasons for failure and success which may be known, shared and acted upon within a sector, but no coherent effort has been made to address the failures of one sector by applying the success factors of another. Within sectors there is a wide variation of performance which depends on many root cause factors including corporate tolerance, scale of operation and resources available for accident prevention and concerns about competitiveness. The new members of the European Union are in some cases at a different stage of development and performance in industrial safety. This presents some new opportunities and challenges.

Research projects on Industrial Safety are funded by a wide range of stakeholders including the European Commission and European member state governments. This investment has

\(^2\) Major accident reporting system. European Commission, Joint Research Centre, Ispra. http://mahbsrv.jrc.it
not been entirely successful because a Europe-wide life cycle process from problem definition through project activity to implementation and exploitation has not been applied consistently. Legislation such as the Seveso and “safety at work” Directives has played a constructive role in setting requirements and standards. Consensus Technical Standard setting bodies such as C.E.N. and I.E.C. have been successful in promoting improvement. The best performers have made their own decisions to be leaders. In so doing, they have initiated, carried out and exploited projects and implemented improved technical standards. In most cases they have adopted an accident free workplace philosophy and used any of the resources available to them.

1.3.2 The Vision:

The vision for industrial safety performance can be summarised as follows.

- By 2020 a new safety paradigm will have been widely adopted in European industry. Safety is seen as a key factor for successful business and an inherent element of business performance. As a result, industrial safety performance will have progressively and measurably improved in terms of reduction of reportable accidents at work, occupational diseases, structural failures lead to environmental incidents and production losses. It is expected that an "incident elimination" and “learning from failures” cultures will be developed where safety is embedded in design, maintenance, operation, fitness-for-service assessment and risk management at all levels in enterprises. This will be identifiable as an output from this Technology Platform with following quantified objectives;
- By 2020 there will be structured self-regulated safety programmes in all major industrial sectors in all European Countries. These will have firm, measurable performance targets for improved structural performance, accident elimination and will meet the annual reduction rate stated in the Technology Platform objectives
- By 2020, accident free workplaces will become the norm

This development will significantly contribute to the sustainable growth of all major industrial sectors in Europe by safer utilisation of emerging technologies and life extension of ageing structures and hence improvement of social welfare.

1.3.3 How can the Vision be realised?

Improved risk control supporting the sustainable growth of European industry needs a co-ordinated effort in research and in identifying and adapting successful practices. Many of the most respected risk assessment and control methodologies have originated or been developed in Europe. Examples include Hazard and Operability Study (HAZOP), Quantitative Risk Assessment (QRA) and Workplace Risk Assessment.

Research work should continue in these fields to develop existing methodologies further by taking into account of emerging technologies and respective risks as well as harmonising the best of them in Europe. The interaction and early involvement of technological knowledge (new technologies, smart structures etc.) in policy development needs improvement. This will
lead to early identification of safety relevant issues and thus can guide introduction of new design and manufacturing technologies, life extension and structural performance assessment methodologies and policy/legislation development and improve the quality and sustainability of the final solutions.

Recognising the challenge and opportunities, a group of experts from industry, unions, authorities, NGOs and research and academic organisations have undertaken to create a Technology Platform to achieve Safety for Sustainable European Industry Growth. This initiative obtained the support in principle of the DG Employment, DG Enterprise, DG Environment and DG Research and has prepared the strategic plan described in this document for research into new technologies and existing best practice and the implementation of results across all major industry sectors. A fundamental expectation for the platform is that the needs of Small and Medium Enterprises will have a high priority. The Platform for Industrial Safety has a clear responsibility to work with other Platforms and suitable existing or new groups as a network of National platforms to ensure success. The Technology Platform offers a superior opportunity to focus this research and clearly define how each project which it supports will play its part in delivering the vision.

The main objectives of the Technology Platform ETPIS, therefore, are:

- To develop and establish framework of safety for the sustainable growth of all major sectors of European Industry by reducing the number of accidents while developing innovative technologies and methods
- To bridge the different aspects of "industrial safety" (Occupational health and safety of the workers & environmental safety including prevention of major accidents and protection of the environment).
- To facilitate and accelerate the breakthrough for progress in industrial EH&S via a co-ordinated, integrated research and implementation process which unifies and shares existing best practice and new research results.
- To manage the Strategic Research Agendas in industrial accident reductions.
- To valorise, exploit and implement the results of Research in Industrial Safety.

1.3.4 What will be done – the general approach

The general approach will be implemented to reach the objectives of the ETPIS:

- Act to gain the commitment from major industrial sectors and key safety related organisations to the accident elimination vision and the milestones of:
  - 25% reduction in accidents by 2020
  - Programmes to be in place by 2020 to continue accident reduction at a rate of 5% per year or better
- Set up consultation and analysis programmes, which identify needs and matches these to potential research projects for management through the Technology Platform. Use knowledge gained to expand the scope of the Technology Platform where needed.
Carry out industry driven research within the following focus areas:

- Risk Assessment and Management
- Advanced Risk Reduction Technologies
- Structural safety
- Human and Organisational Factors
- Emerging risks
- Education and Training, and transfer to industry, in particular SMEs

The research agenda addresses needs of all industrial scales (from SMEs to major multinational companies) operating in the 25 member states of the European Union. Therefore, ETPIS aims to conduct collaborative works to:

- Identify **Best Safety Practices (BSP)** in individual industrial sectors which have potential for multiple sectors.

- Research on needs of identified **Best Safety Practices** to make them world-leading procedures by covering new technologies, methodologies and emerging risks and fully applicable across individual sectors and across multiple sectors.

- Continue a formal structure allowing communication and sharing among all Technology Platforms where occupational and structural safety are of concern.

- Provide intelligent information exchange from one sector to another to allow gaps, barriers and synergies to be identified.

- Require an implementation strategy to be included for the results of funded research endorsed by the Technology Platform.

- Provide newly developed or improved **European BSP documents** to give sector or problem specific guidance on new standards and regulations to achieve the desired improvements in a cost effective manner which delivers social and economic benefits which in-turn enhances the sustainability and competitiveness of the European industry.

- Set up an best knowledge and industrial need driven programme which accomplishes:
  
  - Implementation of results of research and improvement programmes which meet the quantified progress measures in the Technology Platform Vision.
  - Developing **European Best Safety Practice (BSP) Documents** to provide basis for development and further improvement of unified standards
  - Developing and establishing **European Safety Training and Education Network** using material developed within **European BSP Documents and existing standards**
  - Progress measurement (and reporting) against the accident reduction goals in the Vision.
  - Installing the concept of accident statistics and economic assessment as an extension of and in addition to the key financial reporting activities for the enterprises (global safety indicator)
Reporting on the success of implementation for each project funded through or with the support of the Industrial Safety Technology Platform.

Needless to say that ETPIS will use the existing networks, associations and groups are already working in the wide-range of the industrial safety topics to be addressed.

1.4 OBJECTIVES

The Technology Platform on Safety addresses industrial and occupational safety related with the industrial activity as a whole. The Vision of the Technology Platform on Industrial Safety is to reduce significantly the level of accidents in Europe by 2020 with realistic, measurable targets. The platform activities will result in a substantial improvement of industrial and occupational safety and security in all industries, including transportation systems and infrastructures, which will be achieved, maintained the profitability of the industry.

More specifically, it addresses the problem of ensuring the safety and cost-effectiveness of industrial products and services, transport systems and services, facilities and structures across different industries. Several industries are faced with similar problems requiring solutions that are compatible with new work organisation, including the extended use of information technologies, and which impose no damage to the environment. Industries are also going through processes of consolidation, of relocation in different countries, including in industrial parks so that a proper interaction with urban planning and development becomes even more important and critical.

Furthermore, the safety and reliability aspects, which are critical to production efficiency and cost, need to be ensured not only in the design and in the manufacturing phase, but also must be kept during the operational and ageing phases of the products and facilities. In this context, improved structural integrity assessment of welded structures which may contain defects or cracks has paramount significance for the structural durability and hence safety. Finally, in the long-term prospective (up to 20 years) a great deal of effort is to be directed to a change from the traditional approach of hazard control to one of accident elimination. Thus the development and evaluation of inherent safety principles and techniques is a long-term objective, together with ensuring their adoption by all stakeholders.

Moreover, a new threat item has been added to the problem area of safety since the occurrence of tragic events like those of September 11, 2003 in New York and March 11, 2004 in Madrid: the security of the industrial systems and infrastructures. While safety aims at avoiding accidents and damage resulting from normal operation of installations, security aims at safeguarding the installations from voluntary illicit acts, often of terrorist nature. Most of the focus in security is towards decreasing vulnerability of systems by better detection and early warning of the potential threats and/or by making systems more robust or eliminating weak links. In this respect, it is clear that public and industrial safety cannot be ensured if measures are not explicitly taken to also deal with these threats. While some methodological aspects of risk assessment and management are the same, the hazard identification requires new types of actions and thus the risk analysis methods and the resulting reduction measures also need to reflect these new threats. The experience in nuclear safeguards may represent a good starting point in this direction.

This Technology Platform aims at improving the coherence of the approaches adopted by the different industries to deal with the above-mentioned problems, and it provides a strategic
vision for identifying priority research in RTD and demonstration activities. It will also consider the importance and maturity of the technologies being developed and will contribute to the technology transfers among the sectors and to the much needed education and training activities.

The long-term objective of the Platform is to improve the methodologies, technology and the practice, making them more integrated and consistent across industrial sectors and across European countries, as this is the only way of improving the overall level throughout. As long as there are sectors of activity, or countries, with less than satisfactory approaches to safety, the overall objective can be jeopardised. This is particularly critical with Small and Medium Enterprises (SMEs) in general as they often do not always possess sufficient resources and may not be able to lead the processes of safety improvement. This Platform is transversal, crossing all industries and transportation modes, and aims at developing consistent methodologies of risk analysis and management for implementation in the various industrial and transport sectors. On the other hand, the specifics of application of the methods and the details of their implementation in the various industrial and transport practices will need to be dealt in conjunction with the industry-specific Platforms.

1.5 METHOD

1.5.1 Introduction

The ETPIS recognises that only an integrated approach to industrial production, risk assessment and management will help introduce improved and integrated safety standards across the European industry, along with occupational practice that matches the objectives of industrial safety. Such integration includes: man-machine interactions, organisational and cultural factors, influence of safety culture, etc. The ETPIS also recognises that it is through education and training that can be established a context wherein managers, technology developers and designers can create production adapted safety systems, while operators at facility level also know how to operate and maintain them in a safe and efficient way.

The methods relied upon by ETPIS partners include: modelling the risk, as well as reliability and availability of the systems throughout their lifetime. Purpose here is to be able to study the impact of new design, fabrication (e.g. multi-material structures), maintenance and repair schemes on system safety, life cycle costs, reliability, serviceability and quality. Another major problem facing many industrial products, structures and industrial facilities at large is the technical need, or economic pressure, to extend the lifetime of industrial systems and structures. It is therefore critical to ensure that this extension will not degrade the level of safety in industrial activities. This problem is being dealt with in different industries that usually rely on the same main theoretical background but often develop different strategies and approaches. Thus, methods for the assessment of existing structures and equipment (reliability; ageing; etc.) are also addressed by ETPIS. This is also the case of approaches and criteria relied upon to extend, in a safe way, the lifetime of products and industrial systems. Purpose is that this practice of extending lifetime of systems and products is done based on properly identified and accepted levels of risk, reliability and availability.

For safety to be maintained throughout the operational life, safety management systems are required. These deal with physical systems, processes and people; these systems are based on measures including: risk elimination, prevention, control and mitigation, emergency response and recovery. All these features shall be used in different combinations, depending on the nature of hazards, precursors, accidental scenarios (e.g.: from benign incident to worst-case) and potential loss.
The ETPIS is closely co-operating with the existing thematic networks such as S2S, SHAPE-RISK, SAFERELNET, FITNET etc. and industry-specific platforms, such as MANUFUTURE, ECTP, Sustainable Chemistry, transport related TPs... so as to turn the methods and technologies developed within the Platform Industrial Safety into practical, accessible and easy-to-apply principles and tools. This will require an industry-specific approach. The commitment of ETPIS is expected to help industry practitioners to identify and prevent potential risks, understand and improve safety culture, and understand what other factors have an influence on safety.

1.5.2 Analysis of the situation and proposal for a RTD strategy in industrial safety

This paragraph introduces the choice of the focus group topics.

1.5.2.1 Developing new risk assessment and risk management methods addressing the complexity of industrial systems

Today risk management has become a focus area in society at large. Media, annual reports, politicians, industry leaders have it on the agenda. Over the past 40 to 50 years more structured and well documented methods for risk assessment and management have emerged within various industries. Nuclear and space industries lead the development of more scientific basis. Later structural safety offshore, chemical industries, etc. have made important contributions. Today, we still experience different safety regimes and implementations of risk management methods. Examples are the various practices seen for Safety Cases in the onshore hazardous industries (Seveso II), offshore oil and gas production (UK, Norway), international shipping (IMO).

Issues are for instance:
- Performance based (goal setting) regimes,
- Methods versus prescriptive, self regulation (internal control),
- Need for verification by 3rd party,
- Risk based calibration of requirements in rules and regulations,
- Risk based inspection, maintenance, certification, verification, operation
- Risk Assessment and Cost Benefit Analysis (is ALARP acceptable?)
- Harmonisation issues.

The complex and global risk picture more and more emerging clearly reveals that various actors have various perspectives and priorities when relating to risks. Recent benchmarking exercises also reveals that estimated risk levels may vary from one estimator to another showing that standardisation of methods, tools ad data are issues. There are also observations showing that traditional indicators of risk may be incorrect and need a better link between cause and effect.

It is expected that improvement of industrial safety will promote the competitiveness of the European industry. Improved risk control will support the sustainable growth of the European industry. There is benefit to be expected from a co-ordinated effort in research across industry sectors. Today this is fragmented.

In order to understand and manage risks, it is necessary to stresses the functioning of a system as a whole. To understand an accident or an incident, parts and the whole should be
addressed together. Limited views imply limited set of recommendations although the whole system is involved. Many disciplines are required to decipher the various links between parts (from sociology, to human factor and psychology to politics and economy). This complexity requires multidimensional lenses. [Rasmussen ’s sociotechnical system, 1997]

Basic knowledge, methods and technologies need to be developed in:

- Understanding hazardous phenomena to develop safety solutions, equipment and technologies
- Development and validation of methods and tools to improve risk assessment and management
- Impact of natural and man-made hazards on plant safety
- Harmonisation in risk assessment
- Risk management and governance (new forms of participative governance)
- Multicriteria analysis and decision support tools
- Systemic methods to address the complexity of the industrial systems
- Uncertainties in risk assessment and management
- Reliability and safety of network systems
- Methods for dynamic reliability assessment
- Risk metrics and dynamic risk metering

1.5.2.2 Improving technologies to reduce risks at work and for major accidents

According to the internationally accepted definition, risk is the combination of probability of an occurrence of hazardous event and the severity of consequences of this event. The consequences may include fatalities, injuries or damage to health of people as well as economic losses caused by damaged machinery and installations, costs of medical treatment and absenteeism etc. The risk is a natural aspect of each type of activities of the human being, including in particular those connected with use of technologies, systems and devices, complex to such extent that people cannot predict and control all effects of their application. The risk is related in particular to different industrial activities which expose workers of industrial plants as well as the neighbourhood society and the environment to various types of hazards (physical, chemical, biological and psychosocial). Significantly higher level of risk usually occurs when new technologies, machines or production systems are being developed and implemented, thus placing workers, operators and managers in confrontation with much more complex technical systems of not fully recognised behaviour and the nature as well as probability and severity of possible unintended effects.

Thanks to the continuous development of modern technologies, it is possible to design more efficient and advanced productions systems that offer increasing functional possibilities. The development of nanotechnologies, miniaturisation in electronics and robotics, etc. enables the creation of equipments and devices with parameters and possibilities that have not so far been attainable. The rapid progress in information processing technologies gives rise to the development of new methods and tools for manufacturing control devices. The proper use of possibilities afforded by those new technologies for the development of safety systems and components can to a great extent contribute to limiting occupational risks and major accident hazards, and, as a consequence, to reducing the number of accidents at work and occupational diseases.
The fundamental principles of good engineering practice require taking account of safety principles at all stages the life cycle of industrial devices and installations. The basic methodology of risk reduction covers:

- designing systems and devices using inherently safe solutions (to produce safe directly without adding a safety layer on a production system),
- application of technical collective protection measures, such as prevention of access to hazard zones, safety functions fulfilled by control systems, limitation of the effects of hazardous and harmful agents emission,
- where residual hazards and risks cannot be controlled by technical collective protective devices, the use of additional safety measures, which include first of all administrative/organisational arrangements and application of personal protective equipment

In all the above-mentioned activities, use should be made of the newest achievements of science and technology so that these activities are carried out in the most effective way. Therefore, it is indispensable to continuously expand knowledge concerning the possibilities afforded by the development of technologies for ensuring a high level of safety in industry. This concerns both, the use of modern methods and technologies for creating new, safer industrial systems and the increase of the safety level in already existing systems regarding the prevention of accidents at work as well as for major accidents.

In order to effectively use all possibilities afforded by the technological development to increase industrial safety, it is necessary to expand and strengthen research on both the functional aspect of devices being created and the issues of ensuring the fulfilment of intended functions. In particular, the aspect of safety integrity becomes increasingly important along with the increase of production systems complexity.

The need for the continuous use of methods and technologies in the area of industrial safety was the basis for defining the scope of the Focus Group 1 research area. It covers the development of knowledge concerning the use of new methods and technologies divided into the following domains:

1. Technologies for reducing risks at source and for inherently safer design;
2. Technologies for reducing risks by collective protective systems and devices;
3. New materials, technologies and test methods for personal protective equipment (PPE);

By carrying out the research studies proposed in this part of the ETPIS Strategic Research Agenda the following objectives will be achieved:

- continuous expansion of the scientific knowledge concerning the opportunities created by new technologies for ensuring a high level of safety in industry. This concerns both, the use of advanced technologies for creating new, safer industrial systems and the increase of the safety level in already existing production systems;
to provide solutions to the European manufacturing industry that enables the industry to improve safety at work, to the society and the environment at all stages of the life cycle of industrial devices and installations;
- to support achievement of social and economic objectives of the European Union by significant decreasing the number of occupational accidents and diseases as well as major industrial accidents. As a consequence the accident-related costs of losses incurred by the society and individual enterprises will be reduced significantly.

The objectives of research studies proposed in this chapter are relevant to achieving compliance with a number of EU regulations concerning safety and health at work, prevention of major accidents and environmental protection. The most important EU directives taken into account when defining priorities of research are the following:

- Framework Directive (89/391/EEC) on the introduction of measures to encourage improvements in the safety and health of workers at work, together with a number of individual directives concerning specific aspects of safety and health, as for example: exposure to carcinogens at work (90/394/EEC), indicative limit values for workers’ exposure to chemical, physical and biological agents (91/322/EEC); chemical agents (98/24/EC, 2000/39/EC), work in explosive atmosphere (99/92/EC), biological agents (2000/54/EC), vibration (2002/44/EC), noise (2003/10/EC), electromagnetic fields (2004/40/EC) and optical radiation (draft stage - to be issued in 2006);

- new approach directives concerning safety and health requirements for products, such as personal protective equipment (89/686/EEC), equipment and protective systems intended for use in potentially explosive atmospheres (ATEX, 94/9/EC); machinery (98/37/EC), noise emission in the environment by equipment for use outdoors (2000/14/EC);

- environmental protection directives concerning requirements for integrated pollution prevention and control (IPPC, 96/61/EC) and the control of major-accident hazards involving dangerous substances (Seveso II, 96/82/EC).

The priorities of research proposed within this area are also in line with the conclusions of the forecast on emerging physical risks published in 2005 by the European Agency for Safety and Health at Work as well as conclusions of the tripartite seminar on "Promoting OSH research in the EU" held by this Agency in Bilbao, 1-2 December 2005.

Basic knowledge, methods and technologies need to be developed in:
- Technologies for inherently safer design and to reduce risks at source;
  - Technologies to reduce emissions of hazardous substances and aerosols
  - Novel and effective methods for reducing risks related to noise and vibration
  - Novel and effective methods for reducing risks related to electromagnetic hazards and optical radiations (non-laser and laser radiations)
  - Technologies and methods for inherently safer design of industrial plants and installations to reduce major-accident hazards
- Technologies for reducing risks by collective protective systems and devices;
  - Protection systems and smart sensors for machines, production and transportation processes
  - Software tools for detecting dangerous situations in industrial systems

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3 Expert forecast on emerging physical risks related to occupational safety and health, European agency for Safety and Health at Work, Bilbao, 2005.
1.5.2.3 Improving structural safety

All industrial plants, structures and vehicles often include critical structural components. Their structural integrity is essential for a safe operation while their design, fabrication routes and life-cycle assessment methodologies should provide excellent in-service efficiency, high cost effectiveness and environmental sustainability.

Improvement of the technologies for overall structural safety for infrastructures, vehicles and components enhance the industrial safety and promote the competitiveness of the European industry. Improved understanding of the in-service behaviour of existing and new multi-material (hybrid) components has paramount significance for continuation of the safety at workplace and production. Use of new materials, fabrication technologies design and assessment approaches for new and aged structures (with or without welds) require European level of RTD as well as training and education to ensure structural and plant integrity.

An increasing number of structures, plants and aircrafts etc. are expected to reach their declared Design Service Goal (DSG) during next decade. In fact in Europe, a significant part of structural components is aged and methods to assess their integrity and to extend their lifetime in safe conditions are essential for efficient management of assets and resources. Research should provide knowledge and procedural basis to justify extended limits of those aged or repaired structures regarding the susceptibility to local or global failures.

The Focus Group on “Structural Safety” aims to provide European R&D framework for the needed technology and knowledge applicable to all industrial sectors operating load-bearing structures, which require safety to be properly inbuilt in the design and fabrication processes together with structural health monitoring (SHM), fitness-for-service (FFS) to ensure the structural safety throughout their lifetime.

Research needs focus to the risk based design, inspection, FFS assessment aspects of critical components with and without welds subjected to normal service as well as accidental loadings. Hence, six major strategic domains with respective research priorities are identified to meet the societal and industrial needs for existing and emerging structures and plants, which should operate safely and economically.

Objectives

- Better reliability based design principals for safer structures and plants
- Reduction in service failures and accidents by use of fitness-for-service code
- Reduction in number and duration of inspection intervals using SHM technology
- Investigate/identify the “improved” limits of NDT performance and reliability
• Extension of life-cycle of aged & repaired structures and plants
• Designing new advanced light weight and miniaturised robotic vehicles for remote inspection
• Integration of these miniaturised robots and robotic inspection and weld repair tools into structural integrity assessment procedures
• Better assessment of structural durability of advanced welds
• Development of design and FFS guidelines for multi-material components
• Extension of FFS guidelines for structures made of new composite materials
• Improvement of life prediction on the basis of probabilistic assessment
• Full structural management against natural and accidental loads
• Enhanced structural and plant efficiency and cost optimization
• Provision of material for training and education in structural safety

These objectives are challenging and address the RTD needs also identified by other TPs such as SusChem, Construction (ECTP), Aeronautics, Steel, Advanced Materials, Road and Rail Transport. All these TPs have strong reliance to the development of European guidelines and enhancement of design and analysis principles with new knowledge gain on the Structural Safety.

To achieve above listed objectives, RTD topics are presented hereunder. They take into account the existing knowledge, identify areas and future needs in the field of structural safety.

The strategic research priorities identified for the Structural Safety in Europe are:
• Structural reliability based design
• Structural Health Monitoring (SHM) and risk-informed inspection
• Structural Safety of Aged & Repaired Structures and Life Extension
• Fitness-for-Service (FFS) of Structures
• Integrity of Multi-Material (Hybrid) Structures
• Structural Safety against Natural Hazards and Accidental loads

Figure 2 : Integrated Approach for Structural Safety
Structural Reliability Based Design
- Development of new design solutions based on reliability techniques and probabilistic codes by considering the consequences of the structural behaviour with respect to overall plant safety is needed.
- RTD is needed to enhance reliability based design principles for emerging multi-material (hybrid) components and structures.
- Development of integrated engineering damage assessment procedure and sensor systems for real-time prediction of safety margins in corporation of advanced structural reliability models and risk informed inspection techniques for structures and plants.
- Improvement of methods for equipment design by conducting RTD involving topics of; creep design rules, determination of allowable strain, limit analysis of equipments, determination of structural stresses etc.

Structural Health Monitoring (SHM) and Risk-Informed Inspection
- Development of reliable and long-life monitoring systems (NDT, wireless sensors, miniaturised robots etc.) for difficult to access & inspect critical structural locations for early detection of damages and cracks to identify and monitor without impact on service performance of the structure or plant.
- Development of SHM concepts involving cost-efficient and easy to maintain sensors for monitoring of welds and aged and repaired components. Guidance for the on-line assessment of the probability of failure (POF) based on the information on size and location of cracks need to developed.
- Development of a sensor/actuator system: Piezo-electric fibre/film acoustic emission devices as bi-functional sensor/actuator structure (adaptronic) as well as technologies like acoustic emission, guided mechanical wave propagation, topographic imaging and flexible piezoelectric fibre sensors should be improved for monitoring of non-accessible parts of structural safety relevant system (e.g. industrial piping system).
- Development of post-disaster structural health monitoring and assessment methods to evaluate the consequences with respect to structural integrity and reliability of the structures and plants.

Structural Safety of Aged & Repaired Components and Life Extension
- Development and establishment of new concepts to extend the life-cycle of the aged & repaired structures while maintaining their damage tolerance capacities with increased knowledge on the crack initiation and spread of damage at weld repairs.
- Determination of the consequences of weld repairs including distribution of residual stresses and their effects on the structural performance of welded structures.
- Development of European databases and networks to set up materials properties data compilation for aged and repaired materials (metals, welds, concrete etc.), including environmental effects to conduct effective structural integrity assessment.
- Development of advanced techniques for material sampling and characterisation on aged and repaired components. Improved understanding of the degradation mechanisms including threshold degradation rate probabilistic approaches. Use of advanced computer models to simulate material ageing and degradation phenomena.

Fitness-for-Service (FFS) of Structures
- Development and harmonisation of European guidelines related to structural safety involving damage tolerance design, fabrication support and structural assessment of in-service metallic components with or without welds.
• Further development and integration of the European FITNET FFS Procedure with data generated by Structural Health Monitoring (SHM) technology to be able to provide online damage tolerance and structural durability assessment.
• Further improvement of FITNET FFS Procedure involving various aspects of creep-fatigue interaction for defect assessment of high temperature components.
• Further development and harmonisation of European FITNET FFS Procedure for load-bearing critical components made of composite materials by taking into account of special features of the damage mechanisms of these materials.
• Development of FFS guideline on the performance of welded pressure systems after fire or explosion by taking into account of the property degradation due to temperature and high strain rate etc. To assess such severe cases, there is a need to generate European material database.

Integrity of Multi-Material (Hybrid) Components
• Develop and establish the design and fabrication principles of the hybrid (material-mix) components with respect to defect types and specific damage mechanism to be able to conduct structural integrity assessment.
• Develop and establish principles of interface or local engineering for safe design and performance of the multi-material components with improved understanding of the bi-material interface behaviour under various loading conditions. Research must provide guideline for design, inspection and maintenance of such components for safer structural performance.
• Guidance on the damage tolerance analysis route of innovative hybrid light-weight components (metal-metal, metal-composite etc.) of automobile and aircraft industries in Europe.
• Develop guidance for design and damage tolerance analysis principles for “compression after impact” in case of critical components involving reinforced composites and hybrid joints.

Structural Safety Against Natural Hazards and Accidental Situations
• Development of tools for predicting and simulation of the level of structural damage involving accidental loadings (impact, blast, fire) and natural hazards to maintain the structural safety of critical components and welded joints.
• Development of European guidelines for assessment of structural damage on components and industrial facilities due to natural hazards and accidental loads involving earthquake and fire resistant structures.
• Development of modelling concepts of critical structural components in a probabilistic fashion to prevent progressive or detrimental collapse due to fire or explosion.

1.5.2.4 Understanding the impact of human and organisational factors in risk control

Despite there are no solid statistics proofing it, in some domains, like the Process Industry one, the impact of Human & Organisational Factors (H&OF) on accidents causation is widely accepted to be around 90% of all occurrences. Such a strong influence can be most likely ascribable to the fact that in a global productive world automation, intensification and optimisation have become driving forces for industrial economic growth. This has made, on the one hand, productive systems far more efficient but, on the other hand, far more complicated to operate, leaving little or no space to humans to make erroneous actions without strongly impinging on safety.
To substantially improve safety records and minimising negative externalities of productive processes is then necessary mastering H&OF at any level of the process lifecycle, from design to decommissioning.

In the overall safety production this means providing safety analysts, (safety) managers and trainers of integrated methodological solutions that enable them to take systematically into account H&OF during their daily activity. More explicitly, it means to provide them with integrated solutions that enable them to understand, analyse and visualise the interrelations amongst the technological, the organisational-managerial and the human source of risk, both in a qualitative and quantitative fashion. Even further on this the need to move from static approaches, like the classical Hazop and Fault/Event Trees, towards dynamic ones when analysing risks, making safety-critical decisions and training people, both prospectively and retrospectively, is emerging as a must if credible and realistic “predictions”, as well as effective positive results on the safety level, are searched for.

One of the major difficulties to integrating H&OF during safety analyses, decision makings and training activities is the envisioning of all space-time interrelations amongst the aforementioned three sources of risk in a dynamic way.

At present the use of Virtual Reality (VR) tools and techniques to supporting the integration of H&OF during the performance of the so-called three safety actions, i.e., training, safety analyses (risk assessment and accident investigation), and safety management & audit, seems to be the most promising way forward.

Based on this, in the description of FG3 research activities it is assumed VR as an overarching enabler to solve H&OF issues.

![Figure 3: State of the Play in Human and Organisational Factors](image)

**Figure 3**: State of the Play in Human and Organisational Factors
Basic knowledge, methods and technologies need to be developed in:

- Human and Organisational Factors in Managerial Safety
- Factors in Organisational and Managerial Safety
- Human-Centred Design
- Integrated Risk Assessment and Management Methods & Techniques
- Human Performance & Technology Usability
- Human Factors in Emergencies and Crisis Management
- Safety and Quality: Could they be merged, do they really match?

1.5.2.5 Understanding emerging risks

Several important issues related to industrial safety are emerging. They mainly result from the evolution of the industrial context like overall integration, globalisation, advances in information technology and the necessity of improved efficiency, and also they are influenced by the demography and social evolution of the society.

Human and technological advances have created new vulnerabilities, hazards and risks. To deal with these risks necessarily requires flexible, evolutionary approaches that span all the FG’s of the TP Industrial Safety.

Therefore a dedicated FG will serve as a monitor and proposer of the emerging and cross-cutting risk & safety issues which may and/or will appear as relevant for the work of the ETPIS.

The results of the reflection carried out in this FG will give recommendation on methods and tools to be developed to tackle the emerging issues.

Basic knowledge, methods and technologies need to be developed in:

- Future Legislation, codes, standards, and their influence on industry
- New/emerging technologies
- Methodology for identification and assessment of new and emerging risks
- Networks, industrial parks and other interdependencies
- Natural hazards triggering threat to industrial safety
- Attacks on and against industrial installations (security aspects in safety of industrial plants - CBRN Risks)
- Old/aged plants and integration of risk management in to the life cycle of industrial plants

1.5.2.6 Improving education and training activities, knowledge transfer to industry and in particular SMEs

The transfer of knowledge gained from research in risk management and environmental protection is too long and scattered.

At first, an analysis of the situation of knowledge transfer from research to the industry shows that national projects seem to produce results which have an acceptable degree of implementation and their results are mostly implemented within a single member state. The European projects do not seem to have same degree of success. Moreover, industry is not
always enthusiastic – rather passive to implement the findings of the projects produced by collective research. Secondly, the structure of the industrial enterprises is quite different in the various industrial sectors and it depends if the industry is composed by groups or by small structures (SMEs). In the later case, the transfer of knowledge is very difficult because of the lack of time and resources, and also the transfer structure is not always appropriate in a given industrial sector or country.

This analysis of the situation urge to find new methods and technologies to improve the transfer of knowledge in industrial safety to the industry and especially to the SMEs. It is necessary to develop methods and tools to give safety competencies to the worker, the safety manager as well as the student in an engineering university. Promising technologies coming from Virtual reality, multimedia, knowledge management must be further investigated.

If the safety knowledge in the industry will increase thanks to more efficient methods and tools for knowledge transfer, it will help to develop a safety culture that will strongly contribute to achieve the overall objective of the ETPIS which is to reduce the number of accidents/incidents.

Basic knowledge, methods and technologies need to be developed in:
- Maintain Competence
- Open Platforms and modular systems for education and training
- Simulation – Using virtual reality

1.5.2.7 HUB NanoSafe

Industrial needs in terms of nanomaterials are increasing. Many sectors are concerned, ranging from mature high volume markets like automotive applications, high added value parts like space & aeronautic components or even emerging activities like new technologies for energy. Also are concerned domains with a planetary impact like environment and new products and functions for health and safety of people. Nanotechnologies (e.g. nanoparticles) will play a key role in promoting innovation in design and realisation of multifunctional materials for the future, either by improving usual products or creating new functions and new products.

Nevertheless, this huge evolution of the industry of materials could only happen if the main technological and economic challenges are solved with reference to the societal acceptance.

The overall objective of the HUB NANOSAFE is to develop synergies between projects dealing with the safe nanomanufacturing. This includes the development of:

- advanced detection and monitoring technologies at workplace
- secure integrated industrial processes
- a global approach all along the life cycle
- knowledge on health and environmental effects of nanoparticles

Basic knowledge, methods and technologies need to be developed in:
- Technical issues
- Societal issues
- Enabling technology development
1.5.3 A strategy that takes into account the economical context and market opportunities

The improvement of the situation regarding industrial safety is dependent on the economical context and market opportunities.

It is not realistic to rebuild a safer industry where the economic pressure doesn’t enable it. It is more relevant to analyse the situation and identify the industrial sectors where there are opportunities to design safer industrial systems and evaluate where incremental improvement can be achieved without penalising the economic activity.

Therefore, three categories of industries can be identified:

For industrial sectors where only few investments are possible
It is proposed to develop or adapt approaches and tools to proportionate the risk reducing measures to the stake related to incidents and accidents.
For that purpose, research is needed in several fields, for example:
- to assess the performance of safety equipment systems in “real conditions” use and classify them using the IEC61508 standard;
- to develop models and practical tools to accompany the enterprises when they are willing to improve safety management by dealing with the organisational aspects.

For industrial sectors where investments are still open and where processes can be improved (economical opportunity)
It is proposed to develop solutions to allow existing processes to become safer and cleaner, and eco-efficient. For example, some of the batch or semi-batch processes in particular implemented in the chemical industry can evolve in continuous process by using inherent safety concepts.
Research is still needed in several fields, for example:
- to develop a catalogue of examples to change existing hazardous processes in safer ones (this work should focus on design and operation);
- to develop adequate safety control systems and automation tools that should not increase too much the complexity of the producing system;

For industrial sectors to be designed in the future
It is proposed that industry and research centres work together to allow full safe and clean integrated design.
Research should focus on:
- development of processes that implement the principles of inherent safety and clean design for example, in the process industry it can be achieved by using new catalysts, intensification, heat exchanger reactors, spinning disc reactors, micro-reactors and membrane reactors…;
- development of automation tools adequate to inherently safer processes (micro-reactors, nano-components…);
- development of the interface between man and machines, and the adaptation of the organisational safety management to the risk potential of the industrial processes.
1.6 STRATEGIC DEPLOYMENT

The ETP IS can create a dynamic change within the industrial sector to develop research projects aiming at improving safety and environmental protection in industry.

The main drivers for improving industrial safety are:
- Industry competitiveness and sustainable growth
- Policies and regulations responding to societal expectations regarding quality of life

The research work that will be proposed in the ETPIS will have to take into account the expectation from the society as well as the needs for the industry in terms of competitiveness and sustainable growth.

Figure 4: Dynamic changes introduced by the ETPIS, involving the main stakeholders

There is an important need for this type of platform because the subject areas addressed have been tackled separately by the different industries and a common basic approach applicable across industry is still an important gap that needs to be filled with transfer of technology between industries, as well as the advancement of the individual technologies.

This Platform will deal with the development of the main methodologies, approaches and tools that are required to improve safety across the various industrial activities, leaving the specific aspects of the implementation of safety in the various industrial sectors to other Technology Platforms. It will lead Europe to the long-term objective of having a consistent approach to Industrial Safety across the various industries and European countries resulting to a significantly reduced level of accidents by 2020. This Platform will take the necessary measures to ensure the interaction with the industry specific Platforms on subjects related with safety.
2. PARTNERSHIP AND ORGANISATION OF THE TECHNOLOGY PLATFORM

2.1 GENERAL STRUCTURE

The Industrial Safety technology Platform is structured to prepare a common and integrated vision in industrial safety. The main resources, in term of participants, are devoted to the Focus Groups which will specify a thematic vision and prepare the Strategic Research Agenda in the field of industrial safety.

The organisation and the operation of the Technology Platform is described in a “Terms of Reference” document.
2.2 **FOCUS GROUPS AND HUBS**

After the workshop on 20th October 2004 in Brussels, several Focus Groups were created. Then in 2005, other FGs were added according to the needs pointed out by the scientific community including representatives from industry. These Focus Groups correspond to important issues that will enable to improve significantly the safety knowledge and practices. In the document, these safety issues are transposed in research challenges.

Now the RTD strategy is organised in 5 Focus Groups and 2 research Hub. The 5 Focus Groups are:
- Risk Assessment and Management
- Advanced Risk Reduction Technologies
- Structural safety
- Human and Organisational Factors
- Emerging risks.

![Figure 5: Research Focus Groups on ETPIS and industrial sectors for application](image)

The FGs correspond to several **research axes** that are transversal and that can be applied in various industrial sectors. They correspond to the main chapters of this document (Chapter 3 to 7).

In each axe, **domains of research** are identified and organised in several **topics**.

For each topic, several ideas of projects and actions have been expressed by the FG members and identified in the Strategic Research Agenda.
The Strategic Research Agenda is organised with the following structure:

- **Axes** (5 axes corresponding to research challenges)
- **Domain**
  - **Research Topics**
    - Short term research
    - Mid term research
    - Long term research

### 2.3 Research Hubs

Moreover, some industrial challenges are not concerning only one industrial sector, and/or should also take the knowledge and expertise from several Focus Groups. To enable the mobilisation of the critical mass and attract the interested sectors, the ETPIS has decided to create the concept of research HUB. A research HUB is a topic-based group of stakeholders aiming at both exchanging knowledge and starting projects, once they have defined a research agenda that is specific to their topic of interest.

Two research hubs are created in the ETP on Industrial Safety:

- **NANOSAFETY**: it addresses safety-related issues in the field of nano-technologies and nano-materials
- **EDUCATION AND TRAINING, TRANSFER TO INDUSTRY**: it aims at developing new technologies and methods to improve the knowledge transfer to industry, and to the engineers and scientist working in the field of safety.

![Figure 6: Cross cutting hubs on industrial safety](image)
3. RISK ASSESSMENT AND MANAGEMENT

3.1 STRATEGIC RESEARCH AGENDA IN RISK ASSESSMENT AND MANAGEMENT

Objectives:
- To evaluate and stimulate improvement in risk assessment and risk management.
  - To evaluate the state-of-the-art and identify the areas where research could improve the methodologies.
  - To contribute to Harmonised Standards, Implementation and Application in modernised European Safety and Regulatory Regimes.
  - To contribute to effective and innovative ways of managing risks

Risk does not follow industry sectorial borders. Today’s global risk perspective can be illustrated by:
- Security: affects all aspects of life
- Technology: permeates all areas in human, social and business life
- Environment: human activities affected vs. effected (e.g. climate change)
- Business: “zero tolerance”

Managing this more complex risk environment while meeting increasingly higher expectations from multiple stakeholders, will require a continued search for more efficient risk management and continued search for new ways of thinking.

Yesterday’s risk management was reactive to accidents and past failures – dealing with risk issues in a fragmented way. Today’s risk management has become more proactive and total - including financial, technological, safety, health, environmental, reputation, social and ethical risk management. A structured and integrated risk management approach is needed to ensure confidence with stakeholders as well as to enhance performance of systems considered. Creativeness and fresh thinking will be needed to address risks facing us in order to provide a sustainable future.
It is of paramount strategic importance, therefore, that the safety of any industrial activity is assured and, of equal importance, is that the public has a rational perception of the risks posed by it to the environment and to the society at large.

The awareness of this fact, together with the knowledge that the consequences of major accidents are no respecters of national boundaries, has resulted in a number of regulatory initiatives and the formation of organisations aimed at maintaining and continually improving industry safety culture and improved safety techniques. In addition, awareness of the fact that a major accident in one sector of the industry gives no market advantage to a competitor, if it leads to a general loss of confidence by the public in the industry, has recently led to a healthy openness and exchange of information regarding safety issues amongst the major industrial players. Society is also seeking to ensure that industrial risks are clearly identified and assessed, both risks of chronic and acute nature, so that necessary measures can be taken to reduce them to an acceptable level.

Many of the most respected risk assessment and risk management methodologies have originated or been developed in Europe. Examples are HAZOP, QRA. The typical flow chart for methodologies for risk assessment and risk management is shown in Figure 3.

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**Figure 7 : Framework (process) for Risk Analysis, Assessment and Management**

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However, historically there has been little formal co-ordination and the targeted resource funding has been somewhat fragmented. Safety regimes have to a great extent been formed as responses to major accidents. Figure 3 lists some examples from the maritime, offshore and chemical industries. This Figure also shows the growth in applying risk assessment based approaches to manage risks.

Figure 3: The historical development of risk based approaches. Some major accidents that formed international safety regimes (courtesy DNV)

Today the trend is moving from accident driven focus on safety through environmental concerns into an integrated approach also covering Cost, Schedule, Functionality and Quality. Safety management is more and more changing from being reactive and prescriptive to proactive and goal setting. This urges us to develop new means of networking, further improved regulations, and access to new technologies based on research.
The following preliminary needs in the research for new and improved cost-effective methodologies for risk assessment and risk management have been identified:

- approach to pre-and co-normative activities
- focus on the complexity of the system and the level of system safety (variability of the data, integration of activities)
- evaluation of the perception of the risk (safety criteria) and benefits
- risk management to be cost-effective and understood by the operators
- improvement of hazard identification (which is a sort of combination of “imagination” and systematic knowledge)

In this context it will be important to consider specific approaches for SMEs taking account of the combination of efficient production and functional safety as well as practical working procedures. This approach will prepare for a deeper involvement (including the integration of feedback loop(s)) of these kinds of companies (especially the ones belonging to the building sector) in the cost-effective and efficient risk management.

In the following more detailed elaboration is given of the following topics:

1. Understanding hazardous phenomena to develop safety solutions, equipment and technologies
2. Development and validation of methods and tools to improve risk assessment and management
3. Impact of natural and man-made hazards on plant safety
4. Harmonisation in risk assessment
5. Risk management and governance
6. Multicriteria analysis and decision support tools
7. Systemic methods to address the complexity of the industrial systems
8. Uncertainties in risk assessment and management
9. Reliability and safety of network systems
10. Methods for dynamic reliability assessment
11. Risk metrics and dynamic risk metering
12. Further topics to be investigated

### 3.1.1 Understanding hazardous phenomena to develop safety solutions, equipment and technologies

#### 3.1.1.1 Fire Safety Engineer

The vast majority of fire safety regulations are prescriptive in nature, relying on specifications written into regulations. Nevertheless, Fire Safety Engineering (FSE) is a discipline increasingly being used throughout the world in support of performance-based national fire safety regulations. The outcome is that currently various engineering approaches are being introduced into prescriptive design and FSE is becoming a way to supplement prescriptive design by being applied in a performance-based analysis to specific design aspects of a project to reach performance objectives.

FSE relies on an operational, performance-based methodology for engineers to assess the level of fire safety for new or existing built environments. Fire safety is achieved through an
engineered approach based on the quantification of the behaviour of fire and people and based on knowledge of the consequences of such behaviour on:

- life safety
- the conservation of property
- continuity of business operations
- protection of environment
- preservation of heritage;
- cost related issues/aspects.

**Long term research**

The objective is to build a general method for the application of Fire Safety Engineering principles in the case of industrial environment and warehouse building which is based on a scientific appreciation of the fire phenomena, of the effects of fire, and of the reaction and behaviour of people, in order to:

- quantify the hazards and risk of fire and its effects,
- evaluate analytically the optimum protective and preventive measures (including the use of different flame retardants) necessary to limit, within prescribed levels, the consequence of fire on structure and human life.

To reach this objective many points have to be performed such as:

- general methodology of FSE in industrial environment,
- knowledge on fire ignition and fire growth,
- knowledge on propagation,
- structure behaviour,
- human behaviour
- environment protection;
- role of different chemical substances as flame retardants

Particular focus should be given to:

- Behaviour of fires in tunnels and impact of mist and water sprays
- Propagation of fire in the storage of solid material on racks, influence of water spray and the role of flame retardants

**3.1.1.2 Simulation and analysis of dangerous events: dynamics of their evolution and evaluation of the impact areas**

A deeper understanding of dangerous phenomena, such as explosions and fires, is of fundamental importance for a safer industrial engineering in all its phases, from basic design, to plant layout and to protection systems design. Under this respect, the need for a more detailed knowledge of the dynamics of dangerous phenomena (e.g. the onset of BLEVEs), and of the subsequent impact areas (with specific reference to fires, such as Pool fires and Jet fires), is apparent. This would be of great help both in the prevention of their occurrence and in the mitigation of their consequences.

**Short term research**

Numerical simulation can be of great help, both in providing a more theoretical understanding of these phenomena, and in overcoming the difficulties encountered in setting up experimental installations.
3.1.1.3 Dispersion of hazardous material in industrial environment

In the risk assessment field integral plume models and heavy gas dispersion models are those most widely and frequently used. In order to calculate toxic load in the far field these models simulate mechanisms of passive dispersion by 25-year old research. These first gaussian generation models have been based on experimental data and concentration measurement at downwind distances less than 1 km. Now research in atmospheric dispersion has progressed substantially, thus rendering theses models outdated.

Short term research
Next-generation models have been developed to take into account the atmospheric turbulence in a better way. These models have been mainly tested and validated in the field of air quality but applications and validations to accidental toxic cases have to be performed. Moreover most measurements in the experimental data are in the percentage region (> 1000 PPM) and very few data sets could be found in the low PPM region (region of some toxic threshold).

There is a need to adapt and validate new meteorology and turbulence approach modelling in order to improve toxic concentration calculation in the far field.

There is also need for more research on outflow, pool formation, evaporation, dispersion, etc. of two-phase / liquefied substances like LNG, LPG. Specific topics are outflow on water and shift from “dense gas” dispersion to “neutral” dispersion.

3.1.1.4 Explosion of gas, vapour and dust

Evolutions of scientific knowledge about the hazardous processes are required both to help formalisation and inclusion at the QRA stage but also, and may be even more at the stage of the design of « safe » processes.

To this aim, several steps forwards seem required concerning the explosive phenomena:

Explosive properties : only standard data are available which are not always covering all the mechanisms and very often need to be extrapolated to conditions very different from the lab. Experiments have demonstrated the difficulty to do that and the need to develop specific « extrapolation » tools dealing with thermochemistry, heat losses, etc..

Ignition aspects : Much as been done up to now but there is still a big gap between the practical source and the quantification of their efficiency. For instance, the susceptibility of ignition by spark is done in a tube with a punctual electrical spark which is different on all aspects from electrostatic discharges. A accurate assessment is still far away but achievable thanks to a physical analysis of ignition sources on one end and a study of practical sources on the other end.

Explosion development : a number of difficult questions are still opened such as the interaction of the flame with its environment including the shape of the confinement and the obstacles in view of refining the practical prediction tools like the multi energy method or more sophisticated codes. We have to be aware that two phase combustion aspects are still poorly understood like in hybrids (air+vapour+particles) or in droplet-air clouds (as in BLEVEs) and modelling is still largely outstanding.
**Explosion consequences**: concerning disruption of equipment, missiles effects, external overpressure field and sometimes flame ball. The behaviour of structures against explosion effects is dealt with in another paragraph. The external pressure field is a very important piece for major hazards. Unfortunately, current methods for calculating blast effects are usually based on an analogy with explosive (TNT) or on numerical simulations in idealised situations. Several applications to real explosions (like for AZF, Toulouse, 2001) have shown that the pressure field deduced from such methods may be very unprecise. The models assume a sudden disappearance of the walls, simplify the diffraction by obstacles and ignore any incidence of the atmospheric conditions. These points need to be further investigated. In a coherent way, the impulse transmitted to the projectiles needs to be estimated to foresee the trajectories and impact conditions. The last point concerns the heat fluxes. There are transients in explosion but the peak fluxes may be much above those for fires (by a factor of 3 to 10) so that if the flame is large enough a danger may arise. This is particularly true for BLEVEs or explosions of large unconfined gas pockets. It appears that this field has been only very little studied.

3.1.1.5 Protection systems design: multiphase flow in pressure safety devices.

Pressure relief devices (valves and rupture disks) represent one of the most important types of safety systems used for facing emergency situations. Their proper sizing is of fundamental importance both for the integrity of the equipment and for protecting the surrounding population and installations from the possible dangerous consequences of an accident. Sizing methods and equations for single phase flow (gas or liquid) are well established since many years, whereas, for two-phase flow, even if different methods of calculation have been proposed, none of them is presently considered sufficiently reliable to be adopted with a good level of confidence.

*Short term research*

As a consequence, further work in the evaluation and assessment of the proposed models and in the definition of a more accurate procedure are strongly required for a more reliable design of these very important protection systems.

3.1.1.6 Dam failure hazard

Dams are a vital and a critical part of Europe’s infrastructure, providing extraordinary benefits to society, such as: renewable hydroelectric power; drinking water; flood protection; irrigation and recreation, but also represent a public safety issue, as dam failures can result in severe loss of life, economic disaster and extensive environmental damage. Considering that most dams have been designed for an effective life of 50 years, and, as in many other countries, the majority of dams in Europe are quickly approaching this age, rehabilitation of these structures should become a major concern. Moreover, most dam safety programs are typically under-budgeted and under-staffed, in particular, as far as research and innovation are concerned. As a term of reference, which can be somehow compared to the European situation, in USA (~ same number of large dams as in Europe) 1800 dams have been officially assessed as "unsafe", while 9300 as “high hazard” dams, as a consequence of a chronic lack of suitable funding for dam maintenance and for dam safety engineering innovation. On such bases, a special committee of the Association of State Dam Safety Officials (ASDSO) concluded that the cost of upgrading or repairing all US non-federal dams in need of repair would exceed $36 billion. They also highlighted that if proper research and
innovation programs were promptly implemented, they would have been helpful in preventing or reducing the upgrading and repair needs. Coming back to Europe, the situation might be even worse, in particular considering that politics, technical regulations, and social perception of dam safety issues are in general non-homogeneous and often diverging and that European population density is considerably higher than in USA. Since safety activities usually do not provide short-term benefits and no or little funding support is provided at national level, dam owners/responsible naturally tend to curb spending for dam safety programs. So, proper dam safety policy must be provided, driven, and supported at a European level.

Mid term research
A strong support is needed for the development and the validation of:
- risk analysis/assessment/management tools
- monitoring and experimental diagnostic techniques
- models for numerical simulation of dam/reservoir/foundation system
- loads and system uncertainties modelling
- costs/benefits analysis tools
- European dam safety guidelines

3.1.1.7 Global Harmonised System (GHS)
When dealing with the properties of the substances, their classification, the determination of toxicology thresholds, etc., note there is a coming implementation of the Global Harmonised System (GHS) with potential impacts on Seveso II. More classified substances and mixtures may trigger the lower- or upper-tier requirements. Upper tier requirements: Safety Management System, Safety Report, Internal Emergency Plan, Involving the Public. Lower tier requirements: General obligations, Major Accident Prevention Policy, Preparation and Follow-up of Modifications, Controls / Inspection by Authorities.

Short term research
Development of procedures and methods to assess the emerging risks during the development and design of new technologies, processes, products and services. Help with Guides & Training Needed

3.1.2 Development and validation of methods and tools to improve risk assessment and management

3.1.2.1 Advanced probabilistic methods for complex socio-technical systems risk analysis

Current and traditional risk analysis or RAMS probabilistic methods have to be improved in order to address the systems increasing complexity.

Short term research
- Development of risk analysis methods allowing to integrate in an assessment model several kinds of risks that are related to a system (environmental, technological, financial...), several risk factors that can be correlated. It is necessary to develop appropriate methods in order to model and assess technical as well as human or organisational countermeasures.
- Development of methods for programmable systems probabilistic assessment. Such systems are more and more integrated in industrial safety systems, and there is a need
to develop appropriate methods to assess impact of programmable systems on system safety.

3.1.2.2 Methods and guidelines for outcome case selection in the framework of Risk Analysis methodology

A fundamental step in a complete Risk Assessment procedure is the identification of all the possible accidents which can develop in an industrial installation. To this aim, different methodologies have been proposed over the years (Hazop, FMEA, etc.), which presently reached a good level of confidence and are widely adopted in many applications.

However, each single accident can give rise to many different final events (so called outcome cases), depending on many parameters affecting its evolution (weather conditions, release conditions, and so on). In order to quantify the risk associated to a given installation/equipment/piece of equipment, all the identified cases have to be evaluated in terms of impact areas and frequency of occurrence. This is very time consuming, and it not always leads to a more accurate quantification of the risk. As a consequence, a selection phase of the cases is required.

Mid term research
Up to now, no definite methodologies have been proposed and the selection mainly rests on the discretion of the analyst. Based on that, it is clear that more effective and widely recognised methodologies for the selection of outcome cases are urgently needed.

3.1.2.3 Uncertainty quantification

As the stakes of being wrong may be high, confidence in assessing uncertainty is of utmost importance. Predictions, without taking into account information on the uncertainty in the underlying statistical data, are meaningless. At present, there exist methods to represent, aggregate, and propagate different types of uncertainty through reliability models, and they are primarily discussed at the level of scientific community. Few of them are occasionally applied, and none has become widely accessible and practicable. The complexity of the existing methods does not allow adopting and using them in a way that is proportionate and cost-effective. Inconsistency and heterogeneity of the existing approaches to safety across European Industries and Countries aggravate the problem of “easy” uncertainty quantification. This domain for research will aim at developing a practicable tool kit for structured uncertainty quantification fulfilling the needs of different industrial sectors and the size of establishments while bringing in consistency throughout.

Mid term research
The research should focus on

- Adoption and adjustment of the existing uncertainty quantification methods
- Structured expert judgement procedures for uncertainty quantification
- Methods of propagating uncertainty through reliability models
3.1.2.4 Evaluation of the effectiveness of countermeasures

There are a great number of theoretical models describing safety aspects. The interviews and discussions performed in the frame of studies about Safety Barriers and Safety Functions pointed at a further need for better and cost-effective modelling of safety aspects. This should be transformed into suitable tools. A preliminary conclusion is that such a development would require a combined effort from people in different traditions such as human factors, probabilistic analysis, and a general system safety approach.

**Short term research**

The research should focus primary focus on the development of tools able to
- provide an overview of the complex systems that people managing risk have to deal with;
- simulate the defined countermeasure in order to assess their impact (including also virtual reality, three dimensional plant models etc.);
- to support the decision making process (focusing on the link between the risk assessment phase and the risk management one).

The research should also provide methods to assess the effectiveness of Human & Organisational countermeasures.

**Mid term research**

As well the research should support easy ways to be able to set up flexible, reliable and reproducible real scenario to be able to test the effectiveness of countermeasures through experiments in real condition of use to evaluate the risk and its mitigation.

This has to be done through a breakthrough approach, and effective methods for proposing possible small scale scenarios have to be defined within this research domain, being not possible to evaluate the mitigation of risk, for instance, through full scale fire or toxicology tests.

3.1.2.5 Cost benefit analysis

The Technology Platform on Industrial Safety should also include a specific domain on the improvement of qualitative and quantitative cost-benefit analysis which can be a strong leverage for the industry and can contribute to a wider diffusion of a culture on safety and on risk perception, even if a benefit is something that is not easily to be quantified.

Risk involves loss and gain which must be weighed and balanced. This approach leads to the application of performance-based solutions rather than prescriptive requirements.

Cost-benefit analysis is not about putting a value on human life, but on cost-prioritisation of risk mitigation measures.

**Mid term research**

The research in the Technology Platform should therefore focus on the development and validation of methods and tools for
- cost-benefit analysis at company, national, European and international level
• the assessment of economic impact of new organisational and technical solutions in OSH area
• socio-economic analyses linked with micro-and macro-economic data (to evaluate the overall economical aspects of safety improvement).

Long term research
This research area should lead to the design, development, and validation of new comprehensive tools to support managerial decisions (including computer-aided OSH information systems supporting management decisions, development of management games supporting decisions concerning safety and health in companies, etc.)

3.1.2.6 Assessment and management of risks arising from harmful agents in working and living environment

This is an area not fully developed, but where outcome can be very important for the all citizens (European and not European).
Current methodologies in fact have not produced sufficient information about the effects of the majority of existing harmful agents on human health and the environment. The identification and assessment of risks (covering the hazard of a substance as well as exposure of humans and the environment to it) have proved to be slow, as have been the subsequent introduction of risk management measures. The current system has hampered research and innovation, causing the EU chemicals industry to lag behind its counterparts in the US and Japan in this regard.

Short term research
Therefore specific research key topics should focus on:
• Development and validation of methods and tools for assessment and management of risks arising from chemical (including, in particular, fertilisers), biological agents and from electromagnetic hazards
• Assessment and management of risks arising from dangerous agents in new technologies (e.g.: production of nanomaterials, ecological products, genetic engineering products)

Mid term research
• New methods for assessment of exposure to chemical substances (e.g. to persistent organic pollution)
• Models and methods for assessment of exposure to dangerous substances in working and living environment, including assessment of complex effects of exposure to chemical agents
• Assessment of exposure to nanoparticles in working and living environment
• Dermal exposure in industry, agriculture and health care activity

Long term research
• Developing and validating low cost systems for monitoring chemical risks in SMEs.
• Development and validation of methods for prediction of consequences of technological changes for EMF exposure level of people living in urban areas
• Development and validation of methods and tools for assessment and management of risks connected with simultaneous exposure to different harmful agents in working and living environment (like simultaneous exposure of workers to noise, hand-arm
and whole-body vibrations or simultaneous exposure to physical and chemical agents)
- Development and validation of sector-specific methods and tools for assessment and management of risks (e.g. assessment and management of risks in construction, in education, in health and social welfare)
- Design of new data sharing systems.

3.1.2.7 Guidelines and methods for risk assessment in the transportation of hazardous materials

Risk assessment for the transportation of hazardous materials entirely derives from the well-known Quantitative Risk Analysis (QRA) techniques. However, in the case of transportation, a much larger amount of information (weather conditions, release modalities, accident frequencies, territorial information, population distribution, and so on) is required to carry out the calculations, due to the fact that the risk source is moving in a continuously changing environment. This will prevent a wider diffusion of this technique, irrespectively of the appreciation that the associated risk may be comparable with that of fixed installations and that large portions of population can be interested by the corresponding hazard.

**Mid term research**
Based on that, new efforts are required for the definition of specific guidelines and methodologies and, above all, of effective tools devoted to the quantification and assessment of the risk associated to transportation activities involving hazardous substances (toxic, flammable, unstable/reactive). Furthermore, such tools should also be sufficiently, easy-to-use, so that even non-expert personnel can be able to use them in their everyday activity.

3.1.3 Impact of natural and man-made hazards on plant safety

3.1.3.1 Constructive Measures to reduce vulnerability

**Short term research**
Development of guidelines for performance based structural design of industrial facilities for man-made and natural hazards.

**Mid term research**
Development of simple and easy to handle seismic retrofit strategies for existing non-ductile structures and facilities
Development of unobtrusive and aesthetic protection structures against man-made hazards (e.g. impact, blast, fire).

**Long term research**
Development and application of innovative construction methods (e.g. base isolation)
According to specific risk profiles development of post-disaster strategies
- Facilities for man-made and natural hazard.
- Development of simple and easy to handle seismic retrofit strategies for existing non-ductile structures and facilities
• Development of unobtrusive and aesthetic protection structures against man-made hazards (e.g. impact, blast, fire).
• Development and application of innovative construction methods (e.g. base isolation)
• According to specific risk profiles development of post-disaster strategies

Link with ECTP Strategic Research Agenda is established.

3.1.4 Harmonisation in risk assessment

Technological risks are assessed and dealt with differently in different applications (industries) and in different circumstances (regulatory regimes). Decision makers are, therefore confronted with a variety of approaches, methodologies and forms to evaluate and present a specific risk, a fact that makes the comparison of risk studies performed by different analysts or for different end users a difficult task. Non uniformity in methods, cost-benefit analyses, data and applications have significantly hampered the widespread use of risk assessment for decision making purposes.

Differences in the current approaches to risk assessment across different industries and countries mainly come from:

• the extent to which the sequence of the risk assessment process is taken into account
• the explicit or implicit use of the basic risk criteria, probability of occurrence and extent of damage, in some of the process steps (expressed in quantitative, semi.quantitative or qualitative terms and impacts at micro-and macro-economic scale).

The methodological differences have arisen for historical reasons and because the different approaches have developed independently. This is much more important than differences in technology or the nature of the problems and there seems to be no reason in principle why different industries or different countries should not use the same general approach.

The main problem that arises due to these different risk assessment approaches is not so much of compliance, but of transnational operations. For example, companies with sites in different European countries have to adapt their internal safety policies and take care to avoid misunderstandings with different national authorities. Using harmonised procedures, risk assessment would be more cost-effective and would significantly increase understanding of decisions made in other countries or other domains of activities. This would promote a transparent decision making process in which all stakeholders can more easily be involved and thus increase public acceptance of technological risks. Currently, no such widely accepted standard that could be used exists.

The first step should be to try to harmonise the basic approach and definitions in the field of risk assessment to a relevant international standard. It should be a good step for better understanding and co-operation between different industries/fields of application. It is recommended that such efforts should relate to the International Standard that is under development by ISO Technical Management Board’s Working Group on Risk Management (ISO/TMB/WG Risk Management). They are presently developing a top level generic guidance document. It is aimed to provide support to existing and proposed standards and standard-like publications providing terminology, requirements, guidelines and tools related to risk management, risk analysis or risk assessment covering specific industries or activities.
Its purpose is to promote and facilitate harmonisation rather than be seen as replacing existing standards. Figure 5 illustrates the relation between this generic guidance document and other existing normative references.

![Diagram showing the relation between generic guidance document and other normative references.](image)

**Figure 8: Normative risk reference documents**

We need Harmonised Standards, Implementation and Application in modernised European Safety and Regulatory Regimes. These should be:
- Cost effective (Clear criteria, clear process, clear roles, good preparations)
- Consistent (Company to company, country to country, time to time)
- Transparent (Repeatable, logical, easy to understand)
- Complete and accurate

3.1.4.1 Identification of Hazards

Hazard identification is essential (it is in fact the initial phase of each risk analysis). Important elements to support this identification are the imagination and the knowledge. The completeness of the hazard identification phase determines the completeness of a risk assessment.

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Mid term research
A systematic approach has to be researched in this domain to try to develop methods and tools to support and to combine these two “philosophies”, assuring a standardised categorisation and definition of hazards.

This topic should include the development of methods and tools to better understand the risk related to the industrial and the living environment, technologies and methods for identification and monitoring risks in changing global working environment, such as the:

- Development and validation of cost-effective and efficient monitoring systems
- Development and validation of indicators and tools for monitoring working and living environment Intelligent systems for detection and monitoring of safety related parameters of work environment
- Development and validation of methods for identification of new risks in working and living environment.
- Developing and validation of computers tools for modelling and simulation of hazards in industrial systems including cost-effectiveness issues
- Modelling and computer simulation of events in urban areas (epidemic spreading, failures industrial installations and electro-energetic networks) including validation and cost-effectiveness issues.

3.1.4.2 Integration of methods from other areas
Risk assessment and risk management methodologies have to be integrated with research developed in other areas, not being this an isolated domain but strongly related with the others.

Short term research
Particular focus should be given to human factors.

Human error, in fact, accounts for an alarming rate of failures throughout a broad range of industries world-wide. Some industries have attempted to quantify the number of errors ultimately attributable to human faults. In many industries, such as aviation, chemical, maritime, and various other process related fields, an astounding 80 to 90% of accidents are believed to be a result of human error.

With high failure rates and the fact that the results of human error can result in enormously costly failures, including the loss of life, the need for human error analysis and safety assessment is crucial.

Methodologies for analysing human error have to be better developed, improved and validated.

3.1.4.3 Development of Tolerability Doctrine for Societal Risk Criteria
Approach to safety differs considerably across the EU. While on one side there is a basic recognition that “zero risk” is not attainable and that the real aim must always be to identify, control and reduce risk, on the other side, as a sharp contrast, there is still a belief that application of good practice embodied in design and other standards removes risk. Between
the two extremes there are several variations, the simplest one being that as long as risk is lower that a prescribed threshold, it is acceptable, and even that the regulator can accept developments up to that prescribed limit. This situation is obviously reflected in the risk acceptance criteria and the safety legislation.

An attempt has been made in Saferelnet Project to review different criteria across the EU and to try to minimise the differences between the variety of safety approaches in order to develop risk acceptance criteria with the potential to converge to a unified set. The second aim was to develop societal risk criteria completely consistent with the legally applied individual risk criteria. The main reason behind this task was the fact that the anchor points for the criteria in the UK (100, 10^-4), The Netherlands (10, 10^-5) and Hong Kong (10, 10^-4) were mainly based on professional judgement or historical decisions about major hazards. While linking societal risk criteria to individual risk criteria, an interesting aspect of the number of exposed people (in Seveso 2 sense) to whom criteria apply came up. This indicated that, to get the consistent societal risk criteria, one would need to specify the number of people such criteria apply to. Such “consistent” criteria are readily applicable to situations where personnel are exposed to similar levels of hazard, like on an offshore platform. The difficulty arises with population living around hazardous sites; land used planning recognised three regions of hazard (around the facility, middle and outer region) and specifies type and density of usage. However, more research is needed to include the density of people living in vicinity to major hazards site into the societal risk criteria, i.e. to solve the problem from the philosophical point of view.

Short term research
Develop risk tolerability doctrine for the societal risk criteria. This tolerability doctrine should have the following features:
1. Be applicable to population living in the vicinity and away from the hazard source,
2. Be linked to the legally binding individual risk criteria,
3. Be flexible in the sense that the upper and lower boundary should encompass most if not all industrial activities and should be used for orientation and not necessarily for controlling the risk,
4. Have a dynamic factor for controlling the risk, for example like ALARP,
5. Have an acceleration factor (for example, a kind of the precautionary principle) requiring greater urgency in reducing a high risk than a relatively low one.

Mid term research
Finalise the societal risk criteria and develop the following two versions:
1. Compliant to goal-setting approach to safety and risk reduction, preferred in the UK and by industry leaders, and
2. Prescriptive approach to risk reduction preferred in some EU countries and smaller companies.

3.1.4.4 Demonstration that Risks are As Low As Reasonably Practicable

A central purpose of a safety report (safety case, safety assurance document) is the examination of the adequacy of existing safety measures for avoidance, prevention, control and mitigation of major accidents. Such an examination entails considerations of potential further safety measures that could, on grounds of safety, be put in place. This consideration should be consistent with a precautionary principle adopted by EU countries and the ALARP
principle (requiring risks to be As Low As Reasonably Practicable) which is gaining in popularity across the EU.

Recent review of the safety reports in the context of Seveso 2 carried out by European Process Safety Centre (EPSC) has identified significant variations between different EU countries. For example, the effort required producing the safety report varied from 7.5 man-months to 50 man-months, with the inevitable variation in quality. On the other hand, the UK experience since the introduction of the safety case/report regime points to the following issues and areas for improvement:

1. Safety case/report is not being used in day to day business; in many cases it sit on a shelf only to be “dusted down” for re-submission.
2. Safety case/report acceptance (or re-acceptance) is the key objective, and continuous improvement in health and safety is becoming a secondary issue.
3. Little evidence could be found in the safety reports of higher-level Human Factors (HF) considerations, for example end-user or HF practitioner involvement in procurement and design. No evidence could be found of embedding HF into organisational process, for example, structured in-service feedback for development of usability, reliability and safety.
4. The demonstration of safety assurance in many cases seems to be lost in numerical estimates of risk and is considered as an add-on to the numerical process instead of being applied from the description of the facility, good practice, through to hazard identification and demonstration of sufficient safety barriers, etc. Quantitative risk analysis is sometimes misused in this process.

Short term research
Development of a template for safety report/case preparation that would be valid across the EU and would also streamline the effort required. The main aims of such a template should be as follows:

- To enforce the approach based on “what more can be done to improve safety”, instead of focusing on the numbers game;
- To facilitate a full involvement and understanding of risk analysis by all stakeholders (management, workforce, contractors, etc.) in order to avoid complacency;
- To contribute to strong workforce involvement in hazard management;
- To constitute the basis for comprehensive demonstration of safety assurance and inclusion of human, organisational and management factors;
- To make accountability and responsibility visible and well defined;
- It would be part of the Safety Management System (SMS) and it would facilitate day-to-day usage of the SMS;
- To improve the quality of safety assurance demonstration and streamline safety report/case preparation;

Mid term research
- To apply the template to several leading companies in petro-chemical industry in order to pick up the best practice for the management of safety.
- To apply the template to several different industries and countries across EU.
To organise and carry out workshops across the EU in order to facilitate the application and use on the new approach to safety assurance.

3.1.5 Risk management and governance

3.1.5.1 Common language

One of the key factors is the conflict about transparency and the involvement of the different social actors in decision-making.

Any new approach to risk management must, therefore, not be based on the belief that a description of the risk situation via scientific/technical models and methods alone will enable the building of trust in certain technologies and their acceptance.

A participatory approach to risk management would involve all stakeholders early on in the process of characterising and assessing risks rather than presenting a complete finalised solution to them, and would thus truly integrate the risk assessment phase with the risk management one. The success of such an approach mainly depends on its ability to respond to the needs of all stakeholders.

Participatory approaches to risk management do not diminish the role of scientific assessments but are aimed at eliciting the values of the community involved and, thus, at avoiding facts being generated that have no value. From this perspective, present day conflicts and controversies surrounding technological risks do not appear any more to be due to public irrationality or ignorance but, instead, might be seen as a side effect of a participatory democratic society, amplified by recent technological and societal changes.

Mid term research
This research domain should focus on the creation of large database, on the implementation of tools for data sharing, on collection of information etc.

3.1.5.2 Standardising design concepts of reliability databases

Harmonisation of the results of risk analyses across Europe and industries and ability to carry out consistent uncertainty quantification are heavily dependent on the way failure data are collected. As each industrial sector administrates its own collection of failure data, with their own underlying methodologies and targets, and as these databases serve different types of users (maintenance engineers, component designers and risk/reliability analysts), harmonisation of the results of risk analyses can hardly be attained. This domain for research will aim at providing a well-defined methodology for reliability databases, and demonstration its consistency with risk assessments and uncertainty quantification.

Long term research
The research should focus on development of standard design concepts of reliability databases across industries for

- Failures of continuously operating components
- Demand-related failures.
3.1.5.3 Risk Perception

Experience over recent decades has shown that a risk communication strategy needs to focus on understanding how the public perceives risk, how the media translate information received from scientists or public policy-makers, and how representatives of the public and private sector can better relate risk information over a wide range of disciplines. Intensive industrial development, especially of the chemical industry, has often required the communication of technological risk. In democratic societies, decision-making processes have increasingly involved the public as legitimate partners, often creating a 'risk' that the communication would be driven by non-experts. In addition, the implementation of the right-to-know principle now enshrined in many national and international laws and regulations has meant that many assessment procedures now include public participation. This evolution created a need for a systematic approach to risk communication in public policy implementation.

Risk management has to be better understood by the operators. In contrast to risk assessment, in fact, risk management is largely based on politics (response to perceptions) rather than on science (response to facts), and the conflicts and controversies surrounding risk often come from ignoring the fundamental distinction between facts and values. This is especially true at the (inter)national regulatory (and not so much at the company) level and where it concerns the process of risk target setting (and not so much the setting of measures for risk reduction and control).

Risk management significantly differs across industries and countries, mainly as a result of the different perceptions, attitudes and values towards specific risks in different social contexts, which, in turn, also determine the scope and definition of the process steps in the preceding risk assessment phase, resulting in the above mentioned differences in risk assessment methodologies.

As risk perception research has shown, besides the mere facts-based risk criteria, i.e. probability of occurrence and extent of damage, more value-based criteria used to characterise risks are of relevance to characterise and catch the multiple dimensions of risk. Too many times, risk assessment has been considered unsatisfactory by the community affected, which attributed different values to dimensions not assumed in the facts-based analysis. The facts-based risk characteristics of a technology in question cannot be considered in isolation from the human, managerial and material circumstances of its application.

**Short term research**
From the combinations of more facts, and more value-based criteria, different risk classes can be deduced, for which specific risk management strategies have then to be developed. Risk-based decision making is, thus, both a scientific and a social activity and, as such, is concerned with the production of knowledge and a shared understanding of reality.

The operators must be able to operate these tools and take ownership and understand. There is a strong need of easy-to-use tools and models to be available to the users (such as simulators).
A specific topic has to be addressed to the SME sector. In this sector, in fact, the approach should not be too complex for such sectors. Several incidents in Europe recently have occurred by SME’s which are not covered by the Seveso directive.

3.1.5.4 Regulatory Framework

There is still a great variability in risk estimation. It should be

- consistent from company to company, country to country, time to time;
- transparent (repeatable, logical, easy to understand);
- a continuity for occupational safety and for industrial risks (consistent requirements from regulatory framework although it is scattered at the moment)
- complete and accurate.

*Short term research*

This target can be achieved through an harmonisation process, focusing on best practices, as previously presented, but also through a regulation process that has to achieve common standards within compatible rules

3.1.5.5 Inclusive risk management, knowledge-based and comprehensive management

Safety report or safety case regimes in most cases require the safety management system to be established. The purpose of the safety management system is to facilitate management of the hazardous plant, to ensure that evaluated risks stay below the tolerable / acceptable level, to aim for safety improvements, etc. However, the following shortcomings have been identified in practice:

- Safety management system can become paper exercises and sterile documentation full of procedures, which can lead to a) complacency, b) erosion of good practice due to time-consuming procedures of paper work, c) misplaced confidence due to absence of accidents, etc.
- Amount of information transfer from hazard identification and risk analysis through to the safety management system is insufficient. Risk analysis is poorly understood by the workforce and is not being used in day to day business.
- Hazard management in most cases deals with process failures and not with the failures of the management and organisation of the plant; hence human, management and organisational factors analysis is rarely incorporated into the safety management system.

Safety management system should primarily be for the duty holder to assure itself that its operations are safe, and demonstrating this to the Regulator is only secondary matter.

*Short term research*

Therefore there is a need to remedy the above shortcomings and to streamline and energise the safety management system. The effort should focus on linking risk analysis to personnel day-to-day tasks, incorporating human, management and organisational failures into this system, and streamlining the safety management system so that it can better focus on the demonstration that risks are as low as reasonably practicable and that sufficient safety has been incorporated in the design and operation of the facility.
3.1.5.6 Safety Report Approach

A central purpose of a safety report (safety case, safety assurance) is the examination of the adequacy of existing safety measures for avoidance, prevention, control and mitigation of major accidents. Such an examination entails considerations of potential further safety measures that could, on grounds of safety, be put in place. This consideration should be consistent with a precautionary principle adopted by EU countries.

Recent review of the safety reports in the context of Seveso 2 carried out by European Process Safety Centre (EPSC) has identified significant variations between different EU countries. For example, the effort required producing the safety report varied from 7.5 man-months to 50 man-months, with the inevitable variation in quality. On the other hand, the UK experience since the introduction of the safety report regime points to the following issues and areas for improvement:

- Safety reports are not being used in day to day business; in many cases they sit on a shelf only to be “dusted down” for re-submission.
- Safety report acceptance (or re-acceptance) is the key objective, and continuous improvement in health and safety together with their associated costs is becoming a secondary issue.
- Little evidence could be found in the safety reports of higher-level Human Factors (HF) considerations, for example end-user or HF practitioner involvement in procurement and design. No evidence could be found of embedding HF into organisational process, for example, structured in-service feedback for development of usability, reliability and safety.
- The demonstration of safety assurance in many cases seems to be lost in numerical estimates of risk and is considered as an add-on to the numerical process instead of being applied from the description of the facility, good practice, through to hazard identification and demonstration of sufficient safety barriers, etc. Quantitative risk analysis is sometimes misused in this process.

**Short term research**

Therefore there is a need to remedy the above shortcomings and to develop a template for safety report preparation that would be valid across the EU and would also streamline the effort required. The main benefits of this template would be as follows:

- It will constitute a template for comprehensive demonstration of safety assurance and inclusion of human, organisational and management factors;
- It will enforce the approach based on “what more can be done to improve safety”, instead of focusing on the numbers game;
- It would facilitate a full involvement and understanding of risk-benefit analysis by all stakeholders (management, workforce, contractors, etc.) in order to avoid complacency;
- It would raise the awareness of the workforce to safety issues;
- Accountability and responsibility will be visible and well defined;
- It would lead to an efficient and safety management system fully integrated with the risk model and associated cost-effectiveness models;
- It would facilitate day-to-day usage of the safety management system;
- Better understanding of the hazards and the corresponding barriers will reduce human and organisational errors during operations or maintenance;
• It will help the industries to improve the quality of safety assurance demonstration and streamline safety case preparation;
• It will contribute to strong workforce involvement in a cost-effective hazard management.

3.1.5.7 Emergency Evacuation

Emergency evacuation from hazardous facilities (offshore platforms, large refineries, etc) has been modelled in risk analysis using data from emergency response exercises, human factors, network type computer programs, etc. What is absent in all existing models is autonomous decision-making by personnel. So called “agent-based modelling” (ABM) which is gaining popularity offers improvement in this area. In this approach each agent individually assess the situation and makes decision on the basis of set rules. Agents may execute various behaviours appropriate for the system they represent. Even a simple agent-based model can exhibit complex behavioural patterns and provide valuable information about the dynamics of the real-world system that it emulates.

**Short term research**
Develop an agent-based model of evacuation in emergency or chaotic situations with the dynamic development of scenarios (e.g. exits impassable after certain time, etc), and link individual behaviour and decision-making to observed behaviour of real people in emergencies.

**Mid term research**
Improve individual decision-making behaviour by inclusion of human and organisational factors and run the previously developed model. Apply the model to real-life evacuation scenarios. The focus at this stage is to capture emerging phenomena during emergency evacuation.

3.1.5.8 Energising Safety Management System

Safety report or safety case regimes in most cases require the safety management system (SMS) to be established. The purpose of the safety management system is to facilitate management of the hazardous plant, to ensure that evaluated risks stay below the tolerable / acceptable level, to aim for safety improvements, etc. However, the following shortcomings have been identified in practice:

1. Safety management system can become a paper exercise and sterile documentation full of procedures, which can lead to a) complacency, b) erosion of good practice (short-cuts) due to time-consuming procedures of paper work, c) misplaced confidence due to absence of accidents, etc.
2. Amount of information transfer from hazard identification and risk analysis through to the safety management system is insufficient. Risk analysis is poorly understood by the workforce and is not being used in day to day business.
3. Hazard management in most cases deals with process failures and not with the failures of the management and organisation of the plant; hence human, management and organisational factors analysis is rarely incorporated into the safety management system.
4. Safety management system should be based on a socio-technical model exposed to external, process related and human and organisational hazards.

5. Safety management system should primarily be for the duty holder to assure itself that its operations are safe, and demonstrating this to the Regulator is only secondary matter.

**Short term research**

- Develop a model or template for the SMS which would remedy the above shortcomings and streamline and energise the safety management process. The SMS should not just be a document but a “way of life”. It should not be used because of safety audits by a regulator, but because it should be an everyday manual, recording, tracking and brainstorming system, i.e. it should be naturally useful.
- Develop parameters for the proactive monitoring of the system.
- Develop the safety culture model compatible with the template.

**Mid term research**

- Application of the template SMS to several industries across the EU.
- Organisation of workshops across the EU in order to facilitate the development and use of the new SMS model.
- Organise a workshop for the exchange of experience and ideas regarding the new SMS.

3.1.6 Multicriteria analysis and decision support tools

3.1.6.1 Variations in criteria in use across Europe

Approach to safety differs considerably across the EU. While on one side there is a basic recognition that “zero risk” is not attainable and that the real aim must always be to identify, control and reduce risk, on the other side, as a sharp contrast, there is still a belief that application of good practice embodied in design and other standards removes risk. Between the two extremes there are several variations, the simplest one being that as long as risk is lower that a prescribed threshold, it is acceptable and the regulator can accept developments up to that prescribed limit. This situation is obviously reflected in the risk acceptance criteria, cost-effectiveness implications, and the safety legislation.

An attempt has been made in the Saferelnet Project to review different criteria across the EU and to try to minimise the differences between the varieties of safety approaches in order to develop risk acceptance criteria with the potential to converge to a unified set. The second aim was to develop societal risk criteria completely consistent with the legally applied individual risk criteria.

**Mid term research**

While some progress has been made and it is possible to devise the framework that would be acceptable both to goal setting and the prescriptive approach to safety, more work can be done to complete this unifying framework.
In addition, while linking societal risk criteria to individual risk criteria, an interesting aspect of the number of exposed people (in Seveso 2 sense) to whom criteria apply came up. This indicated that, to get the consistent societal risk criteria, one would need to specify the number of people such criteria apply to. However, more research is needed to include the density of people living in vicinity to major hazards site into the societal risk criteria, i.e. to solve the problem from the philosophical point of view by equally considering any micro-and macro-economic impacts.

In an industrial context, there is an increasing need for decision-making methods for industrial applications, when major and conflicting objectives such as safety and costs are at stake. What is the best risk-cost trade off in accordance with stakeholders? (for example, what is the best maintenance policy with respect to safety and costs?).

This issue can be addressed either by multi-criteria decision-making methods or by cost-benefit analysis.

**Mid term research**
New methods, precautionary principle application, dynamic decision-making process.

### 3.1.6.2 Multi-attribute decisions and risk acceptance criteria

Currently, decision-making is concerned with optimisation under specified constraints, e.g., minimising the installation and maintenance cost of a system under given acceptance criteria regarding the reliability of a safety function. Similar constraints are used when evaluating risk, where risk acceptance criteria are enforced. Recent research argues that although such acceptance criteria may be a simple path leading to reasonable allocation of resources, it may not be optimal. In this activity the validity of acceptance criteria will be investigated to find if there are cases where the use of risk acceptance criteria is optimal for health, safety, environment, and economic profit. An alternative approach would be to optimise along several different dimensions: Reliability, economics, ease of use (of a new system), preferences of workers involved, etc. This is known as multi-attribute decision theory.

**Mid term research**
Develop new approaches to multi-attribute decisions and risk acceptance criteria related to complex systems

### 3.1.7 Systemic methods to address the complexity of the industrial systems

**Short term research**
Develop global risk management techniques further (following TRENDS Risk Workshops) to create common elements of risk management for health & safety, environment and corporate social responsibility and understand how they work with and against each other and their impact at the micro-and macro-economic scale.

**Mid term research**
Develop innovative hazard assessment methods for people exposed to bio-hazards, e.g. in biotech industries, food industry pharmaceutical companies and hospitals. Develop sector
specific hazard assessment techniques that are embedded within the operating and customer service processes, develop a forecasting capability rather than the current reactive approach

Introduce formal assessment tools for domestic appliances, where the MMI operating in a faulty manner triggers a hazardous situation – applicable to manufacturing and design processes of domestic appliances

Introduce formal risk assessment methods for assessing the risks versus benefits introduced by mass-produced items, e.g. when applied to hand-tools, construction site vehicles, electric and pneumatic tools etc. Consider liaison with the manufacturers of these items.

3.1.8 Uncertainties in risk assessment and management

The methodologies currently used for risk assessment and management in the industrial practice have been developed some time ago and are being continuously improved. Yet, one crucial issue which can still not be considered satisfactorily resolved is the robustness of the assessment with respect to an adequate quantification of the associated uncertainties and the definition of proper acceptability criteria which account for such uncertainties. This aspect is of fundamental importance for the validity and reliability of the results of the risk analysis and, consequently, for the robustness of the management choices and regulatory decisions which are based on such results. Depending on the examined problem, the uncertainty can arise from several sources:

- insufficient physical-engineering knowledge of systems, processes and related parameters;
- insufficient amount and inadequate quality of the available data drawn from the previous operative experience in similar plants;
- inadequacy of methodology, models and related numerical codes.

These deficiencies have appeared in several occasions in practice, and have been verified for example within International Exercise Benchmarks such as the Assurance European Project. This highlights the need of completing the risk evaluations with a careful estimation of the uncertainties so as to obtain objective results to be used as a basis for design, management and planning decisions. In particular, the necessity arises for a systematic way to the analysis of the uncertainties in the evaluation and acceptance of risk: this is to be achieved starting from an understanding of the accuracy of the traditional techniques and may lead to new approaches for a more robust evaluation of the risk involved in the design, construction and operation of industrial plants. From the methodological point of view, this leads to the need of improving the analysis and simulation techniques so as to provide an enveloping set of methods characterised by different levels of precision in order to better meet the user's needs.

Methods of uncertainty analysis have been developed and are available but often they entail repeating the evaluation of the quantitative models several times, for different values of the governing parameters. In many instances, the computation times required by the repeated numerical solution of the model render these analyses prohibitively costly, so that one has to resort to simplified but fast models or empirical response surfaces. For example, in realistic industrial systems, consequence assessment entails a choice between the use of simple Models, with fast runtimes, or the adoption of more complex models (for example
fluidodynamical codes, CFD), able to treat the physics and the geometry of the phenomena with accuracy but very time consuming.

**Mid term research**
From the above said, the research should focus on:

- Adoption and further development of tools for uncertainty propagation in reliability assessment models
- Adoption and further development of tools for uncertainty propagation in consequence assessment models
- Study of advanced computational methods for the development of reduced consequence models for use within uncertainty analysis methods
- Study of advanced optimisation methods for the identification of parameter values of reduced models for use within uncertainty analysis methods
- Validation on industrial case studies

### 3.1.9 Reliability and safety of network systems

#### 3.1.9.1 Network safety and reliability analyses

In recent years, network safety and reliability analyses have received considerable attention for the verification of the design and for the evaluation of the performance of many real world network systems, such as computer and communication systems, power transmission and distribution systems, rail and road transportation systems, oil/gas production systems, etc.

The assessment of the reliability of a network system entails ascertaining the connectivity of a set of sources to a set of targets in the network. This can be done knowing the system cut or path sets or by a depth-first procedure. These approaches lead to NP-hard problems, which require cumbersome and mathematically intensive methods of solution.

Furthermore, the problem is becoming increasingly critical and complex by the fact that network systems are dynamically expanded and upgraded in response to consumers’ needs. In this dynamic scenario, the standard algorithms entail recomputing the network connection and reliability from scratch each time. In practice, network designs must meet multiple objectives. In addition to high system reliability, there are other critical objectives such as low implementation costs, low risks of damages associated with system failures, etc. These objectives are usually conflicting (e.g., low cost vs. high reliability) so that the final design is always a compromised solution.

**Short term research**
From the above said, the research should focus on:

- Adoption and further development of tools for network safety and reliability assessment
- Study of advanced optimisation methods for network reliability design
- Validation on industrial case studies
3.1.9.2 Reliability and resilience modelling and assessment of dynamic, complex systems

Most existing methods for system modelling come to short when the complexity of the system increases. Some methods can only be used for static systems (fault trees, reliability block diagrams), and most of the methods for dynamic systems can only be used for relatively small systems (Markov methods, Petri nets). The research activity will explore the possibilities of Bayesian belief networks and system dynamics combined with other methods, to analyse complex, and tightly coupled systems in an MTO (Man-Technology-Organisation) perspective.

**Short term research**

Develop new approaches to reliability and resilience modelling and assessment of dynamic, complex systems.

A special emphasis will be put on safety instrumented systems (SIS), i.e., systems comprising sensors, logic solvers (computers), and actuating units like shutdown valves, brakes, and motors. SIS are increasingly used for a wide range of functions and are growing more and more complex. Applications comprise: automatic train control systems, emergency shutdown systems in the process industry, aviation control systems, and systems used in surgery. Malfunctioning SIS have caused several major accidents. There are several significant challenges within this area that need more research. Among these challenges are: the effects of complex diagnostic testing, partial stroke testing, common cause failures in hardware and software, test induced failures, non-perfect testing, human factors in testing, ability to detect deviations and restore functions, resilience properties, etc. If it is possible to fully understand and model these problems, it represents a breakthrough for the design and operation of SIS, and major accidents may be prevented.

3.1.10 Methods for dynamic reliability assessment

Dynamic reliability aims at broadening the classical event tree/ fault tree methodology so as to account in an integrated manner for the mutual interactions between the hardware components of a plant and the physical evolution of its process variables, including the operator influence. The dynamical aspects concern the ordering and timing of events in the accident propagation, the dependence of transition rates and failure criteria on the process variables values, the human operator and control actions. Obviously, a dynamic approach to reliability analysis would not bear any significant added value to the analysis of systems undergoing slow accidental transients for which the control variables do not vary in such a way to affect the component transition rates and/or to demand the intervention of the control and protection devices or the operator. Dynamic reliability methods are based on a powerful mathematical framework capable of integrating the interactions between the components and the environment in which they function. These methods perform a more realistic modeling of the system and hence improve the quality and accuracy of risk assessment studies.

A formal approach to incorporating the dynamic behaviour of systems in risk analysis was formulated under the name Probabilistic Dynamics by Devooght and Smidts in 1992. Several methods for tackling the solution to the dynamic reliability problem have been formulated over the past ten years. Among these, Monte Carlo methods have demonstrated to be particularly efficient in taking up the numerical burden of such analysis, while allowing for...
flexibility in the assumptions and for a thorough uncertainty and sensitivity analysis. For realistic systems, a dynamic approach to reliability analysis is likely to require a significant increase in the computational efforts, due to the need of integrating the dynamic evolution with its characteristic times. The fast increase in computing power has rendered, and will continue to render, more and more feasible the incorporation of dynamics in the safety and reliability models of complex engineering systems. In particular, as mentioned above, the Monte Carlo simulation framework offers a natural environment for estimating the reliability of systems with dynamic features.

The time-description of the dynamic processes may render the Monte Carlo simulation quite burdensome and it becomes mandatory to resort to validated, simplified models of process evolution. Such models are typically based on lumped effective parameters whose values need to be suitably estimated so as to best fit to the available plant data. Applications of reduced, lumped parameters models already exist for example in the field of process monitoring and control. Once the equations of the reduced model have been set up, various approaches can be used for model calibration, i.e. for the search of the optimal parameters values.

**Short term research**
From the above said, the research should focus on:
- Adoption and adjustment of existing dynamic reliability methods
- Verification on industrial case studies of dynamic reliability methods
- Study of advanced computational methods for the development of reduced dynamic models
- Study of advanced optimisation methods for the identification of parameter values of reduced models

### 3.1.11 Risk metrics and dynamic risk metering

#### 3.1.11.1 Monitoring the potential for major accidents

Major accidents are rare and usually come as a big surprise. This is the common reaction immediately after the event. However, after the fact, this view changes. Most major accidents are then characterised as “accidents waiting to occur”. The goal is to unveil this wisdom before accidents occur, and prevent them from occurring. This implies a line of actions that may be seen as a paradox. Major accidents are fairly rare even if we look at all accidents occurring in our society, and if we relate them to different industries and transportation sectors, the accidents are so rare that we forget to be afraid of an accident. We do not feel unease, we become complacent, and we loose our vigilance. This vigilance is essential because without it we loose overview of the major accident potential and status. “If eternal vigilance is the price of liberty, then chronic unease is the price of safety” (Reason, 1997).

**Mid term research**

Develop models and methods that can be used for continuous surveillance of predicted risk of major accidents. Surveillance of the status of the risk of major accidents must be carried out on a continuous basis, and it should be institutionalised in organisations that possess risk of major accidents. Efficient methods for such surveillance need to be developed. This could
e.g. consist of risk indicators measuring the development in technical, human and organisational factors of risk importance.

**Long term research**

Develop models and methods that can unveil early warnings of major accidents seen in a societal perspective. We learn from all major accidents as a whole, with a societal and authoritative perspective, and should be able to predict major accidents based on early warnings and indications. Similar to the way seismology is used to predict earthquakes, we need to find those common symptoms (technical, human, organisational, societal, global, etc.) that provide early warnings of major industrial accidents. The vision is to unveil such early warnings/indications and prevent future accidents. This is not just a goal, it is a vision. No industry or transport sector anywhere in the world, has more than fragmentary knowledge about these major accident symptoms, thus, no one is able to control them. Provision of such knowledge requires long-term, multidisciplinary and holistic research. “Understanding and limiting the occurrence of organisational accidents are the major challenges to be faced in the new millennium” (Reason, 1997).

3.1.11.2 Risk metrics

Over the years, much work has been done in improving occupational health & safety, and the industry can be rightly proud of its achievements. This pattern of improvement has not however been seen in the management of major accident hazards. Many organisations believed that by managing occupational health & safety effectively, they were managing their risks, and if occupational health & safety improved, then major accident potential would improve also. Recent analyses completed by DNV and others covering a range of major accidents over the last 20 years have indicated however, that the trend in both the rate and severity of major accidents is at best static, and does actually display a slight upward trend.

![Figure 9: Trends in occupational safety](image-url)
Much has been said over the years about the classical loss control pyramid, which indicates the ratio between no loss incidents, minor incidents and major incidents, and it has often been argued that if you look after the small potential incidents, the major loss incidents will improve also. The major accident reality however is somewhat different. What is found is that if you manage the small incidents effectively, the small incident rate improves, but the major accident rate stays the same, or even slightly increases.

It is therefore felt that the next step in managing risks is to develop leading indicators for major accident hazards similar to the leading indicators used for Occupational Health & Safety. The use of leading indicators to manage occupational issues has clearly demonstrated performance improvements over the last 15 years.

Moreover, there is a need to develop a range of tools and methods that support “Risk-Controlled Operations”. This should support operational managers with the best information and solutions to maximise safety and business in a real-time situation of risk environment and safeguards status. The idea would be to develop a more on-line reading of the actual risk status of a plant, an activity, a system, etc. This could include input about status of barriers, extract what is known in Company’s own ICT systems, link to relevant Leading & Lagging indicators, current weather conditions, plant status, availability of people, develop suitable graphics for ease of interpretation, develop idea of Hazard Warning (F P Lees), etc.

**Mid term research**
- Move risk assessment further towards including barrier approaches
- Extend metrics to address real time status
- Combine SHE and Asset Integrity aspects
- Develop Operational tactics to address deficiencies
- Make better use of existing data sources as SAP, DCS system, etc
- Make the Safety Case a living document (“Living QRA”)
- Develop a global safety metric suitable for Corporate oversight and reporting
3.1.12 Further topics to be investigated

- Improvement and validation of domino effect analysis
  Multi-accident occurrence in which causation chain other accidents is identified, including systematic risk, dynamic reliability, structure reliability etc.)

- CFD modelling and validation for accident analysis
  Using of grid generators, parallel computing, distributed network etc.

- Development of more effective modelling approaches for the planning and management of emergency responses.
  The best way to manage an emergency is to avoid it in the first place and thus in turn requires that it is detected early. For an efficient Emergency management system it is necessary to monitor the situation continuously to measure possible risks and analyse several possible scenarios to determine under which conditions a real emergency can occur. When some high risk situations are detected, the required protection actions must be taken to try to avoid the emergency and to be ready in case the actual emergency takes place. Emergency management involves different phases which each have their own special needs and requirements: risk analysis and perception (prediction), emergency identification and assessment and emergency extinction.

- Optimise land-use planning on technical and governance aspects
  Land-use planning around hazardous installations is a powerful concept to enable the sustainable development of both the industry and the urban areas with a long term vision. Practices and approaches are quite different across Europe because of the risk assessment approaches and also the juridical tools implemented by the authorities to defines de zones and their use. Research is needed to understand the reasons of the discrepancies across Europe on the technical and governance aspects, and then propose an harmonised approach which will avoid that regulation is some countries is too severe or not enough and then create inequitable framework for the industrial development.

- Behaviour of structures in case of aggression (both internal and external)
  Risk assessment, management methods and insurability for structures (advanced hazards mapping and monitoring systems, event specific vulnerability mapping, decision Support System for priorities and impacts of risk mitigation)
  Prediction and simulation of structures (engineering tools for multiple threat scenarios and design options, programs for calamity simulation and training, advanced constitutive equations for building materials)

- Risk assessment of defects/production malfunctions
  Risk assessment should also include defects/malfunctions in industrial systems. The malfunctions create productivity loss but also very dangerous situations during faultfinding and other correction activities. The designers/ manufacturers normally not “believe” that malfunctions will occur and therefore do nothing to design any “protection” for these activities.

- Risk assessment for safety of machinery
  Risk assessment is a fairly new procedure for assessment of the safety level of industrial machines. It includes the working place for operator and other staff and the safety of control systems and operating parts controlling the moving parts of machinery. Many machine
manufacturers are SMEs and a lot of them have low level of knowledge and small resources to carry out risk assessment worth its name. Development of risk assessment methods according to experience from other fields can be important.

3.2 RESEARCH PRIORITIES FOR 2007 IN THE AREA OF METHODOLOGIES FOR RISK ASSESSMENT AND RISK MANAGEMENT

Key issues for the strategic research agenda were selected during seminars and discussion within the Focus Group. They are presented hereunder:

Harmonisation and Standardisation
- Methods
- Data collection and use (failure frequencies)
- Simplifying to provide cost-efficient solutions for SMEs
- Calibrating the risk level in codes, regulations & standards (also good for SMEs)
- Competency requirements
- QA

Contextual risk assessment methods
- Site specific
- Case specific
- Data modelling

On line” systemic risk assessment – “dash board meter”
- dynamic simulation of actual risk level over time for an installation +organisation+site. (Sometimes called “living QRA”.)
- “Leading” versus “lagging” risk indicators

Integration of issues across Focus Groups (FG)
- Risk assessment
- Human Factors
- Structural Reliability
- Uncertainty / Frequency modelling

Missing models and Phenomena
- Two-phase releases
- Toxicity (use doses instead of exposure)

Application for decision making and risk communication. 4 decision difficulties:
- Complexity (New processes, computer control, science...)
- Knowledge and Uncertainty (Failure mechanisms, human error, impacts...)
- Multiple Objectives (Cost, environment, safety, image...)
- Different Perspectives (Community, employees, company, shareholders...)

Integrating Risk Management into a wider context
- Sustainable development
- Global risks (e.g. terrorism, climate change, reputation/perception
- Concept selection, design, asset operation
- qualification, verification, certification of technologies, systems and operations
- Project and business risks
- Etc.

These needs have to be better understood, developed and evaluated in the roadmap of the Technology Platform in order to properly deal with risk assessment and management and not to obstacle the modernisation of the processes.

Table 1: Research Priorities for 2007 in the area of Methodologies for risk assessment and management

<table>
<thead>
<tr>
<th>Title</th>
<th>Reference to the SRA</th>
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<tbody>
<tr>
<td>Data, uncertainty, dynamics and context specific modelling</td>
<td>3.1.2, 3.1.8, 3.1.11</td>
</tr>
<tr>
<td>Gaps in understanding of hazardous phenomena</td>
<td>3.1.1</td>
</tr>
<tr>
<td>Define and recommend “Best Practices”</td>
<td>3.1.4</td>
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<tr>
<td>- Consistency, integration, harmonisation, standardisation, experience transfer between sectors</td>
<td></td>
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<tr>
<td>- GHS – global harmonised system for labelling/classification of hazardous substances</td>
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<tr>
<td>- Performance based, not prescriptive</td>
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<tr>
<td>Integrating Risk Management into a wider context – decision making</td>
<td>3.1.5, 3.1.6</td>
</tr>
<tr>
<td>Leading indicators – dynamic risk monitoring</td>
<td>3.1.10, 3.1.11</td>
</tr>
</tbody>
</table>

3.3 Previous work, existing projects and networks

3.3.1 European Networks

- SAFERELNET - Thematic Network on Safety and Reliability of Industrial Products, Systems and Structures (co-ordinator, IST, PL) - http://mar.ist.utl.pt/saferelnet
- FITNET: NETwork developing and extending the use of FITness-for-service procedures throughout Europe - http://www.eurofitnet.org/
- SHAPERISK: “Sharing experience on risk management to design future industrial systems” - http://shaperisk.jrc.it/
- ESReDA: European Safety, Reliability and Data Association http://www.esreda.org/
- TCGP CC, http://europe.OSH.eu.int./good_practice/
3.3.2 European Projects (including 6th FP projects at the negotiation stage)

- OMNITOX: Operational models and information tools for industrial applications of eco/toxicological impact assessments
- XPECTION: Innovative residual service time assessment of industrial plant components using real structure analysis by on-site x-ray diffraction
- UPTUN Upgrading of fire safety in existing tunnels
- Risk Observatory (project of the European Agency for Safety and Health at Work)
- EDFORSA - Risk prevention and health protection in adult education (Co-ordinator: VUBP, Czech Republic)
- HERE - Methodology for integrated health
- ARAMIS : Accidental Risk Assessment Methodology for Industries in the framework of the Seveso II directive - http://aramis.jrc.it (Co-ordinator: INERIS, France)
- LUPACS : Land-Use Planning Around Chemical Sites (Co-ordinator: RISOE, DK)
- I-RISK : Development of an Integrated Technical and Management Risk Control and Monitoring Methodology for Managing and Quantifying On-Site and Off-Site Risks (Co-ordinator: Min. Social Affairs, NL)
- MIRIAD 21: Major Industrial Risks in Agendas 21 (Co-ordinator: Ecomaires, FR)
- TRUSTNET-IN-ACTION : Towards an inclusive risk governance (Co-ordinator: Mutadis, FR)
- NW-IALAD "Integrity Assessment of Large Concrete Dams" - Task Group 5.2 "Dam Safety and Integrity Assessment" - http://nw-ialaduibk.ac.at/Wp5/Tg2/

3.3.3 National networks with common interest

France:
- IMDR-SdF : Institut pour la Maîtrise des Risques et la Sûreté de Fonctionnement http://www.imdr-sdf.asso.fr/

Finland

Denmark:
- RISK (the Society of Risk Assessment under the Danish Engineering Society), http://www.ida.dk/fagteknik/fagtekniske_selskaber/RISK/ida_tekst.htm

Belgium
- FEDICHEM Wallonie (Regional section for the Walloon Region of the Federation of the Belgian Chemical Industries), http://www.fedichem.be/
Germany:

Italy:
- 3ASI (the Italian Association of the Environment, Reliability and Safety Analysts, http://www.3asi.it

The Netherlands:
- VNCI – NL, professional body federating all the chemical companies in Holland. www.vnci.nl

Norway
- ESRA-Norge, branch of ESRA (European Safety and Reliability Association), http://www.esra.no/
- The Directorate for Civil Protection and Emergency Planning (DSB), http://www.dsb.no/forside.asp
- The Norwegian Industrial Safety and Security Organisation (NSO), http://www.nso.no/
- The Norwegian Pollution Control Authority (SFT), http://www.sft.no/english/
- The Petroleum Safety Authority Norway (PSA), http://www.ptil.no/English/Frontpage.htm
- The Norwegian Maritime Directorate (NMD), http://www.sjofartsdir.no/english.asp

Poland
- ENVITETECH-NET, initiative of the polish RTD units and academic active in the area of innovative environmental technologies, http://www.ietu.katowice.pl/envitech-net/eng/frame_s.htm

Slovenia
- Slovene Chemical Society, http://www.kemijsko-drustvo.ki.si/
- Slovenian Simulation Society, http://msc.fe.uni-lj.si/slosim/

3.3.4 National projects with common interest

France:
- Follow-up of the implementation of IPPC Directive in France, and assistance to National Authorities in the participation to the BREF writing process
- Risk analysis and prevention of major accident hazards
- Knowledge and tools formalisation for major accident prevention
- Characterisation of flammable mixtures and design of preventive and protective devices
Finland:
- SPASE - Small Plants Assistance with Safety and Environment
- POEM - Process Object-oriented Engineering Methodology
- NDC - New Design Culture
- The Finnish application of behaviour-based safety (BBS)
- Safety management
- Safety knowledge management
- Management of accidental releases in the forest industry
- The rationalisation of the management of corporate environmental risk in abnormal and emergency situations
- Research programme on process safety
- SME-RM: Risk management in SMEs
- CHEM - Advanced Decision Support System for Chemical/Petrochemical Manufacturing Processes

Denmark
- Coping with uncertainty in complex systems. The project is an attempt to couple the concepts of uncertainty, decision-making and the precautionary principle. Through an epistemological analysis of the role of uncertain and imprecise information in decision-making we try to give a formal definition of the 'precautionary agent' and then evaluate existing decision-making theories in order to determine whether these do, or could in principle, embody this agent.

Belgium
- Development of the SEVEX (SEVeso Expert) software
- Development of a methodology for studying domino effects (+ DOMINOXL Software)
- Delimitation of vulnerable zones around Seveso plants (hybrid approach)
- Assist the Walloon Region for the European and international works on climate change
- Environmental management, identification of processes for waste valorisation and recommendations.
- Assist the Walloon Region for compliance and flexible mechanisms of the Kyoto Protocol, Emission Trading Directive, and negotiation on the second period of the Kyoto Protocol
- Study on the cleaner technologies and management of waste

Germany
- Development of SQUAFTA-(Semi-Quantitative Fault Tree Analysis)
- GAP-A fault-tree based methodology for analysing occupational hazards
- Risk analysis for an LPG filling station
- An empirical risk-based approach to land-use planning
- Development and implementation of a concept of a computer-supported audit system for occupational safety
- A procedure for valuating safety management
- Reliability data for process plants
- Modelling of missile generation and flight
- Development and implementation of an M.Sc. course on “Safety and Hazard Defence”

Norway
- HSE, Health, safety and environment in the petroleum sector – A 5 year research program initiated by The Norwegian Ministry of Labour and Social Affairs [http://www.hmsforsk.no/](http://www.hmsforsk.no/)
- Worldwide Offshore Accident Databank, WOAD - [http://www.dnv.com/software/all/woad/](http://www.dnv.com/software/all/woad/)
- Offshore REliability DAta project (OREDA) - [http://www.sintef.no/static/tl/projects/oreda/](http://www.sintef.no/static/tl/projects/oreda/)

**Slovenia**
- Comparative evaluation of the three risk assessment methods: QRA, SPIRS, and RRA (IAEA) on three Seveso II establishments in Slovenia
- Environmental impact assessments and Risk assessments for different industrial clients

**UK**
- Development of an accidental risk assessment methodology for Seveso plants
- Advanced Warning and Runaway Disposal (AWARD)
- HSL support to implementation of the Fundamental Review of Land Use Planning project
- Data and techniques for ALARP decision-making
- Inspection ranking for top tier COMAH sites
- Two-phase venting from systems containing flashing fluids
- Performance testing of weathered passive fire protection (PFP) coating systems
- Techniques for demonstrating ALARP under COMAH
- Environmental risk assessment

**The Netherlands**
- WORM : Workgroup for development of the Occupational Risk Model (ORM)

**Italy**
- Development and implementation of a GIS database concerning major hazards installations location in Italy for emergency planning purposes
- Development and implementation of an accidents database for Seveso plants following accident inspections
- "A study of the effects of uncertainties in the risk assessment of complex technological systems" co-funded by the Italian Ministry of University and Research (years 2003-2004)

**Poland**
- Criteria's of risk assessment for improving the safety of workers from potentially explosive atmospheres
- Implementation of safety management system in Polish hard coal mines
- Criteria's of risk assessment for natural and technical hazards in the mining industry
- Methodology of risk assessment linked with gas and dust explosions in processing industry

**Czech Republic:**
- Integrated Environmental Decision Making and Support to Public Participation Activities

### 3.3.5 Key associations / actors at international level

- UNEP APELL, [http://www.uneptie.org/pc/apell](http://www.uneptie.org/pc/apell)
- Society for Risk Analysis Europe : [www.sraeurope.org](http://www.sraeurope.org)
- European Safety, Reliability & Data Association (ESReDA) - [http://www.esreda.org/](http://www.esreda.org/)
• ISO/TMB/WG Risk management – “Guidelines for Principles and implementation of Risk management”. International standard under development to provide the concept, guideline and a generic iterative process for the management of risk in any size organisation. http://isotc.iso.org/

3.4 PARTICIPANTS
The Focus Group on “Risk assessment and management” is led by:
• DNV (Norway)
• D’Appolonia S.p.A., (Italy)

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The table below presents the participants.

Table 1 : List of participants in the Focus Group Risk Assessment and Management

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4. ADVANCED RISK REDUCTION TECHNOLOGIES

4.1 STRATEGIC RESEARCH AGENDA IN ADVANCED RISK REDUCTION TECHNOLOGIES

4.1.1 Background and objectives
Risk is a natural aspect of each type of activity of the human being. Risks are particularly related to different industrial activities which expose workers of industrial plants as well as the society and the environment to various types of hazards (physical, chemical, biological and psychosocial).
Significantly higher levels of risk usually occur when new technologies or systems are being developed and implemented. Thus effects of confronting workers, operators and managers with much more complex technical systems of not fully recognised behaviour and the nature as well as probability and severity of unintended effects are not identified and studied sufficiently.

Thanks to the continuous development of modern technologies, it is possible to design more efficient and advanced production systems that offer increasing functional possibilities that have not so far been attainable (e.g. by applying nanotechnology, miniaturisation, smart sensors and information technology). Especially the rapid progress in sensor and information technology gives rise to the development of new methods and tools for manufacturing control devices. The proper exploitation of these developments for safety-related systems may to a great extent contribute to limiting occupational risks and major accident hazards, and thus reducing the number of work-related accidents, diseases and environmental and social losses.

To use the technological developments effectively for the increase in industrial safety, it is necessary to expand and strengthen research on the safety integrity of technologies and devices being developed. In particular, fulfilment of intended functions in combination with functional and safety aspects for the increasingly complex production systems, becomes important. These new technologies not only create safer possibilities for production systems, also the transportation and storage of hazardous materials will benefit. New materials, novel sensors and/or warning systems e.g. will make it possible to significantly reduce the risks associated to transport or storage. This is beneficial for the workers but opens as well new opportunities in land-use planning around these activities and sites.

The fundamental principles of good engineering practice require taking account of safety principles at all stages of the life cycle of industrial devices and installations. The basic methodology of risk reduction covers first designing systems and devices using inherently safer solutions, secondly application of technical collective protection measures and third the use of additional safety measures like organisational procedures or personal protective equipment.

The need for the use of new technologies in the area of industrial safety was the basis for defining the scope of the research area of this Focus Group. It covers the development of knowledge concerning the use of advanced technologies divided into the following domains:

1. Technologies for reducing risks at source and for inherently safer design;
2. Technologies for reducing risks by collective protective systems and devices;
3. New materials, technologies and test methods for personal protective equipment (PPE);
This part of the SRA can also be divided into two research approaches with different focus on preventive actions with regard to risks existing at the workplace. The first approach consists of domain 1 with topics which are aimed at making industrial plants safer at the design stage. Domains 2 and 3 represent the second type of approach and include research on various measures applicable for reduction of risks existing at the workplace (remaining risks not possible for cost-effective elimination or reduction at the design stage of manufacturing technologies).

By carrying out the research studies proposed in this part of the ETPIS Strategic Research Agenda the following objectives will be achieved:

- continuous expansion of the scientific knowledge concerning the opportunities created by new technologies for ensuring a high level of safety in industry. This concerns both, the use of advanced technologies for creating new, safer industrial systems and the increase of the safety level in already existing production systems;
- to provide solutions to the European manufacturing industry that enables the industry to improve safety at work, to the society and the environment at all stages of the life cycle of industrial devices and installations;
- to support achievement of social and economic objectives of the European Union by significant decreasing the number of occupational accidents and diseases as well as major industrial accidents. As a consequence the accident-related costs of losses incurred by the society and individual enterprises, will be reduced significantly.

The objectives of research studies proposed in this chapter are relevant to achieving compliance with a number of EU regulations concerning safety and health at work, prevention of major accidents and environmental protection. The most important EU directives taken into account when defining priorities of research are the following:

- Framework Directive (89/391/EEC) on the introduction of measures to encourage improvements in the safety and health of workers at work, together with a number of individual directives concerning specific aspects of safety and health, as for example: exposure to carcinogens at work (90/394/EEC), indicative limit values for workers’ exposure to chemical, physical and biological agents (91/322/EEC); chemical agents (98/24/EC, 2000/39/EC), work in explosive atmosphere (99/92/EC), biological agents (2000/54/EC), vibration (2002/44/EC), noise (2003/10/EC), electromagnetic fields (2004/40/EC) and optical radiation (draft stage - to be issued in 2006);
- new approach directives concerning safety and health requirements for products, such as personal protective equipment (89/686/EEC), equipment and protective systems intended for use in potentially explosive atmospheres (ATEX, 94/9/EC); machinery (98/37/EC), noise emission in the environment by equipment for use outdoors (2000/14/EC);
- environmental protection directives concerning requirements for integrated pollution prevention and control (IPPC, 96/61/EC) and the control of major-accident hazards involving dangerous substances (Seveso II, 96/82/EC).

The priorities of research proposed within this area are also in line with the conclusions of the forecast on emerging physical risks published in 2005 by the European Agency for Safety and Health at Work as well as conclusions of the tripartite seminar on "Promoting OSH research in the EU" held by this Agency in Bilbao, 1-2 December 2005.

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6 Expert forecast on emerging physical risks related to occupational safety and health, European agency for Safety and Health at Work, Bilbao, 2005.
4.1.2 Technologies for inherently safer design and to reduce risks at source

The most effective approach to reducing risks to health and the environment is to reduce them at a source. This approach is based on applying technological solutions which do not result in phenomena and substances that might create hazards for people and the environment. Hazards related to the application of new technologies, such as nanotechnology, smart materials, wireless devices, new chemical substances, genetically modified organisms etc., are not truly recognised by industry and society as a whole. Therefore, implementation and safe use of these technologies, devices and materials call for research studies that guide these technologies to be developed inherently safer and at reducing risks at source.

4.1.2.1 Technologies and methods to reduce releases and emissions of hazardous substances and aerosols

Implementation of new manufacturing technologies in industry should not lead to the release of hazardous chemical substances and aerosols (dusts and fumes) into the environment. It is particularly important for technologies involving new substances whose long-term effects on health and the environment are not known, have not been recognised and cannot be reliably predicted. This approach includes among others introduction of new materials free from hazardous components, design of technologies that contain reliably dangerous substances in safe conditions as well as application of inherently fail-safe design methodology and systems preventing unwanted emissions for new processes, production systems and machinery.

**Short-term research**

The scientific knowledge and understanding of hazards in new chemical technologies and processes are currently not sufficiently developed. Research in this field should focus on investigating the carcinogenic activity of chemical agents, the development of criteria for assessing the levels of exposure to fine particles (including nanoparticles) and the development of criteria for assessing simultaneous exposure to different chemical agents. In parallel the research should focus on the development of technologies for manufacturing new fire-resistant materials, e.g., polyurethane foams. This approach should be consistent with the Montreal Protocol that originally requires a complete phase-out of CFCs and “soft” HCFC blowing agents. New polyurethane products should be highly fireproof.

**Mid-term research**

One of the most important issues of safety and risk reduction in chemical technologies is the assessment of exposure to new chemical and aerosol agents. Research studies in this field should include development and validation of methods and rules for the assessment of exposure to micro and nanoparticles as well as development and effective implementation of monitoring, prevention and control systems of persistent organic pollution (POPs), including PCDD/PCDF emission. Methods for identifying new chemical hazards existing in industrial wastes should also be developed.

**Long-term research**

Long-term research in this area should be aimed at the identification and control of the emission of toxic substances in manufacturing processes, particularly taking into account the application of new materials such as nanomaterials, genetic engineering products, new semiconductors, new alloys and composites, fertilisers, medicines, biocides, pesticides and
other new chemical products. It should also be essential to investigate the mechanism of toxicological effects of these materials. Systematic, long-term studies should lead to establishing the threshold limit values for new chemical agents in the environment, and in particular in biological material, water, soil and food, and to reviewing existing limits. Innovative analytical techniques for measuring chemical pollutants in different environments should also be developed and an effort should be made to create an information system of hazardous chemical substances and aerosol identified in the European industry.

4.1.2.2 Novel and effective methods for reducing risks related to noise and vibration

As a result of rapid technological development an increasing number of noise and vibration sources has been observed. Noise and vibration are the main physical hazards identified in working and living environment. This fact should stimulate research on technologies for preventing and reducing risk related to those hazards. This task requires the development of effective methods for reducing noise and vibration at a source based on prediction of vibroacoustic parameters of machines at the design stage (designing quiet machines) and improving existing machines by applying novel ideas based on active reduction methods. In order to achieve these objectives more accurate simulation (modelling) methods, more effective control algorithms for active noise and vibration reduction as well as new measurement techniques and new measuring apparatus are also required.

**Short-term research**

To fulfill the requirement of reducing risk at a source actuators of active reduction system should be integrated with the noise/vibration sources. This means that special smart materials should be developed for this purpose.

The main part of any active noise and/or vibration reduction system is a control unit based on an adaptive filter and suitable adaptation algorithm. The aim of research in this field will be to use a neural network as an adaptive filter and a genetic algorithm as an adaptation algorithm for different types of filters. This will make it possible to achieve a high level efficiency of active noise and vibration reduction at source especially in non-linear vibroacoustic systems and for systems with unknown parameters.

The development of wireless devices and sensors is also required to monitor noise and vibration during plant operation, for example due to malfunction of an active reduction system applied in this plant.

**Mid-term research**

Computer simulation is a well-known tool used in science and industry to reduce costs and time at the design stage. Research in this area should focus on developing methods, software tools and computer environment for predicting vibroacoustic parameters of machines and industrial processes at the design stage. Computer simulation may be used also to develop new technologies for replacement of high-vibration processes.

Many active noise reduction systems in current use are designed and applied for already existing industrial machinery and installations. The best way to reduce the installation costs of such systems is to take into consideration their future use not later than at the design stage of a project. Research is needed on the development of active noise and vibration control systems which can be easily applied in various installations.
Long-term research

The rules for designing silent machinery are well known. However, the technology changes quickly. The aim of long-term research in this field will be to develop new procedures for designing machines which are quieter than those used at present, and to achieve a substantial reduction in overall noise and vibration levels.

4.1.2.3 Novel and effective methods for reducing risks related to electromagnetic hazards and optical radiations (non-laser and laser radiations)

Technological changes in manufacturing processes, transport, telecommunication, medicine equipment, etc., have resulted in a significant increase in the level of electromagnetic radiations as well as laser and non-laser radiations released in the working and living environment, which may result in harmful effects. In some cases electromagnetic radiation of complex morphology (modulation, frequency, etc.) is generated, which creates a new challenge for adequate identification, measurement and reduction. Some newly generated radiations are also more harmful or they affect the human body in a specific way compared to radiations encountered in previous decades. Research on technologies for preventing and reducing risk related to those hazards should be stimulated, and should focus on developing novel and effective measures of technical reduction at source.

Short-term research

The implementation of new EC Directives in the area of electromagnetic fields and optical radiation (laser and non-laser radiations) requires appropriate activities to be undertaken in each Member States. They should focus on identification of significant types of sources of those radiations at existing workplaces. Studies focused on risk assessment and risk reduction will follow. The aim of research in this field is to prepare an inventory of hazards related to electromagnetic and optical radiations resulting from particular technologies.

Long-term research

The rules for designing safe machinery, devices and equipment are currently well known. However, the technologies used in them change quickly. The aim of long-term research in this field will be to develop new techniques for reducing risks related to electromagnetic and optical hazards at the design stage.

4.1.2.4 Technologies and methods for inherently safer design of industrial plants and installations to reduce major-accident hazards

Despite the best efforts of companies, industrial associations, regulators and policy makers, the rate of accidents in the European process industry no longer decreases significantly. In recent years the threat of terrorism has given additional prominence to this issue. Therefore, a reduction in major-accident hazards is one of the topic tasks.

Taking that into account inherently preventive, safer technologies with high performance must be preferred options. Research should focus on technologies and methods for sustainable prevention of and reduction in risks in production plants and storage sites in the context of the European directives dealing with hazardous installations, in particular, the Seveso II, IPPC and Atex Directives and with the protection of the environment. Implementation of new technologies to improve industrial plant design to reach inherently safer design and operation with a view to avoiding premature failures and thus accidents is very important. This relates to major improvement in the industrial “design-to-operation” cycle taking into account new developments in information and control technology.
Risk reduction at source by inherently safer design constitutes a major challenge in the future (5-20 years). The main objectives of this approach are to better design, structure and understand processes, to reduce storage and to use new constructive measures. The priority is to take inherently safer design principles into account as soon as possible in the development of a process.

At the beginning of 1980s, a new revolutionary concept known as process intensification was born. It is compatible with the philosophy of sustainable development and characterises the novelty in chemical process engineering. It consists of achieving dramatic size reductions in chemical plants (“smaller is safer”), at a given production volume, while increasing process efficiency (enhanced conversion and selectivity) with respect to safety, environment, space, time, energy and raw materials. The opportunity offered by process intensification lies primarily in six areas: safety, compactness, costs, controlled well-defined conditions, time to the market, and company image. It involves the use of novel types of equipment and materials, processing techniques and development methods. Hence, it ensures a large research program spread over a period of several years.

For industrial processes that could not be intensified, industrial initiatives exist throughout EU to invent methods to mitigate the risks. Equipments have been designed and developed up to the market level. Some are well known like vents, suppression devices, extinguishers, safety valves etc., but other are under development like vent on ducts, chemical/thermal barriers... An increased penetration of safety in the industrial substrate can be expected, if such devices happen to be considered as sophisticated industrial goods on a market. There are some strong forces impeding this development among which the lack of « design » rules enabling the supplier to prove to its client that the technical characteristics of the device fulfil the safety criteria of the process. Standards have been written, which is a step forwards, but they do not include a clear way of design (more or less left to the « experts ») or only in very restrictive situations.

To fluidise this market, there is a need to classify the various types of safety equipment and propose design rules first on the basis of the physics of the phenomena involved, second on the characteristics of the process and third on the properties of the safety equipment. In some way, this may lead to a real « engineering of the safety of industrial processes ».

A deep understanding of the physics of the accidents including all consequences is required, justifying some effort of the basic scientific aspects. Only those aspects sufficiently well mastered so that an accurate estimation of the consequences of the accident is reachable could be implemented in design rules transferable to the industry. The work will then mainly consist in processing the available knowledge so as to produce such tools. A validation on realistic situations with experiments will be absolutely required also to define strictly the boundaries. Experiments on the devices will be required to measure the parameters of the system to feed into the design tool.

**Short-term research**

Currently available chemical data sheets do not provide appropriate information on the toxicity of dangerous substances. Taking that into account the dangerous properties and characteristics of the “Seveso directive” substances should be extensively investigated, analysed and fully identified with the aim to develop a database of these substances used in industrial conditions (pressure, toxicity, temperature, mixture...). The research should also focus on identification and investigation of other potentially dangerous substances not mentioned in the Seveso directive. This should improve the credibility of major-accident risk analysis as well as the assessment of major-accident risk and the consequences of major accidents.
One of priorities of research in this domain is the development of continuous miniaturised reactors as an alternative solution to unsafe large batch vessel. The heat exchanger/reactor (compact, modular, structured and intensified) is an interesting example, which couples high heat exchange capacities (high surface-area-to-volume ratio), with plug flow behaviour of the process fluid. It reduces inventories and allows a better control of processes. Exothermic reactions are carried out according to improved operating conditions (better mixing of reactants, higher concentrations, higher temperature and pressure levels, no temperature-induced side reaction) permitting faster kinetics and shorter reaction time.

For other industrial processes, as far as the overall conception of a process is concerned, it is sometimes possible to select less dangerous situations by changing the length of duct, head losses, choosing not sparking equipments, diminishing tribocharging etc. There is a need to adapt safety codes to this rendering them much more flexible.

Mid-term research
The creation of possibilities and path-ways of the newly created under major-accident circumstances hazardous substances is of great importance to risk analysis and assessment. These questions should be investigated and databases should be developed on such processes and substances, including methods of predicting impact of new substances, related to the different precursor substances.

Long-term research
The inherent safety of installations and the use of safe chemical substances (replacement of dangerous substances by safer ones) is the best solution in preventing major-accidents. Extensive investigations and analyses should be done, taking into account progress in the development of Best Available Techniques (BATs) in Europe. The general task and aim of this research should be to develop (in collaboration with industry) improved or new, safer technologies and installations.

4.1.3 Technologies for reducing risks by collective protective systems and devices

Collective protective systems and devices should be applied to prevent workers’ exposure to hazards and risks in such workplaces where it is not possible to reduce risks at source for technical or economical reasons. The workers’ safety can be achieved by separating the worker from the source of the hazard or by eliminating or reducing risks from his or her surroundings. In this case Production Adapted Safety is a key issue to achieve functional safety on the shop floor and means a co-ordinated adaptation between:

- operators qualifications and risk awareness;
- actual working tasks;
- arising hazardous situations/events, and
- production to be carried out.

Technological progress makes it possible to create new and more efficient Production Adapted Safety solutions of collective protective systems. New generations of materials make it possible to develop guards and barriers with better resistance and exploitation properties. Thanks to the application of electronic devices it is possible to control, in an effective way the positions of people and devices to avoid any hazardous situations, which leads to a cost-effective prevention strategy. Novel information techniques make effective monitoring of production systems and detecting dangerous situations possible. Research on new methods and technologies for reducing risks at work by means of collective protective
equipment should increase the level of safety during the operation of industrial systems, improve the organisation of production processes and reduce production costs.

4.1.3.1 Protection systems and smart sensors for machines, production and transportation processes

The development of protection systems for these processes based on the application of human presence sensing devices is aimed at the elimination of hazards that might affect operators and others in the vicinity of hazard sources. The technological development of programmable electronic systems makes it possible to constantly improve them in term of their parameters and growth of capabilities and of the complexity of their safety functions. Therefore research studies in this field should focus on developing a new generation of smart sensors for controlling conditions of machines, processes and structures as well as on new sensor devices for detecting human presence in hazardous conditions, and on an improvement of their parameters, functions and reliability. Also

Short-term research
Progress in the technology of new and more efficient materials opens the way to develop better, more universal, more flexible and cheaper sensors for industrial systems and structures. In the short-term, new types of sensors should be developed, including those for machinery and production systems as well as smart sensor technologies for transport safety systems and structural health monitoring (the latter to be applied in research studies proposed in the part on Structural Safety). Application of these sensors could lead to a decrease in the costs and an increase in the performance of industrial installations and safety systems.

Mid-term research
Application of advanced technologies will help to develop more efficient systems for detecting hazardous situations in machine set-up, operation and maintenance. Research should focus on the further development and application of safety systems based on machine vision, ultrasonic and infra-red radiation sensors.

4.1.3.2 Software tools for detecting dangerous situations in industrial systems

One of the most important problems related to accident prevention and reduction of the effects of accidents is real-time identification of dangerous situations occurring in industrial systems, which would make an immediate corrective action possible. This applies to both hazards caused by process installations and production devices. New information technologies make it possible to develop more effective systems for detecting and analysis of dangerous situations. This concern advanced systems for collecting and analysing data on detected dangerous conditions and real-time software tools for digital analysis of human body characteristics and positions with relation to hazards.

Short-term research
For an effective application of new industrial sensors, it is necessary to develop advanced systems for collecting and analysing data on the detection of dangerous conditions. This should provide a basis for creating new intelligent safety systems for automated production lines and cells, supported by vision systems for simultaneous monitoring manufacturing processes and controlling safety conditions at the workplace.
**Mid-term research**

Neural network techniques are the newest control technology. Research in this field will be aimed at applying neural network techniques for controlling safety in production systems. This should lead to an improvement in their efficiency and to a decrease in the cost of industrial safety systems.

**Long-term research**

The long-term goal consists in the development of advanced, intelligent and distributed systems to analyse, monitor and manage existing risks in industrial installations to protect workers. These systems will be based on the use of advanced risk perception models to supervise the whole process of industrial installation.

4.1.3.3 Systems and devices protecting against noise and vibration

Although a variety of technical solutions for collective protection against risks related to noise and vibration has been developed and applied in industry, the efficiency of those measures is still not satisfactory. For example, the sources of low-frequency noise still constitute a significant risk at the workplace. This kind of noise produced by (among others) vibrating machines parts is dangerous, irritating and it is difficult to reduce with traditional passive methods. Achievements in technology and signal processing make it possible to design novel systems for low-frequency noise reduction, called active noise reduction (ANR) systems. In many cases active noise reduction is the only way to protect people against noise and to reduce the risk to an acceptable level.

**Short-term research**

Industrial soundproof cabins are well known collective protective devices against noise, but their sound insulation for low-frequency noise is poor. Sound insulation at low frequencies can be improved with active noise reduction systems. The aim of research in this field should be to develop combined systems based on active noise reduction at low frequencies and passive attenuation of sound barriers at mid and high frequencies to create general quiet zones in workplaces.

**Mid-term research**

Performance of active noise and vibration reduction systems depends strongly on the architecture of the system and the quality of its control. Research in this area should focus on improving existing and developing new control algorithms and system architecture to advance the performance of active noise reduction systems, especially in 3D space. In some applications, it is also necessary to develop sound sources and detectors that would be able to work in hot, humid or other aggressive environments.

**Long-term research**

Acoustic screens such as noise barriers used commonly in industry have poor performance in the case of low-frequency noise. It is necessary to develop new active barriers by improving existing acoustic screens with the use of active reduction systems mounted on screen edges or to develop a 3D arrangement of an active noise reduction system working as a noise barrier.

There is a similar problem regarding passive materials and absorbers, which typically have poor absorbing parameters at low frequencies. Adding active noise reduction systems to existing passive devices will lead to development of new insulating smart panels and will increase absorption parameters for low-frequency noise and vibration.
4.1.3.4 Collective protection devices against electromagnetic hazards and optical radiations

In many cases an effective reduction of electromagnetic and/or optical radiation (including infrared and ultraviolet) hazards at source is not possible. In some situations (e.g., for a low-frequency magnetic field) passive shielding at workplaces or living areas is not efficient and it becomes necessary to design other appropriate technical measures to minimise risks for people, e.g., by using collective protective equipment to be introduced in the place of particular source of radiation presence.

Short-term research
The health risks related to electromagnetic and optical radiation depends on various factors including the localisation of the workplace or living areas in relation to radiation sources, radiation morphology, environmental conditions (temperature, humidity, air pollution, etc.), as well as the type of protective measures used. The aim of research in this field will be to collect data and analyse the effectiveness of equipment and systems currently applied to protect people against electromagnetic and optical radiation. Based on result of this study, the improvement of exposure conditions and the reduction of radiation-related health risk will be achieved by design and implementation of new protection systems: reducing the radiation levels by the passive or active shielding, as well as protecting against unintended access to areas subject to harmful exposure to electromagnetic or optical radiation.

Mid-term research
Further research in this area should focus on analysis of radiation detectors, elaboration of novel detectors’ system designed for various radiation or exposure conditions and intended for the use within intelligent protection systems. Research should cover also development and design of new materials and protective shields, which structure depends on a type of radiation and its parameters (i.e.: frequency, time, intensity, modulation and polarisation).

Long-term research
The long-term research studies in this field should lead to creation of new intelligent systems of collective protection against electromagnetic and optical radiation. Such embedded intelligent systems should consist of novel radiation detectors integrated with advanced computer-based control units. Depending on the work regime of industrial machinery or installation (i.e. normal or emergency stage) intelligent systems will have to select and activate adequate protection devices. Continuous monitoring of the radiation level will be based on novel detector matrix adapting itself to the current type and intensity of radiation. Monitoring of the properties of newly designed materials and systems should also be analysed from the point of view of their usefulness for passive and active shielding structure. All those activities should lead to increase of efficiency and reliability of collective protection devices, and, as a consequence, to further reduction in the number of users exposed to electromagnetic and optical radiation, an in the level of this exposure.

4.1.3.5 Novel and advanced technology in lighting the workplaces

Lighting workplaces is usually considered to be one of the physical factors in the working environment. Inadequate lighting is one of the most frequent hazards at workplaces and the indirect cause of many occupational accidents. In particular appropriate lighting systems may reduce risk of accidents arising from insufficient or lack of lighting in some areas of workplace or because of wrong luminaries glare limitation. The reduction of that kind of risk
may be achieved by development of new technologies of professional luminaries and implementation of intelligent lighting control systems.

**Short-term research**

One of the main features of new intelligent lighting control systems is to maintain the desired level of illuminance from the mixture of daylight and artificial lighting. This gives the required level of illuminance from mixed lighting throughout the day and lower costs of energy consumption by the lighting installation. In order to improve efficiency of those systems in terms of their influence on working conditions and productivity it is important to carry out studies on the improvement of their usability, ergonomics and safety features and reliability. Research should also include the development of new generation of lighting sources (e.g. based on LED technology), and their implementation in designing the professional luminaries protecting users against the glare.

**Long term research**

Long term research will be needed to achieve permanent improvement of usability, ergonomics and safety features of intelligent lighting systems aimed at significant decreasing the number of workstation insufficiently illuminated as well as reduction of risk level related to low visibility.

4.1.3.6 Application of information technologies in safety-related systems

The application of computers and other programmable devices in industry has grown significantly in recent years in line with a dynamic development of information technologies. Programmable systems perform increasingly complex functions of controlling the production process, particularly in the case of installations where major-accident hazards may occur. The trend is also that embedded systems are used more frequently in the safety-related parts of the control (see Technology Platform Advanced Research and Development on Embedded Intelligent Systems: http://www.cordis.lu/ist/artemis/index.html). The safety is in many cases directly dependent on correct function of the programmable electronics.

**Short-term research**

Current research in this field should focus on controlled machines, distributed control systems, application of virtual and augmented reality in production systems, application of neural networks and fuzzy logic for control of industrial processes, etc. Those systems often fulfil safety-related functions too. Therefore, more scientific studies on reliability, safety, certainty and quantitative cost-benefit analyses of those functions are needed. They should lead to development of advanced systems of functional safety designed with regard to the generic standard IEC 61508 and the sector standards (e.g. IEC 61511 - the process industry, and IEC 61513 - the nuclear energy industry).

Methods for probabilistic assessment of safety performance of industrial control systems (neural networks, fuzzy logic, voice control machines, etc.) should be developed. Principles for achieving the necessary safety level in distributed prevention and control system have to be formulated. Research in this area should also include cost-benefit analyses of safety performance of industrial control systems and estimation of quantitative micro- and macro-economic impacts on competitiveness and innovation.

Another priority area requiring investigation is the structure of future system architectures to be used for dependable systems.

**Mid-term research**

Another way of using the possibilities offered by computer technologies in industrial safety is to support designers of industrial machinery and systems. Computer simulation methods and
virtual-reality systems should be further developed and efficiently used for the identification and analysis of hazards and risks existing in industrial systems. New and advanced software tools developed for such simulations can considerably facilitate the application of the most efficient, cost-effective and safe solutions in the design of production systems and for inspection and maintenance operations.

The increased complexity in future machinery will require research on improvements of:
- time-triggered communication systems;
- handling complex integrated circuits (for instance VHDL);
- validation methods for highly complex systems;
- tools supporting the development of SIL (Safety Integrity Level) components/systems efficiently as well as
- significant shortening of the development time by using model based development of safety critical systems.

The other topics of research needed in the area of application of information technologies in safety-related systems are the following:
- intelligent sensors and actuators with improved self diagnosis properties to increase the diagnostics coverage for application in safety-related systems;
- advanced operator decision support for abnormal situations and potential accidents;
- intelligent systems for monitoring the installations with potentially explosive atmospheres,
- methodology for integrated vulnerability assessment of the information technology and security management (including industrial distributed computer networks and safety instrumented systems for the monitoring, control and protecting) with regard to common criteria given in ISO/IEC 15408 standard.

*Long-term research*

Application of cost-effective systems based on VR technology for designing safe machinery and industrial processes should increase the efficiency of design work. Another possible application of virtual- and augmented-reality scenarios, which could be improved, is monitoring and controlling the processes and plant safety based on environmental sensors. Long-term research on the application of new information technologies should also lead to the development of modern user-friendly modelling strategies for prediction and control of hazards that can boost prevention strategies in many areas of industrial safety.

Another topic for research will be to investigate the use of autonomous decision making systems, which means to build in the intelligence into the system so the machine by itself can take automatically decisions to avoid an accident to occur.

### 4.1.4 New materials, technologies and test methods for personal protective equipment (PPE)

The use of PPE is necessary in many situations of working and living conditions when there is no other possibility to avoid hazardous factors or to reduce them to the safe levels. Given the PPE is in direct contact with the user’s organism, it must be designed, tested and assessed in such a way as to guarantee that protective functions are preserved throughout the whole time of its use, considering the influence of working environment conditions, such as unfavourable microclimate or environment endangered by explosion.
The diversity of hazards, the variety in the intensity of risk, new or unknown combinations of hazards linked to new technologies require continuous improvement and research on new types of PPE and new intelligent materials used for their manufacture.

In order to ensure the user with the optimum level of protection and the minimum level of discomfort, it is necessary to assure that the latest developments in science are implemented into design of new PPE models, with a particular consideration of nanotechnology, active and intelligent systems regulating protective and utility parameters, depending on changing working environment conditions, as well as the level of the user’s energy consumption.

Therefore, a major research issue in this area is to identify phenomena connected with the application of PPE so as to develop methods for assessment of protective effectiveness adequate to PPE usage condition, taking into account the acceptable workload level. Furthermore, an important issue to be taken into account concerns adjustment of the PPE structure to individual requirements of the user. Those issues are vital in extreme situations such as: rescue operations, medical services, and when PPE is intended for special use, for instance for people with disabilities.

Developing relevant test methods and assessment criteria with a clear and unambiguous link to the situation at the workplace is the key to the successful implementation and use of PPE. Since in the field of PPE a lot of EN or ISO standards exist and are harmonised, research in this field should be taken into account in future revision of standards.

4.1.4.1 Test methods and safety requirements for PPE applied against new specific hazards

PPE tests are conducted in the laboratory conditions where a possibility of imitating the functioning of this equipment in the working environment is limited. In the prevailing majority, tests are done on new, prototype products thus assessment of time limits of its safe use is impossible. For this reason, there is an urgent need to carry out research simulating real use of PPE and to apply modern modelling techniques in all those places where the scope of PPE is closely linked with the working environment parameters, such as concentration of chemical substances, type of biological agents, microclimate or intensity of work tasks performed by the worker.

The necessity to carry out research on new assessment methods of PPE is also connected with innovative PPE models, designed against new risks and working conditions where a simultaneous exposure to different types of hazards occur, such as: flames – temperature and water, or during welding: sparks, temperature and UV radiation. Such PPE models require development of new measurement procedures and setting new assessment criteria.

**Short-term research**

In order to increase safety of PPE use, a priority has been given to research aimed at complex assessment of PPE models in real conditions. This will allow to assess validity of laboratory test results and to refer them to the selection and application principles. This issue is particularly important for hearing and skin protection as well as for equipment designed for use in the atmosphere where the risk of explosion exists. The latter issue pertains to a majority of PPE models and a lack of complex solutions in this field, with particular consideration of work characteristic, for instance, mining environs, leads to a lack of single approach to research and assessment of PPE models within the EU. This problem calls for a quick solution in the form of new research methods that would take into account the phenomena linked with static electricity in relation to new materials and PPE structure.

**Mid-term research**

Diversity of hazards, differentiated intensity of their occurrence and the emphasis put on the ergonomic aspects of PPE design require far-reaching research and tests with the use of
modelling of such phenomena as penetration of chemical compounds mixtures through polymeric membranes, the flow and accumulation of heat through vapour permeable membranes or textile composite systems. Computer simulations illustrating phenomena occurring while using PPE will also constitute an important research area. It will increase the capability of the assessment of PPE functioning method, exceeding the situations that can be modelled during laboratory tests.

4.1.4.2 Innovative materials and individual systems for the personal protection of health and life

Simple design of personal protective equipment intended for protection against minimum hazards, should be made of cheap materials that are easy to maintain. However this approach changes when referring to PPE designed for direct protection of life and health. In this case research aimed at development of innovative materials and designs should be carried out, as well as on the application of embedded systems designed for hazard monitoring. The collaboration between different branches of industry should constitute the basis for product innovation. Textronics - a new area of textile industry that uses fibrous detectors and automatic control systems for protecting people, monitoring health condition and signalling hazards - can be mentioned here as an example. Another area of textile engineering is nanotechnology. It enables the increase and differentiation of the functioning of single fibre structure, which is followed by a whole textile product. Thus it makes possible to achieve specific characteristics e.g. efficient barrier against external agents ensuring at the same time lightness and biophysical comfort when using the final product.

Second, very important research topic in the field of PPE technology is providing PPE with detectors signalling the expiry of their safe use, as well as monitoring of selected physiological parameters during the rescue operations in particularly dangerous conditions (e.g. high temperature, oxygen deficiency, unidentified chemical and biological substances).

Short-term research

Traditional materials used for PPE technology do not often meet requirements set in order to ensure sufficient protective barrier in changing conditions of working environment. However combinations of the materials in the form of various composite structures could provide a good solution. It will ensure much better properties, e.g. thermal or endurance property as well as the possibility of active modification of protective parameters. Research studies in this field should concern in particular eye protection devices and the equipment for respiratory system protection against nano-aerosols, vapour and gas, as well as skin protection equipment designed for long-lasting work while being exposed to UV radiation (important problem because of the increase of skin cancer rate and the necessity of intensifying construction work, carried out in open air).

Research in the field should also include development of sensing devices or materials signalling the expiry of the safe use of PPE. Reliable solutions for this new function will especially be needed for gloves protecting against chemical substances and for respiratory protection equipment designed for use in the atmosphere polluted by dangerous vapours/steams and gases.

The other important topic in this area is the development of new designs of hearing protectors. It includes first of all application of automatic attenuation control systems in order to optimise the protection from impulse noise as well as the use of intelligent systems involving active noise reduction based on genetic algorithms and neural networks enabling the adaptation of hearing protectors to hearing of individual user.
Mid-term research
In a longer run, research studies aimed at application of embedded electronic systems that remotely send the data, in order to monitor the state of safety of PPE users will be carried out, as well as on solutions incorporating new elements of miniaturised size (e.g. microcapsules, carbonic nano-particles) that will significantly influence the extension of PPE use and ensure at the same time the highest possible level of protection.

4.1.4.3 Ergonomics innovations for PPE used in work and everyday life conditions

Insufficient acceptance of PPE models by their users is a common problem reported in various sectors and working environments. The necessity of ensuring the high level of protection constitutes often the basic criterion of PPE design - meeting ergonomic requirements is limited to the use of non-irritating materials and ensuring the appropriate system of adjustment. Therefore it is necessary to extend the scope of this issue to such domains as: biomechanics, thermal characteristics, biology and sensory aspects. It should be emphasised that currently published and available anthropometrical data come from statistical measurements carried out on undressed persons, in standard body position. They do not, therefore, take into account body movements, use of clothing and protective equipment as well as work tasks and environment conditions. Therefore dynamic anthropometrical measurements should constitute the basis for ergonomic design of PPE.

Use of PPE has a great influence on the user’s balance and thermal comfort. This problem will intensify with the increase of thermal stress caused by heavy physical activities and inadequate microclimate. It is an issue of great importance when dealing with protective clothing that covers large surface of the human body.

There is also a need for special approach to PPE designed for disabled people. Taking into account the EU policy on equal opportunities for people with disabilities research studies on adjusting the workplaces, including PPE, to their physical capabilities should be carried out.

Short-term research

PPE is commonly used while performing activities where thermal risk factors may occur. In particular this type of protection cannot be eliminated in such occupations as fireman or metallurgist. Hence, the issue of heat exchange between the human body and the environment calls for research aimed at making use of innovative materials such as steam permeable membrane or superabsorbents, as well as modelling appropriate composite system ensuring sweat transport and absorbing in external layer. The research on new technical solutions of clothes structures enabling efficient heat reception (including water vapour) should be carried out in laboratories equipped in advanced apparatus and facilities simulating real conditions of the use of new types of those clothes.

Mid-term research

Individual design of protective clothes and other types of PPE considering their protective functions and ergonomic properties is particularly important in the case of persons with disabilities. In order to facilitate their functioning in the workplace and everyday life, and to increase their performance to the level comparable with not-disabled persons, a special approach to meet their needs is necessary.

Research in this area should also focus on modelling heat-insulating clothes with intelligent control systems and elements supporting protection against cold or heat taking into account individual needs of the user.
4.2 RESEARCH PRIORITY FOR 2007 IN THE AREA OF ADVANCED RISK REDUCTION TECHNOLOGIES

Table 2: Research Priorities for 2007 in the area of Advanced Risk Reduction Technologies

<table>
<thead>
<tr>
<th>Title</th>
<th>Reference to the SRA</th>
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<tbody>
<tr>
<td>Technologies and methods to reduce releases and emissions of</td>
<td>3.1.1.1</td>
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<td>hazardous substances and aerosols</td>
<td></td>
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<tr>
<td>Technologies for inherently safer design of industrial plants and</td>
<td>3.1.1.4</td>
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<td>installations (to reduce major-accident hazards)</td>
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<tr>
<td>New sensors, protection systems and software tools for detecting</td>
<td>3.1.2.1</td>
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<td>dangerous situations in machines and production processes</td>
<td>3.1.2.2</td>
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<tr>
<td>Application of advanced information technologies in safety-related</td>
<td>3.1.2.6</td>
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<tr>
<td>systems</td>
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<tr>
<td>Development and assessment of innovative materials and individual</td>
<td>3.1.3.1</td>
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<tr>
<td>systems for the personal protection against specific hazards</td>
<td>3.1.3.2</td>
</tr>
</tbody>
</table>

4.3 PREVIOUS WORK, EXISTING PROJECTS AND NETWORKS

4.3.1 European Networks

- ADVANCED CREEP: co-ordination of advanced creep activities to improve safety and durability of high temperature plant materials (co-ordinator: European Technology Development Ltd., UK);
- IALAD: Network - integrity assessment of large concrete dams (co-ordinator: VERBUND OESTERREICHISCHE ELEKTIZITÄTSGESELLSCHAFTS AG, Austria);
- EUROSHNET: European Network of Experts from OSH Institutions Involved in Standardisation, Testing and Certification (http://www.euroshnet.org);
- FITNET: Fitness for Service Network (http://eurofitnet.org) (co-ordinator: GKSS Research Centre Geesthacht, Germany);
- PEROSH: Partnership for European Research in Occupational Safety and Health (http://www.perosh.org/home.html);
- RIMAP: Risk based inspection and maintenance procedures for the European industry (co-ordinator: DET NORSKE VERITAS A/S, Norway);
- SAFELIFE: Safety of Ageing Components in Nuclear Power Plants (co-ordinator: Institute for Energy, the Netherlands);
- SAFERELNET: Safety and reliability of industrial products, systems and structures (co-ordinator: IST - Instituto Superior Tecnico, Portugal);
- SAMCO: Structural Assessment Monitoring and Control (co-ordinator: Vienna Consulting Engineers, Austria);
- SHAPE-RISK: Sharing experience in risk management to design future industrial systems (co-ordinator: INERIS, France).
4.3.2 European Projects (including 6th FP projects at the negotiation stage)

- **AIMS:** Advanced Interactive Materials by Design (University of Dortmund, Germany).
- **AMAS-ISN:** Centre of excellence for advanced materials and structures: modelling and durability analysis for engineering design (Institute of Fundamental Technological Research IPPT PAN, Poland);
- **AWARD:** Advanced Warning and Runaway Disposal (University of Manchester);
- **CAS:** Condition Assessment of Aging Ships for Real Time Structural Maintenance Decisions (co-ordinator: Bureau Veritas, France);
- **DECOS:** Dependable Embedded Components and Systems (co-ordinator: ARC SEIBERSDORF RESEARCH GmbH, Austria);
- **EMF-NET:** Effects of the Exposure to Electromagnetic Fields: from Science to Public Health and Safer Workplace (co-ordinator: Institute of Biomedical Engineering CNR, Italy);
- **GAPOGROWTH:** Growth of large GaPO₄ single crystals and the use for special sensor applications (co-ordinator: AVL, Austria);
- **HIDA APPLICABILITY:** Probabilistic and sensitivity of crack assessment in high temperature plan and applicability of High Temperature Defect Assessment procedure (co-ordinator: European Technology Development Ltd., UK);
- **Modelling and design of multi-functional materials** (co-ordinator: MPA, University of Stuttgart, Germany);
- **NANOSAFE2:** Safe production and use of nanomaterials (co-ordinator: CEA, France);
- **NEW OSH ERA:** New and Emerging Risks in Occupational Safety and Health (OSH) – Anticipating and dealing with change in the workplace through co-ordination of OSH risk research (co-ordinator: FIOH, Finland);
- **OMNITOX:** Operational models and information tools for industrial applications of eco/toxicological impact assessments (co-ordinator: Chalmers University of Technology, Sweden);
- **REBASADO:** Reliability Based Structural Design of FPSO Systems (co-ordinator: Shell, The Netherlands);
- **RIMAP RTD:** Risk based inspection and maintenance (co-ordinator: DET NORSKE VERITAS A/S, Norway);
- **TEST-PRO-SAFETY-LIFE:** Centre for Testing and Measurement for Improvement of Safety of Products and Working Life (co-ordinator: CIOP-PIB, Poland);
- **UPTUN:** cost-effective, sustainable and innovative upgrading methods for fire safety in existing tunnels (co-ordinator: TNO Building and Construction Research, the Netherlands);
- **XPECTION:** Innovative residual service time assessment of industrial plant components using real structure analysis by on-site X-ray diffraction (co-ordinator: Fraunhofer Institute für Chemische Technologie ICT, Germany);
- **CHEM-SAFE-FOOTWEAR:** Definition of a standard for footwear protecting against chemicals and micro-organisms (co-ordinator: Centre Technique Cuir Chaussure Maroquinerie, France);
- **SUBZERO:** Thermal Insulation Measurements of Cold Protective Clothing Using Thermal Manikins (co-ordinator: FIOH, Finland);
- **ROBTANK:** In-service inspection robot for structural integrity of tanks filled with hazardous liquids (co-ordinator: ISQ, Portugal);
• AIRPIPE: A prototype for rapid closing of valves to avoid the propagation of contaminants, fire, etc. (co-ordinator: ISQ, Portugal);
• INTCON: Development of a neuro-fuzzy control system to reduce gas emission in grated incinerator (co-ordinator: TPS, Sweden);
• SAFEPIPES: Safety Assessment and Lifetime Management of Industrial Piping Systems (co-ordinator: VCE - Vienna Consulting Engineers, Austria);
• AMICA: Advanced Array Technologies for Optimised Maintenance and Inspection in Critical Applications (co-ordinator: Tecnatom, Spain);
• NART: NDE and Life Assessment of Reformer Tubes (co-ordinator: Tecnatom, Spain).

4.3.3 National networks with common interest

• Process Intensification Network (http://www.pinetwork.org), (co-ordinator: University of Newcastle, UK);
• EXERA: Association des Exploitants d'Equipements de Mesure, de Régulation et d'Automatisme (http://www.exera.com, France);
• AFITE: French Association of Engineers and Technicians in Environment Sciences (www.afite.org, France);
• Centre for Advanced Technologies of Human-friendly Textiles PRO HUMANO TEX (co-ordinator: Łódz University of Technology, Poland);
• ENVITECH: Polish Thematic Network for Environmental Technologies (co-ordinator: IETU, Poland);
• Ministry of Industry and Autonomous Regions, Industrial Safety Co-ordination Council (www.min.es, Spain);
• The Centre for Occupational Safety (http://www.tyoturva.fi/english/centre/, Finland);
• Finnish Zero-Accident Forum (co-ordinator: Finnish Institute of Occupational Health, Department of Occupational Safety, Finland);

4.3.4 National projects with common interest

Austria:
• DESUS - Decision Support System. Knowledge based evaluation system for safety assessment, lifetime prediction and maintenance planning on civil infrastructures.

Finland:
• Occupational Safety Card;
• Investigation of all fatal workplace accidents since 1985;
• Prioritising occupational safety - occupational accident prevention programme 2001-2005 (http://www.tyotapurumaohjelma.fi/);
• Safety24 (http://www.chemind.fi/safety24h).

Poland:
Selected examples of research projects carried out within the framework of a national programme “Adapting working conditions in Poland to the standards of the European Union”:
• Development of augmented reality system for industrial applications;
• Application of intelligent materials in active noise and vibration reduction;
• Computer modelling of mechanical hazards caused by machinery;
• Analysis of accidents in industrial internal transport simulation using VR technology;
• Safety and health requirements and testing methods for protective systems based on machine vision;
• Determination of safe time and usage of hand protection against extremely harmful chemical substances;
• Signalisation penetrations of dangerous chemical substances via protective gloves;
• Model structures of filtering material for bio-aerosols;
• Permeation mechanism of liquid chemicals mixtures through protective materials;
• Dynamics of microclimate humidity as a function of physical parameters of textiles under hermetic protective clothing.

Portugal:
• Causation and typification of work accidents in various industrial sectors in Portugal (co-ordinator: IST - Instituto Superior Tecnico);
• Impacts of work accidents: its consequences at social, organisational and individual level (co-ordinator: ISCTE).

Spain:
• R&D of electronic action and control devices based on smart elastomers for industrial safety applications oriented to elevator devices (INTELASTE);
• Ergonomic solutions and tools integration in intelligent tutors applied to people with disabilities (TUTOR).

United Kingdom
• Risk communication for prevention behaviour;
• Good practice by SMEs in assessing workplace risks;
• Development of virtual risk management system;
• Operational risk analysis;
• Uncertainties of risk analysis of a chemical establishment.

4.3.5 Key associations / actors at international level

• European Agency for Safety and Health at Work (http://europe.osha.eu.int);
• European Safety Federation (www.european-safety-federation.org);
• European Safety and Reliability Association (www.esras homepage.org);
• European Process Safety Centre;
### 4.4 Participants

The Focus Group “Advanced Risk Reduction Technologies” is led by:
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- TNO Built Environment and Geosciences, the Netherlands.

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5. STRUCTURAL SAFETY

5.1 STRATEGIC RESEARCH AGENDA IN STRUCTURAL SAFETY

Background and Objectives

All industrial facilities are based on infrastructures in which work is carried out and equipment is operated. Such equipment includes that installed in industrial buildings and often includes critical structural components such as pressure vessels, piping, cylindrical and spherical containment structures, as well as vehicles in which industrial activity occurs, or which provide transport for industrial products and raw materials, such as offshore platforms, ships, trains, trucks and aircraft. Their structural integrity is essential for a safe operation while their design, fabrication routes and life-cycle assessment methodologies should provide excellent in-service efficiency, high cost effectiveness and environmental sustainability.

Improvement of the technologies for overall structural safety for infrastructures, vehicles and components enhance the industrial safety and promote the competitiveness of the European industry. Improved understanding of the in-service behaviour of existing and new multi-material (hybrid) components has paramount significance for continuation of the safety at workplace and production. Introducing new technologies to improve industrial plant design to reach inherently safe design, and operation, inspection and maintenance (by introducing risk-based design and maintenance, materials selection, probabilistic assessment, etc.) with a view to avoiding premature failures and thus accidents is important. This relates to major improvement in the industrial “design-to-operation” cycle taking into account new developments in information and control technology.

Use of new materials, fabrication technology design and assessment approaches for new and aged structures require European level of RTD as well as training and education to ensure structural and plant integrity. An increasing number of structures, plants and aircrafts etc. are expected to reach their declared Design Service Goal (DSG) during next decade. In fact in Europe, a significant part of structural components is aged and methods to assess their integrity and to extend their lifetime in safe conditions are essential for efficient management of assets and resources. Research should provide knowledge and procedural basis to justify extended limits of those aged or repaired structures regarding the susceptibility to local or global failures.

The trend towards a risk-based approach in industry should be supported by extensive plant operating experience, improved understanding of material degradation mechanisms and the availability of fitness-for-service assessment procedures. Furthermore, in the last decade there has been a significant development in non-destructive testing (NDT) technology increasing both the scope and efficiency of examinations that can be undertaken. One of the key inputs to the risk analysis is the record of both on-line and off-line inspection, including knowledge on deterioration mechanisms and the rate at which deterioration will occur. The quality and accuracy of this information are pertinent to risk assessment and inspection planning. Indeed, the risk is increased when there is a lack of, or uncertainty in, key information required to assess the equipment’s integrity, making the whole Risk-Based Maintenance (RBM) process redundant.
The Focus Group on “Structural Safety” aims to provide European R&D framework for the needed technology and knowledge applicable to all industrial sectors operating load-bearing structures, which require safety to be properly inbuilt in the design and fabrication processes together with structural health monitoring (SHM), fitness-for-service (FFS) to ensure the structural safety throughout their lifetime.

Structural safety is also affected by human and organisational errors as well as it is prone to various risks of the industrial activity, which are external to the structures themselves. Therefore there must be an integrated European approach to assess the safety at the workplace by properly integrating the assessment and management of risks in general, with the safety of structures which may contain primary components with flaw and with the analysis of human and organisational matters, which in fact are three Focus groups of the Technology Platform on Industrial Safety.

The thematic scope of strategic research activities (SRA) proposed by the Focus Group 6 is strictly subordinated to the achievement of industrial safety performance objectives expressed in the Vision statement of the European Technology Platform. This part of the SRA is divided into the six following domains:

- Structural reliability based design
- Structural Health Monitoring (SHM) and risk-informed inspection
- Structural Safety of Aged & Repaired Structures and Life Extension
- Fitness-for-Service (FFS) of Structures
- Integrity of Multi-Material (Hybrid) Structures
- Structural Safety against Natural Hazards and Accidental loads

### 5.1.1 Structural reliability based design

**Short term research**

There is a need to have efficient calculation tools for large and complex systems. It would, however, not be very realistic to think that on short terms we would be able to deal computationally with a completely physically and probabilistically modelled structure. Therefore we should also seek for a defendable strategy on how to break down the unsolvable general time dependent system problem into a limited number of solvable problems.

Another issue is user friendliness of the programs in order to bring the application of reliability theory closer to the every day design engineer. Most practical designers are simply frightened to use present day reliability programs. In this respect it would be worth to think of tools where the classical partial factor approach and probabilistic methods are simply different options that can be chosen by the user. The designer could then first check his design on the basis of commonly used every day verification methods (e.g. partial factors) and then select more refined probabilistic options. The system should be set up in such a way that both options (partial factor as well as probabilistic method) use the same engineering models (e.g. a static elastic finite element model for the total structure and non-linear member checking) and the same set of probabilistic models for the random variables. Given the results of the partial factor method the designer could concentrate on a selected set of limit states and load combinations. He could then start to perform a number of time invariant probabilistic analyses and maybe introduce a more refined time variant analysis later. In many cases he may find out those structures, which do not fulfil the usually
conservative partial factor requirements, may pass the probabilistic requirements. In particular this may hold for accidental actions and robustness requirements. This project further requires the development of probabilistic codes.

Long term research
A long term research need is related to risk evaluation. In the end it is not only the behaviour of a structure that is important, but the consequences of that behaviour to the owner of the structure and/or to members of the society. Will people be killed or injured? What are the economic losses? The modelling of those events is an essential part of the total design and optimisation process. It is impossible to find optimal design solutions without considering the consequences of the structural behaviour in some detail. This may have its repercussions on the reliability techniques.

Furthermore probabilistic approaches and uncertainties assessments for structural reliability are needed by covering following issues;

- Degradations probabilistic and statistic modelling: development of methods based on physical models as well as on probabilistic/statistic models.
- Integration of various uncertainties sources in failure assessment
- Degradations anticipation and predictive assessment for life time management
- Reduction of uncertainties by data assimilation methods or Bayesian reactualization.

5.1.2 Structural Health Monitoring (SHM) and risk informed inspection (RII)

Short term research
There is an urgent need to assess the various inspections and monitoring techniques as far as their Probability of Detection and Accuracy are concerned. The aim of short-tem research is to investigate/identify the “improved” limits of NDT performance and reliability and to assess how this relates to an integrated integrity management strategy for assessing and managing the consequences and risk of failure in a plant/industry. Further there is a need on how to assess in advance the quality and intensity of inspection programs on the basis of rational cost optimisation.

The design of new generic vehicles and robots for remote inspection must be conceived in a modular and versatile way so as to make their application in different industries possible. Initial research must focus on solving generic problems such as the design of mechanical, pneumatic and electronic interfaces with plug in NDT and adhesion module, design of enclosures proof against ingress of oil, water, technology of vision through almost opaque liquids for obstacle avoidance, energy systems, etc. Development of non-contact inspection techniques (laser-EMAT, laser-UT, etc.) useful in complex geometry, hazardous areas (radiation, high temperature, etc.) for inspection speed optimisation will also be required.

Another area that requires attention relates to the transfer of methodology from industrial sectors, where risk-based methodologies are already being used (e.g., nuclear, petrochemical, offshore), to other ones, where this is still an unknown quantity (e.g., power plants, building construction, railways, etc.).
Mid term research

Increasing demand for all forms of energy and worldwide competition has emphasised the need to “produce more product at lower cost” while addressing plant safety and environmental issues. RBM is an integrated strategy for optimising the operation, maintenance and integrity management processes by focusing the appropriate level of maintenance resources (both capital and labour) and management effort at the highest risk areas of plant.

A broader application of risk-based methods is currently driven by the need to do more maintenance as equipment ages but with fewer resources and less manpower. This has created the need for smart systems that integrate information from many different sources, to enable maintenance and inspection decisions to be made effectively and safely. Research will aim at developing a knowledge-based system that deals with all relevant data and evaluates both the consequences and risks of failure. The tool which will be developed will have to be not only economically viable but also flexible so as being capable of being customised according to the requirements of a given plant/industry and expanded as more detailed assessments is necessary.

Failure and integrity assessment or life prediction and calculation on the basis of probabilistic assessment are another area that requires further investigation. The existing deterministic concept of safe life for a required number of years should be replaced by a conservative concept of probability of failure and its consequences or required performance over a predetermined period.

It will be necessary to do further research on designing advanced light weight and miniaturised (a few centimetres in size) robotic vehicles based on light and resistant multi-functional materials, flexible and customised scanners adaptable to different walking surfaces, wireless communication, multi-technique miniaturised electronics for NDT inspection, etc. Developing miniaturised and versatile robot heads for carrying inspection and weld repair tools and for carrying out other tasks such as installation of sensors during plant operation, etc., will also be required.

As inspection vehicle might have to carry an on-board payload of a 6- or 7-axis inspection arm module; the arm itself should be ultra-lightweight. Performance and flexibility can be improved through investigating nanostructured materials for their load-bearing components.

The definition of strategies for global position is critical due to the required accuracy. Air-coupled UT sensors are proposed to obtain this information but they are not exempt of risk. Scanning strategies must also be designed as well as defect mapping in large area structures. The recognition of furniture or geometrical elements must also be taken into account. Noise and interferences produced by mechanical elements in NDT systems must be reduced so as not to impede high-quality inspection.

Further, advanced visualisation tools will be developed and integrated allowing the robot to capture full 3D dimensionally accurate models of otherwise inaccessible areas. There is also a need to develop methods to improve and evaluate reliability and robustness of such robots, in order to ensure their use in industrial framework. Industry may be reluctant to use such new advanced robots if they are not reliable enough.

In-line defect classification is required in some industrial processes that include non-destructive examination for quality control in the same production line (bars and rods production in the steel industry or welding processes, including in-line hot inspection of the
generated product). The production process itself is also examined (to check the adequate performance of rolling mill components, etc.) as is the steel/weld produced (to reduce scrap and to direct the final product to the right customer based on quality requirements with the aim of producing zero-defect products).

Long-term research

Long-term research will deal with integrated risk-based planning and management covering the “whole industrial cycle” from design and material selection to plant maintenance and repair to plant disposal at the end of its useful life. At every stage the risk can be calculated and incorporated into the plant cycle thus reducing conservatism, costs and risk to plant operators and the surrounding environment.

Long-term research studies will also be needed on the development of remote control technology for the new robots for use in remote or long-distance applications such as monitoring and inspection of cracks in gas and oil pipelines in remote areas and the inspection of railway lines/ tracks, etc. The position could be determined by satellite technology and the inspection data could be remotely sent to the central office for further processing. Development of an efficient and accurate navigation systems will have to be developed (based on acoustic sensors, GPS, etc.) as well as additional systems for obstacle detection (in storage tank inspection). Decision rules to negotiate obstacles will have to be implemented.

The final step will consist on an efficient management of defects and storage in databases for controlling production process. Historical data would be stored to produce automatic reports and statistics on the industrial processes under consideration.

Figure 11 : Integrated Approach for Structural Safety
5.1.3 Structural Safety of Aged & Repaired Structures and Life Extension

Short term research
Repaired and aged structures are require special consideration by taking into account of material degradation, sizing of damage and effect of repair process on performance and durability of the component. The aim of the research should focus on the how to extend service life without any compromise on structural safety and an increase of limitations on use.
In assessing the structural integrity and damage capability of the structure to withstand a service period of extended operations
New assessment methodologies for crack initiation and spread of fatigue damage at weld repairs (less conservative approach to residual stress) are need to be established.
Furthermore, materials properties data compilation for aged materials, including environmental effects require research effort. Additionally, influence of concrete repair, both on durability, as on resistance capacity needs attention.

Mid term research
Research is needed for the development of advanced techniques for material sampling and characterisation as well as determination of residual stress profiles around the repaired locations.
Development of technology for structural health monitoring and guidance for damage tolerance assessment of aged structures containing "multi-site-damage (MSD)" are needed.

Long term research
Guidance on the repair and residual life assessment methodologies as well as damage tolerance analysis routes for corroded locations of new generation of integral (welded) metallic fuselage structures needs to be developed.
Development of methodologies for repair and life extension of multi-material components is essential for the future use of new generation of innovative light-weight structures.
Development of computer models to simulate material ageing and degradation phenomena including accidental loadings including impact, blast and fire are needed.

5.1.4 Fitness-for-Service (FFS) of Structures

Project ideas and initiatives:
Fitness-for-Service analysis of engineering structures aims to provide better design principles, support for fabrication of new components, prevention of service failures due to fracture, fatigue, creep and corrosion damages. The use of such technology involves making an assessment of a structural load-bearing component (bonded, welded or un-welded) containing a flaw to ensure its structural safety for its intended design life or until its next inspection period. The outcome of the structural safety assessment of a component in service is a decision to operate as is, repair, monitor or replace.
There has been a work on this conducted by FITNET thematic Network to cover metallic materials only. However, there is a need to extend this into the non-metallic structural materials such as composites. These materials may have fundamentally different damage evolution process, which needs to be investigated and included.

**Figure 12 : Fitness-for-service**

*Short term research*
Harmonisation of fatigue damage approaches and damage tolerance principles for structural safety assessment of welded advanced metallic structures.
Inclusion of thermal fatigue in European FITNET FFS Procedure

The above options should not only hold for design, but also for the assessment of existing structures and the decisions with respect to inspection and maintenance. This means that in conjunction with the structural analysis, automated procedures for posterior and preposterior analysis are required.

Further development of design methods for bolted flange connections involving following issues
- Validation and - if necessary - modification of the new design method for metal to metal contact type bolted flange connections ENTS 1591-3; according to resolution of CEN TC74 the Technical Specification ENTS 1591-3 will be upgraded as official EN standard after validation
- Development of a new design method for full face gasket applications

*Mid term research*
Development of FFS methodology for load-bearing composite materials is needed. For this end, it is essential to take step for harmonisation of the existing knowledge on the metallic
structures by taking into account of the special damage initiation and growth mechanisms of
the composite materials under static and dynamic loadings.

Tools for training/qualification of FFS engineers using European FITNET FFS Procedure
specifically for design of new welded structural components for safe service.

Research on the advanced damage accumulation approaches for pressure equipments
involving interactions of failure mechanisms e.g. creep /fatigue, corrosion/erosion.

**Long term research**
Integration of the data generated by Structural Health Monitoring (SHM) technology into the
fracture mechanics based engineering flaw assessment methods to be able to provide online
structural assessment.

Development of European structural safety concept for damage tolerance design, fabrication
support and structural assessment of in-service components of advanced (integral) light-
weight aerospace metallic structures.

Development and harmonisation of European FFS guideline for load-bearing critical
components made of composite materials by taking into account of special features of the
damage mechanisms of these materials.

5.1.5 **Integrity of Multi-Material (Hybrid) Structures**

Advanced structures are increasingly using multi-material design principles to increase cost-
effectiveness and structural durability as well as reduce the overall weight. The materials will
be selected for specific locations of the structural components for their specific structural
performance. These hybrid-multi material components are manufactured by using advanced
joining technologies and hence require stringent structural safety assessment principles
which currently not available. Research on the structures made of metal-metal (dissimilar)
and metal-composite components need to be focused to assess their structural safety.

**Short term research**
Short term research is needed to identify the design and fabrication principles of the hybrid
structures with respect to structural safety issues. Depending on the fabrication technology
used, the typical defect or damage types need to be surveyed with corresponding
(applicable) NDE techniques for such hybrid configurations and their accuracy must be
established for structural safety analysis.

**Mid term research**
Mid term research is needed to establish principles of interface or local engineering for safe
design and performance of the hybrid components. This requires fundamental understanding
of the bi-material interface behaviour under various loading conditions. Research must
provide basic road-map for design, inspection and maintenance of such components for safe
structural performance. Better understanding of the damage process at interfaces between
different materials and describing the damage mechanism to be assessed in a generic FFS
procedure.

**Long term research**
Long-term research is needed to develop and establish the structural safety principles of the
hybrid components increasingly used in automobile and aerospace manufacturing industries.
The outcome of the research should focus to deliver a European procedure for the structural
safety (European Damage Tolerance Design Handbook for Hybrid Components) of the hybrid structures to be used in design and safety assessment. Furthermore, development of guidance for design and damage tolerance analysis principles for “compression after impact” in case of critical components involving reinforced composites and hybrid joints is needed.

5.1.6 Structural Safety against Natural Hazards and Accidental Loads

Structures can suffer from unintentional external loads; such as earthquakes, blast, fire and overloads. Structures must provide sufficient resistance to such loading types at any period of their service life. Material selection, design (including thermal barriers, innovative protection systems and means for crack arrest) and fabrication techniques must provide needed safeguard for safe operation. Prevention and mitigation of structural consequences on structural components and buildings derived from the release and ignition of combustible substances are among the objectives of the research. Since natural and accidental hazards do not respect national boundaries, co-ordinated and collaborative research is required at the European level to improve the structural safety against natural and accidental hazards.

Short-term research
Research should focus on the development of tools for predicting and simulation of the level of structural damage involving accidental loadings (impact, blast, fire) and natural hazards to maintain the structural safety of critical structural components. Development of guidelines for innovative performance based structural design of structures for natural hazards and accidental loads involving seismic and thermal loadings. Effect of overload in damage tolerance behaviour of welded aerospace structures need to be investigated to generate structural safety principles including crack arrest potential of new generation fuselage structures.

Mid-term research
Control and mitigation of the consequences of a component failure or an accident in various critical structures (e.g. storage of fuels, energy carriers, aircraft structures etc.) in safe design methods need to be developed to prevent or limit the structural damage or occurrence of domino effects during the process of accident. Therefore, mitigation of consequences by the use of innovative materials, components, design, construction and retrofitting techniques should be further developed.

Long-term research
Development of engineering tools for prediction and simulation of structural safety of structures and plants by considering of multiple threat scenarios and design options as well as advanced constitutive equations for materials and protective coatings. Research is also needed for the development of modelling concepts of critical structural components in a probabilistic fashion to prevent progressive or detrimental collapse due to fire or explosion. European guidance for post-disaster structural health monitoring and assessment methods to evaluate the consequences of the event with respect to structural integrity and reliability of the structures and plants need to be developed.
5.1.7 Structural Safety from Accidental Loads

Project ideas and initiatives:

Structures can suffer from unintentional external loads; such as earthquakes and overloads. Structures must provide sufficient resistance to such loading types at any period of their service life. Material selection, design and fabrication techniques must provide sufficient framework for safe operation.

Short term research

Effect of overload in damage tolerance behaviour of welded aerospace structures need to be investigated to generate structural safety principles including crack arrest potential.

5.2 Research Priorities for 2007 in the area of Structural Safety

Table 3: Research Priorities for 2007 in the area of Structural Safety

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<tr>
<th>Title</th>
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<tr>
<td>To develop reliability based design and structural health monitoring (SHM) and risk based inspection technologies</td>
<td>5.1.1</td>
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<tr>
<td>To develop unified method to assess structural integrity of Multi-Material (Hybrid) structures</td>
<td>5.1.4, 5.1.5</td>
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<td>To develop methods to maintain safety of aged and repaired structures and provide technologies for life extension</td>
<td>5.1.3</td>
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<tr>
<td>To develop Fitness-for-Service (FFS) assessment routes for advanced welds with integration of SHM technologies</td>
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5.3 Previous work, existing projects and networks

5.3.1 European Networks

- ADVANCED CREEP: Co-ordination of advanced creep activities to improve safety and durability of high temperature plant materials (co-ordinator: European Technology Development Ltd., UK)
- IALAD: Network – integrity assessment of large concrete dams (co-ordinator: VERBUND OESTERREICHISCHE ELEKTIZITAETSWIRTSCHAFTS AG, Austria)
- FITNET: Fitness for Service Network (http://eurofitnet.org) (co-ordinator: GKSS Research Centre Geesthacht, Germany)
- RIMAP: Risk based inspection and maintenance procedures for the European industry (co-ordinator: DET NORSKE VERITAS A/S, Norway)
- SAFELIFE: Safety of Ageing Components in Nuclear Power Plants (co-ordinator: Institute for Energy, the Netherlands)
5.3.2 European Projects (including 6th FP projects at the negotiation stage)

- HIDA APPLICABILITY: Probabilistic and sensitivity of crack assessment in high temperature plan and applicability of High Temperature Defect Assessment procedure (co-ordinator: European Technology Development Ltd., UK)
- RIMAP RTD: Risk based inspection and maintenance (co-ordinator: DET NORSKE VERITAS A/S, Norway)
- XPECTION: Innovative residual service time assessment of industrial plant components using real structure analysis by on-site x-ray diffraction (co-ordinator: Fraunhofer Institute für Chemische Technologie ICT, Germany)
- SAFEPIPES: Safety Assessment and Lifetime Management of Industrial Piping Systems (co-ordinator: VCE – Vienna Consulting Engineers, Austria)
- NART: NDE and Life Assessment of Reformer Tubes (co-ordinator: Tecnatom, Spain)
- CAS: Condition Assessment of Aging Ships for Real Time Structural Maintenance Decisions (Co-ordinator: Bureau Veritas, France)
- REBASDO: Reliability Based Structural Design of FPSO Systems (Co-ordinator: Shell, The Netherlands)

5.3.3 National networks with common interest

5.3.4 National projects with common interest

Austria:

5.3.5 Key associations / actors at international level

- European Safety and Reliability Association (www.esrahomepage.org)
- European Pressure Equipment Research Council (EPERC)
- European Structural Integrity Society (ESIS)
- International Institute of Welding (IIW)
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6. HUMAN AND ORGANISATIONAL FACTORS

6.1 STRATEGIC RESEARCH AGENDA IN HUMAN & ORGANISATIONAL FACTORS

The Focus Group “Human and organisational factors” after prioritisation has identified the following 5 domains of research where improvements are more urgently called for:

1. Human and Organisational Factors in Managerial Safety;
2. Human-Centred Design;
3. Integrated Risk Assessment and Management;
4. Human Performance & Technology Usability;

The five domains are put in order of priority and reflect, at present, the thoughts of all stakeholders who met at the seminar in Milan on the 1st and 2nd of December 2005.

It is important mentioning that for each of the below mentioned research priorities, SMEs adaptation, though not specifically mentioned, will be taken for granted during the development phase as a second side of the coin.

6.1.1 Human and Organisational Factors in Managerial Safety

Factors in Organisational and Managerial Safety

6.1.1.1 Resilience Engineering

Over the last 20-30 years the accumulation of major mishaps and case studies have made it clear that organisations must revise their handling of processes and capabilities to address not only technical but also human and organisational risk factors. The traditional fields of practice, such as risk analysis and probabilistic safety assessment (PSA), have been unable to providing the much needed solutions because they are rooted oversimplified accident models. It is not enough that systems are reliable so that the failure probability is acceptably low; they must also be resilient and have the ability to recover from irregular variations, disruptions and a degradation of expected working conditions.

Vulnerabilities, as well as resilience, often arise from interactions between socio-technical system dimensions. For instance, a decision to deregulate railway operations in a country may have impacts on the political level (e.g., increased media attention to safety), the inter-organisational level (e.g., increased competition), the organisational level (e.g. reduced economic margins, outsourcing of activities), and to the levels of work-groups, individuals and hardware. Thus, the processes that create vulnerabilities and resilience cut across traditional disciplinary barriers, such as those between political science, sociology, psychology and engineering. Only a few attempts at multilevel analyses, e.g., explaining a single accident by integrating phenomena at the individual, group and organisational level, are found in the research literature. In this research activity, multi-level approaches will be prioritised.
To improve companies’ safety performances it is necessary to develop methods and tools to cope with the complexity of risk generation and events propagation and to propose answers regarding the following issues:

- How to identify, evaluate and reinforce the robustness and resilience of the organisations, including subcontractors and networks.
- How to improve the reliability of the operational activities considering the changes in the working and managerial practices or in the existing organisations.
- What is the safety management and what is its position compared to others management systems.
- How are external changes or new constraints in the companies’ environment taken into account through the managerial and organisational stratum.
- How to transfer or to adjust the methods and tools developed to the SMEs, worksites, agricultural and health sectors considering the various professional identities or the cultural differences between the countries.

The analysis of the impacts of the changes in several dimensions (or changes in their interactions) of the socio-technical systems and their impacts on safety performance requires interdisciplinary approaches using several theories issued from various disciplines such as political sciences, sociology of the organisations, psychology of work, anthropology, ergonomic and engineering in order to explain the phenomenon across the different levels of the organisations from activities to external environment level, through individual, group, managerial, and organisational levels.

**Short Term Research**

In the short term, the most pressing need would be to find out ways to analyse and provide an estimate of the resilience of organisations in their operating environment so to enable proper monitoring of organisational activities. Mobilising grounded theories based on empirical data collection on the fields of various risks’ industries, the analysis of the existing Human Performance tools and methods permitting improvement of the operational and managerial practices and the analysis of the existing safety management systems integrated in industries. (the links and interactions of these tools and safety management systems with others existing management systems, practices and organisations will be analysed as also changes in the practices, introduction of news practices or safety management systems in existing organisations). The focus should be on providing models of the socio-technical systems for safety-critical productions integrating the main dimensions and their interactions influencing the safety performance.

**Mid Term Research**

The “mid” step would be that of producing techniques to model and predict the short- and long-term effects of changes and decisions on risk, thus enabling to highlight the dimensions of the socio-technical systems, the changes in operational or managerial practices, and permitting the assessment of the vulnerability of the organisations. In practice, develop new knowledge concerning how humans and organisations contribute to the resilience of an existing technological system. In order to meet this objective, it is necessary to bridge three research traditions: (1) study of safety barriers, (2) studies of problem solving and improvisation, and (3) theory of high reliability organisations. A promising approach is to conceptualise human contributions to resilience in terms of (a) contributions to safety barriers, (b) robust work practices, and (c) capacity for improvisation. Incidents and near-misses with successful recovery will be explored as a possible source for knowledge about organisational and human preconditions for resilience.
**Long Term Research**

In the long run it would be suitable to link safety with negative externalities by means of tools and methods to improving an organisation’s resilience vis-à-vis the environment and the social fabric.

6.1.1.2 Feedback experience

Improvement of the integration of Human & Organisational aspects in Feedback Experience is not limited to the development of methods & tools for detection, analysis, and capitalisation of experiences from the accidents, incidents, near misses (weak signals) or from routine, daily, or normal activities. Beyond this, the following issues ought to be addressed:

- Integration & perpetuation of this safety device in the existing organisations, management and social systems (social climate, practices…),
- Impacts of legal aspects (openness…),
- Involvement of all the stakeholders in the process (management, employees, subcontractors, external authorities or public…),
- Building of the experiences (competencies, memory of the situations…) considering renewal of the employees or functioning with a network of subcontractors.

**Short Term Research**

In the short term the following topics have been identified:

- Analysis of the existing standards, methods, tools (qualitative and quantitative aspects) and organisational process for detection, analysis, and capitalising experiences from the accidents, incidents, near-misses (weak signals) or from routine, daily, or normal activities. Comparative analysis of these elements integrating cost/benefit aspects, industrial environment (external constraints such as regulation, legal aspects, and involvement of all stakeholders)
- Analysis of the existing standards, methods, tools (qualitative and quantitative aspects) and organisational process for detection, analysis, and capitalising experiences from “positive” feedback experience (transfer and memorisation of best practices and knowledge). Comparative analysis of these elements integrating cost/benefit aspects, industrial environment…
- Understanding the capacity of the organisations to integrate and perpetuate these safety device (levers and breaks to improve the integration of Human and organisational factors in the feedback experience process)
- Analysis of research development in the fields here above mentioned and comparative analysis integrating the assessment of the potential integration of these elements in various industries (including SMEs)
- Lessons learned from events (accidents, incidents and crisis)

**Mid Term Research**

- Development of methods and tools permitting the assessment of the socio-organisational and human impacts of the integration of these methods and tools in the existing organisations, managerial and social systems of the industries and development of means in order to limit these impacts
- According of the results of the previous research development/improvement of adapted methods, tools (qualitative and quantitative aspects) and organisational process for detection, analysis, and capitalising experiences from the accidents, incidents, near-misses (weak signals), from routine, daily, or normal activities or from “positive” feedback experience, integrating criteria in order to implement the best
tools considering the type of incidents, the industrial environment…. and also experimentation of these methods and tools on real industrials situations

Long Term Research

- On the base of the lessons learned from events, routines activities or using the methods and tools developed for detection, analysis… of events development of methods and tools permitting the assessment and reinforcement of the resilience of the organisations (support tool for audit, safety quantitative and qualitative assessment..)

6.1.1.3 Integration of HF into Safety Management Systems

One of the barriers to industry uptake of HF is that it commonly perceived to as an “add on” or “nice to have”, rather than being core to a safety system. It is also a true to say that HF expertise might be deemed too expensive or unnecessary. The criticisms have to be fought on several fronts because failures or breakdowns in application of human factors are often invisible to the casual observer and maybe even to the job performer, but it is often these very same factors that are the primary causes of major accidents.

Short Term Research

- Understand how the innate knowledge and experience of personnel can be supported by external processes and aids to flowing into the safety management system to support and improve the overall Safety Management

6.1.1.4 The Transaction Costs approach to choosing the amount of resources to allocate to prevention

In the economic perspective, non market risks caused by a single business firm with its production activities, determines negative externalities or social costs to other companies (per example pollution) or to stakeholders (per example families whose members suffer personal injuries at work).

Social costs mean the failure of the market as a regulator mechanism, which legitimates the ruling and compulsory action of the State. Social costs measure investments sustained to prevent non-market risks and the damage payments made to victims of company production activity. They have different nature and computation methodology from production costs but they are reported in same terms and nomenclature in the balance sheet.

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<th>Sanctionatory mechanism</th>
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<td>Social costs</td>
<td>to maintain firm value</td>
<td>Law and managerial forecasted evaluations</td>
<td>Intangibles (reputation, brand value, financial funds)</td>
<td>Social consensus and legitimate, Law</td>
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<td>Production costs</td>
<td>to increase firm value</td>
<td>Legal contracts</td>
<td>Tangible (products)</td>
<td>Market (i.e clients and competitors)</td>
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Managers must be aware of the different nature of social cost in doing two remarkably activities of their job:
- to decide the economic investments in risk prevention and safety policy, that is how much to allocate financial resources in safety;
- to control the implementation of the safety policy, that is how efficient has been the concrete accomplishment of risks prevention plans or how has been respected the safety budget

**Short-Term Research**
The short-term research should aim at studying two themes:
- the *transaction costs* approach (O.E. Williamson) applied to the managerial prevention and safety decisions in business firms;
- the design (or to re-design) the accounting system in order to show and to report efficiently investments and social costs sustained either in the internal budget process, either in the external social reports.

**The transaction costs approach to safety management.**
The transaction costs approach enables to measure forecasted risks prevention and damages social costs *ex-ante* the safety managerial decisions. The availability of social and production costs allows managers to face efficiently risk prevention problems as it is possible to figure alternatives of actions (per example to organise internally or in outsourcing the safety unit? To reach safety level (and correlated investments) A or B, etc.) and to choose the one which presents the lowest amount of total costs (social and production ones).

Research objectives are defined as follow:
- the bibliography research to define social costs applied to risks prevention and safety management applying the transaction costs approach; (in the short period)
- the case studies collection of significant managerial decisions in safety policy and management to prove the usefulness and validity of the theoretical social costs system designed in the previous phase (in the medium term);
- the design a tool to help managerial decisions in risk prevention. The objective is to design a cost decision support system to help managers to meet their safety responsibilities (in the long period).

**6.1.1.5 Accounting Control Systems and Reports vs. Social Reports on Safety Management**

Existing accounting systems are inadequate to supporting decision-making processes as not integrated in the existing accounting systems and procedures.
Search for new methodological approaches enabling to integrate social and prevention costs for better financial decision making and control.

Traditional accounting systems are designed to control and to report production costs, as they represent the basis to forecast sales and profits. This mean that costs sustained for “internal services” like those of human resources or personnel management (in which are include safety costs) are all mixed under a general label, that of labour costs.
This choice in designing the accounting system has two consequences: the missing economic managerial accountability on safety in the budgeting process; a poor information in social reports concerning safety investments and results.
In the budgeting process each manager has an economic responsibility, as he is a cost centre owner.
Consequently his performance in meeting his cost centre responsibilities will be evaluated. Traditionally general safety economic responsibilities are not considered in designing cost
centre contents. This missing action hides safety costs which are not reported analytically in social reports.

**Short-Term Research**

In the short-term, research objectives are defined as follow:

- the bibliography research to redesign a traditional accounting system to treat specifically risks prevention and safety costs in order to use them in budgeting and reporting processes or in other words to design a safety centred cost accounting system (in the short period);
- the empirical application of a safety centred cost accounting system in a significant sample of business firms (in the medium period);
- the implementation and the automation of the safety centred accounting system to be applied easily by business firms.

6.1.1.6 Safety Culture & Safety Climate

It is well-known that human and organisational failures are involved as causal factors in a majority of industrial accidents. A safety critical establishment may seek to control the potentially negative effect of such factors through Safety Management and Safety Culture. Safety management is a systematic and structured approach to control of all structural elements (procedures, rules, routines governing training, manning, co-ordination, communication, learning and feedback etc.). Safety culture concerns the shared interpretation and understanding of how structural (as well as external) requirements shall be transformed into actual practice and behaviours. Safety culture includes perception of leadership, communication, prioritisation of safety.

There is an increasing recognition that enhancing safety culture is a never-ending “journey”, however industry efforts to enhance safety culture do not always take into consideration that safety culture improvement practices need to be “matched” to how well-developed the existing safety culture is. Guidance on how to achieve the best match is required.

It is generally accepted that national, regional, industry and organisational cultures have an influence on how a safety culture develops, however the specific mechanisms are poorly understood. These other cultural influences can act as enablers or inhibitors to the development of a strong safety culture, but the precise mechanisms are unclear.

Finally, there is a need to enhance the quantitative methods predominantly used to assess safety culture, to include qualitative techniques (e.g. observation, interviews, focus groups) which provide.

Broadly speaking, research needs are:

**For Safety management:**

- review and analysis of best-practice organisations, possibly using methods of observation and analysis used for characterising “high-reliability organisations”
- assessment of the impact of leadership styles on safety performance
- developing practical methods of assessing the quality of safety management and integrating these into safety audits
For Safety Culture:
- developing and validating tools and techniques to reliably assess the quality of culture, enabling benchmarking and identification of weak points and compare of given organisations
- development and test of effectiveness of safety culture intervention programmes against safety outcomes
- developing methods of establishing common safety perceptions between mother companies and contractors (outsource companies).

6.1.1.7 Safety Culture of SMEs with regard to Safety Expenditures

What is the organisational culture of SMEs that makes them think that acting safely is too expensive? The project would develop remedial programme/approach applicable to SMEs in manufacturing/warehousing and engineering.

6.1.1.8 Communicate with greater clarity what are the main elements of safety culture in the process industries
- For each element of safety culture, describe a range of practices which will enhance each element;
- Develop methods to enhance industry’s capacity to match safety culture improvement actions to their current stage of safety culture development;
- Clarify and explain why and how national cultures impact on the development of safety culture
- Develop qualitative methods which help organisations to understand and enhance their current safety culture

6.1.1.9 Impact of HF Knowledge throughout organisations
Outside of consulting organisations, some businesses employ human factors specialists. What is the role conducted by these specialists? How much of their time is spent on human factors issues, and to what degree? How much of an impact are they able to have within organisations of different sizes (e.g. SME’s v Multinationals)? It would be interesting to study the answer to these questions as part of the development cycle of a plant where in the design phase, ergonomics might be a priority, in the operation phase, user friendly procedures would have a focus and finally unsafe behaviours would be addressed by behaviour based safety programmes.

- Understand the actual impact HF knowledge has in SMEs and Multinational companies;
- Understand what is the role of HF experts within organisations;
- Methods to integrate control room issues (like alarm handling, decision support, information management) into a broader safety philosophy, carried through all layers of the organisation;
6.1.2 Human-Centred Design

Considering that design failures could be root causes for accidents, it is essential to improve the integration of Human and Organisational Factors (H&OF) during design activities; no matter whether they are performed for new plants or revamping and/or modifications/maintenance projects (technical and/or documentary projects) of industrial risky processes.

The design process of technical means is realised in specialised engineering offices by several design teams. Because of the high complexity of contemporary technical means, several offices and teams are involved in the design process. H&OF-related issues are based on specific knowledge from disciplines like ergonomics, biomechanics, safety engineering, psychology, occupational medicine, law and the like. Many of them are supported by more or less sophisticated computer applications. This specialised knowledge does not belong to the “classic” engineering background and is rather relegated to specialists.

In order to improve the communication within the designers’ community and the relations between designer and operators, a participatory design approach should be introduced. Thus, a common Virtual Reality (VR) platform should be created and used as an overarching means for better communication, with VR tools “tailored” to needs of each participant and accessible during the common design sessions.

In this approach, the subject of the designing process arises gradually from strategic phase to implementation phase. The technical features are explored and in parallel completed with H&OF-related ones.

Thus, in practice, instead of high sophisticated VR tools in hands of narrow group of high qualified designers, a broader access to VR-supported specialists to the solving of common design tasks is desirable. Human body modelling, ergonomics analysis, biomechanical analysis and other H&OF-related tasks, belongs to rather seldom widespread skills within designers’ teams. In line with this, H&OF-related design problems to solve in SMEs environments could be supported more effectively. The dissemination of the H&OF-oriented knowledge is possible by means of participatory design approaches based on suitable Knowledge Engineering methods which can be fostered by means of VR-based tools.

The approach will consider the standards, expectation of the safety authorities, the development of simulation, modelling or virtual reality applications tools but also methods and tools in order to observe on-site or simulated normal or accidental working situations. The exploitation of Feedback Experience results (incidents, accidents, real or simulated working situations analysed) will be considered also as the possibility of maintenance during operation of the process designed or modified or the renewal projects mixing new and old technologies (hybrid process).

The aims of the research is to develop an approach permitting a better integration of Human and Organisational factors in the design and renewal projects in order to assess, as soon as possible and during all the phases of implementation of the projects, the impacts of the design and modifications on working situations. The trend will be improvement of the safety performance of the risk process and also the performance of the project in terms delays, quality, costs and acceptance of its products taken into account the needs of the stakeholders and real working situations.
6.1.2.1 Virtual Reality Applications for Real-Time & Human and organisation-Centred Design

For engineering companies spending further time on safety reviews than that already spent is far from being commercially tempting. This is true unless the task would be compensated by a reduction of designing time and resources while assessing the ergonomic features, either anthropometric or cognitive, of plant layouts. In recent years modern 3D visualisation technologies are slowly substituting, through more or less elaborated forms of CAD-like applications, conventional “paper-based” approaches and techniques for designing and performing safety reviews. Thus, they are partially promising to help designing more quickly and efficiently. In this context more advanced approaches, such as real-time applications of Virtual and Augmented Reality (V&AR), as well as Collaborative Virtual Environments, would help boosting the validation of each designing process by means of an integrated approach that will allow taking into deserved consideration even human and organisational factors while testing the goodness of design features.

**Short Term Research**

The most urgent need is to streamline Virtual Reality (VR) applications and make them more compatible with existing CAD-like files/approaches so to enable engineering companies to move towards VR applications and allowing them to make more efficient safety design reviews by means of human and organisation-centred approaches.

There is also an urgent need for research on the design of production lines that stimulate the use of the innovative force of employees and flexibility. This knowledge should be built in virtual systems to support designers and engineers in designing these lines taking also into account the health and production effects of a whole day work.

The short-term research needs are in particular:

- Methods, existing data and techniques for implementing a human and organisation-centred design approach (standards, expectation of safety authorities, feed back experience data, methods to observe on-site activities or simulated normal or accidental working situations....), and
- Adaptation of easy-to-apply usability test methods to designs ranging from instrument displays and tools to large-scale task environments such as control rooms. Test methods may range from prototypes, desktop simulations, VR-applications, to full-scale simulations. In order to exploit the potential of human and organisation-centred design it is important to base predictions on either validated models or actual tests of usability.

**Mid Term Research**

Starting from the assumption that often engineering companies, more than simply designing plants, are even asked to construct and commission them. Thus just after a successful application of VR application as “super” visualisation tools to help the safety design review, the need would be to produce interactive and real-time Virtual and Augmented Reality Applications that could enable designers to anticipate flaws in the design operating layouts before start building them in reality.

Development of approaches that may be used by designers who will typically have no specific background in human and organisational factors or ergonomics with selection criteria in order to choose adapted approach to face the risks and impacts identified, and permitting a better integration of Human and Organisational factors in the design and renewal projects
and also possible integration and perpetuation of the approaches in the existing engineering procedures and organisations.

**Long Term Research**

The long term target would be to produce VR applications that could enable engineering companies to designing plants and layouts almost only by means of VR applications and enabling them to speed up the mean time need to designing and revamping plants and layouts while using a human-centred approach. In short find ways to enable designers making real-time changes to the layouts of the Virtual Environments without being forced to go back to CAD files for modifying them. The feature of being able to move from a CAD drawing (3D) to a Virtual world seems very promising for future research. However, we should not only focus in one direction only. The ability to after creating a model, be able to import it in a VR installation and then after making changes (model moving, shaping, texturing, etc) re-import it in the first CAD software for further processing would aid and significantly decrease design cost (in all aspects of resources).

6.1.2.2 Inclusive design for sensitive workers (like disabled people, pregnant women, older workers)

The application of human centred criteria in the field of work environment adaptation plays an important role in order to promote the social and occupational integration of functional limited workers.

- For employing disabled people it is a need to identify areas of mismatching between work environment demands and worker functional abilities.
- Protection of motherhood from ergonomic work-related risks is a common need and aiming in many countries all over the world.
- Improvement of the ageing workers’ quality of life by preventive strategies focused on avoiding or minimising problems related to ergonomic working conditions, contributes to the improvement of the employment and the enlargement of working life.

**Short Term Research**

Knowledge of the main ergonomic problems that the ageing workers have in their labour activity, determine the influence of physical workload in musculoskeletal disorders and in other ergonomic problems that cause a worsening in health and in quality of life of ageing workers, and determine the main factors that cause a reduction in functional capacities related to ageing that should be considered in the existing methods for risk assessment.

**Short-Term Research**

- Mapping the needs of people with disabilities for the adaptation of the demands of working environments to functional capacities of people with disabilities in different contexts: selection of new employments, adaptation of work environments for people working, return to work of injured people, etc.
- Mapping of ergonomic problems of pregnant women at the workplace and development of risk levels and design guidelines.
- Research on main problems of people with disabilities.

**Mid Term Research**

- Development of methodologies for adapting work environments to people with physical, sensorial and/or mental limitations.
- Elaboration of procedures focused on ergonomic evaluation of working conditions for pregnant workers.
- Integration of the needs of ageing workers into methodologies for ergonomic risk assessment.

**Long Term Research**
- Development of global, customised tools for ergonomic risk assessment and work environment re-design taking into account long life working needs and covering temporal and permanent situations of special needs.

### 6.1.3 Integrated Risk Assessment and Management Methods & Techniques

#### 6.1.3.1 Integrating Human Factors into Quantitative Risk Analysis (QRA)
In QRA human error is usually grouped as one of those hazards that lead to initiating events. In fact, many studies show that human error is the biggest contributor to accidents/ incidents in the chemical process industry. The type considered most of the times are direct (operator) errors. This could not be disputed in totality because operator performance, for instance, decision making depends on their ability and qualifications. However, human error does not occur in solitude. There are many human factors that play a major role in the production and propagation of operator errors. These factors include organisational structures and design, which are referred to as latent conditions (Reason 1990). They are dynamic and are heavily influenced by the technological advancement. This rate of change has introduced another level of uncertainty to the probability values that are assigned during the quantitative analysis phase.

#### Short Term Research
For an engineering standpoint, the integration of H&OF into PSA is one the trickiest task to perform. Present methods do not provide thorough paradigms to integrating H&OF into quantitative safety analyses. A methodology to “capture” design flaws and organisational factors that influence operator performance are urgently called for.

#### Mid Term Research
Present static methodologies for risk analysis seem to be quite inadequate to modelling the growing complexity of productive processes. The development of dynamic methodologies, allowing safety analysts to make realistic predictions on future scenarios in which the technological will be analysed together with the H&OF one in a dynamic manner, will be desirable.

#### Long Term Research
In the long run it will be useful to device new paradigms that will allow considering systemic deviations and anticipating systems components behaviour both statically and dynamically.

#### 6.1.3.2 Operator Cognitive Models
Human error is still the major cause of undesired events. An error occurs when the operator fails to execute the right action or executes a wrong control. This could be contributed by operator’s cognitive process limitations. An operator acts on a certain situation depending on the mental image formed concerning that particular situation. Increasing automation and
complexity of plants have transformed the role of the operator to that of monitoring the process in production. It has increased the cognitive aspects of human performance.

**Short Term Research**
To understand people mind in terms of cognitive maps used/produced when making decisions at any level of an organisation are urgently called for, as that would allow designing tasks, HTIs and organisational set-ups more efficiently. In particular, understanding how cognitive errors are generated, understanding the strategies that operators undertake to solve specific problems during normal, transient and emergency situations, and finally understand the effects of cognitive tasks if more than one operator is working on interrelated tasks (task-sharing).

**Mid Term Research**
In the mid term would be extremely useful to try having a “unified theory of cognition” with regard to the aforementioned issues so to supporting safety-related decision making at any level of an organisation.

6.1.3.3 Human factors in Task Management
Humans are likely to remain the most flexible and innovative manufacturing resource in the foreseeable future. For this reason, it is required a healthy and motivated work force. Nowadays, productivity, quality, worker’s motivation and health are considered as the key elements for successful manufacturing. However, in many manufacturing companies, the production lines are mainly designed from a production point of view.

**Short Term Research**
Development of knowledge to find the individual optimum between over and under load

**Mid Term Research**
Development of simulation systems for small tasks that predict all day effects
Design of management/control systems that takes into account all human variations and aspects
Development of simulation tools to test organisation, technology and human aspects for complete jobs
Systems that support self control organisations with simulation tools enabling continuous improvement
Design systems for dynamic allocation of functions individual workload

**Long Term Research**
Design computer-aided collaborative self-design and self-control systems

6.1.3.4 Data Retrieval
Human error is usually grouped as one of those hazards that influence the initiating events. The type considered most of the times are direct errors. This could not be disputed in totality because operator performance, for instance, decision making depends on their ability and qualifications. However human error does not occur in solitude. There are many factors that play a major role in the production and propagation of operator errors. These factors include organisational structures, design, personal factors etc. They are dynamic and are heavily influenced by the technological advancement. This rate of change has introduced another level of uncertainty to the probability values that are assigned during the quantitative analysis
phase. Further investigation is required on this field to identify how this change of technology and change in organisational goals has affected the human error probabilities. In this field a database of human reliability is also required.

**Short Term Research**
Ways to collect reliable data on human responses in a wide range of daily operational activities, such as control room operations, field operations, maintenance operations, as well as during emergency situations.

**Mid Term Research**
Methods to manipulate data on human responses which enable to perform Quantitative Risk Assessments both static and dynamic ones.

6.1.4

6.1.5 Human Performance & Technology Usability

6.1.5.1 Decision making and handling of conflicting objectives

Inadequate handling of conflicting objectives has been repeatedly identified as a contributing factor in accidents. Moreover, effective utilisation of risk methods requires that the methods are adapted to the decision context where they are used. We want to integrate behavioural and organisational theories of decision making in a way that enables us to understand (1) how conflicting objectives related to safety are handled at different levels, and (2) how such processes at different levels interact and affect the risk level.

**Short Term Research**
Develop knowledge and methods that can improve the understanding of human and organisational decision making and handling of conflicting objectives related to safety.

6.1.5.2 Human Performance in Virtual Environments

As far as VR applications are becoming an appealing way forward to tackling H&OF issues, their impact on human performance need to be carefully investigated. The Human-Virtual Environments interaction certainly imposes in-depth analyses to through the light on the effect that virtual worlds have on perception and then on performance. At present very little is done and much work has to be spent on this matter in the years to come.

**Short Term Research**
A systematic and thorough benchmarking of “natural and virtual manoeuvrings” will provide the first big portion in the understanding of what the human performance in Virtual Environment is. Through this analysis further issues may arise that would for sure lead the way towards the improvement of human performance in virtual environments.

6.1.5.3 Effective Knowledge Transfer to Improving Human Performance

The effective Knowledge transfer is a key issue to the improvement of human organisation efficiency for risk management. The knowledge includes formal knowledge of phenomena and processes, methodologies, data about substances, but also the tacit knowledge of all the
actors of the process. Most of the potential for improving safety resides in the capacity to make this expertise explicit and available to all the actors of the risk management process.

- Short Term Research
- In the short term it would be useful to find practical techniques to make the “subjective” knowledge present in companies’ operators, evident, clear, available, and, above all, usable to all of those that, for many reasons, might need to use it while performing safety activities. An example is the useful knowledge about the little flaws, imperfections of components behaviour that only specific operators hold and that, in case of maintenance or repair activities, could be of help if the operator that knows intimately the apparatus is not present.

6.1.5.4 Team-working
Team-working is arguably a more mature area of research and industry application than safety culture improvement. The benefits of team-working for non-safety outcomes are generally recognised. There is clear evidence from other domains, particularly aviation, of the beneficial effects on safety performance of well-structured team-working.

Longitudinal research on the performance impact of developing “safe teams”, which includes using knowledge gained from Crew Resource Management programmes in the aviation industry
Better understanding of the nature and typology of team errors (as opposed to individual errors), and how to prevent or mitigate such errors

6.1.5.5 Alarms Handling & Design

Alarm Design and Management is still an open area of research that needs strong improvements. Alarms devices are very important supporting tools for decision making and can play either a positive or a negative role in human performance during the human intervention on technological systems. This is true for normal operations, i.e., those performed during the normal activity that follows well defined tasks, as well as during off-nominal and, above all, emergency situations. Alarms and alerts can act as key driving and supporting factors to an effective and efficient human intervention especially in safety-critical circumstances. Clear knowledge on the use of alerting systems, limitations and boundaries is urgently called for especially in light of the growing complexity of technological systems and their associated control systems.

At present, when designing control panels, systems and devices, the trends seems still to be that of putting as many alarmed links as possible to systems variable so to enable the operator to keep them all under control. A correct prioritisation of alarms and alerting devices, as well as a logical interlink amongst them, capable to support the decision making, is still lacking.

Short Term Research
Studies and experimental work aimed at defining human boundaries in handling alarms and alerts. Knowledge on the potentials of alarms and alert systems vis-à-vis the human being, such as the maximum number of alarms processable according to the circumstance, the best means by which alarms should be communicated, i.e., auditory, visual, tactile, etc., and the best frequency of the stimuli, would be highly desirable.
Mid Term Research
Definition of techniques capable to provide designers with robust tools for designing ergonomic interfaces that can ease the decision making in normal as well as critical circumstances especially when the response time is dramatically reduced.

Long Term Research

6.1.5.6 Human-centred design of tools and machines
Materials, machines and technical procedures employed in the production of goods and services are essential to the activities of European enterprises. European machine tools manufacturers represent over 50% of the world production and employ more than 150000 workers in more than 1400 companies. In the last years, the strong competition from Asian countries’ manufacturers of machine tools (mainly Japan, China, Taiwan and South Korea) represents a serious threat for the future of this sector in Europe. More flexible, sophisticated and exact machines are the answer to the requirements of users, supplying constantly updated and innovative products. The application of ergonomic criteria to the design of machinery constitutes a key point in this strategy of innovation. Human centred design may improve user performance when using the machinery and improve the quality of the final product or of the productive process.

Mid term research
Development of emotional based interfaces.
Development of interfaces based on haptic and virtual technologies to improve ergonomics.

Long term research
Development of ergonomic and natural human-machine interfaces.

6.1.5.7 Human-Virtual Environment Interfaces
Nowadays Virtual Reality applications are slowly imposing as the most promising tools to supporting the identification, the analysis and the quantification of the impact of H&OF to the safety level. Complex and highly risky working environments require adequate training to allow operators to reducing at minimum level the commission of erroneous actions. Designing ergonomic interfaces for a natural and nimble use of Virtual Environments (VEs) is then becoming as must as the use of VR is slowly extending to the daily practice and activities and not only as an exception to dealing with critical scenarios.

Short term research
Usable and reliable interfaces are fundamentals enablers to allow H&OF experts to perform in-depth investigations and studies on the impact of H&OF on safety production. Interfaces need improvements in terms of sectorial usability benchmarking specifically carried out for specific safety applications. In addition, other priority is to find out common means to benchmarking Human-Virtual Environments Interfaces and enable their ranking, as well as setting design interfaces specifications and codes, derived from cognitive studies. Finally a clear definition of what the absolute limitations, i.e., those limitations that will never overcome, of VR applications are urgently called for.
Mid term research

Mid term priority would be to find out new and more efficient interfaces for human adaptation to Virtual Environments. Research should not only be limited to human adaptation but should further improve current issues concerning important factors such as VR-sickness and interface ergonomics (weight, shape, etc). Additionally materials improvement should be another very important area of further needed research concerning the interfaces between the human being and the virtual worlds.

Long term Research

6.1.5.8 Development of integrated systems to implement intelligent capabilities in the Personal Protective Equipment (artificial vision, speech recognition, haptic interfaces, sensors for environmental perception, etc)

The main goal of the integrated monitoring systems used in personal protective equipment is to ensure the most effective control of physiological condition of PPE users, taking into account environmental conditions and the workload. Through the design and production of miniature sensors as well as data transmitting systems, such embedded systems may form an integral part of protective clothing, hearing protectors, head and eye protection, respiratory protective devices etc. Dynamic development of technology of materials, together with progressive miniaturisation and the increased computing performance of signal processing systems will make it possible to design an innovative personal protective equipment of unique properties.

Short-term Research

Research in will include usability studies of possible embedded systems applied for PPE, concerning for example vision support through long-distance transmission of images; use of speech recognition systems, and personal sensors signalling hazard level due to exposure to physical and chemical factors.

Moreover, the assessment of correct functioning of PPE intelligent systems requires research on the development of new testing methods, which will allow verification of their protective properties and practicability.

6.1.5.9 Biomechanics and anthropometric requirements integration in PPE design

The use of personal protective equipment is always related to a significant psychophysical load of a human body. It results in negative reactions that may lead to possible rejection of protection equipment. Therefore it is necessary to develop rules and guidelines for design and assessment methods of PPE ergonomic features.

Short-term Research

The research in this field should include anthropometry, biomechanics, and thermal characteristics as well as biological and sensory aspects. In particular it will be important to carry out anthropometrical measurements taking into account body movements limited by the use of PPE while performing work activities in various working conditions, and to carry out assessment of additional load of movement organs or movement difficulty assessment resulting from the use of PPE.
Mid-Term Research
Moreover, development of computer simulations picturing the phenomena occurring during the use of PPE will constitute an important research topic. The results will increase the possibility of assessing the PPE functioning in situations exceeding capabilities of workplace models used so far in laboratory conditions.

6.1.5.10 Rehabilitative and assistive systems: intelligent machines to enhance the abilities of disabled or elderly people
Rehabilitative and assisting systems are products, instruments, equipments or technical systems used by disabled or elderly people in order to avoid, compensate, reduce or neutralise their deficiency or disability and improve their personal autonomy and quality of life.

6.1.5.11 Research in emotion-based interfaces
Approaches to be considered:
- Emotional Design of user interfaces: Customisation of Emotional Design tools for their application in the context of user interfaces in safety control systems.
- Affective computing developments in safety control systems (consideration of the emotion-cognitive dimension in the involved human decision making processes).
- Signals and signs design: Customisation of Sound Design an Emotional Design tools for the elicitation of awareness of risk.

6.1.5.12 Human-Technology Interfaces design for sensitive collectives at work (Disabled people, pregnant women, young and older workers)
The pace of technological advancements has seen productive processes evolve rapidly into very complex facilities all due to economic reasons. For instance heat and mass transfer have been optimised; automation increased and new process control strategies introduced. This has led to reduction of cost through higher quality and efficiency in production and energy savings. It has though introduced a new challenge. For the operator it is getting more and more difficult to foresee the effects of his actions when operating the plant. Investigation is needed to determine how this new challenge is affecting the operation of a plant.

6.1.6 Human Factors in Emergencies and Crisis Management
Emergencies and Crisis Management in highly intensified and congested productive environment are becoming essential to avoid disaster. The role of H&OF during both emergencies and crises management is key for prompt reaction and efficient action plans. After major accidents such that recently happened in Toulouse, the investigation of what are the most suitable organisational set-ups during emergency and crisis management have to be one of the primary point of attention of the H&OF research in the next years to come. Even in this case, the use of VR applications will be particularly suitable for testing reactions and predicting the dynamics of complex scenarios where many actors play a key role in the resolution of the situation.

Short term research
The identification, definition and characterisation of salient H&OF which play a key role during emergency ought to be a driving force of the short-term research agenda.
6.1.7 Safety and Quality: Could they be merged, do they really match?

The principles of occupational safety and health management systems implemented by many European enterprises according to different standards (e.g. ILO-OSH 2001, OHSAS 18001, BS 8800, PN-N-18001) are based on PDCA cycle that is a basic concept for the quality management system specified in the ISO 9000 standard and for the environment management system specified in the ISO 14000 standard. This makes the OSH management system compatible with QMS and EMS. However there are also some significant differences between these standards, mainly with regard to risk assessment and ensuring appropriate preventive measures and controls. The main ‘beneficiaries’ are also very different: for the OSH management system the ‘prime beneficiaries’ are workers, and for QMS the ‘prime beneficiaries’ are customers.

Because many of the elements of different MS are common or very similar, some organisations are trying to integrate those systems in one overall management system. Such approach is also widely promoted by certification and consultation companies however influence of such integration on safety and health performance has not been explored yet. Therefore there is the need of carrying out research on effectiveness of the “stand alone” safety and health management system in comparison with integrated management systems covering OSH issues. The main result of such research should be recommendations for integrated management in the field of quality and safety ensuring high effectiveness in the both fields.

6.1.8 Organisational forms & Managerial Practice to preventing accidents and managing risk in SMEs

According to Eurostat, the average rate of fatal accidents at work in the EU in 2001 accounted for 2.7 per 100,000 workers, while the fatality rate was twice as much in the micro- and small-sized enterprises. The current EU strategy on OSH states that SMEs (…) should be the subject of specific measures in terms of information, awareness and risk prevention programmes. At the same time the current enforcement of OSH regulations is based on the “pro-active approach”, where the employers themselves are expected to take steps to ensure a satisfactory level of OSH with a minimum government intervention. This means that development of appropriate work organisation and management practice is necessary to fulfilling OSH-related regulations by enterprises and improving working conditions.

In recent years the concepts of OSH management systems have been developed on national and international levels which can support implementation of the “pro-active approach” to OSH. Some systems are specified in international documents such as ILO-OSH 2001 or OHSAS 18001. In some countries (e.g. Denmark, Poland, Spain, UK) national standards on OSH management have been adopted. But these systems are generally aimed at large enterprises and they are mainly used by small elite of companies rather than a broad majority. Such situation indicates the need of further research on organisational forms and management practices which are adapted to the needs of SMEs and could be easily and broadly implemented by them. The main result of such research should be a model of OSH management system adapted to SMEs followed up by a set of tools and methods supporting safety and health management implementation in SMEs.
6.2  **HUMAN & ORGANISATIONAL FACTORS AREAS UNDER DEVELOPMENT**

6.2.1  Risk perception & Risk Communication

6.2.2  Human Factors Knowledge Engineering & Management

6.2.3  Health & Social Issues

6.3  **RESEARCH PRIORITIES FOR 2007 IN THE AREA OF HUMAN AND ORGANISATIONAL FACTORS**

Table 4: Research Priorities for 2007 in the area of Human and Organisational Factors

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<td>Human-Centred Design</td>
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<td>Integrated Risk Assessment and Management</td>
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<td>Human Performance &amp; Technology Usability</td>
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<td>Human Factors in Emergency and Crisis Management</td>
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6.4  **PREVIOUS WORK, EXISTING PROJECTS AND NETWORKS**

6.4.1  European Networks

- PRISM: Process industries safety management; network on human factors (EPSC, UK)
- EFFIMACH - European Network of Excellence for High Efficiency Machining Processes (Co-ordinator: IDEKO Technological Centre, Spain)
- MOST Centre Network initiative (under creation)

6.4.2  European Projects (including 6th FP projects at the negotiation stage)

- CISMS - Collaborative international Study of Managerial Stress (Lancaster University, UK & University of South Florida USA)
- ERGOADAPT- Ergonomics and Disability. Workplace adaptation for people with disabilities (Universitat Politècnica de València, Spain)
- VIRTHUALIS: Virtual Reality and Human Factors Applications for Improving Safety (Politecnico di Milano, IT)
- ENHIP: Ergonomic Instruments Development for Hip Surgery
- HILAS: Avionics, VR and human factors.
- ERGOMACH: Ergonomic design of tools and machines
6.4.3 National networks with common interest

France
- IMdR-SDF : Institut de Maîtrise des Risques – Sûreté de Fonctionnement
- SELF : Société d’Ergonomie de Langue Française

6.4.4 National projects with common interest

Italy
- Evaluation of the appearing hand-arm syndrome probability for workers exposed on the hand-arm vibration in selected occupational groups on the ground of the epidemiological data
- Optimisation back of the seat angle and placement and characteristic of foot pedal in the case of load of lower extremity joints
- Development of an algorithm for muscle fatigue assessment based on the shape of the EMG power spectrum.
- Determination of factors affecting medical, social and occupational rehabilitation of people with disabilities employed in the telework system

Finland
- Organisational culture and management of change –project (The Finnish national research programme on Nuclear safety SAFIR 2003-2006)
- User-centred design of control room interfaces (The Finnish national research programme on Nuclear safety SAFIR 2003-2006)
- Accident investigations in maritime sector
- Developing vessel traffic service operator working practices
- Safety management in health care sector

6.4.5 Key associations/actors at international level

- ESReDA : European Safety Reliability & Data Association
6.5 PARTICIPANTS
The FG is led by:
- Politecnico di Milano (Italy)
- EDF R&D (France)

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Table 4: List of participants in the Focus Group Human and Organisational Factors

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7. EMERGING RISKS

7.1 MISSION STATEMENT OF THE FG

Due to the increasing complexity and interdependencies of industrial systems as well as global (political) disturbances in the outside societies, there is an urge to emphasise emerging and cross-cutting risk and safety issues that are not traditionally covered under the term “industrial safety”. Emerging risks are considered as both “new” and “increasing” (EU-OSHA, 2005), and a multitude of trends, developments, driving forces and obstacles affects the nature of risks and the context in which they are managed (OECD, 2003).

The risk is considered “new” if:
- the risk was previously unknown and is caused by new processes, new technologies, new types of workplace, or social or organisational change (e.g. risks linked with nanotechnology, biotechnology, ICT technologies, new chemicals, etc); or,
- a long-standing issue is newly considered as a risk due to a change in social or public perceptions (e.g. stress, bullying); or,
- new scientific knowledge allows a long-standing issue to be identified as a new risk, e.g. in the situations where cases have existed for many years without being identified as risk because of, e.g., lack of scientific knowledge.

The risk is “increasing” if the:
- number of hazards leading to the risk is growing, or
- the likelihood of exposure to the hazard leading to the risk is increasing, (exposure level and/or the number of people exposed), or
- effect of the hazard is getting worse (e.g. seriousness of health effects and/or the number of people affected).

Taking into account the concept of Technological Platform, the FG Emerging risks is focused to the new risks, representing the first alert group within the TP on this type of risks. This FG aims also to develop new knowledge and solutions to solve these new problems new technologies, new processes, new materials, new work organisations and work force, like for instance those related to (but not limited to):

- New/emerging technologies (e.g. nanotechnology, biotechnology, etc.)
- New materials and chemicals (e.g. hazard-based approaches/issues and implications coming from novel regulations such as REACH)
- Energy (e.g. renewable energy technologies)
- Interlinking and interaction between industrial safety and natural hazards and risks (e.g. Natural hazards triggering threat to industrial safety)
- ICT, telecommunications
- New characteristics of work force and work organisation (e.g. Networks, industrial parks and other interdependencies)
- Transportation
- Banking and finance

7 The European Agency for Safety and Health (EU-OSHA 2005), Risks Observatory http://riskobservatory.osha.eu.int/risks/).
- Power and Water systems and other utilities
- Emergency services, both governmental and private
- Defining methodology for identification and assessment of new and emerging risks
- Ensuring reliable data and agreeing qualitative and quantitative minimum acceptance criteria in order to help with validation of any future approaches
- Prevention strategies development, testing, and their socio-economic assessment
- Future trends of economical and competitiveness related aspects of risks and risk management – “Economic Price & Value of risk and risk management” (e.g. in cases when the decision is to build a new plant rather than ‘retrofitting’ the old/existing one or produce somewhere else with sometimes dramatic influences on the competitiveness and innovation in Europe.)
- Attacks on and against industrial installations (security aspects in safety of industrial plants - CBRN Risks)
- Future legislation, codes, standards for new and emerging risks
- Globalisation

Some Relevant EU Legislation Examples:
- Council Directive 96/46/EC on the approximation of the laws of the Member States with regard to the transport of dangerous goods by rail;
- Directive 94/55/EC transport of dangerous goods by road, Directive 96/49/EC transport of dangerous goods by rail;
- Communication from the Commission - Fostering Structural Change: An Industrial Policy for an Enlarged Europe (COM/2004/0274 final);

Figure 13: Integrating risks related to various industries and technologies (“Integrated Risk Management”)
Figure 14: Integrating various aspects of risk (“Integrated Risk Management” - IRGC Risk Governance Framework)

The emphasis of FG5 will, therefore, be on Integrated Risk Management (Figure 13) and it must include the issue of Perception of Emerging Risks (Figure 15).

Another dimension of this integrated approach is the one related to the “globalized” market – for instance, it is toady a usual practice that industrial plants have multiple and combined vendors, suppliers or subcontractors. During the life time of a plant they may be “disappearing” in mergers and acquisition, and communication to them hampered due to language barriers. Use of web can bring additional challenges to the dissemination and making available of confidential or sensitive data, what all can end up by putting the risk assessor/manager in front of insurmountable problems.

Other, additional topics could be included within the scope of FG Emerging and cross-cutting risk & safety issues, but always keeping focus on new risks. In addition, the FG5 will be clearly linked to other FGs, delivering to them new ideas and incentives, and looking to receiving the results from their work for the further.

The future risk management approaches to the emerging and cross-cutting risks must capture the interdependencies and interactions among the complex systems, and the increasingly important international dimensions.
7.2 RESEARCH PRIORITIES FOR FP7 IN THE AREA OF EMERGING RISKS

Table 5: Research Priorities for FP7 in the area of Emerging Risks

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<th>Emerging risks and their relation to the following aspects of FP7:</th>
<th>Relevance</th>
<th>Examples</th>
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<tr>
<td><strong>Main Thematic Priorities of FP7</strong></td>
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<tr>
<td>1. Health</td>
<td>Very high</td>
<td>E.g. risks of artificial organs</td>
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<tr>
<td>2. Food, Agriculture and Biotechnology</td>
<td>High⁸</td>
<td>E.g. risks related to long-term effects GMF</td>
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<td>3. Information and Communication Technologies</td>
<td>High⁸</td>
<td>E.g. risks of large-scale ICT-system crashes</td>
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<td>4. Nanosciences, Nanotechnologies, Materials and new Production Technologies</td>
<td>Very high</td>
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<td>5. Energy</td>
<td>Very high</td>
<td>E.g. long term risks of renewable technologies</td>
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<td>6. Environment (including Climate Change)</td>
<td>Very high</td>
<td>E.g. interaction between nature and technology hazards/disasters</td>
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<td>7. Transport (including Aeronautics)</td>
<td>High⁸</td>
<td>E.g. risks related to transportation of (new) hazardous materials by (new) means of transportation</td>
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<td>8. Socio-economic Sciences and the Humanities</td>
<td>Very high</td>
<td>E.g. societal risks related to possible failures of critical industrial plants and systems</td>
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</tbody>
</table>

⁸ Issue tackled by TPIS, but NOT a declared primary priority of TPIS (yet)
## Emerging risks and their relation to the following aspects of FP7:

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<th>Aspect</th>
<th>Relevance</th>
<th>Examples</th>
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<tbody>
<tr>
<td>9. Security and Space</td>
<td>Very high</td>
<td>E.g. risks related to “garbage” in space, or risks related to terrorists’ attacks on industrial installations</td>
</tr>
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<td>Ideas</td>
<td>Very high</td>
<td>Per definition, industrial safety is a typical multidisciplinary area and as such predestinated to be a “generator of (new/innovative) ideas”</td>
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<tr>
<td>People</td>
<td>High</td>
<td>TPIS involves people from very different areas: it will have to do it even more for emerging risks</td>
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</table>

### Capacities

- **Research Infrastructures**
  - Very high
  - Self-sustainable structures in the area have already been initiated (e.g. MOST, VRi, …)

- **Research for the benefit of SME’s**
  - High
  - Most of them expected from the networking and infrastructures

- **Regions of Knowledge**
  - Yet to be assessed

- **Research Potential**
  - Very high
  - TPIS has already formed a unique “think tank” for the area of emerging risks

- **Science in Society**
  - Very high
  - TPIS provides already a unique way for tackling political and cultural aspects of (new) technology related risks

- **Activities of International Co-operation**
  - Very high
  - Intensive international collaboration with US, Japan and non-EU European countries already established
7.3 GOALS OF THE WORK OF THE FOCUS GROUP

The main practical goals of the FG *Emerging and cross-cutting risk & safety issues* are TO
1. identify new trends, challenges and consequent emerging risks,
2. build priorities for the research to be done
3. identify relevant stakeholders and
4. support and concert/co-ordinate the initiatives related to the new/emerging risks coming from the different stakeholders’ groups.

In addition, FG *Emerging Risks* will:
- Improve on the definition(s) of emerging risks; this will involve a critical review of all the main documents (e.g. OECD, IRGC, etc.)
- Focus on the recognition period – how do we pick up the issues before they are ready to be “released” (e.g. GMOs)
- Focus on the new risk criteria (non fatal, etc.) suitable for the emerging risks. E.g., when there are reasonable criteria then there is less need for “risk debate”, and vice versa, in the absence of criteria there is a need to “spin”. UK is a good example where a flexible and dynamic risk criteria are still applicable and accepted, however only in the area of major accident hazards (chemical, offshore, transportation, etc.). There is a need for say “non fatality” criteria suitable for new risk types.
- Expand on the classification and categorisation along the lines in our brief brainstorming session.
- Identify and systematise practical topics for the future research.

In particular, FG *Emerging and cross-cutting risk & safety issues* will initiate, concert and support all new initiatives contributing to the achievement of the above goals, in particular the EU projects on emerging risk identification and explore the corresponding possibilities like, e.g., the next European Commission SSP call (open date 22/12/05 and close date 22/03/06). Correspondingly, this FG will serve as a monitor and proposer of the emerging and cross-cutting risk & safety issues which may and/or will appear as relevant for the work of the TP. Periodically, the FG will deliver to the TP a ranked overview of the above emerging issues with the suggestion how to tackle them, e.g. in terms of their practical linking and/or inclusion into the SRA.

The above has to be synchronised and matched with the EU actions like, e.g. the FP6 actions on “New and Emerging Risks” (Figure 16).

7.4 FORMAT OF PRESENTING THE PROPOSALS OF THE FG

Wherever possible, when dealing with a particular “emerging issue” the FG has tried to identify:
- Short-term research
- Medium-term research
- Long-term research
- Significant examples
7.5 STRATEGIC RESEARCH AGENDA ON EMERGING RISKS

Importance of the systematic and reliable hazard identification is known in the traditional risk assessment process. The same applies to emerging and cross-cutting risks: the sooner the hazards are identified the sooner the risks can be assessed and managed. Currently, there are no systematics for identification of emerging risks. The most urgent research need is, thus, to develop a generic methodology to identify the systems, situations, products and services, where emerging risks may occur. The next step then is to develop the necessary specific methods for different problem areas.

In the following subchapters some examples of the issues to be tackled by the SRA are given.

7.5.1 Future Legislation, codes and standards, and their influence on industry

Lack of unified and consolidated legislation, codes and standards: The EU directives, codes and standards (e.g. PED, 1997, in the area of pressure vessels or REACH) have caused or will cause further unification at the European level, whereas codes/legislation relevant for application of this EU code (e.g. inspection and maintenance in case of the PED) are still practically exclusively national. For the risk-based approaches it can mean that for the same area they are, e.g., partly allowed on the EU level, but rejected on the national level. Further unification of approaches on EU vs. national level is therefore urgently needed.

Figure 16: Example of the EU action related to “New and emerging Risks” (NOTE: Current, still open actions are not directly suitable for the scope of FG5)

The following examples from current practice can be referred to: Council Directive 96/82/EC of 9th December 1996 on the control of major accident hazards involving dangerous substances; Commission Directive 2004/57/EC of the 23rd April 2004 on the identification of pyrotechnic articles and certain ammunition for the purposes of Council Directive 93/15/EC on the harmonisation of the provisions relating to placing on the market and supervision of...

The legislation regarding the terrorist attacks, security, fraud, should be reviewed as a topic in FG5 Emerging Risks and in the TP in general, given the special envisaged activities in the FP7.

### 7.5.2 New/emerging technologies

Industry has to deal with both new and ageing technology and their combinations. Emerging risks are connected to new technologies like developments of nanotechnology, biotechnology and new chemicals as well as the increasing use of information and communication technologies. Many new innovations offer appealing solutions to industry, but too often all their properties and possible influences on other systems are not known.

Introducing more and more decentralised and combined plants, diversifying, e.g., energy production with renewable energy systems and similar measures lead to completely new issues: How to assess the risks of the unknown? Especially of long-term and complex impacts and effects? How to obtain data needed for reliability or risk assessments for the "one-of-the-kind" systems components and systems with virtually no operation record? Some of the issues are covered by the emerging documents (Figure 17), but the issue is still
completely open, especially for industries which are traditionally less “risk-aware”. The questions like, e.g., how to assess the risks of the unknown remain. Practices are to be developed, which include the hazard scenarios identification into the design and development of new products and technologies as well as a requirement and a procedure on the generation (laboratory testing, etc.) and collection of the data needed in the risk assessment of the new product or technology.

On ageing plants, industry is facing new challenges when the lifetime of the plant and its systems is prolonged well beyond its designed lifetime. Old plants are often economists’ short-term favourites – economic pressure to increase the plant life can be huge and possible benefits (e.g. no need to ask for new permits, etc.) appealing. But the decisions can be made on unrealistic basis, when assessing risks of old plants is often done by younger engineers who do not have experience of the plant and who may lack of reliable, even basic data. It is important to keep in mind, that in many cases the decision to build a new plant rather than ‘retrofitting’ the old/existing may have dramatic (positive!) influence on the competitiveness and innovation in Europe.

Real integration of the life-cycle of the plant and the technology and assessment of medium and long-term risk is not necessarily the priority for the owner or for the inspector. Nevertheless, for the society, especially if combined with new technologies or refurbished plants it can be really a huge problem, in particular, when the one responsible for the risks/causes/consequences (e.g. a bankrupt company) is not accountable any more.

Short-term research
1. Development of procedures and methods to assess the emerging risks during the development and design of new technologies, processes, products and services. (May be an application of /similar to the methodology developed for the identification of emerging risks in general)
2. Cyber security and the threats for safety automation and other automation systems - work on standards.

Medium-term research
New, secure ICT solutions for new and old plants - includes
- implementation of standards
- Development and implementation of networking equipment and standards for managing security of electronic commerce in industry

Long-term research
On line risk assessment, the bases for which are to be developed during the design phase.

Examples
- CO₂ storage (“Zero Emission” TP)
- LPG storage
- H₂ storage
- Deep-water off-shore technology
- …
7.5.3 Methodology for identification and assessment of new and emerging risks

Some methodologies are already available or under development, but a consolidated widely accepted methodology is still due to be done. The general methodology could follow the path presented in the next figure.

![Figure 18: Emerging Risk Estimation Process](image)

7.5.4 Networks, industrial parks and other interdependencies

The industry has nowadays outsourced maintenance and other activities that are not considered as their core business. This way they have created complicated networks, where service providers have also outsourced their activities to subcontractors, which use other subcontractors and so on. Industrial sites are also split into several companies according to the different production activities and activities supporting the production. This trend is creating industrial parks where several separate organisations are working on the same site and responsibilities are not always clear. How to ensure safety, security and reliability of the networks and industrial parks is one of the key questions in the field.

Today industrial installations have several interdependencies with systems and installations that are not under the same (safety) management. This has increased their vulnerability against secondary hazards when the primary source of hazard is one or several of their network partners. That creates situations in which all risks are not identified or identified risks cannot be affected by the identifier. For instance, large industrial areas involving chemical installations with substantial amounts of dangerous substances hold the risk of one accident triggering a chain of reactions of major incidents at neighbouring plants. These chains of hazardous events are called "domino effects". Domino effects can also be caused by other interdependent systems than neighbouring chemical installations.

The evaluation of these multi-risk scenarios requires multi-scientific approach and co-operation between experts from different field of technology, social and economical sciences.

**Short-term research**
- to develop the identification of interdependencies and the vulnerability of the installation against disturbances in other systems
- to identify the new characteristics of work force & work organisation after outsourcing and networking, and consequences to industrial safety

**Medium-term research**
- to develop multi-scientific approach to build and evaluate the hazard scenarios in complex networks

**Long-term research**
- to examine the possibilities of the on-line risk assessment
7.5.5 Future trends of economical aspects of risks and risk management – “Economic Price & Value of risk and risk management”

Risk and safety are not only issues “of rules and regulations”. They are also an economic category, “merchandise” in a way, having its price, its market(s), its traders… Those who invest in e.g. risk mitigation or reduction (including prevention strategy development, testing, and their socio-economic assessment) expect an economically measurable benefit, too. This change of paradigm, means in the practice that it is more important to know and manage the risk, than to necessarily reduce or eliminate it "by all means...".

Safety limits are usually imposed by law (e.g. radiation related ones in nuclear power plants, or pollutant emissions in chemical plants) – it means that if the risk of certain averse event in the plant must be kept below the limit, otherwise the plant will be shut down. Economic limits (e.g. in conventional thermal power plants) mean that the additional cost due to experienced and/or potential damage (increasing e.g. the insurance costs) will burden the operation so much that the plant will have to be shut down as non-profitable. In the case that the measures have been successful, the plant can be kept in operation for longer time (Figure 19). For example in the case of a power plant only boiler and piping maintenance cost over the lifetime of the plant can reach the level of the 10% of the capital cost for the whole plant. Therefore, the main issue appears to be finding of the right balance between

- gain/profit obtained by risk-reduction measures (e.g. life extension, higher availability and similar), and
- cost of the risk reduction measures.

In the conditions of the liberalised and globalized market, the above approach is not sufficient, because it does not take into account the fluctuation of market prices.

![Figure 19: Time-dependency of cost, safety and risk (after introduction of risk reduction measures)](image)

Assessing risks of a plant built on the global market – multiple and combined vendors, suppliers or subcontractors “disappearing” in mergers and acquisition, language barriers, use of web (imposing often additional challenges to the confidentiality of sensitive data) can become an insurmountable problem for the assessor.

Several emerging trends in banking and finance threaten the safety and soundness of the industry. These trends include:
• Deregulation and increased competition, which can result in less marginal capability to absorb the costs of added security measures.
• Convergence of technologies in computing, communications, networking, and encryption, which increases the efficiency and flexibility of transaction support, but can add vulnerabilities.
• Internationalisation of commerce, which gives new, non-domestic entities unprecedented access to national systems and information.
• Changing definitions of value. For example, the form of money and the way that information about money is managed have become valuable assets.

**Short-term research**
- Build a theory to represent the correlation between different decisions and solutions and the total safety of the system.

**Medium-term research**
- Create theory and methods to assess the total economical value of safety for a system or company

**Long-term research**
- Model possible impacts of safety and security (risks) onto economical balance sheet

### 7.5.6 Natural hazards triggering threat to industrial safety

There is growing evidence that the climate in different regions of Europe is changing and unexpected natural hazards like floods and forest fires are occurring across the Europe. The natural hazards can trigger the industrial site beyond its safety measures and cause technological hazards. The natural disaster is also affecting several industrial facilities simultaneously and critical utilities like water, power, and communications may not be available. Most industrial sites are not prepared for unexpected natural phenomena, which overloads their system's capacity and makes them vulnerable for technological accidents and loss of production capabilities. Natural hazards affecting industrial safety are cross-cutting risks that require expertise from different scientific fields. In FP6, there are on-going projects, in which natural and man-made risks are dealt with together from the civil protection point-of-view (e.g. IP-PREVIEW, IP-ORCHESTRA).

**Short-term research**
- to identify installations in zones of possible natural risks and the possible consequences of e.g. floods, forest fires and earthquakes
- to identify and evaluate the future trends in the global climate change and if they affect the industrial safety in EU-25

**Medium-term research**
- to develop technologies that tolerate natural and other unexpected hazards
7.5.7 Attacks on and against industrial installations (security aspects in safety of industrial plants - CBRN Risks)

Many industrial installations and especially chemical processes can be operationally risky, environmentally harmful and potentially dangerous when abnormal or destructive situations occur. This makes them attractive to extremist groups to attack a plant. In the third millennium people can realise a new observation of the influence of terrorism in new risks emergence. Geopolitical context has induced risks which cannot be completely avoided. It is illustrated by a lot of events: Sarin Attack in Tokyo Subway (1995), Anthrax Letters (2001), Limburg Attack (2003), September 11, 2001, in New York, London attacks in July 2005 etc. Moreover, we can noted new threats and new hazards appearance: drinking water contamination, bacteria use, attacks on industrial sites...

Especially chemical and nuclear installations can be seen as potential targets that can cause massive devastation outside their fences. They can also provide raw materials for other activities, or they can be used simply for the purposes of intimidation. Industrial installations are also more and more interdependent with other systems and organisations, which increases their vulnerability against domino effects and secondary hazards. Attacks against the external services can cause unexpected interruptions on the vital utilities causing unidentified interferences in the process. On the other hand, outsourced services grant an access for employees of the service providers, which are not under the company's own recruitment system. And most sites are accessible by transportation of raw-materials and products, which may be used as an access route to the site.

It should be remembered that the targets of intentional acts are not necessarily those considered as major accident hazard installations. It is possible that SME’s are more attractive targets than bigger installations, especially if they are easier to enter and if their location is attractive e.g. among high density population or next to a strategic construction or activity. Often SME’s do not have enough resources and knowledge to identify neither their vulnerable targets nor interdependencies with other vulnerable systems. SME’s may also be harder to identify by decision-makers and emergency planners, if there is no national legislation that covers their activities.

**Short-term research**

- to define needs and requirements for further improvement of safety and security of industrial installations, in order to support public and private decision-makers and other stakeholders to take necessary steps in protecting their critical infrastructures.
- to evaluate vulnerability of chemical installations to intentional acts and how the existing methods and legislation cover the intentional acts against chemical installations
- to identify the possible actors and their objectives in order to better understand and prevent the possible risks they may cause. If the malicious actions are meant to cause as much harm as possible, there are differences in targets and outcomes based on who wants to harm and whom

**Medium-term research**

It is impossible to provide 100% foolproof security, around the clock and at all times. Thus, a systematic process risk management strategy is essential to make industrial installations a less attractive and less vulnerable targets for intentional acts. Traditionally, hazard analysis in the chemical industry is used for loss prevention where loss refers to the financial loss of a damaged plant, third party claims and lost production (e.g. Lees, 1980; Lees, 1996). Design and operation procedures have been developed to eliminate or control the most common
hazards like fire, explosion and toxic release, and new procedures have been incorporated into codes and standards. Intentional acts have been considered very unlikely, and thus risk analysis processes have concentrated on human errors, component reliability and protection systems.

Accident scenarios for intentional acts create new challenges for the future process design. Traditionally, accident scenarios have consisted of an event followed by a sequence of predictable consequences. Now, multiple events with unpredictable consequences need to be considered. There is also increasing number of scenarios to evaluate, when earlier improbable scenarios are considered as credible. The number of event combinations and sequences to be considered is increasing exponentially, especially when the interdependencies between chemical industry and other service providers increase.

**Long-term research**

There is a need to build up domino scenarios as well as scenarios with multiple attacks in an interdependent network of vulnerable targets. Today chemical installations have several interdependencies with systems and installations that are not under the same (safety) management. This has increased their vulnerability against secondary hazards when the primary target is one or several of their network partners. The evaluation of these multi-risk scenarios requires multi-scientific approach and co-operation between experts from different field of technology, social and economical sciences.

Multi-event scenarios have effects beyond the design ranges of an industrial installation. Unexpected multi-attacks can trigger the process outside its predefined critical conditions, when the existing safety systems are not any more sufficient, the assumed "safe state" is no more the proper choice, or the equipment is run beyond its design tolerances. To prevent major consequences, more information and data is required of processes and their behaviour when they are exceeding their critical boundaries as defined for the current scenarios. The results can then be used in the design for more robust and inherently safer processes as well as for more appropriate control measures for multi-event scenarios.

7.5.7.1 Management of CBRN Risks in EU-25 and globally

In European Community, there are a lot of existing initiatives of different natures according to diverse competencies and areas in nuclear, radiological, bacteriologic and chemical Risks. But if we consider these activities, a little of these organisations can work in real time, 24 hours a day. Furthermore they are not able to give their Expertise in all the CBRN Risks. Moreover, all the European Countries are concerned by CBRN Risks, and Public Authorities required co-operation between the Member States in case of an inter-state accident (secured network for data exchanges).

**Short-term research**

- To this purpose, the European Commission has established a Community mechanism to facilitate reinforced co-operation in civil protection assistance interventions of making more efficient the capabilities of the European Union and the Member States in the field of civil protection.
- The first objective could be to define a European Network of Real Time Expertise in CBRN Risks which will cover all the Members States Territory. This Network will have to inter-operate and to make safety data exchange.
- This Network needs to develop several research fields and to realise specific studies:
  - Interoperability between different structures in CBRN emergency.
- Development of an EU communication network
- Creation of a data base of the different structures in Europe
- Exchange in real time of data with interoperability and protecting network
- Creation of a system for the treatment and the exchange of data in the same manner

In operational terms, this axis development aims at address the operational and technological issues that need to be considered, to the crisis managers in case of CBRN emergency or technological accidents, from three perspectives:
- crisis prevention;
- operational preparedness;
- management of declared crisis.

**Medium-term research**
The main interests are:

- to globalise Intentional Risks (terrorist acts - threats) and Accidental Risks;
- to globalise CBRN Risks and Industrials Risks (e.g. a Toxic Storage is a Target for Terrorist Act but it could become a Weapon in case of an Attack in this Installation);
- to contribute to the European Union Organisation; the project will define a tool which could be used by the future European Protection Agency.

### 7.5.8 Old/aged plants and integration of risk management in to the life cycle of industrial plants

On ageing plants, industry is facing new challenges when the lifetime of the plant and its systems is prolonged well beyond its designed lifetime. Old plants are often economists’ short-term favourites – economic pressure to increase the plant life can be huge and possible benefits (e.g. no need to ask for new permits, etc.) appealing. But the decisions can be made on unrealistic basis, when assessing risks of old plants is often done by younger engineers who do not have experience of the plant and who may lack of reliable, even basic data. It is important to keep in mind, that in many cases the decision to build a new plant rather than ’retrofitting' the old/existing may have dramatic (positive!) influence on the competitiveness and innovation in Europe.

Real integration of the life-cycle of the plant and the technology and assessment of medium and long-term risk is not necessarily the priority for the owner or for the inspector. Nevertheless, for the society, especially if combined with new technologies or refurbished plants it can be really a huge problem, in particular, when the one responsible for the risks/causes/consequences (e.g. a bankrupt company) is not accountable any more.

### 7.5.9 Interaction with other FG’s of TPIS and other TP’s, as well as other emerging risk aspects yet to be elaborated

It is obvious that, being the “incubator” of new issues and ideas, as soon as some of these issue “overgrow” the limits of emerging risks, they will be passed over to other FG’s or other TP’s dealing with the related issues already (Figure 20).
In the future releases of this chapter dealing with the activities of FG5 the following aspects will be considered and elaborated more in detail:

- **“Blind” application of tools**
  Software systems are nowadays widely used and calculations of the consequences made, but it often remains transparent what assumptions were made and details are frequently hidden in the “black box”. The same often applies to data coming into the risk management systems from other software systems (e.g. monitoring systems, plant databases, etc.) – these data are often not really visible for the analyst.

- **Globalisation**
  Assessing risks of a plant built on the “globalized” market – multiple and combined vendors, suppliers or subcontractors “disappearing” in mergers and acquisition, language barriers, use of web (imposing often additional challenges to the confidentiality of sensitive data) can become an insurmountable problem for the assessor.

- **Risk perception, Political Price & Value of risk**
  Similarly to its economic aspects, risk has also its “political” one. The elections can won or lost on the issues like risk and safety. The major difference to the economic aspects are that the political ones are very much linked not to the real risks, but rather to their perception.
7.6 RESEARCH PRIORITIES FOR 2007 IN THE AREA OF EMERGING RISKS

Based on the above considerations and on the discussions held at FG5 meetings the following main 4 Priorities are described in the table hereunder.

Table 6 : Research Priorities for 2007 in the area of Emerging Risks

<table>
<thead>
<tr>
<th>Title</th>
<th>Reference to the SRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agreed methodology for identification and assessment of emerging</td>
<td>7.5.3</td>
</tr>
<tr>
<td>risk, including development of &quot;Unified / consolidated legislation,</td>
<td></td>
</tr>
<tr>
<td>codes, standards&quot;</td>
<td></td>
</tr>
<tr>
<td>Risks emerging from interaction of all (technical and non-technical)</td>
<td>7.5.4</td>
</tr>
<tr>
<td>aspects of risk including interdependencies, complexity and</td>
<td></td>
</tr>
<tr>
<td>unknown phenomena</td>
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<tr>
<td>Risks emerging from introduction of new technologies including</td>
<td>7.5.5, 7.5.9</td>
</tr>
<tr>
<td>methodology of integrated risk management for new technologies</td>
<td></td>
</tr>
<tr>
<td>Risks emerging from operation of “Old/aged plants” and “Integration</td>
<td>7.5.8</td>
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<tr>
<td>of risk management in Life cycle</td>
<td></td>
</tr>
</tbody>
</table>

7.7 PREVIOUS WORK, EXISTING PROJECTS AND NETWORKS

7.7.1 European Networks and European Projects
This part of the FG5 work will be done together with other FG’s, it is not FG5-specific.

7.7.2 National networks with common interest
This part of the FG5 work will be done together with National Mirror Groups. At the moment, they are envisaged in/for:
- Germany
- Austria
- UK
- France
- Hungary
- Poland
Other National Mirror Groups will be included as soon as they are established.

7.7.3 National projects with common interest
This part of the FG5 work will be done together with National Mirror Groups. At the moment, they are envisaged in/for:
- Germany
- Austria
- UK
- France
- Hungary
- Poland

Other National Mirror Groups will be included as soon as they are established.

### 7.7.4 Key associations / actors / standardisation bodies at the international level

This part of the FG5 work will be done together with other FG’s, it is not FG5-specific.

In particular, the following ones should be included:

- “Risk observatory” ([http://riskobservatory.osha.eu.int](http://riskobservatory.osha.eu.int))
- PEROSH
- CEN TC’s

### 7.8 PARTICIPANTS

The FG is led by

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The table below presents the participants as of December 2005.

#### Table 5 : List of participants/contributors in Focus Group 5

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8. HUB INNOVATION FOR EDUCATION AND TRAINING

8.1 STRATEGIC RESEARCH AGENDA IN EDUCATION AND TRAINING

The hub is a transverse activity of ETPIS, involving all its other actions. Each new development or proposal of new development must be analysed to identify their potential for education and training, promoting a better safety culture and safer behaviour of all persons involved in industrial processes.

Nuclear plants have extremely relevant safety rules, it is assumed that it is the safest sector in the World, nevertheless it run always the same process with the same products. Chemical industry, more complex and divers in number of substances and processes involved, might play a central role in the planning of the activities of the hub, being a sector having one of the most strict safety standards and compromises. This compromise is being promoted through public activities such as the Responsible Care®, and producing one of the lowest indexes of accidents in all industrial sectors (excepting nuclear power plants). Moreover, the management and safety improvement systems developed by the chemical industry can be easily incorporated to other sectors. However, the levels of education and training common in the chemical industry are not frequent in all industrial sectors.

The specific focus of the hub will be on activities for education and training of managers, workers and public on all issues, principles and methods relevant to industrial risk analysis, risk prevention, risk mitigation, risk management as well as on occupational health and safety, along their life, from school to universities, work time, and social activities.

Training and Education has a major role in:
> Safety knowledge and safety culture.
> Creating and enhancing skills for identifying, assessing and managing risks.
> Maintaining and enhancing personal awareness and professional competencies in safety issues.
> Collaborating to improve safety.
> Disseminating and implementing research results.

The strategy for innovative research actions must always cover:
1. How people learn in the academic and industrial environment.
2. How learning is translated into culture.
3. How learning is translated into action.
4. How knowledge is updated and maintained (with and without continuous use).

According to the conclusions and recommendations of the report of the OECD “Workshop on sharing experience in the training of engineers in risk management” (16-March-2004), the education and training programmes for students and engineers should provide them with adequate knowledge in risk assessment and risk management, because their actions may have an impact on human health, the environment, or the property.

In the OECD report the obligations of the engineers were clarified with respect to risk management. Some recommendations are listed below:
• “The moral obligation to take account of the consequences of their work should be instilled in all engineers throughout their training. Specifically, engineers should be encouraged to think about the potential risk of their actions and decisions...”.

• “Safety risk considerations should be integrated into the core of every engineer’s activities and not be considered an add-on activity. Nor should safety be considered a concern only of safety specialist”.

• Engineers may have different roles within organisations/enterprises due to the diversity of their work e.g. design engineer, auditor, policy and rules assessor, etc., activities which demand that they have the appropriate skills and education.

• “One responsibility of engineers should be to influence the culture of their organisations in order to improve safety consciousness (both to be aware of risks caused by the organisation’s activities, and to take actions to improve safety and reduce risks). Engineers should be able to influence corporate decision-making, to raise the awareness of senior executives and educate them with respect to issues concerning safety and risk”.

• “Engineers have a duty to identify safety issues and to provide leadership with respect to safety issues to others in their organisations and to their communities in general.”

• “Hazard and risk assessment activities should be undertaken proactively to predict potential problems, and thereby maximise inherent safety of facilities, rather than only undertaking retrospective reviews in order to identify concerns or justify an existing situation.”

• Effective risk communication (among engineers’ peers, with their superiors, with the community, etc.) is a key element for improving safety of installations and activities.

In the OECD report also appear recommendations regarding training programmes for students and engineers. Some of them are listed below:

“...training is moving to a more integrated approach, involving concepts from a number of disciplines (including social sciences and humanities) to expand the perspectives of engineers and to promote a multidisciplinary approach to decision-making.”

“...the training of all engineers should, at a minimum, include concepts of risk and risk management, while recognising that specific training programmes should take into account the different educational systems ..”

“...engineering programmes should include a special course in risk management...”

“...training on risk should, to the extent possible, integrate perspectives of different relevant engineering disciplines as well as related social sciences and humanities (such as business management, law, economics or psychology)”.

“...concepts of safety and risk, including risk assessment and management, should be introduced to all students in schools and universities (in addition to specialised engineering courses) in order to develop a safety culture in society generally.”

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“...simulations, case studies and other tools designed to provide practical experience are important components of training programmes. However, it was recognised that efforts should be made to refine such tools...”

The content of the SRA has been prepared by trying to cover the detected points of the OECD workshop, and considers that the applicability of tools for education and training is the main way to increase the awareness of people working in the industry.

Conclusions of the above mentioned OECD report should not be restricted to the engineering professionals. While taking into account the different responsibilities and roles of all persons involved in production processes – from plant operators, storage responsible and maintenance personnel to managers – most of the conclusions of the OECD report can be applied or adapted to each case. As seen in the report, education and training is the key to reach high safety conscience and implication.

In this context, the organisation of the activities within the HUB “Education and Training” is described as shown in the figure below.

![Figure 21: Organisation of the activities in the Hub](image)

Activities to be done within this HUB “Education and training” will include research, developing, adapting, and promoting the existing tools and techniques, which are already success factors, as well as those novel ones proposed by other ETPIS Focus Groups.

8.1.1 Support activities

8.1.1.1 State-of-the-art

It is well recognised that many universities, institutions, trade unions and insurance companies offer special training to many different collectives, nevertheless it is also recognised that more and more effort should be done. As an initial research it is necessary to know the actual situation, the state-of-the-art, in Europe.
**Short term research**

In order to identify the actual needs or gaps in safety research “specifically for training and education”, prospective activities should be realised by approaching the safety stakeholders across the different industrial sectors and nations, collecting their feedback, and acting upon it.

In addition to this, a mapping of existing training and educational tools will be done, e.g. integrating and extending the research done within other European activities such as “S2S, a gateway for plant and process safety”, or the SAFERELNET thematic network. This is an important starting point to compare the different approaches between industries and countries. Furthermore, an online database on available training materials such as brochures, transparencies, presentations, books, seminars, conferences, e-learning courses, etc. will help national platforms to choose the most suitable training material for national dissemination. To supplement this activity, validation of the existing simulation resources should be done for usage and particular application areas.

8.1.1.2 Risk perception & risk communication

Dissemination of the existing safety knowledge is the key to maintain the competence of safety practitioners and the broad spectrum of people working and exposed to risk, to achieve reduction of incidents to gain sustainable industrial development.

Some industrial activities are seriously concerned about the social perception of their risks. Chemical industry is perhaps the clearest example. Communicating the concept of risk and giving public information on industrial risks in a right way is one of the most difficult issues in risk management. As a consequence, special attention must be paid to tools and methods useful for education and training in this matter.

**Short term research**

It is necessary to know and understand the mechanism building the risk perception independently, during or after a crisis for all the stakeholders, considering local cultures and laws.

A big effort should be put on determining the best internal and external communication policy to be used in all possible situations, from normal days to possible accidents.

**Mid term research**

Written official documents such as laws or regulations in general can influence safety culture and risk perception. Both extremes are possible; from consider a fatal situation as absolutely possible and certain to avoid it because any situation of that risk could be done.

The real influence and how to focus them to the best situation from the point of view of having a maximum safety surrounding should be done.

8.1.2 Tools for Education and Training

The use of tools in training aims to build the safety culture necessary to develop and devise, at all levels of industrial activities, the proper actions and measures for reducing accidents,
injuries, losses, and claims. In the context of this document, “tools” are methodologies, frameworks and systems which model and reproduce reality or help to understand it. They will allow users to visualise, experience and analyse consequences of possible unsafe actions or physical failures and will be utilised as a guide for making decisions to eliminate, avoid or mitigate potentially dangerous effects.

Beside the classical and modern methods of safety analysis which still waiting to be harmonised across the different industrial sectors and nations, the field of education and training for industrial safety can greatly benefit from two main areas of technological development of the tools: simulation software, and artificial intelligence. Their hybrids offer the possibility of dramatically enhancing the learning process, and making it consistent, user-friendly, more effective and persistent. In addition, the potential for self-training is realised effectively.

The proposed tools can be developed ad-hoc for educational purposes or can be adapted from other applications both existing and proposed by other focus groups or axis within the ETPIS. In both cases, suitable user interface must be designed according to the training and education plan.

8.1.2.1 Application of “Simulation software” for education and training purposes

Numerical simulators are gaining a principal role for training and education purposes. Their development aims at the optimisation of safety, risk assessment, risk management, and behavioural response. Some simulation programs exist already to mimic industrial processes, for instance chemical reactions. Using these tools, the student will be able to understand error consequences, unsafe behaviours and the relevance of good practices, among other things.

Similarly, simulation of potential accidents as a tool to promote better practices in all sectors concerning industrial processes and manufacturing, and simulating other aspects concerning risks (chemical, electrical, fire, etc.) can be used for specific training purposes, from promoting responsible behaviour of operators to design and creating emergency response plans.

Within the group of “Simulation software” it has been included: “Direct numerical simulation”, “Screen simulation”, “Full extend simulation”, “Virtual reality” and “Extended reality”.

Two prime objectives have been identified for this domain:
1. Adapting and further developing of the existing simulation software, which was initially developed for supporting the design, control or management of industrial processes, for their application in “Training and Education” to cover the identified needs
2. Developing those new proposals made by other axis or focus groups of the ETPIS.

**Direct numerical simulation**

The simulator gives numerical results with little graphical support. This level requires an important capacity of abstraction and good skills in using a computer. However, it can be used, for instance, to learn about the extent of the consequences of accidents in chemical environments, release/spread of smoke/gas, fires, explosions, electrical risks, etc. and to acquire skills in designing or operating processes to the principles of Inherent Safety.
Screen simulation
This kind of simulators is usually used in computer games, such as motor racing or flight simulators. An imaginary reality is created in the computer screen. It requires little or no special hardware.

Care is needed to maintain the purpose of such simulators to avoid the user treating them as games. This HUB can exploit their flexibility in education and training.

Full extend simulation
Training is carried out in a copy of the controls of a real system. The unique difference is that behind the control there is not a real facility, device or machine, but a simulator. Users identify the situation as “real with no risk” generating a high-performing learning process.

It is being used in the training of operators of critical systems, such as aircrafts or nuclear power plants. The high cost of the associated hardware limits the applications of full extend simulators to critical operations.

Virtual reality
A non-real but visible and possible to “touch” copy of the control of a real system or the whole real system is created by the simulator and communicated to humans using special interfaces. Virtual reality could contribute to reduce costs of, e.g., full extend simulation, or used to analyse manual operations of assembly, maintenance, etc.

Short term research
Existing software for simulating physic phenomena, such as gas release, thermal behaviour in chemical processes, fire and explosions in industrial environments, among others should be adapted for training engineers and workers as well for teaching undergraduate students. The results of a simulation offer evidence if certain process conditions and concrete situations run to a fatal accident. They could predict the damage produced due to an uncontrolled event.

Simulation software for structural safety, emerging risks from bio and nanotechnologies will be also analysed and updated for teaching and training purposes.

Mid term research
Software for carrying out the simulation of the identification of the risk is much more complex because it takes into consideration a lot of external phenomena with a high level of random or chaotic behaviour, for instance atmospheric conditions. Nevertheless, it should be considered as a mid term objective.

Existing or novel tools should be adapted for teaching and training risk and safety management.

8.1.2.2 Application of “Artificial Intelligence” for Education and Training
In the context of training and education for safety enhancement, the huge world of Artificial Intelligence would be taken into account. However, a functional classification can be proposed:
Decision support systems
A decision support system is a tool that guides users to select the best option. Such systems need a big amount of information normally achieved from workers and engineers, sometimes also from head units or operation.

Diagnostic tools
Diagnostic tools allow guiding users to detect possible causes of a problem containing a high number of uncertainties.

Process planning and scheduling
These tools are methods helping to select the better ways to carry out an operation or process preventing unwanted or unexpected events.

Analysis of human behaviour
Here are considered those tools proposing the most probable human actions in front of different circumstances, allowing detecting critical errors that should be anticipated, prevented and used to detect the system against them.

Both of them are being used recently for training people operating in control rooms. Its use under the role of this HUB is considered very useful because allow to exercise people on taking decisions with no real dramatic or dangerous consequences.

8.1.2.3 Short and medium term research

In the table hereunder, the themes which need to adapt or develop tools for Training and Education both short and medium term are listed.

<table>
<thead>
<tr>
<th>Short term</th>
<th>Medium term</th>
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<tbody>
<tr>
<td>Prevention of Major Accidents.</td>
<td>Risk identification</td>
</tr>
<tr>
<td>Prevention of risk coming from new and emerging technologies, such as bio and nanotechnologies.</td>
<td>Safety and risk management</td>
</tr>
<tr>
<td>Prevention of risks arising from a major use of computers for production tasks.</td>
<td></td>
</tr>
<tr>
<td>Prevention of thermal risk in chemical processes as possible cause of Major Accidents.</td>
<td></td>
</tr>
<tr>
<td>Prevention of fire and explosions (i.e. compliance of ATEX Directive).</td>
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</table>

8.1.3 Techniques for Education and Training
In this context a “Technique” is identified as a method for attracting, maintaining, and stimulating the attention of the user, focusing their activity according to predefined objectives, verifying their progress, and assessing new activities.
Techniques would come essentially from other areas, especially from psychology, didactics and pedagogy supplemented with e-learning techniques. However, they should be analysed and validated from the point of view of their suitability and impact to increase the industrial safety.

Techniques should be useful for:
- Course design
- Contents design and management including simulation and artificial intelligence interface:
- Creation of open platforms and modular systems for education and training, creating shared databases of materials for training and education in industrial environment, meeting points to share information, web-based courses, etc.
- Evaluation of performance and re-engineering of courses and their impact in industrial safety.

Engineers or high level personnel normally know or can imagine what could happen if something is wrong during a process operation, nevertheless accidents occur all over the World without a real decrease. Workers are trained and advised about their risks, but still today they suffer from many incidents and accidents due to inadequate use of safety equipment or safety rules. Managers often do not know the exact consequences of their orders in terms of safety and risks.

A research on how the knowledge should be transferred in industrial environments in the most adequate way is absolutely necessary.

Other facts should be taken into account: in most of the industries a reduction of number of workers and an increasing age lack between them is produced. In this situation it is absolutely necessary to know the best way to transmit the necessary knowledge to run all processes in the best suitable way. It is necessary to maintain and improve their competencies and to enhance their personal awareness.

At the end, the way to convince authorities and managers that workers are humans are not machines should also be found.

Short term research
Prepare training programmes for industrial companies covering form workers to engineers and managers. The special issue of risk perception and communication should have central relevance.

Prepare educational programmes for secondary schools and universities, both for scholars and teachers as well as students and professors.

Safety is the central issue of ETPIS, but taking into account some social characteristics; security should be taken into consideration also. Matters concerning prevention of sabotage, intrusion or terrorism between other could integrate substantial parts of the formation and education programmes.
8.1.3.1 Short and medium term research

<table>
<thead>
<tr>
<th>Short term</th>
<th>Medium term</th>
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<tr>
<td>Increase safe behaviour.</td>
<td>Promote inherent safety.</td>
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<tr>
<td>Techniques in support understanding of the risk.</td>
<td>Prepare emergency response systems.</td>
</tr>
<tr>
<td>Prepare training and educational programmes for being used within the companies.</td>
<td>Social communication of risk.</td>
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<tr>
<td>Prepare training and educational programmes for being used in the school or universities.</td>
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<tr>
<td>Development of innovative tools for web-based courses and e-learning.</td>
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<tr>
<td>Improving social perception of the risks of certain industrial activities.</td>
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<tr>
<td>Prevention of intrusions, terrorism, etc.</td>
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8.2 RESEARCH PRIORITIES FOR 2007 IN THE AREA OF EDUCATION AND TRAINING

Based on the above considerations and on the discussions held at the meetings the following main priorities are described in the table hereunder.

Table 7: Research Priorities for 2007 in the area of Education and training

<table>
<thead>
<tr>
<th>Title</th>
<th>Reference to the SRA</th>
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<tbody>
<tr>
<td>Understand the particularities for the pedagogy in the field of safety (based on risk perception), and improve education and training for students, workers and safety managers</td>
<td>8.1.1</td>
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<tr>
<td>Develop simulators for complex risky situations by using screen simulation, full extend simulation and virtual reality to train and educate</td>
<td>8.1.2</td>
</tr>
<tr>
<td>Creation of open platforms and modular systems for education and training</td>
<td>7.5.5, 7.5.9</td>
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8.3 PREVIOUS WORK, EXISTING PROJECTS AND NETWORKS

8.3.1 European Networks
- S2S, A gateway for plant and process safety. Network, which aims to improve the plant and process safety by offering existing knowledge in an organised way, as well as, tools for process auto assessment.
- **HarsNet**
  A network created to support the hazard assessment of highly reactive systems. Results obtained:
  - HarsMeth methodology, which is a short cut method for chemical process safety assessment procedure specially, designed for SMEs.
  - HarsBook, which is a source of background and reference material on the subject of exothermic reaction hazards.

- **Saferelnet**
  SAFERELNET that is developing training modules and computer based technology for safety and reliability training. S2S is developing training modules for process safety.

- **Safetynet**
  Network with the objective to set up a common European information market for process safety.

- **Process Industries Safety Management - Thematic Network on Human Factors, Prism**
  Network working for the improvement of safety in the European process industries through raising awareness of, and sharing experience in, the application of human factors approaches.

- **Social Learning on Environmental Issues with the Interactive Information and Communication Technologies, Virtualis**
  This network brings together a consortium of specialists in information technology, sustainable development, environmental modelling, public policy and governance, learning psychology and open learning, to develop computer-based learning tools on ecosystems and natural resources.

- **European Network of Excellence on Aspect-Oriented Software Development (AOSD-EUROPE)**
  Open development platforms for software and services. It supports systematic identification, modularization, representation and composition of crosscutting concerns such as security, mobility, distribution and resource management.

- **Supply Networks (CO-DESNET)**
  The creation of "knowledge communities" in production technologies.

- **INTUITION Network of Excellence**
  Network of excellence focused on virtual reality and virtual environments applications for future workspaces.

### 8.3.2 European Projects (including 6th FP projects at the negotiation stage)

There are some projects under the LEONARDO programme dealing with training aspects for safety applications (SAFEHOTEL, e-rescue). The experience of these projects will be considered.

The HUB “Education and Training” is a transverse or horizontal activity within the ETPIS, so basic development is already cited by the other focus groups. This work group must continually communicate with the other FGs to serve them and learn from them.
8.3.3 National networks and projects with common interest
The national networks in the field of occupational health and safety will be considered. Gaps and redundancy need to be assessed in order to maximise efficiency without missing vital needs or opportunities.

8.3.4 Key associations / actors at international level
- European Agency for Safety and Health at Work (osha.eu.int).
- National equivalent agencies
- National Competent Authorities on several subjects:
  - Safety and Health at Work
  - Industrial operation and development
  - Major accidents
- Trade Unions : www.etuc.org
- Associations :

8.3.5 Participants
The HUB is led by:
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Dirk Oberhageman : ober@safetynet.de

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</table>
Further organisations to be integrated are at a first step organisations working on education and training aspects for different kind of industry.

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<th>Name</th>
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9. HUB NANOSAFE

9.1 MISSION AND OBJECTIVES

Industrial needs in terms of nanomaterials are increasing. Many sectors are concerned, ranging from mature high volume markets like automotive applications, high added value parts like space & aeronautic components or even emerging activities like new technologies for energy. Also are concerned domains with a planetary impact like environment and new products and functions for health and safety of people. Nanotechnologies (e.g. nanoparticles) will play a key role in promoting innovation in design and realisation of multifunctional materials for the future, either by improving usual products or creating new functions and new products. Nevertheless, this huge evolution of the industry of materials could only happen if the main technological and economic challenges are solved with reference to the societal acceptance.

Those concern the mastering, over the whole life cycle of the products, of the potential risks, by an integration of the elaboration channels, while taking into account recycling. Some initiatives have already proposed a global concept for risk evaluation and management (NANOSAFE 2 Integrated Project), a next step, industrial production-oriented, is will start in 2006 with SAPHIR Integrated Project, with the objective to add the missing industrial bricks to the desired responsible approach, by means of the development of the concept of the future “factory for nano’s” and to set it up for a selected number of representative examples.

The overall objective of the HUB NANOSAFE is to develop synergies between projects dealing with the safe nanomanufacturing. This includes the development of:

- advanced detection and monitoring technologies at workplace
- secure integrated industrial processes
- a global approach all along the life cycle
- knowledge on health and environmental effects of nanoparticles

In operational terms, the HUB NANOSAFE will to bring together companies, research institutes, the financial world and regulatory authorities at the European level to define a common research agenda mobilising a critical mass of National and European public and private resources.
9.2 STRATEGIC RESEARCH AGENDA RELATED TO THE HUB NANOSAFE

9.2.1 Technical issues
- Chemical reactivity of nanoparticles (in gas, solid and liquid phases, catalysis; fires)
- Explosivity (detonation) of nanoparticles
- Initiating sources leading to reactivity and explosibility (i.e., thermal runaway, electrostatics, mechanical sparking…)
- Life cycle risk analysis (from creation to disposal)
- Dispersion of nanoparticles in air, water, soils
- Toxicology and ecotoxicology (human, animal, vegetal)
- Epidemiology

9.2.2 Societal issues
- Legislation / standardisation, legal framework
- Health, environmental and financial risk assessment

9.2.3 Enabling technology development
- Metrologies (detection, identification and characterisation at nanomaterial scale)
- Metrology for basic health and safety data obtention
  - Toxicity and ecotoxicity (i.e., biomarkers, DNA markers, …)
  - Reactivity, explosion, and dispersion
- Filtration technology (gas, liquid …)
- Inherent and integrated safety technology (i.e., process intensification …)
- Risk assessment and management tools and methodologies integrating human and organisational factors, the notion of risk due to scientific and technical uncertainty associated with this technology
- Risk governance and communication, dialogue with society
- Education and training
- Development of demonstration and pilot production lines like described in the following figure

9.2.4 A Two-Pronged Approach:
The specific goals and means of HUB NANOSAFE are define in order to reduce and even eliminate environmental, safety and financial barriers associated with this emerging technology. HUB NANOSAFE will enable an efficient deployment, by providing new tools and methodologies to socially and responsibly handle health, safety and environmental risks associated with the deployment of such a technology.

9.2.4.1 Bottom-up (vertical)
Construction of a targeted nanoparticle platform so as to screen and focus on relevant tools and methodologies needed to safely deploy this emerging technology.

9.2.4.2 Horizontal
Cross fertilisation with other platform or networks so as to reduce duplication, improve complementarity, and share benefits from multihorizon developments (i.e., construction, chemistry…).
9.2.4.3 Implementation
This approach is declined in terms of:
- Pillar type expertise (vertical): (instrumentation, metrology, …)
- Crossing expertise (horizontal): cross field integration of proven methodologies for the safe design and commercialisation of multi features nanomaterials based products.

9.2.4.4 General Outputs
- Sharing the best practices in term of technologies through networks of suppliers and consultants
- Provide proven safety groundwork (methods, metrology, guidelines…) so as to ease the deployment and the appropriation of the best practice technologies through EU SME’s.
- Spur technology development through EU SMEs, rather than keeping it within large multinational companies
- Facilitate and improve the implementation of the EU legal framework.

9.3 RESEARCH PRIORITIES FOR 2007 FOR THE HUB NANOSAFE
The HUB NANOSAFE consists in applied risk research to develop proven methodologies for the safe and secure development of this emerging technology taking into account the societal and financial uncertainties.
In term of innovation, the HUB NANOSAFE intends to:
- Foster new enabling technologies (specific metrology for nanoscale materials…)
- Foster new development in risk assessment, management, decision making taking into account societal, technical and economic deployment uncertainty specific to such emerging technologies
- Assist SMEs to develop activities in the field of nanotechnologies
- Implement new technologies to improve education and training

Table 8 : Research Priorities for 2007 in the Hub NanoSafe

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<td>Organisation of an international workshop on detection technologies used for nanomaterial</td>
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<td>Development of detection and measurement technologies at the industrial scale</td>
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9.4 **Structuration of the HUB – Methodology**

According to the main objective, the structuration of the NANOSAFE HUB partnership will be achieved through the **synergy development** of 4 Integrated Projects.

- **NANOSAFE 2** (Risk Assessment & Risk Management)
- **SAPHIR** (Industrial deployment of nanomanufacturing through demonstration platforms)
- **MEDITRANS** (development of nanoparticles for medical applications)
- **NANOSECURE** (development of nanomaterials for security and environment)

![Figure 22: Structuration of the Hub NanoSafe](image)

Each of these projects will take strong benefits from its interaction with the others through the HUB.
Figure 23: Relation between Hub NanoSafe and existing projects

- Synergy between NANOSAFE 2 and SAPHIR

NANOSAFE 2 represents the first approach to this cross fertilisation process. NANOSAFE 2 will develop **innovative detection, traceability and characterisation** techniques for engineered nanoparticles. Both **air and liquid media** will be investigated.

The project will create a **database** on toxicology related to nanoparticles in order to collect and organise all the available knowledge from literature. Industrials will be solicited for sharing data or supporting toxicological tests for specific nanoparticles, they will provide knowledge to the consortium regarding internal test results. A methodology, based on an **innovative generic technology for analysing toxicity** of such nanoparticles, will be the second major deliverable.

NANOSAFE 2 will develop **advanced technologies to limit both exposition to nanoparticles and leaks to environment** by designing safe production equipment, handling automation, dynamic confinement, individual protection devices, filtration, etc. **New procedures** developed in this program will then be qualified at industrial sites in the frame of the **global risk management strategy** proposed in NANOSAFE 2.

NANOSAFE 2 will evaluate both societal and environmental impacts and contribute indirectly to new **legislation and standardisation** measures relevant for nanoparticles, by involving **regulatory bodies** (HSL, HVBG-BIA which are members of CEN). This project will insure a large **dissemination** of knowledge on nanoparticle safety by organising workshops.
with world wide standards organisations, promote population awareness, academic and professional training activities.

As an industrial continuation of NANOSAFE 2, the objective of SAPHIR is to develop industrial demonstration platforms to prove the safe integration of nanotechnologies in different pilot lines. Therefore, the concept of “factory for nano’s” proposed by SAPHIR requires a highly integrated approach since the safe production of final products should encompass different steps, from the safe production of nanoparticles (nanopowders, nanotubes), through recovery & conditioning, to their transformation towards multifunctional nano-structured products.

These challenges for example include safe integration of nanopowder metallurgy, safe development of carbon nanotubes application and in general nanoparticle based industrial systems avoiding exposure of workers to possible risks from the beginning to the end of the complete production line. In particular, the innovations generated in NANOSAFE 2 in terms of advanced detection and monitoring technologies will be tested on real cases at industrial level in SAPHIR and implemented on the demonstration lines.

- **Synergy between NANOSAFE 2 and MEDITRANS**

The development of new nanocarriers for drug delivery needs previous toxicity tests concerning those possible new nano carriers. A strong synergy between NANOSAFE 2 and MEDITRANS could be used on two aspects:

- the development of new in vitro toxicity screening test
- the early toxicity screening of some nanoparticles (for example carbon nanotubes)
• Synergy between SAPHIR, NANOSECURE and NANOSAFE 2

The different technologies developed in SAPHIR concerning in particular surfaces functionalisation by nanoparticles on large areas for catalytic applications will be used in NANOSECURE project in order to safe produce demonstrators for detoxification panels. Some technological development of NANOSECURE in particular for the detection of hazardous substances could also be used for the detection of some nanoparticles in the atmosphere at workplace. It is for example the case of recognition by peptides.

Another goal of this combination of projects is the communication aspect. These 4 projects will simultaneously show to the public:

- a responsible global approach
- the possibility to manage safe nanomanufacturing at industrial level
- the immediate and concrete benefit of nanomaterials (health, security, environment, transport, energy) through technological demonstrators

The first phase of structuration of the NANOSAFE HUB will also permit cross fertilisation with other European Technology Platforms through the participation of the different industrial partners involved in the 4 integrated projects of the structuration phase (Nanosafe 2, Saphir, Meditrans, Nanosecure). These partners will constitute the first contact point between the hub and the sectorial European Technology Platforms.

![Figure 25: Structuration of the NANOSAFE HUB with other TPs](image-url)
9.5 CO-OPERATION AT GLOBAL LEVEL AND BENEFITS OF THE NANOSAFE HUB

9.5.1 Network of collaboration at a global scale
A future objective of the NANOSAFE HUB will also be to create a network of collaboration at a global scale, including for example US (Rice University), Canada (Nano Quebec), Japan (NEDO), China (Univ of Beijing). This network of competencies will be structured through a NANOSAFE CYBERLAB in the next few years.

![Figure 26](image)

9.5.2 Benefits of the NANOSAFE HUB
The NANOSAFE HUB will create new enabling technologies (metrology for nanoscale material, advanced detection systems, integrated production lines, etc.), and will promote new development in risk assessment as well as in decision making taking into account societal concerns specific to emerging technologies. Moreover the HUB will provide rapid toxicity screening methods and a toxicity database which can form the basis for best industrial practice and regulatory measures.

9.5.3 Interaction with the other focus groups
The NANOSAFE HUB will also benefit from knowledge and methodologies generated by the different focus groups. So a strong interaction will be developed.

![Figure 27](image)
9.5.4 National level through mirror technology platforms

As it is the case in France through the national technology platform, the HUB will disseminate and transfer knowledge through the national mirror groups.

Figure 28: Example of ECRIN webportal in France
9.6 PARTICIPANTS

The Hub is led by CEA (France) and INERIS (France)

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