

Information Society Technologies (IST) Programme



SENSATION

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Project Presentation

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Authors		Dr. Evangelos Bekiaris (CERTH/HIT) Stella Nikolaou (CERTH/HIT) Giulio Ruffini (STARLAB) Steve Dunne (STARLAB)	
Contributors		Torbjorn Akerstedt (KAROLINSKA) Peter Anderer (TSG) Pierre-Damien Berger (ATMEL) Serge Boverie (SIEMENS VDO) Georg Dorffner (OFAI) Anand Kumar (MEDCARE) Paco Lopez (STARLAB) Stavroula Maglavera (POULIADIS) George Matsopoulos (ICCS) Jean-Bernard Michel (CSEM) Eduardo Monton (ITACA) Tilo Schwarz (DaimlerChrysler) Howard Smith (CAMNTECH) Jouko Viitanen (VTT) Mathaios Bibas (ICCS)	

	Ernest Mendoza (Un. of Surrey) Juan Ramon Morante LLeonart (UB-EME)
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List of Abbreviations

3D	THREE-DIMENSIONAL
A/D	ALTERNATING/DIRECTLY
BAN	BODY AREA NETWORK
BP	BLOOD PRESSURE
CMOS	COMPLEMENTARY METAL OXIDE SEMICONDUCTOR
CNS	CENTRAL NERVOUS SYSTEM
CNT	CARBON NANO-TUBES
ECG	ELECTRO CARDIOGRAM
EEG	ELECTRO ENCEPHALOGRAM
EMC	ELECTROMAGNETIC COMPATIBILITY
EMFi	ELECTRO MECHANICAL FILM
EMG	ELECTRO MYOGRAM
EOG	ELECTRO OCCULOGRAM
FPN	FIXED PATTERN NOISE
NIR	NEAR INFRA RED
PDPU	PERSONAL DATA PROCESSING UNIT
PERCLOS	PERCENTAGE OF EYE CLOSURE
PTT	PULSE TRANSIT TIME
QoL	QUALITY OF LIFE
R&D	RESEARCH AND DEVELOPMENT
SAS	SLEEP APNOEA SYNDROME
SME	SMALL AND MEDIUM ENTERPRISE
SP	SUB-PROJECT
SPO2	PARTIAL OXYGEN PRESSURE (ONE OF THE CRITICAL PARAMETERS REGULATING INSPIRATION AND RESPIRATION)
UI	USER INTERFACE
WAN	WIDE AREA NETWORK

Executive Summary

Sleep loss, excessive fatigue, stress and inattention constitute the social diseases of our century. Within the "24 hour society" people tend more and more to exchange sleep and serenity for gain or pleasure. This gradually leads to an excessive rate of sleep disorders, roughly 20% of the population suffer from one, at least mildly or temporarily, as well as to a boom of stress and anxiety related diseases. In addition, a significant percentage of severe traffic and industrial accidents seem to be caused by the involuntary human transition from wakefulness to sleep or by prolonged inattention. SENSATION aims to explore a wide range of micro and nano sensor technologies, with the aim to achieve unobtrusive, cost-effective, real-time monitoring, detection and prediction of human physiological state in relation to wakefulness, fatigue and stress anytime, everywhere and for everybody.

Deliverable 5.1.3 entitled 'Project Presentation' aims to describe the project concept, objectives and expected results and provide an overview of the work to be performed within the four years of its duration. This deliverable starts with an Introduction section (Section 1), where the problem of lack of sleep is analysed and the need for monitoring and detecting sleep deprivations and disorders is highlighted. Section 2 is focusing on the presentation of the medical and industrial applications where the project is focusing and schematically outlines the layers of the architecture plan, whereas the Expected project outcomes are briefly presented in Section 3. Finally, the contact details of the Project Coordinator (Section 4), the Consortium synthesis (Annex A), a Short Project Presentation providing a brief but consistent summary of the project (Annex B), as well as additional project information (Annex C) including extended technical information and project expected impacts, consist the last Sections of this deliverable.

1. Introduction

We all need to sleep, the longer we put it off the greater the need becomes and it is a battle we will always lose.

Our sleep patterns are governed by an internal body clock, called the circadian rhythm. This is a 24-hour cycle that has two peaks of sleepiness, one in the very early hours of the morning and another in mid afternoon.

Although some famous (or infamous) characters have claimed to manage on a mere 4 hours sleep, for most of us this cycle requires between 7 and 9 hours.



Any disruption of this cycle leads, as you would expect, to sleepiness at times when we would normally be fresh and awake. This effect is

cumulative and will, over time, result in chronic sleepiness. Less than 4 hours a night and a person's performance can be impaired.

We live in a 24-hour society that puts pressure on some and provides the means for others to sacrifice sleep in favour of other activities. As people juggle long working days with raising families they are also conscious of their free time. Quality of life is often measured in how you spend this free time and people are reluctant to give it up, even to sleep. This sleep loss can have many negative effects on people's health and their ability to handle a wide range of tasks. Sleepiness increases reaction time and reduces alertness and concentration. The speed at which information is processed and the quality of decision-making, are both impaired.

While sleepiness is often seen as relatively benign, continuous sleep deprivation results in excessive fatigue, prolonged inattention, hypovigilance and stress, which are known to be among the key causes of serious industrial accidents.

If this claim seems extreme take a look at the following:

- Chernobyl, Three-mile Island and several US island nuclear accidents are clearly related to fatigue.
- The Bhopal chemical disaster in India, the Challenger shuttle explosion and the Exxon Valdez grounding are all considered to be fatigue related.
- The night work in the automotive industry has seen an increase of 43% in accidents.
- The US coast guard has identified 16% of vessel casualties and 33% personal injuries in US coastal waters as fatigue related.
- In Japan, the Maritime Research Institute states that between 1985 and 1991 53% of groundings and 38% of collisions were fatigue related.
- In 2000 three major train crashes in New Zealand were fatigue related.
- Around 40% of fatal accidents on US highways are fatigue related
- In the UK as many as 25% of all crashes are related to driver fatigue.
- According to the NASA Aviation Safety Reporting System approximately 21% of US aviation incidents are fatigue related.
- In Australia 7% of aviation accidents are fatigue related.
- The collision of the Progress 234 rocket and the MIR space station in 1997 was caused by pilot fatigue related drowsiness.

As much as 20% of the general population suffer, to some degree, from sleep disorders. These include hypersomnia, narcolepsy and sleep apnoea. These disorders may cause the kind of extreme tiredness, loss of concentration and inability to function responsible for the above accidents.

2. Aims

The SENSATION project aims to promote health, safety and quality of life as well as protect the environment by reducing the number and scope of such accidents. This shall be done through the novel use of micro and nano sensors and related technologies, at low-cost and high-efficiency, for physiological state monitoring.

The project aims to design, develop and test 2 new nanosensors and 17 new or miniaturised microsensors.

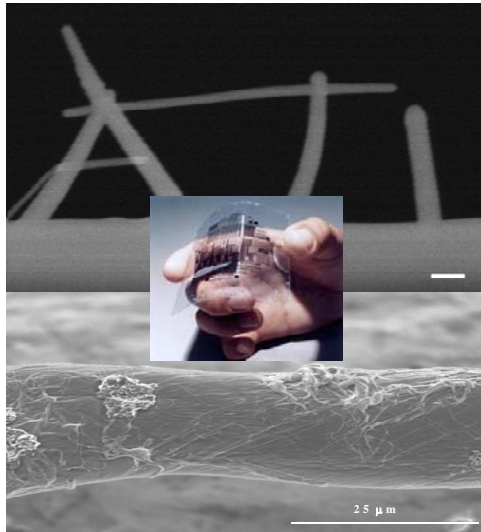


Figure 1: Carbon Nanotubes & Nano electronics (Uni. Of Surrey)

Carbon Nanotubes (CNTs) are sheets of graphite rolled up into tubes with diameters of the order of nanometer. The resulting material has a list of unique characteristics, including unparalleled tensile strength, heat conductivity, etc.

Project sensors, actuators and their processing and telecommunication units are to be integrated in a wide range of materials such as bed and pillow textiles, plastic for wrist applications, seat linings and the frames of glasses. A miniaturised power consumption optimisation module is also to be developed.

The SENSATION consortium also aims to offer insights into the realm of sleep in order to enhance our lives and make them safer.

Sleep and Alertness monitoring systems can monitor aircraft pilots to make sure they are awake but equally they can be used to make sure babies are sleeping soundly.

Accurately and routinely monitoring sleep can help diagnose sleep disorders. It may open the way to answering questions like: Can we learn while sleeping? Can we detect early disease markers in sleeping subjects? Can we actively improve our well-being and performance by adjusting sleep patterns? Can we do with less sleep in certain conditions?



Figure 2: Design proposal of the finger ring sensor (EiVD)

Miniaturized sensor for monitoring pulse and blood oxygen saturation (SpO2) in a finger ring device. SpO2 is especially important to detect apnea conditions. The system provides two outputs; heart rate and relative SpO2 fraction.

The project has four main research areas:

- **Biosensing:** development of ubiquitous and novel biosensing technologies, including neurosensors.
- **Core Computation:** signal processing & computational intelligence algorithms development & implementation to study human state, focusing on consciousness, sleep, stress, attention and fatigue.
- **Medical:** the application of Biosensing and Core Computation to Medical and Neurology early diagnosis and treatment.
- **Industrial:** the application of Biosensing and Core computation to critical (in terms of time and accident impact) industrial processes.

3. Applications

One of the project goals is to develop a multi-purpose sensing platform to assess the physiological state of a user. This platform will be:

- **Autonomous:** will operate in real-time, continuously monitoring the user.
- **Non-supervised:** diagnosis will be displayed to the user without any online intervention from an expert.
- **Non-intrusive:** no wires or cables, the subject or user will not be overly aware of the system.
- **Robust:** will need to function in an unpredictable real world environment where conditions cannot be controlled.

In the medical world the cost of diagnosis and treatment of sleep disorders is very high. This is because diagnosis is usually carried out in dedicated sleep laboratories. What's more, these labs result in very long waiting lists.

Currently 2/3 of sleep studies for diagnosis are performed in laboratories. The average cost of in-lab studies for health care purposes is about 390 Euro/study. The average cost of mobile studies with EEG is around 120 Euro/study, i.e., 30% of the in-lab cost.

Half of current users are not satisfied with their current mobile systems so there is a clear need for a new system. Such a system would reduce costs, increase capacity, improve sleep patterns and be easier on the patient. Most users do not expect extensive automated interpretation of data. What they want to see are screening and follow-up of SAS, epilepsy, Periodic Leg Movements and also insomnia and narcolepsy.



Figure 3: SENSATION - The present and the future in medical applications.

Some of the applications SENSATION aims to provide to the medical community are:

- Medical Diagnosis
- Medical Treatment
- Home-based diagnosis
- Home-based treatment

In industry a wide range of sensors have been used in the past; often were single sensor technologies that did not succeed in real world situations. This is where multi-sensor systems win out; they are much more robust and reliable in these situations. Historically these systems were not very un-obtrusive; this will be also addressed in SENSATION by taking the sensors down to the micro and nano scales and exploiting new technologies. The types of industry that can benefit from this project include:

- Air Traffic Operators
- Traffic Management Centres
- Crane Operators
- Machine operators
- Chemical Factories
- Nuclear Power Stations
- Aerospace Industries
- Research passenger cars
- Truck driving simulators
- Navy ships
- Civil Aviation Administrations

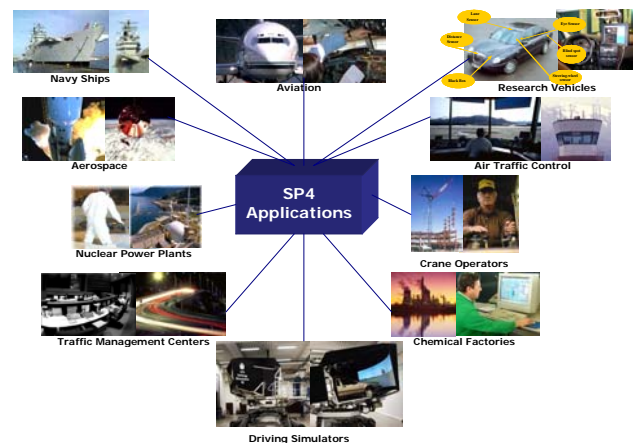


Figure 4: SENSATION Industrial Applications

4. System Architecture

The System Architecture will be modular, open, efficient and flexible.

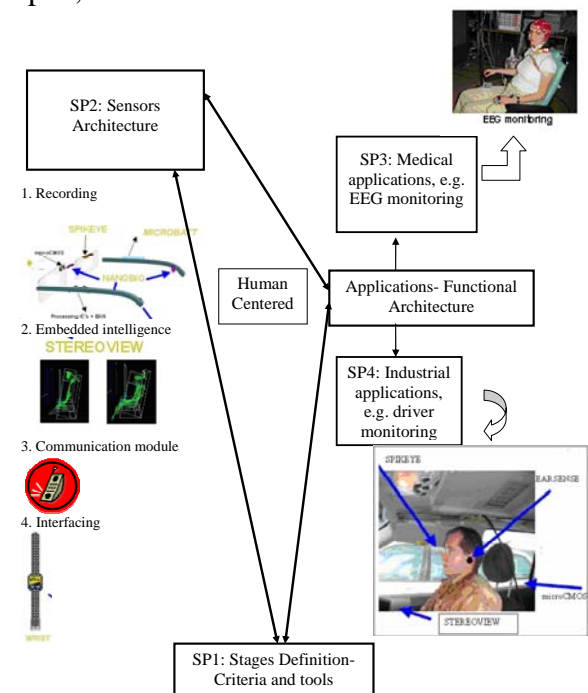


Figure 5: SENSATION Architecture

5. Expected Achievements

What SENSATION is ultimately all about is producing real solutions and systems such as the following:

- Improved (more reliable, more cost-effective, quicker) medical diagnosis and treatment of many sleep-related diseases.
- Moving treatment from hospital to the home.
- Improved patient monitoring.
- Real-time operator hypovigilance *detection* in a variety of industrial environments (i.e. air traffic control, etc.).
- Real-time hypovigilance *prediction* of operator in a variety of industrial applications (i.e. while driving a vehicle).
- Real-time warning systems in the above cases.
- Sleep assessment and management to improve shift workers working conditions.
- Sleep quality enhancement schemes for patients and non-patients alike for improved quality of life.

6. Expected Impacts

Future advances in research focusing on diseases associated with our social habits require unobtrusive monitoring of physiological and psychological parameters in order to gather information in real life, everyday situations. Studies in many countries (for example Sweden and the Netherlands) have shown that work and social/family pressures cause a rise in the occurrence of stress related disease. Research

based on obtrusive equipment makes it virtually impossible to carry out large-scale longitudinal studies to follow responses to real life stressors, for example in daytime blood pressure, heart rate, EMG and nighttime sleep disturbances. Therefore only small cross-sectional studies are carried out. Unobtrusive equipment will make this possible and will provide entirely new research opportunities.

The same type of equipment will also revolutionize medical diagnostics, since information on patients' physiological status can be obtained unobtrusively, quickly and cost effectively, even in the patient's normal environment.

SENSATION intends to have a significant impact on the detection, prediction and resolution of attention, vigilance, stress and other sleep related problems.

7. SENSATION Consortium

The SENSATION Consortium consists of 45 partners from 20 countries, covering the following research areas: brain-sensing, neurosensing, computational neuroscience, signal processing, materials science, optical and optoelectronics, microelectronics, intelligent user interfaces, telematics, data fusion, sleep research, human physiological measurements, industrial process supervision, clinical and medical research. The global representation of the Consortium can be seen in the figure below:



Figure 6: Countries representation within SENSATION Project

7.1 Project Coordinator

Centre for Research & Technology Hellas/
Hellenic Institute of Transport (CERTH/HIT)

Dr. Evangelos Bekiaris

6th km. Charilaou-Thermi Rd.
57001, Thessaloniki, Greece
Tel: +30-2310-498265, Fax: +30-2310-498269
E-mail: abek@certh.gr, Url: www.hit.certh.gr

7.2 Project Technical Manager

Starlab Living Science

Dr. Giulio Ruffini

Edifici de l'Observatori Fabra, Muntanya del
Tibidabo
Cami de l'Observatori s/n, 08035 Barcelona,
Spain
Tel: + 34 93 254 0362, Fax: +34 93 212 6445
E-mail: giulio.ruffini@starlab.es,
Url: <http://starlab.es>

SENSATION Project Url:

www.sensation-eu.org

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Annex A: Consortium List

Participant name	Participant short name	Country	Type
Centre for Research & Technology Hellas / Hellenic Institute of Transport	CERTH/HIT	Greece	Research Centre
Starlab Barcelona S.L.	Starlab	Spain	SME
SIEMENS VDO Automotive	Siemens	France	Industry
DaimlerChrysler AG	DC	Germany	Industry
Centre National de la Recherche Scientifique	CNRS	France	Research Centre
UNIVERSITAET BASEL, Centre of Applied Technologies in Neuroscience	COAT	Switzerland	Research Centre
Karolinska Institutet, Dept of Public Health Sciences, Division of Stress Research	KI	Sweden	Research Centre
POULIADIS ASSOCIATES COPORATION	Pouliadis	Greece	Industry
The Siesta Group Schlafanalyse GmbH	TSG	Austria	SME
Medcare Automation B.V.	Medcare BV	Netherlands	SME
UNIVERSITAET STUTTGART	USTUTT	Germany	University
Technical Research Centre of Finland	VTT	Finland	Research Centre
Institute of Communication and Computer Systems	ICCS	Greece	Research Centre
STATENS VAEG- OCH TRANSPORTFORSKNINGSINSTITUTET	VTI	Sweden	Research Centre
FORMATION ET RECHERCHES EN NEUROSCIENCES APPLIQUEES A LA PSYCHIATRIE	Forenap	France	Research Centre
INSTYTUT MEDYCYNY DOSWIADCZALNEJ I KLINICZNEJ IM.M.M. POLSKIEJ AKADEMII NAUK	GBAF	Poland	Research Centre
MicroVitae Technologies	MicroVitae	France	SME
CENTRO RICERCHE FIAT SOCIETA CONSORTILE PER AZIONI	CRF	Italy	Industry
Universidad Politécnica de Madrid	UOM	Spain	University
PHILIPPS-UNIVERSITAET MARBURG	UniMarburg	Germany	Hospital
Beijing University of Aeronautics and Astronautics	BUAA	China	University
NATIONAL AND CAPODISTRIAN UNIVERSITY OF ATHENS	UoA	Greece	University
Finnish Institute of Occupational Health	FIOH	Finland	Research Centre
DEUTSCHES ZENTRUM FUER LUFT- UND RAUMFAHRT E.V.	DLR	Germany	Research Centre
ATEL GRENOBLE SA	Atmel	France	Industry
GTD Sistemas de Informacion S.A.	GTD	Spain	SME
UNIVERSITAT DE BARCELONA	UB	Spain	University
Österreichische Studiengesellschaft für Kybernetik	ÖFAI	Austria	Research Centre
CSEM CENTRE SUISSE D'ELECTRONIQUE ET DE MICROTECHNIQUE SA - RECH ET	CSEM	Switzerland	Research Centre

Participant name	Participant short name	Country	Type
DEVELOPPEMENT			
INSTITUTO DE APLICACIONES DE LAS TECNOLOGIAS DE LA INFORMACION Y DE LAS COMUNICACIONES AVANZADAS-ITACA	ITACA	Spain	Research Centre
TECMIC - Tecnologias de Microelectrónica, SA	TECMIC	Portugal	Industry
INESC Inovação, Instituto de Novas Tecnologias	INOV	Portugal	Research Centre
CAMBRIDGE Neurotechnology Ltd	CAMNTech	UK	SME
The University of Surrey, Large Area Electronics (LAE) Group	Surrey	UK	University
Aristotle University of Thessaloniki	AUTH	Greece	University
University of Technology, Sydney	UTS	Australia	University
University of Malta	UoM	Malta	University
SmartEye AB	SEYE	Sweden	SME
ATC ROM SRL	ATC	Romania	SME
PSICHOFIZIOLOGIJOS IR REABILITACIJOS INSTITUTAS	IPR	Lithuania	Research Centre
HAUTE ECOLE SPECIALISEE DE LA SUISSE OCCIDENTALE	EiVD	Switzerland	Research Centre
KITE Solutions SNC	KITE	Italy	SME
Medcare Flaga hf	Medcare HF	Iceland	SME

Annex B: Short Project Presentation

SENSATION (Advanced Sensor Development for Attention Stress Vigilance and Sleep/Wakefulness Monitoring) is an FP6 Integrated Project co-funded by the European Commission under the 'micro and nano sensors' area of the Directorate-General 'Information Society' (DGINFSO). The total project effort reaches the amount of 17 MEuro, of which 10 MEuro are funded by EU. SENSATION was officially launched in January 2004, accompanied by a kick-off meeting held in January 14-16, 2004.

SENSATION aims at promoting the health, safety and quality of life of people and protect the environment by reducing relevant accidents and thus the impact on environment through the application of novel micro and nano sensors and related technologies, of low-cost and high-efficiency, for physiological state monitoring. The focus of the work will be the physiological activity, including the sleep and wakefulness states and their boundaries, stress, inattention and hypovigilance states, for hypovigilance detection, prediction and management as well as diagnosis, treatment and remote monitoring of sleep disorders.

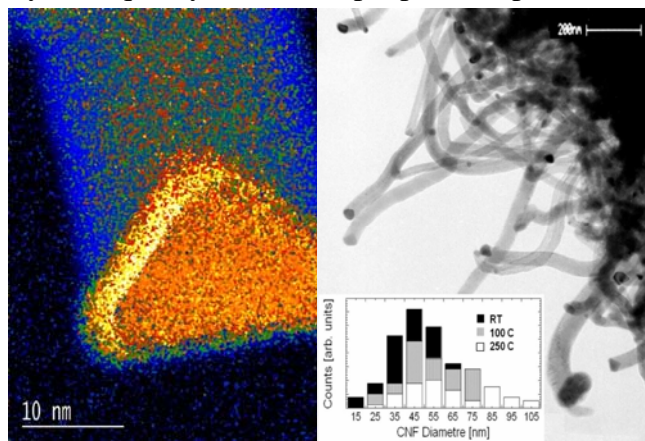


Figure 7: Carbon Nano-fibres (Un. Of Surrey)

The SENSATION Consortium aims to offer insights into the realm of sleep, stress and other emotions, striving to make it:

- ♦ **Safer:** Sleep and Alertness monitoring systems will assess behavioural and physiological measures to reduce sleep-related critical incidents. From aircraft pilots to sleeping babies, we can all benefit.
- ♦ **Better:** Accurately and routinely monitoring sleep will provide clues on how to enhance diagnosis of sleep disorders and to improve sleep quality. We can also learn to use our sleep time in a better way. Can we also learn while we sleep? Can we optimise our well-being and daytime performance? Understanding the mechanisms behind sleep will also lead us to understand if and when we can do with less sleep.

In conclusion, if we manage to primarily analyse the human physiological activity in order to identify the sleep to wakefulness stages and subsequently develop the required micro and nano sensors in order to monitor, predict and detect human physiological states, we will then have reached a new horizon towards the enhancement of the quality of life and the reduction of all accidents related to sleep, by applying new, innovative and totally unobtrusive systems for medical, industrial, transport and tourism applications. SENSATION aims to achieve the long-awaited breakthrough on sleep studies and offer to the European society and each individual European citizen safety, comfort and 'better way of living'. Notwithstanding that the aim is high and the road to its achievement is tough, the SENSATION Consortium is ready to accomplish it.

The project aims to design, develop and extensively test 2 new nanosensors and 17 new or miniaturised microsensors. Project sensors, actuators and their processing and telecommunication units are integrated in a wide range of materials (bed/pillow, cloths, textile), such as plastic for wrist applications, seat foils and glasses, etc.. A specific power consumption optimisation module is also developed at a miniaturised level.

Concluding, the project targets the following visionary applications:

- Improved (more reliable, more cost-effective, quicker) medical diagnosis and treatment of many sleep-related diseases (such as sleep apnoea, insomnia, hypersomnia, restless legs syndromes, narcolepsy, hypoglycemia treatment for diabetics, etc.).
- Treatment migration from the hospital to the home environment.
- Improved patient monitoring.
- Real-time hypovigilance detection of operator, in a variety of industrial applications (i.e. nuclear /chemical factories, air traffic controllers, etc.).
- Real-time hypovigilance prediction of operator in a variety of industrial applications (i.e. while driving a vehicle, a crane, an airplane or performing other critical tasks).
- Real-time operator effective warning.
- Reliable sleep assessment and management for improved working conditions of shift workers.
- Sleep quality enhancement schemes for patients and non-patients (QoL enhancement of all people).

Annex C: Additional Project Information

SENSATION Objectives

SENSATION aim is targeted through the following main intermediate objectives and achievements:

- (1) Definition of sleep / wakefulness and their transition states, as well as stress, inattention and emotional states, by a set of measurable criteria and their correlation with measurement methodologies and tools, all included in a benchmarking database and used through a knowledge-based sleep/wakefulness clustering tool.
- (2) Modelling of sleep stages and extraction of requirements and specifications for sensors to measure the required model parameters.
- (3) Construction of a wide pattern database of sleep/wakefulness, as a knowledge basis for the development and evaluation of sleep detection and management criteria, tools, sensors and systems.
- (4) Construction of a wide pattern database of involuntary wakefulness to sleep transition (from a series of real life tasks), as a knowledge basis for the development and evaluation of hypovigilance detection and prediction criteria, tools, sensors and systems.
- (5) Development of technologies, micro and nano sensors for unobtrusive monitoring of physiological state and activity.
- (6) Development of wearable micro and nano sensors, on the wrist, textile, bed, pillow blanket and ear, for physiological and activity measurements, to estimate the person's vigilance, stress and emotional state.
- (7) Development of camera-based micro sensors for high precision, cost-efficient and high-speed measurement of EOG and motility parameters and estimation of the person's vigilance and attention (to the task) level.
- (8) Development of posture (seat, foil-based) and capacitive micro sensors for measurement of physiological and activity related parameters, to estimate the person's vigilance and attention state.
- (9) Development of eyelid and skin micro and nano sensors for respiration and skin conductivity measurements (autonomic functions) to estimate the person's sleep/wakefulness state and analyse its characteristics (i.e., differentiating normal from abnormal sleep).
- (10) Development of embedded connectivity at the body (Body Area Network), the local (Local Area Network) and the wider (Wide Area Network) area, to guarantee the wireless, low-cost and high-speed operation of all developed sensors and systems.
- (11) Development of innovative signal processing and computational intelligence algorithms for data fusion, data management, sensor integration and power consumption minimisation.
- (12) Development of user-friendly, modular and intuitive user interfaces for sensor output presentation as well as to provide real-time warnings to the user in case a problem is detected (based on intelligent agents, adapted to the task and the operational environment as well as to the user cohort, i.e., patient or not).
- (13) Development of new medical diagnosis and treatment applications, using the new sensors, databases and knowledge, for a wide range of sleep-related disorders.
- (14) Development of innovative systems for hypovigilance detection and real-time prediction in a variety of applications fields and environments, based on combinations of the above sensors, as well as effective hypovigilance warning systems.
- (15) Development of new and individualised sleep management systems and sleep quality improvement schemes, combining enhanced sleep models with personalised data from the application of the new sensors.

(16) Provide visions and a roadmap for future applications in this area as well as for further sensors improvements and miniaturisation.

Technical Approach

The aim of SENSATION is the unobtrusive, cost-effective, real-time monitoring, detection and prediction of human physiological state in relation to alertness, fatigue and stress anytime, everywhere and for everybody.

This aim is technically addressed by the following tasks:

- Defining the human physiological states (sleep/wakefulness, inattention, stress and emotions) and their transitions; and developing the necessary reference databases (of hundreds of people worldwide) for correlating those states with various physiological biosignals and bioparameters (EEG, EMG, ECG, EOG, skin conductivity, brain activity, breath activity, motility, etc.) parameters. Such correlations will be used for the design and development of relevant human state monitoring, detection and prediction systems, as well as for objective assessment of their reliability.

This work is conducted within SENSATION Subproject 1 (SP1), “Stages definition, classification, criteria and tools”.

- Developing a wide array of novel micro and nano sensors for unobtrusive monitoring of human physiological state and activity; their interconnection through embedded connectivity at the body, local and wider areas and their integration in multi-sensorial systems through innovative signal processing and computational intelligence algorithms for data fusion, data management and power consumption minimisation.

This work constitutes the Centre of Gravity of this IP, and is conducted within SENSATION Subproject 2 (SP2), “Micro and nano sensors development”.

- Developing new medical diagnosis and treatment applications, using the new sensors, databases and knowledge for a wide range of sleep disorders, as well as enhancing the sleep quality of all people.

This work is conducted within SENSATION Subproject 3 (SP3), “Medical and Neurological Applications”.

- Developing innovative algorithms for hypovigilance detection and prediction in a variety of industrial application fields and environments, based on multi-sensorial systems, to enhance safety and comfort at work, as well as the quality of life of people.

This work is conducted within SENSATION Subproject 4 (SP4), “Industrial Applications”.

- Integrating effectively all four above areas of research, through a range of common cross-project activities, including management, training, dissemination, exploitation, user awareness and acceptance, ethical and legal issues, system architecture, evaluation framework and standardisation.

This work is conducted within SENSATION Subproject 5 (SP5), “Cross-Project Activities”.

IP Structure

The SENSATION IP is organised along 5 closely related Subprojects (SPs), as just described. The structure is illustrated in Figure 8.

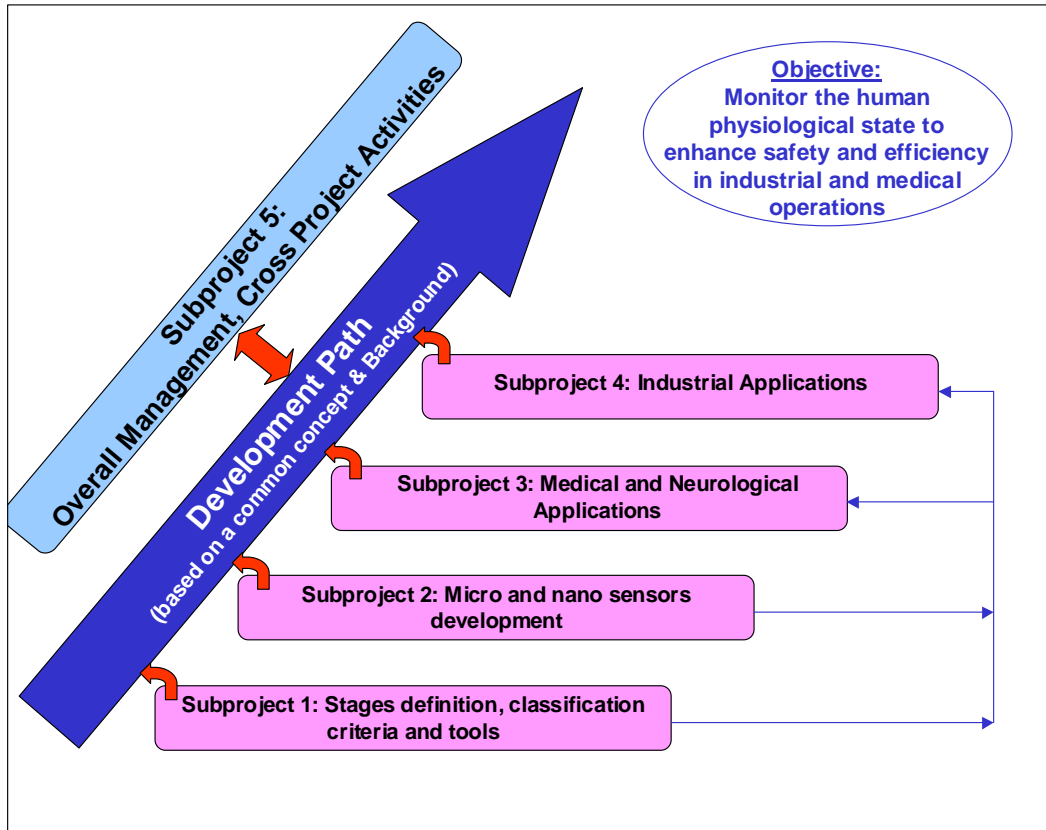


Figure 8: SENSATION IP structure.

Subproject 1: Stages Definition, Classification Criteria and Tools

The general objective of Subproject 1 is to define the requirements for the detection of the human physiological state in terms of wakefulness/sleep, stress, attention and fatigue and to provide the necessary data platforms to further study these phenomena.

SP1 involves four major areas:

- ◆ Understanding and defining the human physiological states and their transitions.
- ◆ Developing clustering tools and transition models for these states.
- ◆ Establishing databases with recorded data on voluntary and involuntary wakefulness to sleep transition, as knowledge pool for future developments.
- ◆ Verification of developed criteria and tools.

The main results expected from the work of this Subproject are:

- ◆ Quantified and precise sensor requirements for human physiological states identification.
- ◆ An on-line, user-friendly multimedia database, regarding existing criteria, tools, best practices and methods for sleep stages, stress, inattention and emotional states and their estimation.
- ◆ A knowledge-based diagnostic support system for sleep/wakefulness classification and diagnosis.
- ◆ Improved models for sleep prediction and management, extensively used in the industry for

shift-work planning.

- ♦ A database with around 350 polysomnographies (including all conditions and existing data), covering night and daytime, all genders, ages and different countries.
- ♦ A database with roughly 200 entries from 6 different tasks with involuntary transition from the awake to sleep states. The database will contain data of high quality, covering a wide range of physiological, behavioural and subjective parameters.

Subproject 2: Micro and Nano Sensors Development

The general objective of Subproject 2 is to develop the appropriate sensors and their support modules, to unobtrusively, cost-effectively and reliably measure the required parameters for human physiological state identification and monitoring.

SP2 involves three major areas of work:

- ♦ Specifying, designing and developing an array of different micro and nano sensors for physiological measurements.
- ♦ Developing the necessary supportive technology (embedded connectivity, micro power supply, data fusion, user interfaces and integration platform) for seamless and optimal operation of the sensors.
- ♦ Laboratory verification of developed sensors, including future research specification.

The main results expected from the work of this Subproject are:

- ♦ Development of an on-line, multimedia database of available sleep, vigilance, stress, fatigue and attention measuring sensors as well as specifications of required sensor functionalities.
- ♦ 1 nanosensor and 1 microsensor for brain activity monitoring.
- ♦ 5 micro and 1 nano wearable sensors for physiological data recordings.
- ♦ 3 micro and 1 nano sensors for eye-related physiological measurements.
- ♦ 3 different motility and posture micro sensors, fused between them.
- ♦ 2 new microsensors for autonomic functions measurement.
- ♦ 2 new microsensor batteries, for power supply to other microsensors.
- ♦ Embedded connectivity of all developed and other (existing) sensors, able to provide remote sensor data retrieval and processing.
- ♦ Combinations of different WP2.2-WP2.6 sensors with user-friendly interfaces and functioning optimally.
- ♦ Multisensorial platforms of high reliability, able to be used in real medical and industrial environments with safety and security (including EMC conformance).
- ♦ Roadmap (with actions, dates, sensor specifications) for future micro and nanosensors development for human state monitoring.

Subproject 3: Medical and Neurological Applications

The general objective of Subproject 3 is to integrate SP2 sensors in multi-sensorial systems and use them to develop medical diagnosis, treatment and emergencies applications for the promotion of public health.

SP3 involves three major areas of work:

- ♦ Development of relevant diagnostics, treatments and other medical interventions (application framework).
- ♦ Development of multisensorial systems for performing the above medical and neurological applications.

- ♦ Verification of the developed applications and systems in a series of medical Pilots and specification of future research needs.

The main results expected from the work of this Subproject are:

- ♦ Clear selection and prioritisation of medical applications to be realized and tested, using the SP2 sensors. Correlation of sensors with each application.
- ♦ Development of unobtrusive, highly reliable, secure and cost-effective mobile system for assessment of selected sleep disorders.
- ♦ New sensorial systems, able to improve in terms of cost, time and reliability the treatment of sleep and stress-related diseases, such as sleep apnoea, cardio respiratory diseases and other consciousness descentnesses.
- ♦ Universal prototype for home-based and pre-hospital diagnosis of sleep-related emergencies.
- ♦ Harmonised and intuitive UI for all developed systems. Interoperable and integrated systems able to cooperate in combined diagnosis-treatment.
- ♦ Full testing of all developed systems and treatments within SP3, including technical, operational, cost-efficiency and socio-economic evaluation.
- ♦ Roadmap (with actions, dates, sensor specifications) for future medical applications using novel micro and nano sensors (of SP2 and beyond).

The research and technological development of the SENSATION medical applications are summarised below:

- Research issues:**
- Which sleep related diseases to focus priority on?
 - How can sensor development be optimised to unobtrusively and cost-efficiently diagnose disease?
 - How can the measurement capacities of the new sensors be exploited for therapeutic monitoring?
 - How can emergency-related and ambulatory applications be transferred from the hospital to the home environment?

- Technological development issues:**
- Development of multi-sensorial systems for medical diagnosis and treatments.
 - Development of multi-sensorial systems for home/ambulatory monitoring.
 - Development of an applications integration platform and of multi-sensorial systems user interfaces.

Concluding, the present situation as well as the future aim of SENSATION for the medical applications is schematically presented in the figure below:

Subproject 4: Industrial Applications

The general objective of Subproject 4 is to integrate SP2 sensors in multisensorial systems and use them to develop human operator hypovigilance detection and prediction to promote safety, comfort and QoL.

SP4 includes three major areas of work:

- ♦ Development of hypovigilance detection, prediction correlation and operator warning algorithms.
- ♦ Development of multi-sensorial systems for hypovigilance detection, prediction, sleep management and operator warning.

- ♦ Verification of the developed applications in a series of industrial Pilots and specification of future research needs.

The main results expected from the work of this Subproject are:

- ♦ Clear selection of industrial applications to be realised, and their aetiology, taking into account expected impacts, technological feasibility, cost-effectiveness and overall application viability.
- ♦ Identification of one global system or specific systems for different situations and/or applications and/or environments, able to detect human sleep, prolonged inattention and stress within few seconds of their occurrence (hypovigilance detection).
- ♦ Improved and personalised sleep management support services.
- ♦ Real-time hypovigilance prediction system and several support algorithms for its adaptation, according to the task.
- ♦ Modular and intuitive user interface for hypovigilance warning, easily adaptable to the task and with efficiency rate over 80% and user acceptance rate over 70%.
- ♦ Full testing of developed hypovigilance detection and prediction algorithms within SP4.
- ♦ Roadmap (with actions, dates, sensor specifications) for future industrial applications, using novel micro and nano sensors (of SP2 and beyond).

The selected application areas are preliminary and can be extended according to the research findings during the life of the project to other emerging industrial areas. Beyond all dispute, the integration of the SENSATION developed sensors in industrial systems, for unobtrusive and effective monitoring, detection and prediction of operator's sleepiness will bring a sound innovation in European safety standards.

Concluding, the research and technological development of the SENSATION industrial applications are summarised below:

- Research issues:**
- Which physiological parameters should be monitored and how should they be correlated for hypovigilance detection? Which physiological and other parameters should be monitored and how should they be correlated for hypovigilance prediction? How can sensor measured physiological data be correlated to sleep assessment and management models, in order to improve and personalise them?
 - How should people be warned effectively and safely in case they are drowsy?

- Technological development issues:**
- Development of sleep and stress detection systems for critical process operators.
 - Development of sleep prediction systems for critical time operations.
 - Development of hypovigilance warning systems.

Subproject 5: Cross-project Activities

The general objective of this sub-project is to correlate the different areas of research within the other 4 SPs, to provide them with a common research framework and cater for common activities such as dissemination, exploitation, management, interface to users needs and wants, legal and organisational aspects, standardisation and policy issues.

SP 5 gathers a set of activities that are common for all four sub-projects 1-4. This includes the Consortium Management, innovation-related activities (dissemination, exploitation, legal and organisational issues, user acceptance, gender issues), training activities, a common System Architecture and Evaluation framework and standards and policy measures, recommendations. These activities are rather heterogeneous and have been gathered together for organisational rather than technical reasons and, thus, each has its own specific objectives.

The main results expected from the work of this Subproject are:

- ◆ Good and efficient project management.
- ◆ Verified, effective training content, tools and curricula for scientists, critical process operators, people suffering from sleep disorders and the general public.
- ◆ Wide dissemination of project concept and results. Promotion of gender equality.
- ◆ Guidance of the project towards cost-effective results. Issue of an effective, pragmatic and viable business plan and exploitation scheme for project results uptake and marketing.
- ◆ Integration of public opinion into the project design and development process.
- ◆ Ethical and legal procedures for project work conduct.
- ◆ System Architecture Framework for the project.
- ◆ Evaluation Framework for the project.
- ◆ Standards and Policy measurements, recommendation, certification accreditation guidelines.

Sensors Development

SENSATION planned sensor/component technological developments are briefly presented in the following table.

SENSOR/COMPONENT	TYPE	ACRONYM	APPLICATIONS	DESCRIPTION	RATIONALE	NANO/ MICRO
Carbon nanotube electrophysiology sensor prototype	E&M	NANOBIO	All Electrophysiology: EEG, ECG, EOG, EMG. Implants.	<p>The aim of this development is to produce dry electrodes for applications such as Electrocardiograms (ECG) and Electroencephalograms (EEG). Currently used electrodes use a conductive gel to create a good electrical contact between the skin and the electrode. The use of these gels is both time consuming and inconvenient to the user (patient), and certainly one of the factors limiting their use in everyday life.</p> <p>In the proposed electrodes the tip of the electrode will be covered with a forest of Carbon Nano Tubes (CNT). CNT are a relatively recently discovered form of carbon called to revolutionize several disciplines.</p> <p>They exhibit an unmatched strength per mass ratio and excellent electric conductivity. A /brush /made out of thousands of CNT with diameters in the range of 10-50 nanometer will easily penetrate the outer layers of the skin (consisting of dead cells) improving electrical contact. CNT-based electrode tips will be combined with on-electrode amplifiers to create highly sensitive and noise immune dry electrodes.</p>	Current sensors are bulky, unstable and need gels. Carbon nanotubes have many properties that make them potentially exceptional sensors for measuring electric potentials at the surface or else (including implantables).	N
Multiple Site Flexible extra-flat microelectrodes prototype	E&M	FLEXELECT	Electrophysiology (EMG, EEG and EOG). Implants	Based on patented micro-technology process, multiple-site extra flat electrodes for recording neural activity at skin surface will be developed. These electrodes are based on plastic technology and specific 3D design. From mechanical point of view, such electrodes are extremely flexible, thus easy to use. From electrical point of view, these electrodes provide very low contact impedance.	Prototype 3D flexible microelectrodes already exist, developed for cochlear nerve monitoring. New designs will be realised for multiple sites active microelectrodes specially adapted to skin scales.	M

SENSOR/COMPONENT	TYPE	ACRONYM	APPLICATIONS	DESCRIPTION	RATIONALE	NANO/ MICRO
New wrist sensor prototype	Wearable	WRIST	On line wrist-worn pulse rate recording including algorithms and software.	Develop a wrist-worn device that measures the physical movement of the subject by means of miniature accelerometer technology. The new device will be smaller, lighter and use less power than existing devices. In addition, the wrist worn device will act as an interface/control for sensors from other partners and allow communication of these data in real time. By combination of data from other sensors, it is possible to make physiological measurements from the subject such as physical activity level, stress, heart rate and SPO2 (partial oxygen pressure – critical parameter regulating inspiration and respiration).	Develop method for on-line wrist-worn pulse rate recording including algorithms and software. Develop integrated wearable system to incorporate Actigraphy, light, temperature measurement including algorithms and software. Develop existing system to improve size/weight.	M
Textile based sensors and connectivity at selected applications	Polymer material	TEXTSENSE	Motility, limb movement, small muscle activity	Wearable, textile based thin film sensors will be developed by using thin film electrostatic material that utilizes novel electret polymer (EMFi), which its orders of magnitude are more sensitive than, e.g., piezofilm based sensors. It is also non-toxic and the material is compatible with existing synthetic textile materials. The film can be applied at various positions of the body to measure motility, limb movement, and if attached tightly, also small muscle activity. The sensor element and material itself is a commercial product, but R&D work is done in SENSATION for adaptation of the sensor shape and size for the attachment on a person; development of proper electronics and signal processing for extracting the relevant activity signals at various positions.	Substitution of piezofilm-based sensor, by much more sensitive, miniaturized electret polymer material based sensors.	M
New mattress-based microsensors	Polymer material	MATSEN	Detection and pre-processing of patient motility signals	An existing product consists of thin polymer film sensor that can recover the pulse rate when installed under the patient mattress. In SENSATION, film sensors, electronics and signal processing are further developed, so that physiological signals (pulse, breathing, muscle/body activity) can be detected with better spatial selectivity, and also possibly the sleeping position of the person. The patient motility signals are to be used as additional features for sleep stage definition, and sleeping position and physiological signals for, e.g., sleep apnoea diagnostics.	Based on a thin polymer film sensor, that can recover the pulse rate when installed under the patient mattress. Pillow applications require smaller area films to be provided.	M
Ear-based microsensor	Optical/ Infrared	EARSEN	Ear Sensor for pulse detection	An embedded miniaturized demonstrator for monitoring pulse with an ear clip is being developed. The sensor can be also integrated in an earphone and combined with portable audio devices. The technology is similar to that of the finger-ring (FINGER) sensor. In addition, an embedded accelerometer provides a motion signal allowing the provision of a reliable pulse signal even if the user is walking or running.	New wireless photosensor for photoplethysmographic registration of cardiointerval duration based on Bluetooth.	M

SENSOR/COMPONENT	TYPE	ACRONYM	APPLICATIONS	DESCRIPTION	RATIONALE	NANO/MICRO
Nanobio sensor feasibility report	E&M	NANOBIO-MAT	EEG	The feasibility of integrating carbon nanotube (CNT) based electrodes in textile materials for application in the bed environment will be studied. Electrodes embedded in pillows or in blankets would have a large potential to study or monitor individuals while at sleep, with obvious applications to monitor small children or elderly people. Only dry-electrodes requiring no skin preparation can be useful in this context. The development of these sensors is therefore dependent on the development of the Nanobio CNT-based electrode also within the Sensation project, and of the characteristics of these sensors. This particular task will study the feasibility of this integration through the development of very rudimentary prototypes.	Integration of Carbon nanotube electrophysiology sensor prototype of D2.2.3 to mattress-based sensors.	N
Finger ring SPO ₂ sensor	Wearable	FINGER	Monitoring of pulse and SPO ₂ saturation	A miniaturized sensor for monitoring pulse and blood oxygen saturation (SPO ₂) in a finger ring device. SpO ₂ is especially important to detect apnoea conditions. Existing systems for wrist and ear-located monitoring of cardiovascular parameters developed and patented will constitute the basis of the work. They use the transmission of light through the blood-irrigated tissues and measure the relative proportions of the oxygenated and deoxygenated haemoglobin. The development will concentrate on comfort for the user with the right level of pressure on the finger, reliability of the measurement despite the motion of the user and ambient light artefacts, and on the reduction of power consumption. Advanced data acquisition and processing techniques will be used for this.	The development of an embedded miniaturized demonstrator for monitoring pulse and blood oxygen saturation (SPO ₂) in a finger ring device in order to obtain a robust and accurate solution.	M

SENSOR/COMPONENT	TYPE	ACRONYM	APPLICATIONS	DESCRIPTION	RATIONALE	NANO/ MICRO
CMOS high dynamic camera	Optical E&M	MicroCMOS	CMOS micro camera, tracking and detecting forms, postures, attitudes, etc.	CMOS image sensors are high image quality sensors. CMOS sensor is a complete camera-on-a-chip solution including advanced and very flexible image processing. The sensor is easy to integrate in any application. Development of new specific CMOS process steps will be undertaken in order to meet system requirements in the field of automotive; improved pixel and sensor architecture to obtain a high level of dynamic range without the inconvenience of the Fixed Pattern Noise (FPN), the sensor will have to work with additional NIR light units operating in pulse mode The sensor will be placed in a system including a set a 2 camera sensors with their dedicated optics plus a specific HW for camera and light unit synchronisation and PC communication, drivers, etc. for a stereoscopic application.	High dynamic range (up to 100 dB), good sensitivity, high temp stability, high speed (200 Hz), precision for the eye-gaze orientation: 5°, precision for head position measurement around 3-5cm.	M
Stereoscopic 3D vision platform for eyelid gaze posture and motility analysis	Optical/ Infrared	STEREOVIEW	Eyelid, eye gaze, head and body position and movement	STEREOVIEW is a stereovision sensor platform including 2 micro cameras, dedicated lenses, specific NIR illumination units for night use and a dedicated HW for cameras' drivers and communication toward digital processing unit. The STEREOVIEW platform will be used to perform several "non invasive" functions aiming to monitor the subject attitudes in relation with vigilance: <ul style="list-style-type: none"> • Eyelid movement • Eye gaze • Activity and movement of the upper part of the body, arms and hands, head. The STEREOVIEW sensor, with its dedicated processing, will be integrated into vehicles for driver vigilance monitoring purpose but it may be also used for other applications like monitoring of air-traffic controllers, etc .	Automatic creation of individual 3D-map for new subject; PERCLOS and eye closure status; easy to use measurement analysis tools package. Improvement of stereoscopic vision algorithms, classification and diagnostic.	M
Eye spike detection by a micro coupling detector	E&M	SPIKEYE	Measurement of blinking rate	The eye spike signal detector is a highly innovative sensor, which will be non-invasive and will be integrated to the eyeglasses. The eye spike signal will be detected by two electrodes mounted on an eyeglass, one at the nose top and the other at the ear top of the glass, and through an A/D converter, the recorded data by the use of a microwave link will be remotely transferred to a base station for storing and further analysis. Finally, signal processing will be carried out in order to estimate the eye spike patterns and frequency.	Could be very small blinking event detector. The rather strong amplitude as well as the short duration of the signal (100 ms) allows the possibility of detecting the signal with a non-contacting micro sensor detecting the electric field generated near the eye environment.	M

SENSOR/COMPONENT	TYPE	ACRONYM	APPLICATIONS	DESCRIPTION	RATIONALE	NANO/ MICRO
Eyeglass-based microsensors	E&M	EYEGLOSS	Measurement of blinking rate and other EOG parameters.	The system is a sensor, which will be able to monitor user reactions (vigilance and attention). The sensor comprises of a CMOS Micro camera with predefined specifications, which will be placed on an eyeglass to be worn by the person under study. The output of the camera will be remotely sent to a base station, which will store consecutive images of the eye pupil and will provide with measurements of the eye motion. Eye opening measurement and blink detection and duration measurements will be performed in the base station using image processing and pattern recognition techniques.	Integration of D2.4.1 microcamera on eyeglasses for filtering of glass glare in EOG measurements and seamless EOG acquisition.	M
Seat foil sensor prototype	Pressure	SEFO	Posture, breathing, heart rate	A new seat foil sensor will be developed, that is more sensitive and has improved sampling frequency capabilities than present seat sensors. The seat sensor will be capable of detecting seat occupancy, posture and weight of a person with respect to the pressure applied against the various seat parts, and also possibly muscle stiffness relaxation that predicts sleepiness, when used in combination with other sensors. The main R&D effort will be focused on recovering the actual physiological signals from the sensors in a noisy environment that can be found in cars and industrial environments.	New generation of foil sensors, more sensitive and with better sampling frequency capabilities.	M
Capacitive sensor prototype	E&M	CAPSENSE	Measurement of head position in 3D	CAPSENSE is a capacitive sensor setup targeted at measuring the posture of a seat occupant. The seat can be in a passenger car or the seat of a controller in a plant control room for example. The sensor has the ability to measure whether the seat is occupied at all, if the person is moving on the seat, the head position of the person and some other characteristics. The functional principle is that of a big capacitor. The seat is equipped with a transmission electrode and around the person are receiving electrodes, e.g. in the ceiling of the car. If the seat is not occupied the receiver receives only a weak signal from the transmitter. If someone sits on the seat, the occupant effectively decreases the distance between the transmitter and receiver by acting as a conductor and the received signals at the electrodes close to the person are stronger than elsewhere. By analysing all received signals the determination of various posture parameters is possible.	Integration of one or more electrode arrays in vehicle sky. The aim is not only to measure static posture but also to detect movement in time.	M

SENSOR/COMPONENT	TYPE	ACRONYM	APPLICATIONS	DESCRIPTION	RATIONALE	NANO/ MICRO
Finger pulse sensor for motion insensitive and fast-response for arterial pressure and reliable analysis of PTT	Wearable	FINGERPULSE	Finger pulse for PTT and arterial tone	Sleep loss and fatigue have among others immediate impact on cardiovascular and hormonal systems. In addition, in a middle-aged population from the incidence of sleep loss increases, due to various minor airway disturbances, like snoring etc. One of the promising measures, reflecting effects of disturbed sleep, is the level of oxygen in blood. With the present technology blood oxygen levels are measured quite reliably in clinical settings. Whereas the present clinical measures focus on the average levels to avoid effects of artefacts, the effects of stress, attention levels etc. are potentially present in smaller and sudden changes of oxygen in the blood. More advanced sensor technology needs to be developed to get reliable and more sensitive measures in the ambulatory situations in the field. The innovation will also focus on improving embedded signal processing by using physiological knowledge of interaction within the cardiovascular system.	PTT is a novel approach to estimate BP changes that is a reliable measure of autonomic arousal or attention. Finger pulse signal used for PTT needs to be measured reliably and with a fast response. In addition, pressure tone adds additional value to the interpretation of autonomic arousal.	M
Combined sensor for accelerometer, respiration and ECG for correcting for position and movements	E&M	COMBINE	ECG, respiration and accelerometer	The German word 'atmen' for respiration sounds the same as the ancient Sanskrit word which means soul. Any change in attention, either aversive or pleasant has immediate impact on respiration and heart. Instability of both the breathing and the cardiac activity is also an indication of reduced rest during sleep. The sensor technology needs to be advanced to measure cardio respiratory instability any time and anywhere in unobtrusive and ambulatory settings. In addition, this sensor will be combined with the finger pulse sensor to process information from the peripheral flow and ECG to estimate changes in blood-pressure.	The correction of various measures for position and acceleration, while detecting stress at any time and anywhere, in easy and unobtrusive manner, is essential.	M
BAN Modules	Building blocks of BAN	BAN	Communication, UI and monitoring modules	The aim is to make possible the communications of all the sensors used in the same user's environment with a wearable central device (called Personal Data Processing Unit - PDPU) through wireless low-power links in order to concentrate all the data acquired by the mentioned sensors. Thus, those sensors and the PDPU will form a Body Area Network with a communication range a little beyond the user's body. The task of the PDPU will be to process the information received from the sensors in order to interact with the user or resend this information to application servers in both local and wide environments, always leaning on wireless communication technologies.	The characteristics of the body communication devices are the low power, short range, it must be an embedded subsystem with very low power consumption and of course the UI must be as simple as possible. Provides the wireless and embedded communication of all style sensors used on or around the person.	-

SENSOR/COMPONENT	TYPE	ACRONYM	APPLICATIONS	DESCRIPTION	RATIONALE	NANO/ MICRO
Fuel cell micro batteries	Power Component	MICROFUEL	Micro fuel cells	The aim is to develop a miniaturized micro fuel cell, to be used as a micropower supply for stand-alone microsystems and sensors. These devices will be based on the DMFC (direct methanol fuel cell) approach, which constitutes a suitable option for miniaturization of the devices. It will be operable around room temperature and using short charging time. The potential use for microsystems and sensors power supply and re-designs of these microgenerators, using different chemical sources, will also be explored.	Microgenerators are needed to support new microsensors. Especially important for potential future implant in the human body	M
Motion micro batteries	Power Component	MICROBATT	Motion powered micro batteries	The aim is to develop a micropower generation system to be adapted to the requirements of some of the developed sensors in order to guarantee their autonomous operation. It will be based on the scavenge of the ambient energy coming from the vibrations in the environment. It is formed by three parts: a micromechanical vibrating structure, an electromechanically coupled transducer and a rectifier and regulator stage.	Microgenerators are needed to support new microsensors. Especially important for potential future implant in the human body.	M

Table 1: SENSATION sensors summary sheet..

Project Key Deliverables

Deliverable No	Deliverable title	Delivery date	Nature	Dissemination level
D5.1.1	Project Management, Quality Assessment plan	M2	R	RE
D2.1.1	Sensors and technologies database	M12	s/w	CO
D2.7.3	BAN Modules	M16	P	CO
D2.2.2	Status report and recommendations on all sensors	M18	R	RE
D1.5.2	Improved mathematical and EEG-based models for sleep prediction and management	M20	R	CO
D1.6.1	Sleep/wakefulness pattern database	M20	s/w	CO
D1.7.1	Alertness Monitoring database	M20	s/w and R	CO
D1.8.1	Consolidation of developed criteria, models and tools	M24	R	RE
D2.4.4	Eyeglass-based microsensors	M24	P	CO
D2.5.1	Seat foil sensor prototype	M24	P	CO
D2.6.2	Finger pulse sensor for motion insensitive and fast-response for arterial pressure and reliable analysis of PTT	M24	P	CO
D2.5.2	3D vision for posture analysis sensor prototype	M26	P	CO
D2.5.4	Capacitive sensor prototype	M26	P	CO
D2.5.6	Integrated posture and motility prototype	M26	P	CO
D2.6.3	Combined sensor for accelerometer, respiration and ECG for correcting for position and movements	M28	P	CO
D2.2.3	Carbon nanotube electrophysiology sensor prototype	M30	P	CO
D2.2.4	Multiple Site Flexible extra-flat microelectrodes prototype	M30	P	CO
D2.3.2	New wrist sensor prototype	M30	P	CO
D2.3.3	Textile based sensors and connectivity at selected applications	M30	P	CO
D2.3.4	New mattress-based microsensors	M30	P	CO
D2.3.6	Finger ring SPO2 sensor	M30	P	CO
D2.3.7	Ear sensor for pulse monitoring	M30	P	CO
D2.4.2	Stereoscopic 3D vision platform for eyelid and eye gaze monitoring	M30	P	CO
D2.4.3	Eye spike detection by a micro coupling detector	M30	P	CO
D2.8.7	Fuel cell micro batteries	M30	P	CO
D2.8.8	Motion micro batteries	M30	P	CO
D4.5.3	SENSATION application framework	M30	P	CO
D5.4.2	Cost-benefit analysis report of developed sensors, Cost-effectiveness analysis and socio-economic aspects	M30	R	CO
D2.8.6	Data fusion subsystem	M32	s/w	CO
D3.2.3	Pilot mobile system for in sleep, cognitive and emotional disorders diagnosis	M36	P	CO
D3.3.2	New sensorial system for sleep apnea and cardiorespiratory activity treatment	M36	P	CO
D4.2.2	Sleep and stress recognition systems prototypes	M36	P	CO
D4.4.3	Integrated driver hypovigilance prediction system	M36	P	CO
D3.4.2	A universal prototype for home-based monitoring with both wireless and wire connectivity	M38	P	CO
D3.5.1	Testbed for the SENSATION medical applications	M38	P	CO
D4.3.2	"Sleep well" index to alert sleepers	M38	R	CO
D5.4.4	Final exploitation plans	M42	R	CO
D3.6.2	Pilot consolidation and recommendations	M48	R	RE
D4.6.2	Pilot consolidation and recommendations	M48	R	RE

Deliverable No	Deliverable title	Delivery date	Nature	Dissemination level
D5.2.5	Training schemes evaluation	M48	R	PU
D5.9.3	Policy and standards recommendations	M48	R	PU

R = Report

PU = Public

P = Prototype

RE = Restricted to a group specified by the consortium (including the Commission Services).

D = Demonstrator

CO = Confidential, only for members of the consortium (including the Commission Services).

O = Other

Expected Impacts

Future advances in research focusing on diseases associated to our social habits require unobtrusive monitoring of physiological and psychological parameters in order to gather information in real life, daily situations. Studies in many countries (for example Sweden and the Netherlands) have shown that work and social/family pressures cause a rise in the occurrence of stress related disease. Research based on obtrusive equipment makes it virtually impossible to carry out large-scale longitudinal studies to follow responses to real life stressors, as for example in daytime blood pressure, heart rate, EMG and night-time sleep disturbances. Therefore only small cross-sectional studies are carried out. Unobtrusive equipment will make this possible and will provide entirely new research opportunities.

The same type of equipment will also revolutionize medical diagnostics, since information on patients' physiological status can be obtained unobtrusively, fast and cost effectively, even in the patient's normal environment.

SENSATION intends to provide a significant impact on the detection, prediction and resolution of the problems of attention, vigilance, stress and other sleep related problems. Specifically, SENSATION impacts to safety, health, quality of life and the society are further discussed in the following sections.

Safety impacts

Judging from the serious implications of the lack of alertness to a high percentage of industrial accidents, as described in the introductory section of this deliverable, SENSATION is expected to have tremendous impact to the safety enhancement in the European society. SENSATION sensors and systems will strongly contribute to the avoidance of a wide series of accidents that are attributed to the fatigue/sleepiness of the operator, by detecting in real-time the critical human state and dealing efficiently with each individual case.

The exact safety impacts of SENSATION can only be addressed and calculated during the pilot iterations and at a wider extend during the introduction of the deriving products in the market. Nevertheless, it is expected that the multi-sensorial platforms sensors developed within the project, along with their innovative human-centred design and warning methods, will achieve a serious reduction of the accident rates (related to roughly 30% of serious road accidents and over 15% of industrial accidents) and offer a safer industrial environment for the European citizen.

Health impacts

Due to the substantial innovation of the recording and automatic analysis devices, resulting in unobtrusive, fast and cost effective measurements of physiological status, SENSATION is expected to have a great impact on health care in the European society. For the first time, it will be possible to evaluate objective measures of sleep and wakefulness (vigilance) in large-scale occupational health examinations in risk groups (e.g. shift-workers) and even in the general population, resulting in improved disease prevention. An important additional benefit will be the possibility to compare subject/patient data with a large, carefully selected normative database of healthy controls of both genders and all age groups. Similarly, these normative data will enhance quality of medical diagnosis. Quantification of disease-specific patterns will lead to more reliable and sensitive diagnostic criteria (evidence-based medicine).

On the basis of a more accurate diagnosis, the choice of the appropriate therapeutic intervention can be improved substantially. Indeed, alterations of specific parameters in patients due to disorders – when compared to normal controls – are opposite to changes induced by drugs intended for the treatment of these disorders – when compared with placebo (key-lock principle). Moreover, since the new equipment will facilitate repeated measurements, a better prediction of treatment response and better regular therapeutic monitoring will be achieved.

Furthermore the results of the SENSATION project will certainly stimulate new applications in the field of medicine and health care such as epileptic monitoring, electrophysiological neuroimaging, etc.

Finally, three specific and key fields of health care that are expected to benefit more from SENSATION are the following:

Distance Monitoring: It is not always easy for people to travel to the physician's office to communicate face-to-face. Distance monitoring includes computerized communications (i.e., the use of a computer, modem, and other interfacing equipment to transmit medical data between a patient and a provider) as well as telephone communications (i.e., telephone follow-up care, telephone screening) to interact. SENSATION will enable the patients to upload information to their physician as well as ask questions. Physicians will be able to review data from the patient and respond to the patients.

Patient Reminders: When people are faced with a chronic illness or complicated medical situation it can be difficult to remember everything that must be done for treatment (e.g., taking medication, appointments with physicians). Reminders, or prompts, are messages that arrive at the time of decision-making. Prompts can be very effective in bringing patients' attention to necessary health actions. In this project, patients will be prompted about doctor appointments, taking medication, and performing measurements.

Incentives: Sometimes patients need incentives to follow through with appropriate self-care behaviors. Incentives can motivate patients just enough to perform the appropriate actions. SENSATION will provide small incentives to encourage patients to perform very important self-care behaviors.

Impacts to QoL

Quality of life is a rather nebulous term that refers to the ability for self-care, lack of pain, physical abilities, mood, energy, etc. It is partly covered by health and safety, but is best seen as a global description of fulfilling life. Obviously, the prevention of fatigue accidents will improve QoL in all its subcomponents. Also the improvement in sleep diagnostics will increase the number of days with a high QoL.

An innovative aspect of SENSATION is also the intended possibility to optimize sleep wake patterns through the use of sensors and mathematical models. This will enable the individual to maintain a lower fatigue level through adhering to the advice of the sleep/wake predictor. Since fatigue is the main component of day-to-day variation of subjective health, the latter will be increased. The feedback of fatigue and the need of sleep will also improve daily functioning, including memory and intelligence, since both are sensitive to improved alertness states. Feedback systems of optimal sleep/wake pattern will also help pain-afflicted individuals improving their sleep and their quality of life. Similar effects may be seen in the elderly, depressives, insomniacs and shift workers - large groups in society. Sensors that also monitor environmental light will help all four groups integrating sleep activity, and light exposure in order to optimize alertness, sleep and mood.

Similar effects may be obtained using similar sensors, with a particular emphasis on heart rate, activity and others, in order to feed back information on stress levels impacting on quality of life and sleep.

Impacts to the Society

The societal impacts are sited below per are of social activities/problems.

Impact on employment

The principal impact of SENSATION on the volume of employment is strongly positive, in particular through the effect on the competitiveness of EU economies, as outlined below. Within the health-care system itself, positive effects on employment can be expected despite the fact that telecommunications and information technologies are often seen as threatening to substitute for human labour input. Health-care is an area of the economy where the volume of activity is significantly restrained by lack of resources. The better deployment of resources which SENSATION systems enable will help meet more of the demand without leading to release of staff. In addition, significant improvements in the working life of health care and social service professionals can be expected. The services concerned relieve pressure on the staffing of services during unsocial hours, as patients can be reached quickly and effectively and a significant proportion of needs met without staff travelling in the field. Better accessibility improves the degree of control staff have over the timing and content of their work, potentially - given the appropriate organisational context - improving the overall quality of their working life.

Of course, also the development of innovative multi-sensorial platforms is expected to create a whole new service and products area (that of human operator monitoring and support) with leading edge at Europe, thus creating new job opportunities at the scale of several thousands Europe-wide.

Contribution to competitiveness

From the point of view of EU member states, deployment of home-care services promises very great savings in resources, with a significant increase in the quality of care. The savings due to the former effect reduce pressure on public budgets and enable Member States to reduce the taxes and insurance levies applied to economic activity, reducing the prices of goods and services and making the businesses concerned more competitive.

The major contribution to competitiveness comes from improved health of citizens. Working days lost by key staff can be reduced, whether these are due to their own illness or due to their responsibility for the care of dependent minors or elderly relatives. The improvement in overall staff availability can make a significant contribution to the effectiveness of companies in reacting to client demands, improving their competitiveness.

The same is true in the improvement of competitiveness of the overall population. Better sleep management means improved capacity to work and produce, thus implicitly the new sleep management models and schemes will significantly enhance the competitiveness of the European industry.

Contribution to cohesion

One of the major difficulties in supporting the independence and economic viability of peripheral and remote regions of the European Community is to deliver the public services essential to maintain economic activity without excessive cost. Health-care and care of citizens suffering from chronic sleep related diseases represent a very important segment of public service. Enabling the remote provision of health-care and social support services has obvious advantages in facilitating the delivery of cost-effective health-care services to remote and isolated regions. SENSATION systems thus have the potential to make a significant contribution to cohesion in the European Community. An additional effect is the improved support, which can be given to EU migrants with less than perfect competence in the local language of their host country. From a safety point of view as well, industrial accidents at the periphery or less developed parts of EC are much more frequent (including road accidents) and the effective human operator monitoring is expected to normalise them and help areas with less safety measures and more dangerous operator behaviour (i.e. risky drivers, overworking operators) to improve.

Elimination of social exclusion

The reduced mobility which comes with some chronic diseases and afflicts many due to ageing processes threatens not only quality of life of those afflicted but also threatens them with social exclusion. Studies carried out on the communication activity of citizens suffering from sleep related chronic diseases show how their network of friends shrinks not only due to the higher levels of mortality in their age group but also because of the difficulty of maintaining social relationships when movement and travel is restricted. Increasing exclusion leads to a reduction in social competence and a downward spiral of withdrawal from social life and loss of more general and essential abilities to care for one-self. Systems such as SENSATION to enable support to be delivered to those threatened by exclusion can provide significant help in this area.

Impact on the environment

In addition, increased support to home-care is expected to have an impact on the volume of travel in the EU, for instance reducing trips to hospital and reducing the frequency of doctors' and nurses' rounds. The decreased costs and increased effectiveness may lead to an increase in care provision overall, to some extent negating this effect. Nevertheless, on balance and for a given level of care, improved support to home-care can be expected to reduce the amount of travel and this way to have a significant, very positive impact on the environment.

Other socio-economic benefits

Deployment of SENSATION services is expected to provide a (private and public) financial return to its promoters, and a number of socio-economic benefits to third parties as outlined above - impacts on employment, competitiveness, cohesion, integration and quality of life.

The miniaturisation and cost-reduction of sensors targeted at SENSATION will result in more cost-effective applications not only for small user groups, but also for all citizens (drivers, people with sleep related diseases, shift workers, etc.).