A Vision of Structural Assessment Monitoring and Control

Strategic Research Agenda

March 2006

Content

01 Introduction

Introduction

SAMCO, the European Network for Structural Assessment Monitoring and Control consists of high level representatives of European and global stakeholders involved in monitoring assessment and control. It has taken the challenging task to define an ambitious yet realistic vision of an improved integrated intelligent system for 2010 and beyond.

One of SAMCO's main missions is to elaborate a strategic research agenda defining priorities and roadmaps with the ambition that it will serve as a reference for the definition of future research plans. SAMCO in combination with I-SAMCO has brought around the table all stakeholders involved in structural assessment monitoring and control to define the necessary research activities for a better future. The future is characterised by

- Intelligent embedded systems invisible but most helpful for the user
- Complex decision support routines that relieves the user of routine work
- Diagnostic methodologies that allow a quick assessment of any structure after unusual events
- Information on the lifecycle management of structures in order to enable future planning and budgeting
- Considerable increase of usability and user safety
- A major contribution to security and extraordinary event awareness
- Increasing of the user comfort while reducing the user costs
- Useful Codes and Standards for general application

The competitiveness and sustainability of Europe's industry, transport systems, energy supply and security management will be focused. This process will support the Lisbon criteria and contribute the Union's goal to become the most competitive and dynamic knowledge based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion.

This initial SAMCO publication reflects the consensus on the vision 2010 – 2020 – and beyond of the SAMCO community as it stands today. This strategic research agenda will be elaborated in more detail and regularly maintained with increasing knowledge. The latest status can be downloaded under www.samco.org/researchagenda

02 SAMCO Structural Assessment Monitoring and Control

Monitoring has successfully conquered the laboratory work, then the production facilities and is now progressing into every aspect of human life. The management of the infrastructure is one of the young fields of monitoring, assessment and structural control. Today's monitoring technology supports science and development and subsequently conquers practical applications. Never the less any new technology raises further questions and enables practical solutions for given problems.

Technology Management in the field of construction is a precondition for the successful market introduction of new and innovative developments. The long way from the idea to the commercial application shows hurdles consisting of a lack of references, a lack of codes and recommendations, as well as the insufficient information and awareness of decision makers.

Construction is traditionally a conservative business. As it represents almost 10% of GNP in Europe any improvement has considerable positive effects on the European development, growth and employment. To acknowledge this fact the role of construction related research projects within the European framework programs has been considerably strengthened over the years. Many outstanding results have been achieved. Anyhow the exploitation of the results has faced the following problems:

- Conservative End Users in the construction business are not sufficiently aware of research and development achievements made trough EU projects.
- Many sophisticated solutions are not applied due to a lack of reference projects or demonstration cases.
- The engineering community is too diversified and uses too many different approaches (lack of benchmark tests).
- Many promising technological approaches lack success due to the lack of raw data or opportunities to get this expensive information.
- Complex technical matters are often seen from diversified point of view. It takes a whole life - whole costs approach to model reality and assess the risks.
- Education is not picking up new technologies fast enough to improve the knowledge of End Users and engineers sufficiently for the acceptance of new ideas.
- Key question of structural dynamics like a consistent definition of damping are not answered by the ongoing research and development projects.
- Experimental methods are little used by the designers due to insufficient knowledge and lack of access to the facilities.

- There are no standards, codes or recommendations for the new technologies. This makes positive decisions for innovative projects by authorities unlikely.
- Recent earthquakes (i.e. Turkey, Taiwan, Greece in 1999) showed that society and engineering is insufficiently prepared and educated for those natural hazards.
- General dissemination and exploitation problems are experienced.

The SAMCO Objectives comprise to offer solutions to above mentioned problems as follows:

- To create a centre of knowledge and reference at JRC in Ispra, Italy.
- To carry out benchmark tests and distribute the raw data freely from a database.
- To work out a recommendation as a basis for a code for monitoring, assessment and control.
- To define necessary steps for a better handling of natural hazards (earthquake, landslides, floods, etc.) loads and the related structural response.
- To provide information about the experimental testing capabilities and allow a big audience to see the tests, use the capacities and learn from it.
- To disseminate the idea of a whole system – whole life approach in structural engineering.
- To address the specific situation of the transportation sector, particular the railways.
- To generate an environment where reference projects can be developed and exploited.
- To organise summer academies for improvement of the education situation.
- To define the needs for further research and development as well as the enhancement of optimal consortia and solutions targeted on the next framework program.
- To convince conservative owners by demonstration projects and material.
- To create a certification agency.
- To compare the European knowledge, standards, technologies and testing techniques with non-European countries.
- To improve the existing bridge management in Europe
- To offer newest monitoring and assessment technologies to bridge management
- To create a feedback from bridge management to the structural engineers and other expects

03 Development of a Strategic SAMCO Research Agenda

The idea of a European Research Area (ERA) created the demand for the coordination of activities and for drafting a joint research agenda based on a vision for 2020 and beyond. The formation of European Technology Platforms (ETPs) brings together all stakeholders of an industrial sector. SAMCO understands itself as a European Technology Platform for structural assessment monitoring and control. Being too small, compared to construction or other ETPs, and having relevance for many of the already founded ETPs, SAMCO decided to formulate its own vision and strategic research agenda. It shall be offered as subsection to the big platform such as:

ECTP – European Construction Technology Platform

ARTEMIS – High lever group on embedded systems

e Mobility – Mobile communications and technology platform

ESTEP – European Steel Technology Platform

ERTRAC – European Road Transport Research Advisory Council

ERRAC – European Railway Research Advisory Council

European Technology Platform on Industrial Safety

and others to be identified

This document is a product of the strategic discussions held during the numerous SAMCO events over the past years and particular of the Strategic Vision Workshop held in Berlin in April 2005, the SAMCO Summer Academy in September 2005 in Zell am See, and the valuable input by SAMCO members.

04 Vision and Challenges for 2010 -- 2020 – and beyond

Vision

Structural Assessment Monitoring and Control, by the year 2020, is expected to play a central role in all aspects of any sustainable infrastructure. The technology will substantially expand on the current concept of "Individual Application" to new paradigms to be summarized in the following:

> *"Europe's infrastructure is sustainable maintained by an environment that enables user friendly, safe, secure and economic management of critical infrastructure systems"*

This vision statement demands that the starting point of the design of future systems and services should be consideration of society's basic needs and interests. The development of the key elements of SAMCO is seen in brief:

- The hardware will develop from isolated systems into integrated sensor networks towards fully embedded systems. Robust reliable and cheap sensors will be embedded everywhere.
- The methodology will develop from the current isolated methods towards harmonized methods that allow integrating various sources of information and end in standardised methods open to a wide range of users.
- The use of the technology, which is currently performed by experts only, will develop into common software tools and end into embedded freeware in every application supporting decision making.
- The application will develop from isolated projects with targeted interest towards an integration of all disciplines and ending in full system integration. SAMCO will be part of everyday life.

Item	2010	2020	beyond 2020
Hardware	Isolated systems	Sensor networks	Embedded systems
Methodology	Isolated methods	Harmonized methods	Standardized methods
User Interaction	By expert only	Software tools	Embedded freeware
Application	Isolated projects	Integration of all disciplines	Full system integration

Objective

SAMCO aims to support the long term and sustainable success of the construction industry, infrastructure operation and associated services, by providing a renewed incentive for research and innovation, both at the industry level and at the government level. It consists of a network of strategic and intellectual alliances to foster the entire innovation process.

- The European construction, infrastructure and associated industries will remain competitive based on technology leadership and innovation.
- Mastering the research challenge will generate new generations of products and services with enhanced properties leading to new applications in many industrial sectors.
- Better use of materials and methodologies will enable increased eco efficiency of the industry and the SMEs.
- The industry will have a reputation as a reliable safe and responsible partner in society.
- Europe will provide an effective framework for sustainable innovation and will straighten its excellence scale base.

Scope

The SAMCO network is made up of 3 sections focusing on key technology areas for development identified by stakeholders:

- Lifecycle management for the existing stock of infrastructures
- Decision support and context awareness in sensor networks with everywhere interfaces supporting mobile user appliances
- Monitoring assessment and mitigation of natural hazards for the protection of the citizens

A horizontal issues group sets the overall context and brings stakeholders together to identify potential barriers to innovation and establish solutions to these challenges. Among other issues, it addresses potential health, safety and environmental concerns for new technologies, as well as factors such as appropriate skilled workforce, knowledge and technology transfer, protection of intellectual property, access to venture capital and SME involvement.

05 Detailed Strategic Research Agenda

The detailed items of the Agenda are represented in Priorities.

- Sensors and Sensor Networks
- Computational Framework
- Understanding the Mechanisms
- Smart Structures
- Environmental Issues
- Safety and Security
- Life Cycle Monitoring
- Risk Assessment and Analysis
- Human Factor
- Cultural Heritage

Sensors and Sensor Networks

- **Embedded Systems** including devices, middleware, software and tools for the construction of intelligent subsystems capable of monitoring and controlling a broad range of structures, appliances and industrial systems. This includes the basic infrastructure of society such as roads, railways, pipelines and communication or electricity networks.
- The objective is to develop **Standard Hardware** to gain comparable structural information. The project shall develop a standard application methodology that enables comparison between different structures. Based on existing hardware, an innovative conception shall be designed and tested, flexible enough to cover future developments. It is intended that a digital inspection tool will replace the current visual inspection.
- The under laying **Neural Network** shall take care of methods to automatically detect sensor defaults, system failures or environmental exceptions.
- Developing **Wireless Sensors** with infinite life, capable of surviving in harsh environment, with a better accuracy which do not need batteries or external magnetic fields for power supply, relying on harvesting vibrational energy to sense information and to wirelessly transmit data.
- **Auto Adaptive Systems** which consider the conditions of the particular structure and environment. The learning system will improve its performance over time.

- **Mobile acquisition and assessment system** with concentration on a mobile acquisition unit including sensors, GPS facilities, a converter, onboard computer and the module for immediate assessment included in the software. The connection shall be done through wireless transmission means to any control room or Internet Protocol Address. Acquired datasets are types of time series (high volume) for detailed investigations.
- An **intelligent instrumentation system** for distributed data collection on large structures. This includes smart interconnection and power autonomy solutions, as well as intelligent interfaces to data networks, incl. internet access. The measuring network must be capable to collect at least 32 channels of data from over 1 km distance with a sampling synchronisation of better than 1 ms. Full 24 Bit dynamic range must be supported up to 50 Hz signal range per sensor. Such instrumentation is the key to a feasible hardware solution.
- An industrial **Continuous Monitoring System (CMS)** for structural damage detection. Its use will mainly be for level-1 **damage detection**, but the possibilities for damage localisation/quantification will be explored. Introducing system identification in an embedded CMS system is innovative and brings the maintenance strategy to a higher level: from being preventive time-based to predictive condition-based.
- A **Periodic Monitoring System (PMS)**, integrating the technology for the **level-2/3 damage assessment**. It is recognised that an embedded CMS only covers the needs of relatively recent, long-span, high-cost bridges and that the condition assessment of older, more common bridges requires a Periodic Monitoring System. Such a system can be deployed for a limited time and can move from bridge to bridge. Such system is currently not available.
- **Monitoring of non-accessible parts of structures:** Novel technologies like acoustic emission, guided mechanical wave propagation, tomographic imaging and flexible piezoelectric fibre sensors shall be applied/developed.
- **Sustainable Instrumentation and Digital Inspection:** A standard technology shall be developed that enables application to all kind of structural systems and comparison of them.
- **Smart Sensor Development based on nano-scale PZT-fibre and film technology:** All aspects of a quick realisation have been considered from conditioning, registration, evaluation of signals, design and optimum positioning in the structural system.
- For **Overhead Power Lines** intelligent instrumentation systems are required with increased sampling rates of 100 Hz to record Aeolian vibrations (Von Kahrman Vortex Shedding). Wireless diagnostics of sensors and sensor systems from the ground shall enable to operate them properly. Communications are to be improved in order to transfer information from the ground over major distances. The possibility to profit from the local environment to catch energy from the structure itself shall be checked. Automatic positioning on a span is desired.

Computational Framework

- The objective is to compile a variety of **Parameter Assessment Tools** which will fill the factor matrix with information. The current modal analysis practice is fragmented and relies on expert judgement. The objective is to bring the various approaches together and to implement closed solutions using multi parameter approaches that compute the basic key figures and characteristics of any structure.
- The objective is to consolidate existing methods and to develop **Modal Analysis Tools** into an automated software element. Embedded systems and distributed computing shall be included in this module. Processing of the raw data shall be done remotely to limit the transfer of information to the necessary quantity. This module shall also cover interconnection of multiple sensor types in our built environment, which, when linked, will make a considerable contribution to the quality of assessment.
- The development of a comprehensive **Knowledge Based Systems**, models and tools of human factors that would encompass the whole lifecycle of infrastructure systems from design to maintenance.
- New system design requirements for relevant environments including the definition of critical system roles in connection with **Human Performance**.
- **Data mining:** Rapid advances in monitoring resulted in millions of records. They are expanding on daily basis. Machine oriented automated methods for analyzing large data sets are required. A combination of statistics, machine learning, pattern recognition, data bases and high performance computing is necessary. The objective is to discover interesting and previously unknown information in the data sets. Only simple tools are available which do not fit the complex purpose of today's environment.
- **Image data processing:** Image data are complex and highly heterogeneous. An intelligent analysis of image data remains a problem area with few functional software tools available. A combination with traditional data and network solutions is targeted.
- **Generic algorithms:** Modern times are challenging organizations and their leaders to adapt quickly to complex circumstances under varying conditions. Data sources are numerous, distributed and contradictory. Problems are difficult to detect and diagnose, widely disbursed and constantly changing. Sources of knowledge and expertise are distributed, of varying quality and difficult to integrate. The available tools are increasing in technological sophistication, computational intensive and require specialized hardware, software and maintenance.
- **Information design and visualization:** To maximize the effectiveness of applications design and visualization must be included in the process. Incorporating perception techniques of visual hierarchy helps to clarify and group information and speed the interpretation process. The target is to help users to gain knowledge from data quick and easy.

Understanding the Mechanisms

- The use of **Satellite Images** to gain added value information on structures and their environments. From the information gained from ENVISAT frames on surface temperature, radiation, and actual seasonal changes, exposure to natural hazards can be determined. The image processing and change detection routines shall be developed.
- There are needs for a comprehensive study on the nature of **Crowd Dynamic Loading** that considers factors such as nature of event generating the crowd, the density of the crowd, whether the crowd is stationary or in transit, how people synchronise and the contributions of psychological and physical factors on behaviour.
- Loading **Code Development** is a major factor on design, but there remain significant gaps in knowledge about loading characteristics (extreme values, distributions, etc. for seismic and wind loads). There is a particular lack of information about multiple support seismic excitations.
- Better understanding of **Damage Mechanisms**, causes and their effects on the behavior will be understood by the expert systems. Within the next 8 years structural health monitoring should be able to demonstrate and convince operators and manufacturers of structures that the new methods are ready for application and that they can increase reliability of the structures and reduce maintenance costs by early detection of damage.
- Evaluation of **dynamic properties of soil and buildings** by ambient vibrations measurements. The focus is on the evaluation of the likelihood of one of the greatest earthquake induced risk: the double resonance, that is the coupling of soil and building frequencies. The fundamental period of soil is evaluated by the H/V spectral ratio approach, according to the recommendations and standards provided by the guidelines of EU Project SESAME, while building's modes by the usual FFT analysis

Smart Structures

- **Smart Structures** are the consequence of monitoring in combination with control. Structures like buildings or bridges will be able to provide real time information on their structural health, and react after the assessment of the obtained data. Development shall concentrate on additional research for optimization and integration of existing knowledge and technologies, rather then basic development.
- **Structures** shall be considered as **intelligent** or smart, able to make a self-diagnosis and reporting autonomously on its structural health. We should have better and more sensitive methods for the evaluation of the measured raw data and interpretation which enables the operator to make safe decision on further maintenance and operation.

Environmental Issues

- The objective is to define and formulate the **Effect of the Environment** on structural condition. The effects of temperature, humidity, exposure to sunshine and a number of other environmental factors influence the lifetime behavior of structures. The objective is to find and discriminate the distinct relations between a site and environmental effects. A transferable methodology shall be developed and stored in the history database. Simple input from meteorological stations and geodynamic observations should be enough for future applications.

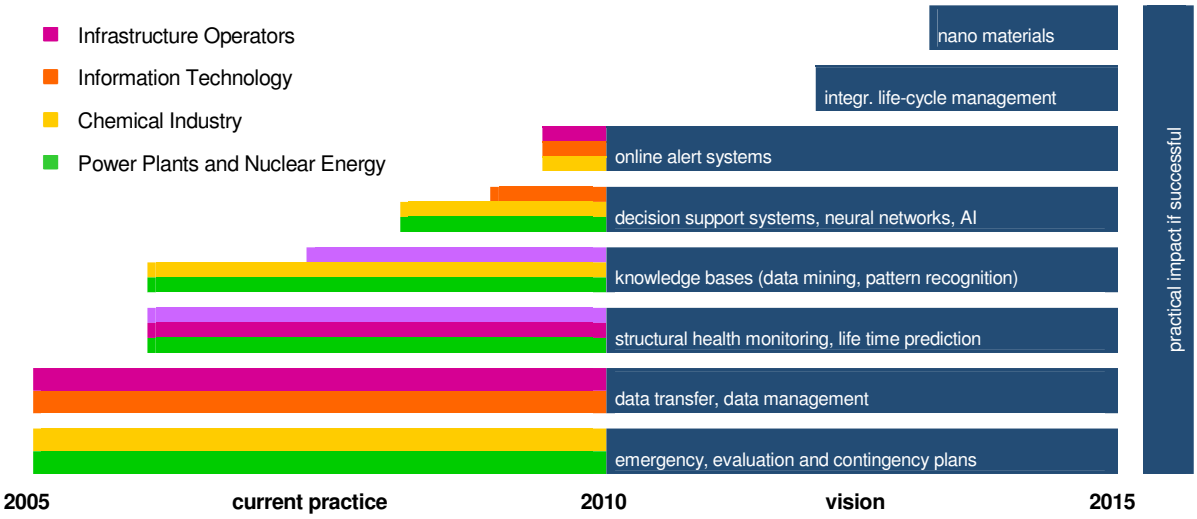
Safety and Security

- **Online alert systems** as safety relevant applications in means identification of critical situations due real-time data evaluation, risk assessment as well as predictive modelling.
- **Knowledge based systems** as a rapid, flexible data mining, pattern recognition and machine learning system that integrates analytical data mining methods for prediction, discovery and deviation detection with data and information visualization tools.
- Increased effort on **Security Issues** is proposed in order to enable early warning systems. New design strategies, materials and techniques are required to prevent and/or reduce the consequences of natural and/or malicious induced structural collapses.

Life Cycle Monitoring

- The link from singular to **Integrated Systems** shall be made by an electronic decision support system based on neural computing technologies. In this context, health monitoring will be analogues to human health management, serving as the backbone of an integrated asset management program at the systems levels from civil infrastructures to automotive and aeronautic bodies as well as complex plants like an offshore wind energy park.

Risk Assessment and Analysis



Human Factor

- Evaluation of the **Human Factor Models** in 2 specific environments: the design process and the operation and maintenance process. The evaluation should concentrate on emerging display and control technologies, assess the role of the actors and come up with solutions that support the operators.

Cultural Heritage

- Evaluation of the **Human Factor Models** in 2 specific environments: the design process and the operation and maintenance process. The evaluation should concentrate on emerging display and control technologies, assess the role of the actors and come up with solutions that support the operators.
- Combined structural, environmental and safety monitoring systems will provide data on deterioration processes and situations endangering historic materials and structures and will support early warning systems preventing loss of **Cultural Heritage.**

06 Other Issues of Consideration

Information in every Day Life

All appliances and applications of daily use will interact intelligently to relieve users of routine work. Considerable effort is undertaken in the background, which shall not necessarily be recognised. Internet, embedded chips and wireless technologies will enable this vision. For a market implementation it requires research and the will of industry and society.

The key is to provide information and messages in a simple and clear way. An invisible next generation of “post it” is required.

Machines shall communicate in a simple way. Without contribution of humans this so called peer to peer communication will enable to exchange data and to make decisions. The computing power shall be provided back to the source of activities, and will be embedded everywhere in the background. They replace the current centralised PCs. Nevertheless the user does not want to be confronted with this complex technology, but rather desires to be relieved from routines.

The demand for smart systems is high. The main criteria are usability (intuitive operation), versatility (multiple applications) and pleasurability (providing pleasure for the user).

A typical example is the MP3 player I-pod, which provides a well done reduction of complexity at a very high level of performance. Another important aspect is design of this product, which contradicts the desire of invisibility.

A vision is the intelligent glasses, which combines the obvious usability of traditional objects with modern information flow. A typical example would be this glasses with display, multi sensors, antenna, microphone and integrated intelligence. The clou is that these glasses can be overruled by putting them off.

Embedded Systems

Embedded systems include devices, middleware, software and tools for the construction of intelligent subsystems capable of monitoring and controlling a broad range of structures, appliances and industrial systems. This includes the basic infrastructure of society such as roads, railways, pipelines and communication or electricity networks. Embedded systems have a wide range of applicability into many market sectors and their importance is growing continuously.

Embedded systems are a vital combination of information and communication technologies (ICT) and material and process research (NMP) as well as natural hazard (Envi) related. To close the gap between the users and the research community a close cooperation between these 3 segments and research programs has to happen.

In 2003 there was an average of 8 billion embedded programmable micro components worldwide. Conservative estimates foresee a doubling of this figure to 16 billion by 2010, making it almost 3 embedded devices for every person on earth. The annual growth rate of embedded devices markets is estimated to be over 10% above the forecasted growth of the overall IT sector and well above GNP growth.

The challenge for SAMCO is seen in the data integration, the decision support systems and the subsequent alert modules. In the past embedded systems have increasingly been an enabling technology providing safety, comfort and higher levels of productivity, these systems have mainly worked in isolation. Functions and services were usually derived by monitoring and acting locally upon physical environments.

The major revolution brought about by miniaturization, communications and digital conversions is leading to a major shift in embedded systems which are moving beyond local interfacing to globally connected systems. This provides scope for increased levels of "collective intelligence" that in return has the potential to lead to new levels of comfort, safety and productivity in all areas from the individual to social and industrial societies.

The increasing level of connectivity including connections to the internet and to public infrastructures, is leading to the increased availability of data and information, anywhere and in real time. It offers a huge potential for product and service innovation, for increased productivity and better control of the large scale systems our societies rely upon. It also presents great challenges in terms of system interoperability complexity and vulnerability.

Networked embedded systems must be made save and secure. It is important that increased complexity does not compromise their dependability and safety of use.

The strategic objectives in this segment are:

- Achieve world leadership in embedded technologies that support European competitiveness in intelligent systems, products, services and processes
- Advance European solutions for the deployment of global networked interoperable embedded systems that can connect to the internet and are open to third parties
- Favour the creation of new markets and enable societal scale applications that enhance the safety, security and well being of citizens

What the User really wants

Integrated intelligence bares chances with today's users. Typical examples of the past decade are Handy, Notebooks, MP3, DVD etc. The extrapolation to the next decade is rather difficult because we intend to project future as a linear continuation of our presence. The role of innovation is recognised as driving factor, which lead to a not predictable non linear development. A good example is the development that can be found in new cars. Currently a trend towards less interference by computers becomes visible. A chip controlled shopping will not be successful if the desires of the users will not be properly considered. The border between privacy and big brother shall be carefully watched.

07 Realisation of the SAMCO Vision

The previous chapters have described the various aspects, both technical and non technical, of the present situation of structural monitoring assessment and control applications and markets as well as the relevant market and policy frameworks. The past 10 years of continued effort in research, technology and manufacturing have developed methodologies into a rapidly growing, increasingly global infrastructure environment. Maintenance budgets are falling constantly and the demand for more economic approaches is high.

Expectations and Targets

Future design and construction has to be seen as an integrated system. The research objectives are generic but important criteria to effectively fulfil the functional research targets identified in the previous chapters. Competitive and sustainable design and production systems will ensure that the European products are attractive to customers in and outside of the European Union.

- Embedded systems as a vital combination of information and communication technologies (ICT) and material and process research (NMP) as well as natural hazard (ENVI) related are represented everywhere and deliver data continuously.
- Data integration and data fusion in a plug and play manor will enable the application of monitoring systems quickly and easily. The barriers of current expert handling will be removed.
- Development of reliable, ready to use, multi algorithmic procedures for structural assessment to detect, localise and quantify damage will be ready for application. The integration of disciplines from users comfort on vibration and noise to health and security issues will be completed.
- The development of low cost, small size, long life, multi purpose sensors, which are easy to integrate into complex systems, will support the methodologies.
- Alert systems will be integrated into any application able to detect the presence of unusual and/or risky objects / situations in our infrastructure environment.
- Diagnostic tool kits for quick application after natural disasters or manmade harm to the infrastructure enabling uninterrupted operation.
- Online lifecycle assessment tools operating in the background and providing the necessary information for decision making.
- Integration with Traffic Telematics in order to support the decision making process enabling an uninterrupted functioning of the transport infrastructure.

- Determination of the optimal use of the structures with respect to the use of materials and products and the end of life disposal. The reuse and recycling of 98% of the infrastructure is a definite target.
- Cycle times from new product concept to market will be reduced by at least 50% from today's best practice standards through application of virtual tools and accompanying monitoring.
- Evolution of virtual tools for future development within the sector to reduce the costs of infrastructure and its products and components by 10% to 30%.
- Increase of the productivity of the transportation infrastructure to a maximum level.
- Application of robust, reliable and innovative manufacturing systems to allow 100% utilisation of production sites.
- Information on condition and prospective everywhere anytime.

Based on the long term technical potential, at least 50% of Europe's vital infrastructure could be equipped with embedded systems by 2020. Chapter 5 of this agenda outlines a vision of the technology, bearing in mind that development will continue beyond this date, as the full long term potential will not yet have been exploited and a continued substantial growth can be expected. According to this vision, by 2020, large scale applications of decision support systems integrated and embedded in structures will have occurred and will offer a range of support and information contributing to infrastructure management. In this context, embedded systems will provide an important contribution to the sustainable development of our infrastructure.

08 Implementation of the Strategic Research Agenda

It should be noted that also the present developments are very encouraging, they are partially scattered; sometimes technology driven and sometimes policy driven. In order to achieve the vision, activities need to be shaped into a coherent, long term market oriented strategy that includes targeted transitional actions. Given the potentials of structural monitoring assessment and control ongoing activities can be strengthened by adapting such a strategy thereby enabling accelerated cost reduction, build up of new competitive solutions and a strong industrial base. The key elements for such a strategy are:

- The need for a concerted effort, with continuity and full support of all stakeholders
- A comprehensive and structured approach
- Additional focus on critical technological issues
- Proportional accompanying measures

Specific Issues

To achieve the SAMCO vision, the following specific issues should be addressed:

Increasing RTD efforts

While a considerable amount of research funds are presently directed towards construction the level of effort needs to be increased to be in balance with the present market demand and the potential of the technologies. In order to account for the long term strategic nature of these research expenditures, dedicated research and development programs should be designed. Particular action is required in countries where national research efforts on structural monitoring and control are scarce.

Alignment of Strategies and Goals

It is crucial to position structural monitoring assessment and control adequately over time with respect to its future contribution to transportation, environmental and social benefits. The strategies and goals should clearly be formulated and separated into the short term (until 2010), the medium term (until 2020) and the long term (beyond 2020).

Continuity and Long Term Action

Given the time scales needed to realise the full potential of structural and environmental monitoring assessment and control, continuity of action is essential. Technology development and falling costs have been a reality and with support, this trend can be expected to continue, thereby enabling progressive developments of new competitive markets. Together with liberalisation in the construction sector, this will provide new business opportunities.

Addressing the Barriers

Beside the evident issue of high costs, several other barriers exists which hinder the large scale deployment of structural monitoring assessment and control. These include technical issues, hardware issues, the structure of the construction sector, standardisation, financing, education and training of operators and market awareness/public acceptance. The different barriers needs to be systematically clarified and addressed, with the involvement of all stakeholders including those outside of the structural monitoring assessment and control community.

Improving Technology Transfer

One of Europe's weaknesses, not specific for structural monitoring assessment and control, is the difficulty of rapid transfer of technology from research to application. Over the past decade, various attempts have been made to improve the structural, institutional and financial approach favouring technology transfer and many positive results have been achieved, supporting the spirit of entrepreneurship, risk taking attitudes and focus on success.

Nevertheless cooperation between science and industry can still be improved in favour of a rapid technology transfer. The technology transfer is seen to benefit strongly from close cooperation between professionals from different environments.

Construction Industry Issues

When it comes to dissemination of structural assessment monitoring and control it is not sufficient to have excellent research results in the laboratories. The technological solutions developed need to be compatible with industrial requirements and end users needs. In application oriented research, these aspects should be addressed at an earlier stage in full cooperation with the construction industry. Moreover, SME related issues needs to be better addressed in targeted calls for SMEs.

Enabling Critical Mass

European research activities, both in academia and industry, are characterised by a large range of projects, research groups and companies. While this situation has grown naturally and favours healthy competition as well as a broad set of different technology options, it can hamper the formation of critical mass to penetrate the market successfully. By clustering different activities more effectively, overlap can be reduced in favour of complementary strength. The European research area in its current development stage does not provide the adequate background for such developments.

Joining Forces and Competences

The structural monitoring assessment and control sector can benefit from stronger exchange and cooperation with other sectors of research (e.g. materials, nano technology, natural hazard, GMES and environmental issues), industry (e.g. machinery, equipment manufacturers, building industry, chemical plants) and the energy sector (e.g. power plants, pipelines, overhead lines, storage facilities). A proactive dialog can result in new synergies where different competences allow promising new partnerships. By combining the use of structural monitoring assessment and control with other technologies synergies develop, as monitoring is particularly incorporated in almost any industrial application. The benefit can resolve some of its inherent weaknesses.

Sustainable Markets

The global market for structural monitoring assessment and control has been growing rapidly over the past years. However the market can be vulnerable due to policy changes which create insecurities for investment. Even if market support schemes are transitional measures, it is important to develop sustainable support schemes which favour private investment in the domestic and export markets. Not much has been achieved so far in this aspect.

Interesting markets for structural assessment monitoring and control systems exist in rapidly growing economies. Applications can offer an attractive option to cover basic needs, but non technical barriers exist such as export limitations, difficulties with financing, in adequate infrastructure, lack of maintenance availability and skills, quality and education. Instruments to improve this situation will be highly desirable for the community.

Involving Stakeholders and Decision Makers

Structural assessment monitoring and control is confronted with diverse opinions, between positive short term possibilities and unreasonable doubt on long term relevancy. Mostly the wrong attitude is presently hindering the application of the most suitable solution. With the present level of technology and market experience, the discussion should be able to move from fundamentally driven opinions towards a constructive and factual dialog, involving different stakeholders and decision makers.

Defining adequate policy Frameworks

A variety of polity initiatives have been developed over the past few years, both at the EC and member state level. However there are considerable inconsistencies in policy objectives. Different policy approaches should be fully assessed and compared to allow lessons to be learned and to ensure that the future European structural assessment monitoring and control policy framework can be founded on quantitative and not qualitative arguments.

Approach

This document outlines, in broad terms, a strategic action plan necessary to achieve the vision. This action plan will need to be developed in the future in more detail, to better encompass what should be done, by whom and in what timeframe. The proposals presented here cover 3 main areas of intervention:

- Research and technology
- Industry and SMEs
- Policy

To advance rapidly these 3 areas should be connected more strongly by the establishment of a structural monitoring assessment and control technology platform. It might be connected to one of the existing platforms particular the ECTP (European Construction Technology Platform). A strong connection is needed to accelerate the process because technology development is not a sequence of linearly connected activities, but rather a parallel process with pronounced independencies.

Enclosed graph and table classify the key aspects of the research and technology, industry and policy areas in relation to stakeholder activities and interests. These intervention areas have different but complementary drivers.

09 Conclusion and Main Recommendations

The items of this Research Agenda are valid for many Sectors, Industries or Programs. They should be embedded in the Construction Sector, Mechanized and Chemical Industries, relate to Safety and Risk questions and concern the management of our infrastructure. Therefore a broad collaboration between the NMP, ICT, ENVI, TRAN and Health Programs is recommended.

Assuming that the same instruments defined for FP6 are available and considering current state of the art and practice worldwide the following is recommended:

- Hardware development is considerably ahead in the U.S. To utilize this fact targeted SSA and CA proposals should be called enabling the best use of this innovative hardware. To support the European ideas STREPS on very specific items should be added.
- To achieve a breakthrough in methodology, where Europe is leading, it is recommended to call for at least 2 integrated projects (iP's), which allow the necessary integration of the existing ideas and technologies as well as a harmonization of data, formats, metadata protocols and communication tools. The 2nd initiative shall concentrate on a knowledge base with a specific model of collaboration of the fragmented groups developing in this segment. To enhance research on the subject a major number of STREPS shall be called on the items specified under chapter 5. All projects shall be enforced to contribute to the knowledge base. This activity can only be successful if approached on very wide scale and would provide a major advantage of Europe against its competitors.
- To bring the user interaction to a breakthrough it is recommended to disseminate the results worked out in the previous chapter using SSA and CA instruments creating major demonstration cases and allowing an implementation and incorporation into the education process. Main focus shall be on the development of simple and low cost methodologies, which are freely available for everyone. A number of STREPS in collaboration with the ICT programs shall be called. The proposal of an IP on end users level should be considered.
- To achieve full integration of the applications the collaboration of all disciplines shall be enhanced. This could be achieved through a joint call over all thematic priorities with strong possibilities of international collaboration. The most appropriate instruments are demonstration projects, SSA and CA calls and some specific STREPS to create the necessary tools.

The absolute priority shall be in the category methodology, where the European position provides a major chance for a breakthrough and competitive advantage.

10 Glossary

SAMCO **Structural Assessment, Monitoring and Control**; CTG2-2000-33069, European Network supported by the European Commission within the Fifth Framework Programme under the Competitive and Sustainable Growth Programme, www.samco.org

ERA **European Research Area**; A term introduced by the European Commission, ERA is regrouping all Community supports for the better coordination of research activities and the convergence of research and innovation policies, at national and EU levels.

ETP **European Technology Platform**, http://www.cordis.lu/technology-platforms

I-SAMCO **International SAMCO**; FP6 003766, Specific Support Action under the Sixth Framework Programme, Priority 2&3, http://www.samco.org/isamco

GNP **Gross National Product**; The total market value of goods and services produced during a given period by labor and capital supplied by residents of a country, regardless of where the labor and capital are located. GNP differs from GDP primarily by including the capital income that residents earn from investments abroad and excluding the capital income that nonresidents earn from domestic investment.

EU **European Union**

JRC **Joint Research Centre of the EU Commission**; As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national

ECTP **European Construction Technology Platform**, www.ectp.org

ERRAC **European Rail Research Advisory Council**, http://www.errac.org/

ESTEP	**European Steel Technology Platform**
ERTRAC	**European Road Transport Research Advisory Council**, www.ertrac.org
ARTEMIS	**High level group on embedded systems**
SME	**Small and Medium Sized Enterprise**; employs fewer than 250 people, has a turnover of less than EUR 40 million per annum or net balance sheet assets of less than EUR 27 million, must be less than 25 percent owned by a larger company/companies which do not qualify as an SME themselves.
GPS	**Global Positioning System**
CMS	**Continuous Monitoring System**
PMS	**Periodic Monitoring System**
PZT	**Lead Zirconate Titanate**; is a ceramic material that shows a marked piezoelectric effect - that is, it develops a voltage difference across two of its faces when compressed, and ferroelectric effect. It also features an extremely large dielectric constant. It is used to make ultrasound transducers and other sensors and actuators, as well as high-value ceramic capacitors and FRAM chips.
ENVISAT	**Environmental Satellite**; advanced polar-orbiting Earth observation satellite which provides measurements of the atmosphere, ocean, land, and ice.
NMP	**Nanotechnologies and Nano-Sciences, Knowledge-based Multifunctional Materials and New Production Processes and Devices**; activity area in the Sixth Framework Programme of the European Commission
ICT	**Information and Communication Technology**
IT	**Information Technology**

DVD	**Digital Versatile Disk**
GMES	**Global Monitoring for Environment and Security**; GMES is a joint initiative of European Commission and European Space Agency. GMES represents in simple terms a concerted effort to bring data and information providers together with users, so they can better understand each other and agree on how to make environmental and security-related information available to the people who need it. www.gmes.info
EC	**European Commission**; Like the Parliament and Council, the European Commission was set up in the 1950s under the EU's founding treaties. The Commission is independent of national governments. Its job is to represent and uphold the interests of the EU as a whole. It drafts proposals for new European laws, which it presents to the European Parliament and the Council. It is also the EU's executive arm – in other words, it is responsible for implementing the decisions of Parliament and the Council. That means managing the day-to-day business of the European Union: implementing its policies, running its programmes and spending its funds.

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12 SAMCO Partners, Members and Associates

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ASAG	Alpen Straßen AG	Innsbruck, Austria	Klaus Fink
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IKI	Univ. für Bodenkultur Wien, Inst. für Konstruktiven Ingenieurbau	Vienna, Austria	Konrad Bergmeister Alfred Strauss
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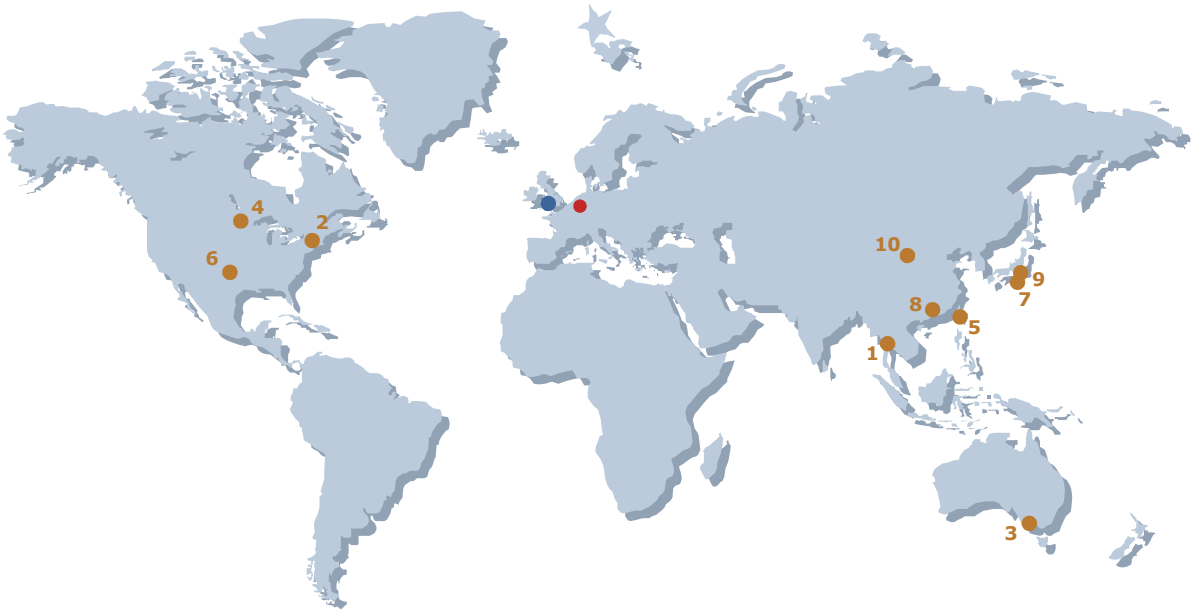

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