EVALUATION OF CRITICAL AND EMERGING SECURITY TECHNOLOGIES FOR THE ELABORATION OF A STRATEGIC RESEARCH AGENDA

DELIVERABLE D5.1

Intermediate Report on Emerging Technologies

Partner:	Author
FOI:	Steven Savage, Anna Pohl, Britta Levin, Malek Khan
CEA:	Dominique Noguet, Géraud Canet
Tecnalia:	Javier Herrera Lotero
Isdefe:	Jesús López Pino
Morpho:	Stéphane Revelin
CSSC:	Matteo Bonfanti
Fraunhofer INT:	Klaus Ruhlig, Guido Huppertz

November 2013

1 ETCETERA Work Package 5

1.1 Task Description

Work package WP 5 “In-depth Analysis” directly continues the work of WP 4 “Scanning for Emerging Technologies” in strand “Emerging Technologies” of the ETCETERA project. In the latter a number of technologies was identified, that have implications for public security or security applications and are expected to lead to applications in years 2020 to 2030.

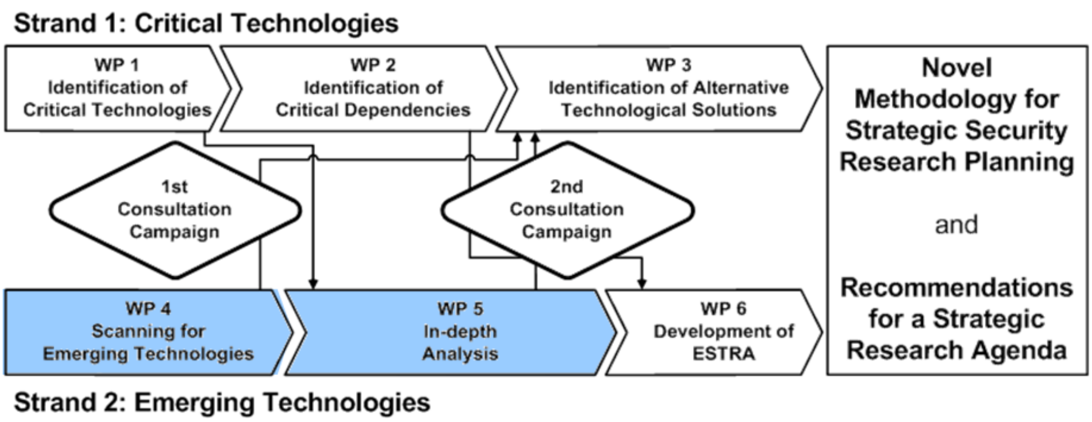


Figure 1.1.1: ETCETERA project workflow with strands for emerging and critical technologies [Source: Fraunhofer INT].

Six institutions were involved in task 5.1 as analysers of an emerging technology:

- FOI (Sweden) 2 analyses
- Tecnalia (Spain) 2 analyses
- Morpho (France) 2 analyses
- CEA (France) 1 analysis
- Isdefe (Spain) 1 analysis
- Fraunhofer INT (Germany) 1 analysis

A list of the themes of the analyses is shown in section 1.3. In section 2 technology profiles for each of the analyses are provided. Besides the mentioned six analysing partners there were three end-users of security related technologies involved (ComSec from Germany, SSBF from Sweden and ASTS from Italy) in order to balance the theoretical assessment of the technologies by first-hand experience on technology usage and relevant user needs.

The technologies identified in work package WP 4 were prioritised according to a process illustrated further below in section 1.2. In task 5.1 of Work Package 5 this prioritisation process is advanced in order to identify a small number of nine technologies that were investigated more deeply. As depicted in the following figure the selection of a certain number of technologies from the list of D4.1 plays a central role for tasks 5.1 to 5.4 of this work package, since essentially tasks 5.1 to 5.3 investigate the same set of technologies by applying different methods. In task 5.4 the evaluation of ethical and regulatory implications associated with the respective technological developments are investigated. This task also fulfilled the role of an ethical helpdesk for other tasks in this work package and the project as a whole.

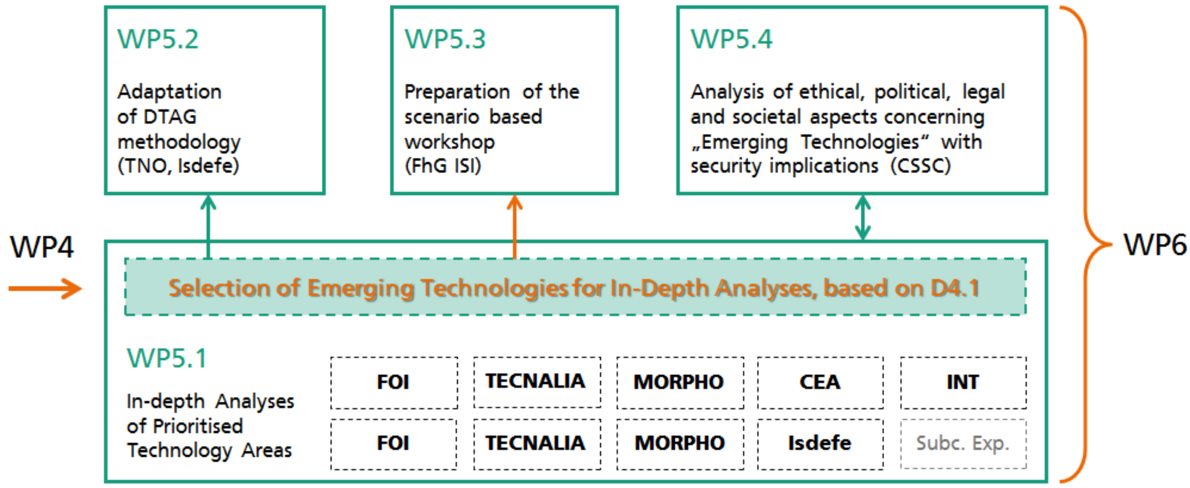


Figure 1.1.2: Scheme explaining the thematic intersection between work packages WP 4 and WP 5. The selection of the technologies based on deliverable D4.1 was a precondition for all tasks in WP 5 [Source: Fraunhofer INT].

Tasks and partners involved in work package WP 5 „In-depth Analysis“:

- Task 5.1: “In-depth analyses of prioritised technologies“ (preparatory for Task 6.1)
  Leader: Fraunhofer INT
  Analyses: FOI (2), Tecnalia (2), Morpho (2), Isdefe (1), CEA (1), Fraunhofer (1)

- Task 5.2: “Adaption of the DTAG methodology“ (preparatory for Task 6.4)
  Leader: TNO
  Contributor: Isdefe

- Task 5.3: “Preparation of the scenario based workshop” (preparatory for Task 6.5)
  Leader: Fraunhofer ISI

- Task 5.4: “Analysis of ethical, political, legal, and societal aspects concerning Emerging Technologies with security implications” (preparatory for Task 6.6)
  Leader: CSSC
  Content: Collection and discussion of official EU documents on the issue. Meta-analysis of reports and surveys concerning EU public opinion. Comprehensive discussion of gaps, input of ethical aspects for 2nd Consultation Campaign. Provision of an “ethical helpdesk”.

The in-depth analyses of prioritised technology areas in task 5.1 were performed by internal experts of the respective partners. The analyses followed a template or generic structure developed in task 4.2 to ensure comparability and coverage of relevant aspects among different technology topics and for assessment in following work packages.

The analyses comprise around 15 pages each and are organised in six sections:

1.1 Technology Description
1.2 Security Relevance
1.3 Time Frame
1.4 Application and Market Potential
1.5 Ethical Consideration
1.6 Technology Profile

Each of the nine technology analyses formed a non-publishable working document for use in downstream project work. Characteristic features of each technology are incorporated in this deliverable D5.1 in form of a technology profile, see section 2. Additionally, for each theme of an in-depth analysis a technology card is given in section 3 of this document. These technology cards were used as information in the selection process described in the following section.

1.2 Selection Process

During the course of Work Package 4, a set of initially 142 technologies identified by three ETCETERA partners was harmonised to a provisional list of 127 technologies. This list forms the central part of deliverable WD4.1.
In order to assess which of those technologies might be most promising in the sense of the ETCETERA project, this list needed to be prioritised with respect to different criteria. Since the identified technologies embrace the whole range of technology landscape a broad range of expert knowledge needed to be involved in this process. This could only be operationalised by a decentralised process. Consequently a spreadsheet containing the list of technologies was distributed among the work package partners, containing questions concerning the rating of

- Security relevance
- Time Frame
- Market Potential
- Application Potential and
- Ethical Consideration.

The partners were asked to let specialists rate those technologies in the spreadsheet matching their competence. Since the spreadsheet did only list technology designations that might have perhaps different connotations or raise different associations among the involved experts a set of technology cards was distributed to establish a common understanding of the meaning of a technology. The technology cards contained an explanation about the general meaning of a technology, the connection to security applications and a first expectation about its further development. Some examples of technology cards are depicted in figure 1.2.1.

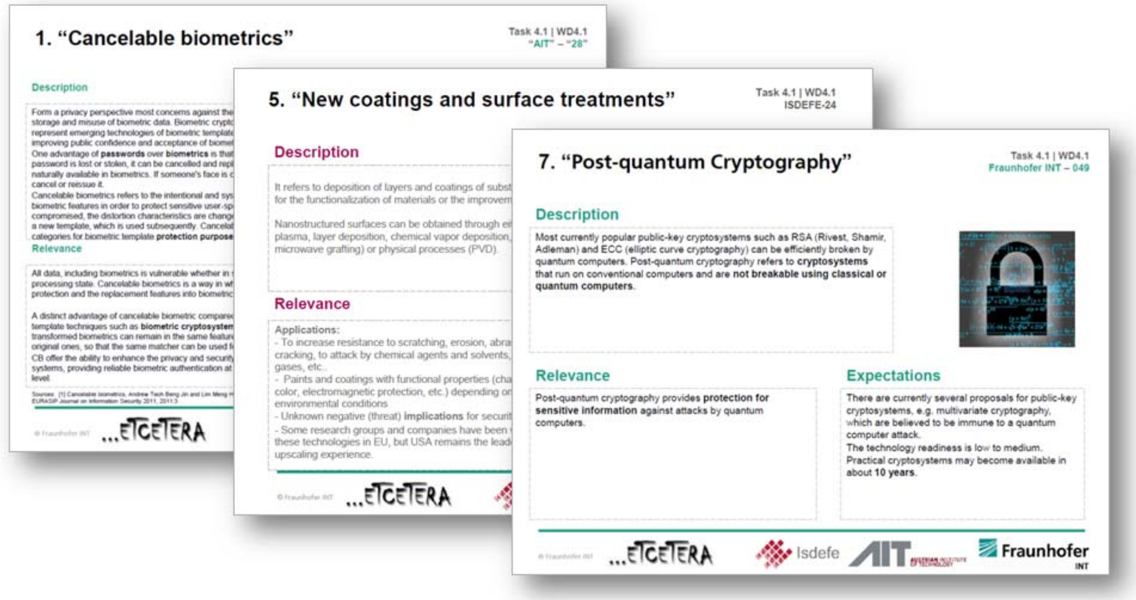


Figure 1.2.1: Examples of technology cards used for the prioritisation and selection process in work package WP 4 respectively WP 5 [Source: Fraunhofer INT].

Based on this common information, each expert should rate the technologies of his competence field. In this respect "rating" meant choosing from a small range of predefined values by ticking boxes (see figure 1.2.2). Finally, all results were collected and accumulated by applying different weights to the different categories of answers. The results of this Weighted-Bit Assessment Method (WBAM) were then compiled into a prioritised list of technologies published in deliverable D4.1. In this deliverable additional information on the procedure can be found. Figure 1.2.2 displays a generic example of the spreadsheet used for the WBAM assessment. Figure 1.2.3 shows one possible order of technologies in the prioritised list when "Security Relevance" is chosen as the main criterion. For a different choice of main and additional sorting criteria the order of the list will obviously change.

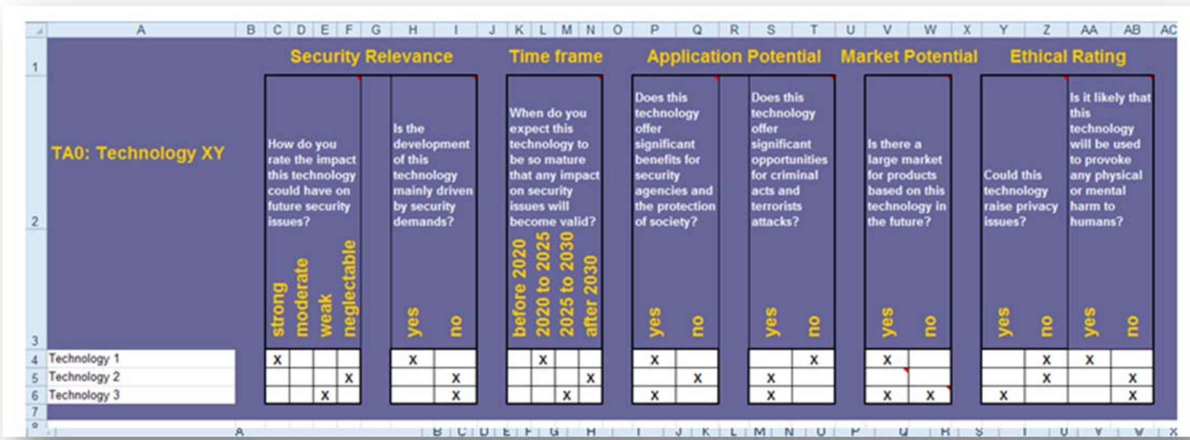


Figure 1.2.2: Example of the WBAM assessment table used in WP 4 [Source: Fraunhofer INT]

	TA7: Human Science	SecRel	Time	Market	Appl	Ethics
20	Automated Human Behaviour Analysis	5	3	3	3	0
21	Dark Web Terrorism Research	5	0	-3	3	0
22	Broad-Spectrum Antiviral Therapeutics	4.5	6	3	3	6
23	Reality mining - Machine Perception and Learning	1	3	3	-3	0
24	Agent based Modelling	1	3	1	-1	4

	TA8: ICT and Electronics	SecRel	Time	Market	Appl	Ethics
25	Quantum Computers	3	3	-1	1	4
26	Nanocomputers	1	0	1	-3	6

Figure 1.2.3: Detail of the list of prioritised technologies as published in deliverable D4.1. Identified technologies are arranged in thematically closely correlated groups, called Technology Areas or TA. Numbers in five right hand columns show result of the WBAM process described in the text. The shown list results when sorting according to parameter “Security Relevance” SecRel [Source: Fraunhofer INT].

If from the provisional list of technologies (i.e. WD4.1) any technology is excluded that does not have a positive value for “Security Relevance” (SecRel > 0) or a non-negative value for criterion “Time Frame” (Time ≥ 0), the list shortens to a set of seventy technologies. These can be found in deliverable D4.1.

In subsequent tasks following Work Package 4, some technologies have been assessed using different methods. This on the one hand served to deepen and cross-validate the findings about technologies by complementary approaches, on the other hand it delivered methodological insight. Since a complementary deep analysis of the economic or societal potential of seventy technologies was beyond the scope of this project, from the list of seventy technologies a total of nine technologies had to be chosen for further investigation.

This selection was performed in a two-step process by the work package partners active in WP 5. In the first step from the list of interesting technologies those were identified that matched specific areas of expertise of the participating organisations. The rational is that both depth and validity of the technology assessment are proportional to the expertness of the analyser. This shifted the focus to nearly half of the technologies, with a set of 30 pre-selected technologies. Out of those pre-selected candidates in a final step those were chosen that seemed to be of highest relevance from a stakeholder point of view, i.e. from the perspective of an end-user or a founder of research.

Altogether three different strategies to select technologies out of deliverable D4.1 were implemented:

- technology driven — based on WBAM rating in D4.1 technologies are identified
- capability driven — based on the expertise of the WP5 partners and end-users suitable technology areas or technologies are identified
- demand driven — technologies are identified based e.g. on the usefulness for the ETCETERA objectives (finally: security and wealth of EU citizens) or with respect to the requirements of other tasks.

Examples of a "technology driven" approach are:

- sorting of all Emerging Technologies in D4.1 with respect to parameter "Security Relevance" (or some combination of parameters) without regarding thematic relationships between technologies
  - advantage: "absolute most relevant" technologies will be selected
  - drawback: selection will probably be thematically unbalanced

- sorting of all Emerging Technologies in D4.1 with respect to parameter "Security Relevance" (or some combination of parameters) and accounting for thematic relationships between technologies (technology areas).
  Pre-selection of technology areas and choosing of top N technologies in each area, before final selection step.
  - advantage: balanced selection assured
  - drawback: some promising technologies might be sacrificed

Examples of a "capability driven" approach are:

- inquiry about preferences of WP5 partners who will perform the analyses
  - advantage: higher quality of reports compared to unfamiliar themes
  - drawback: selection possibly thematically imbalanced

- inquiry about preferences of end-users in WP5
  - advantage: higher relevance and quality of feedback for technology analyses
  - drawback: selection probably thematically unbalanced

Examples of a "demand driven" approach are:

- pre-selection of technology areas or even determination of individual technologies from D4.1, e.g. with regard to ethical aspects, ecological aspects, legal issues, or similar societal demands.
  - advantage: higher regard to societal or critical demands
  - drawback: selection possibly thematically unbalanced

- selection of technologies according to availability of data for economic assessment in WP6, or with respect to suitability for DTAG, Scenario Based Workshop or other methods in downstream Etcetera tasks.
  - advantage: higher quality of results in downstream Etcetera tasks
  - drawback: selection possibly thematically unbalanced

From the gathering of over hundred potentially relevant technologies at the beginning of Work Package 4 to the choice of nine promising, exemplary technologies in Work Package 5 the selection process – illustrated in figure 1.2.4 – was organised to account for a number of different aspects of the given project task. The resulting list shown in table 1.3.1 necessarily is a compromise with respect to single aspect. However these nine technologies should not be mistaken as a pure selection of the most promising technologies with the highest economic or application potential.

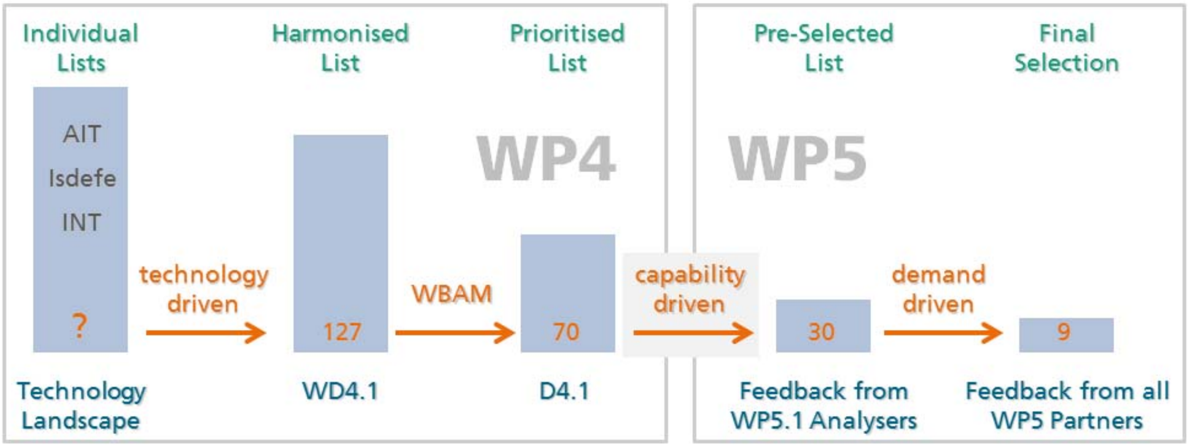


Figure 1.2.4: Illustration of the complete technology selection process from the start of work package WP 4 to WP 5 [Source: Fraunhofer INT]

1.3 List of Selected Technologies

Table 1.3.1: List of the nine technologies chosen for in-depth analyses. Technology profiles can be found in section 2 of this deliverable.

No.	Technology	Partner
1	Indoor-Navigation	CEA
2	Smart Textiles	FOI
3	Small-scale Energy Harvesting	FOI
4	Homomorphic Encryption	Fraunhofer INT
5	Explosive Traces Integrated Sensors	Isdefe
6	Sensors on unconventional Substrates	TECNALIA
7	Cognitive Radio	TECNALIA
8	Terahertz - Imaging and Substance Identification	MORPHO
9	Technology Area: CBRN Identification	MORPHO

2 Technology Profiles

The following pages contain short profiles of the technologies that were analysed in depth in Work Package 5. The authors of the analyses and profiles are as follows:

2.1 Indoor Navigation

Author: Dominique Noguet, Géraud Canet (CEA)

2.2 Small-Scale Energy Harvesting

Author: Steven J. Savage, Malek Khan (FOI)

2.3 Smart Textiles

Author: Anna Pohl, Britta Levin, Malek Khan (FOI)

2.4 Homomorphic Encryption

Author: Klaus Ruhlig (Fraunhofer INT), Matteo Bonfanti (CSSC)

2.5 Explosive Traces Integrated Sensors

Author: Jesús López Pino (Isdefe)

2.6 Sensors on unconventional Substrates

Author: Nieves Murillo, Fernando Seco, Javier Herrera (Tecnalia)

2.7 Cognitive Radio

Author: Javier Herrera (Tecnalia)

2.8 Terahertz – Imaging and Substance Identification

Author: Stéphane Revelin (Morpho), Matteo Bonfanti (CSSC)

2.9 Technology Area CBRN Identification

Author: Stéphane Revelin (Morpho), Matteo Bonfanti (CSSC)

1.1 Indoor Navigation

Technology Description	■ INDOOR navigation is navigation under conditions with no satellite coverage. ■ INDOOR localization with both infrastructure dependent and infrastructureless solutions ■ Sensor fusion for enhanced efficiency ■ Application focus is indoor localization to ensure safe & efficient operations indoors and out. ■ Numerous technologies are developed. Research and promising technologies are MEMS, inertial, visual odometry and radio wave-based methods
Security Relevance	■ Indoor navigation has direct influence on emergency response operations in buildings ■ Indoor navigation indirectly improves security applications by tracking people for people safety
Time Frame	■ TRL is LOW to MEDIUM for most technologies ■ While systems are becoming available that can meet the requirement of many enterprise and security applications, firefighter tracking is not yet commercially available. Given the inherent challenges of the firefighting environment (smoke, heat, water, ...) , and the life safety nature of the application, extensive field trials and staged development are required.
Application and Market Potential	■ Location based services ■ The market is expected to reach $2.5 Billion by 2017
Ethical Consideration	■ The main ethical consideration is the protection of data coming from the location tracking.

1.2 Small-scale Energy Harvesting

Technology Description	- Small-scale energy harvesting technology. - Application focus is on concentrating energy freely available in the environment and converting this to electricity. The electricity generated may be stored and/or used immediately to power security devices such as sensors, computers, data analysis, and information transmission. - Research is widely distributed throughout the world but is concentrated to the technologically advanced nations in Europe, North America and Asia. Research is done in many universities, research institutes and companies.
Security Relevance	- Small-scale energy harvesting directly influences security technology because this relies very heavily on many different sensors and communications devices including computers and wireless data transmission to accumulate, collate, analyse and transmit information in a particular situation or context. - Small-scale energy harvesting directly improves security applications because it can supply the power essential to drive many devices used in security application, both mobile and static. This enhances security systems by reducing their size and cost to install and operate. - Potential misuse could be for covert surveillance.
Time Frame	- TRL is MEDIUM (taking the technologies as a whole). - First applications already exist in special applications in space, but more everyday applications in security systems will be implemented within 2-3 years.
Application and Market Potential	- Small-scale energy harvesting can be used by any person or organisation using security systems. Applications in remote areas or for mobile devices are perhaps most relevant at the present time. Examples include surveillance and information collection. - It is one solution among others suited to achieve independence from a grid-based power supply. The main advantage is to eliminate or reduce the reliance on batteries or permanent connection to the grid. - The market value is impossible to estimate with any degree of accuracy, but as an example the 2020 market for only PV cells is estimated to be about $70 billion. - Small scale energy harvesting is not a substitute but a complement to existing technologies, but will eventually begin to compete with secondary batteries.
Ethical Consideration	- Small-scale energy harvesting sub-technology can be misused for covert surveillance. - There are no severe ethical issues known for small-scale energy harvesting other than it will enhance the use of surveillance systems. - Small-scale energy harvesting today (e.g. in the form of solar cells) is widely accepted by the public for outdoor activities.

1.3 Smart Textiles

Technology Description	■ Smart textiles are used to provide enhanced functions to fabrics. Examples include body sensors that can measure ECG, pulse, breathing frequency, sweat and dehydration. Wearable antennas are used when transmitting/receiving measured information. Smart textiles can also provide body protection. ■ Research is performed world-wide at universities (University of Arkansas, Swedish Textile University in Borås), research institutes (Kaunas textile institute in Lithuania; WIWeb in Germany; Swerea IVF in Sweden, NRC in Canada), industries (BAE systems worldwide, Öztek tekstil in Turkey) and small companies (SMARTEX in Italy, FOV fabrics in Sweden)
Security Relevance	■ Health monitoring is used for monitoring and increased survivability. The user could be a first responder or other types of emergency personnel as well as patients in emergency care.
Time Frame	■ The TRL is MEDIUM or MEDIUM to HIGH for some of the products. ■ Some products are already commercially available. ■ There is a need for better flexible conducting materials.
Application and Market Potential	■ The applications of smart textiles are not only found in security but also in safety. ■ A different market is the sport and outdoor industry, which has a huge potential.
Ethical Consideration	■ Potential misuse could be privacy offensive. Smart textiles could contain hazardous agents. ■ Some of the agents used, for example nanoparticles, could possibly be health hazardous and harmful to the environment.

1.4 Homomorphic Encryption

Technology Description	■ Homomorphic encryption allows computations to be carried out on encrypted data which is not possible using conventional encryption methods. ■ Homomorphic encryption can be (roughly) divided into partially homomorphic and fully homomorphic encryption schemes. ■ Fully homomorphic encryption supports arbitrarily complex computations on encrypted data. ■ Current research is mostly done at universities. However, there are also research activities at companies like IBM or Microsoft.
Security Relevance	■ The new security feature of homomorphic encryption is that these techniques ensure confidentiality even while data is processed. ■ Homomorphic encryption schemes cannot reach the highest possible security level for encryption. ■ Homomorphic encryption can be misused by criminals to hamper the work of the police because it can be used to conceal criminal activities in the Internet.
Time Frame	■ First applications of partially homomorphic encryption, e.g. in the form of electronic voting systems, are already available. ■ Fully homomorphic encryption will only be practicable in the long-term, if ever. ■ Somewhat homomorphic encryption may become practical much earlier. ■ TRL of partially homomorphic encryption is HIGH. ■ TRL of somewhat homomorphic encryption is MEDIUM. ■ TRL of fully homomorphic encryption is LOW.
Application and Market Potential	■ Probably the most important application will be cloud computing since homomorphic encryption may significantly increase the attractiveness of this technology. ■ Other possible applications are: ▪ Private information retrieval systems ▪ Electronic voting systems ▪ Spam-filtering encrypted emails
Ethical Consideration	■ Homomorphic encryption can help to enhance privacy. ■ However, enhancing privacy also means a possible impediment to detection of criminal activity.

1.5 Explosive Traces Integrated Sensors (ETI Sensors)

Technology Description	■ ETI Sensors is a kind of Explosive Detection System based on the use of compatible and complementary sensor systems to cover a high variety of explosives traces with a low false alarm ratio. ■ Application focus is Homeland Security: Border Protection, seaports, airports and other critical infrastructure protection. ■ Research is concentrated at industry at the system level, while universities are making advancements in basic techniques which require further development.
Security Relevance	■ ETI Sensors has direct influence on Homeland Security activities, mainly in border security aspects. ■ ETI Sensors indirectly improves security applications on Explosives Detection Systems (EDS) by lowering the rate of false alarms and increasing reliability.
Time Frame	■ TRL is quite technology dependent, but as innovation arises from the integration of several individual technologies, the current technology maturity, based on the ESRIF classification would be MEDIUM as it requires further applied research both in terms of integration and fusion as well as in some own detection technologies. ■ First applications in form of a multisensory system are expected around 2016.
Application and Market Potential	■ ETI Sensors can be used by border protection forces, fire squads, police and other security forces for parcel, container, vehicles or persons screening at airports. Seaports, borders, checkpoints, infrastructure entry points... ■ It represents a unique solution suited to achieve best results in a wide range of environments and capable of facing most types of explosives in different conditions thus making it ideal for most of the possible threats. ■ Could replace current technology as standalone IMS with an estimated market volume of currently 3,5 billion euro worldwide per year and increasing.
Ethical Consideration	■ It is of paramount importance the public opinion is duly informed about what the technology is and what the procedure of being screened entails. Informing the public is a matter of transparency but also good way to get public's trust in and acceptance for the deployment of an ETD integrated system.

1.6 Sensors on Unconventional Substrates

Technology Description	▪ Manufacturing technologies to be used for the development of new sensors or smart functions for the threat detection, and/or identification, or the people treatment in the post event phase. ▪ Applications: ✓ Blast exposure sensor ✓ Textile Switch ✓ Conductive textile ✓ Strain sensors ✓ Wireless passive sensor ✓ Energy harvesting sensors for ICT security systems ✓ Vital constant or on body monitoring systems for first responders or law enforcement agents. ✓ Gas sensors for early alarm for attack prevention ✓ Smart dosage devices ✓ Victims identification tag ✓ Perimeter sensor for post event control ▪ Research institution and companies involved on the unconventional sensor development: Peratech, Smartex, Electrical Engineering & NanoFab (University of Texas at Arlington), VTT, Tecnalia, MIT, Cutecircuit, Eleksen, Yonsei University, Tufts University.
Security Relevance	▪ Sensors on Unconventional Substrates will allow the detection, identification or prevention of threats and the victims' treatment to increase the EU resilience, first responders and law enforcement agent's security and citizen quality of live increase.
Time Frame	▪ TRL is from Medium to High in a great number of applications. ▪ Some products are in the market like Peratech or Smartech product. ▪ A multidisciplinary research is needed to put into the market the applications described in this document.
Application and Market Potential	▪ Currently, the main sectors where incipient technologies developments are under development are the healthcare, food, water, textiles, energy, etc. amount security.
Ethical Consideration	▪ Encryption of confidential information transmission ▪ Citizen information privacy ▪ EU Guideline for sensor countermeasurement ▪ EU cultural aspect ▪ Ethical and legal issues related the false alarm

1.7 Cognitive Radio

Technology Description	■ Cognitive Radio Systems are defined as "*A radio system employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained*". (Source: Report ITU-R SM.2152.) ■ They improve performance of communications systems by allowing different systems to share a single frequency band, mitigating interference between those systems, improving networks flexibility, and allowing communications devices to become universal. ■ Underlying technologies which must be still further researched are: *Spectrum Sensing, Dynamic Bandwidth Allocation and the design of reference architectures*, *Coexistence amongst radio technologies.*

Security Relevance	■ The "cognitive" or "intelligent" feature of CR systems and networks should have a positive impact on Security and Emergency scenarios, since a rapid and optimal response is always required for this kind of applications.
	■ Some Examples of applications to an emergency scenario are:
	  ■ Network Extension for Coverage and Reachback
	  ■ Dynamically Access to Additional Spectrum
	  ■ Temporarily Reconfigure Emergency Communication Device Priorities
	  ■ Interface to external users

Time Frame	■ TRL is LOW to MEDIUM. ■ Technology development depends highly on the approval of favourable legislation. ■ First applications in form of commercial devices are not expected before 2020.
Application and Market Potential	■ Cognitive Radio technology could be used for applications in the commercial, military and security market. ■ Key issues for its future success are more efficient use of spectrum and interoperability. ■ In the military market, the U.S. provides each year $1.8 billion in funding for R&D in tactical radios. ■ In public safety and private land mobile radio, roughly 1-2 million radios are purchased per year.
Ethical Consideration	■ The main ethical consideration is the risk of interfering with protected users. ■ Every research in this area should take the above mentioned problem into account.

1.8 Terahertz – Imaging and Substance Identification

Technology Description	■ Terahertz is far-infrared electromagnetic radiation between 100 GHz and 10 THz ■ Creates an image of an object by measuring the intensity of reflected or emitted energy ■ Gathers information on the chemical composition of an object ■ Passive imaging detection techniques rely on collecting naturally occurring radiation ■ Active imaging systems illuminate the detection space with a beam of terahertz power
Security Relevance	■ High expectations, especially from transportation security operators ■ Main limitations of THz technology are water vapour absorption, cannot go through metal, explosive signature, acquisition speed, SNR, size and cost.
Time Frame	■ First products of THz technologies exist ■ TRL is MEDIUM ■ Security relevance may be reached in the time frame 2020-2030 (TRL HIGH) ■ Significant improvements are expected in this time frame (wet environment limitation, explosive THz signature, size, cost)
Application and Market Potential	■ Transportation and sensitive infrastructure security ■ Bio-medical
Ethical Consideration	■ Monitoring of long-term effects on health must be done ■ Privacy issues because THz imaging reveal anatomic details

1.9 Technology Area CBRN Identification

Technology Description	■ CBRN identification technologies enable the detection and/or identification of explosives, chemical agents, biological, agents and nuclear/radioactive material ■ Emerging and promising technologies are: Raman Spectroscopy, Quantum Cascade Lasers, Mass Spectroscopy, Differential Mobility Spectroscopy and Photofission.
Security Relevance	■ Growing threats, especially from homemade explosives ■ Current technology solutions still suffer from drawback and performances limitations ■ Main issues are sensitivity, selectivity, range of detected/identified substances, level of false alarms and speed
Time Frame	■ First prototypes/proof of concept of selected emerging technologies exist. ■ TRL of selected emerging technologies is MEDIUM ■ Security relevance should be reached in the time frame 2020-2030 (TRL HIGH) ■ Significant improvement in performance (sensitivity, selectivity, speed...) is expected in this time frame
Application and Market Potential	■ Airport, sensitive infrastructure and homeland security ■ Baggage screening, air cargo, seaport cargo, border cargo, vehicle screening ■ Other possible applications are: civil security and safety for factories and buildings (toxic chemical or biological agent leak, radioactivity detection...)
Ethical Consideration	■ Future special attention must be paid to the technologies to prevent privacy and health issues.

2 Technology Cards

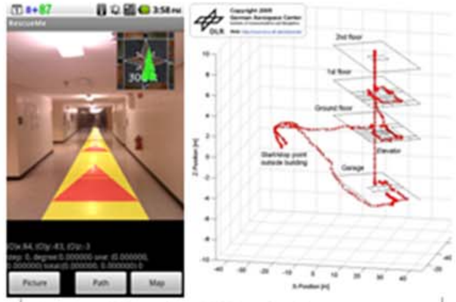
On the following pages characteristics of the technologies described in section 2 are detailed in one-page technology cards. These technology cards were compiled in task 4.1 of Work Package 4 by the three partners Isdefe, AIT and Fraunhofer INT.
The cards served as background information throughout the prioritisation and selection process described in section 1. The complete set of cards is contained in deliverable WD4.1 of the ETCETERA project.

“Indoor Navigation”

Task 4.1 | WD4.1
Fraunhofer INT – 035

Description

In environments without line-of-sight (LoS) connection to navigation satellites (GNSS), as for indoor and comparable locations like urban canyons, additional solutions for navigation and localisation tasks are needed. These solutions comprise inertial navigation (INS), odo- resp. pedometry or different radio-based localisation techniques. For navigation with respect to complex or dynamic 3D surroundings, systems with integrated camera using “**visual navigation**“ would be most valuable, what is challenging. This would enable independency from dedicated and expensive radio infrastructure. Uninterrupted indoor + outdoor navigation (“**seamless navigation**“) would serve different applications, e.g. industry envisions a big civil market potential for “**location based services**“.



Source: University of Colorado, German Aerospace Center DLR

Relevance

In police, fire-rescue, SAR or disaster relief operations the central **coordination of forces** and the **orientation of the individual action forces** needs reliable information. Due to signal damping inside buildings the **indoor usage of unmanned systems** depends on autonomous indoor navigation capabilities. In case of **mass evacuation**, persons could be guided by personal mobile devices. There are also security related application ideas like **child tracking**. Also applications like **asset tracking, airport apron surveillance** or **Car-to-X communication** rely on seamless navigation.

Expectations

Currently in Europe a lot of research related to indoor navigation concentrates on hybrid solutions based on the introduction of the GNSS **Galileo around year 2020** in combination with INS or radio-based methods. Research on **visual navigation** is emerging. TRL for visual navigation is low, for other indoor navigation techniques medium to high.
The market potential for seamless resp. indoor navigation could be high, e.g. with respect to autonomous unmanned systems for indoor usage.

“Smart Textiles”

Task 4.1 | WD4.1
Fraunhofer INT – 059

Description

Smart textiles are fabrics, that enable computing, digital components, electronics, energy supply and sensors to be embedded in them. They belong to the development of **intelligent clothings.** There are currently discussed different approaches, e.g.: 1.) **Functionalization** of cotton using carbon nanotubes for improving its mechanical properties. 2.) Development of **photovoltaic fibres** for energy supply. 3.) Embedding fibre optics into textiles for medical monitoring. Smart textiles are actively developed for fire fighters in order to increase work **safety** and the **efficiency** of fire fighting interventions. To this end advanced protective textiles which include **sensing** and **communication** and **positioning** technologies are developed.

Source: http://www.textilforschung.de

Relevance

Smart Textiles will improve the **situational awareness** of fire fighters, police men etc. They will allow a **robust communication** even during difficult missions.
Cotton fabrics coated with nanotubes that are modified with enzymes capable of **detecting** and **detoxifying** chemical warfare agents could offer a new line of comfortable chemical protective clothing for the military and civilian first responders.

Expectations

It is expected that advancements in the field of nanotechnology will allow a high degree of integration of different requirements (energy supply, communication, protection) into textiles and clothes. First simple applications may be available in approximately 5 years, more advanced applications in 5 to 10 years.

"Small-scale energy harvesting"

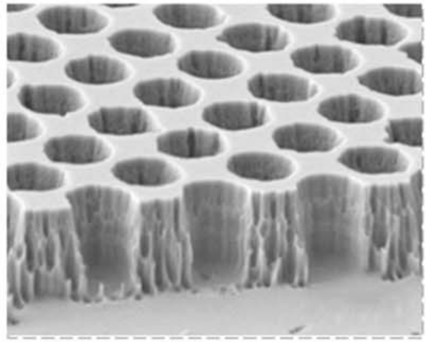
Task 4.1 | WD4.1
ISDEFE-13

Description

Energy harvesting is the process by which energy is derived from **external sources**, captured and stored.

Energy harvesting systems are usually **embedded** as subsystems, producing power without interfering the tasks of the main system. Their energy source or fuel is **freely available** in the environment, and captured passively by the energy harvesting system. The energy source can be temperature gradient, movement, vibrations, radiation (nuclear, RF, solar) or a fuel (e.g. blood sugar, air).

There is a number of different technologies in the field of energy harvesting with high potential and low development degree to be used in security applications.



Relevance

Small-scale energy harvesting systems are an enabling technology for different systems:

Reliable, cheap energy harvesting systems would enable the development of unnatended sensor networks for a wide range of security applications, as protection of sites and infrastructure, integrated border management and protection of distribution and supply networks.

Furthermore, the use of these systems embedded in micro and nano systems (as UAVs or robots) would increase their autonomy.

Expectations

The development of these systems relies on advances in nanotechnology and sensor market pull.

As the current number of possible sources and technologies for energy harvesting is wide, it is expected that ad-hoc solutions for each sensor type and environment of use will be selected.

“Homomorphic Encryption”

Task 4.1 | WD4.1
Fraunhofer INT – 033

Description

Homomorphic Encryption is a special type of encryption that permits **computation on encrypted data**. In contrast to other encryption types, there is no necessity to decrypt encrypted data for the purpose of processing. As a consequence, the confidentiality of the data is ensured anytime. There can be distinguished partially homomomorphic encryption schemes and fully homomorphic encryption schemes. Partially homomorphic encryption schemes allow only a few number of operations on the ciphertext, while fully homomomorphic allow arbitrarily complex computation on the ciphertext.

Relevance

Homomorphic encryption is of relevance in all areas, in which continuous confidentiality of data is important. The most interesting application area of homomorphic encryption is **cloud computing**, where a lot of (sensitive) data is outsourced to external service providers. Another interesting application area is the field of **search-engines**, which ensure the confidentiality of the inquirer, the inquiry and the results. A problem could be the fact that homomorphic encryption schemes cannot reach the highest possible security level (**CCA-secure**) of encryption schemes. Research in homomorphic encryption is focused on fully homomorphic encryption and is nearly exclusively done by universities and research facilities.

Expectations

Fully homomorphic encryption was a long time considered as the holy grail of cryptography and the existence of fully homomorphic encryption schemes was doubted. A new approach in 2009 showed the first fully homomorphic encryption scheme, but it is not practical. Some improvements were made in the following years, but fully practical homomorphic encryption schemes seem realistic in the long-term. The readiness of this technology is low.

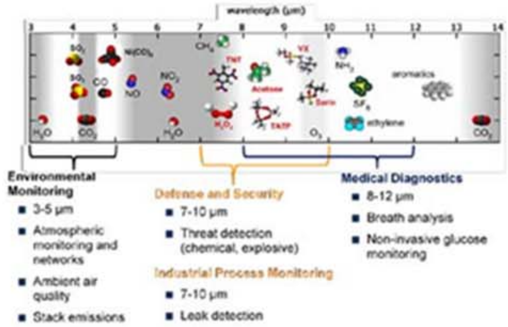
“Explosive traces integrated sensors”

Task 4.1 | WD4.1
ISDEFE-05

Description

This technology comes from the integration of different technologies creating a **system of systems** which combined can yield a highly efficient system to **detect explosive threats**.

Candidate single technologies could be **Differential Mobility Analysis**, **Mass Spectrometry**, **biodetectors**, **lab-on-chip**, **data fusion**...



Relevance

A few technologies are today capable to detect and identify traces of explosive materials. They require generally preparation of a sample and do not cover all posibble threats. The proposed technology integrates some of these technologies to **boost detection capability in real time without interaction with the explosive device**.

A system of this type could be used in public infrastructures and public building protection. Information from these systems can be employed in coordination with other security technologies to identify, track an capture criminals.

Expectations

There are high capacities in university and reseacrh labs on the individual technologies.

Some industrial actors have started to apply this principle in technology demonstrators (from SME to big corporations) which provides good expectations in the mid term.

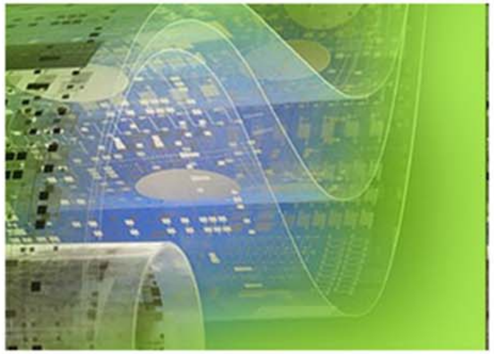
...ETCETERA Isdefe AIT AUSTRIAN INSTITUTE OF TECHNOLOGY Fraunhofer INT

"Sensors on Unconventional Substrates"

Task 4.1 | WD4.1
Fraunhofer INT – 056

Description

The significant efforts dedicated to the development and implementation of electronic components on flexible and stretchable substrates could also give way to new types of **sensors with new functionalities**. The main focus is on the production of environmental sensors on plastic an flexible foils for **wireless applications**. Other types of flexible substrates such as paper, thin metal sheets, textiles, and biodegradable materials are also conceivable.



Relevance

Besides a strong potential for **cost-effective** production based on additive processes with a reduced infrastructure, the benefits of printing devices on plastic foil and other unconventional substates include their potential to be light weight, foldable/rollable, transparent, thin and conformal, wearable, disposable, and produced on a large scale, depending on the processing technology involved. Typical examples are cheap and portable temperature, humidity, and gas sensors.

Expectations

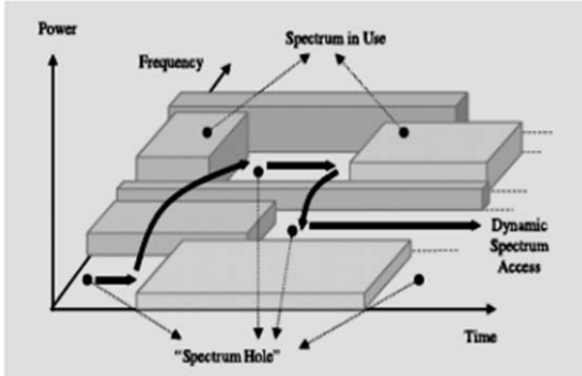
The emerging industry of large area manufacturing and organic and printed electronics is bringing about new opportunities for the realization of sensors on unconventional substrates that should lead to first applications in **2020**. It is foreseeable that the fabrication of physical and chemical sensors on plastic foils will evolve towards all **printable** technological solutions.

"Cognitive Radio"

Task 4.1 | WD4.1
Fraunhofer INT – 019

Description

A Cognitive Radio is an adaptive radio, that can change its transmission parameters, for example transmission power, carrier freuency, bandwidth and modulation scheme, dependent on the momentarily boundary conditions. The crucial parameter is the actual usable **frequency range**. A Cognitive radio should monitor the parts of the electromagnetic spectrum which come into question, detect momentarily available ranges (spectrum holes) and uses the best available free spectrum range (dynamic spectrum access). By this means that the electromagnetic spectrum is used more efficiently.



Relevance

A possible security-related application of a Cognitive Radio is a **Disaster Management Radio System**. In the case of a disaster a radio system needs to operate in destroyed environment and eventually without external communications infrastructure and has to be highly flexible.

Expectations

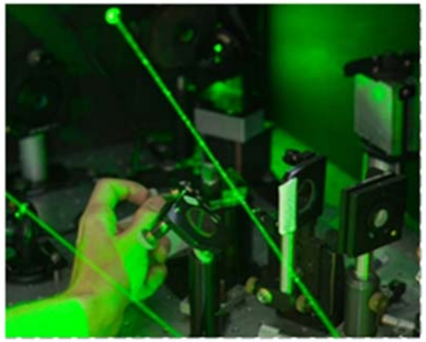
The readiness of this technology is low to medium. Practical Cognitive radios could be expected within the next 10 years. So called Full Cognitive radios that can also provide the user automatically with appropriate services and information dependent on his actual needs could expected not earlier than 2030.

1. "THz signature for substance recognition"

Task 4.1 | WD4.1
"AIT" – "8"

Description

Terahertz technology has attracted the attention of researchers for many years, and it has seen many advances over the past decades. Special interest for the use of this technology is directed to the **detection** of illegal drugs, explosives and other hazardous materials. These materials exhibit characteristic signatures at terahertz wavelengths which may be used to identify them.



Relevance

Some areas of application are: **Medical imaging** (Contrary to X-rays, terahertz radiation has a relatively low photon energy for damaging tissues and DNA.), **Security** (they can penetrate fabrics and plastics, so it can be used in surveillance, such as security screening), **Spectroscopy** (methods of **THz time-domain spectroscopy** (THz TDS) and **THz tomography**), **Communication** (they are used above altitudes where water vapor causes signal absorption: aircraft to satellite) and **Manufacturing** (sensing and imaging are proposed in quality control, and process monitoring).

Expectations

The development of innovative terahertz (THz) **imaging systems** has recently moved in the focus of scientific efforts due to the ability to screen substances through textiles or plastics. The invention of THz imaging systems with high spatial resolution is of increasing interest for applications in the realms of quality control, spectroscopy in dusty environment and security inspections.

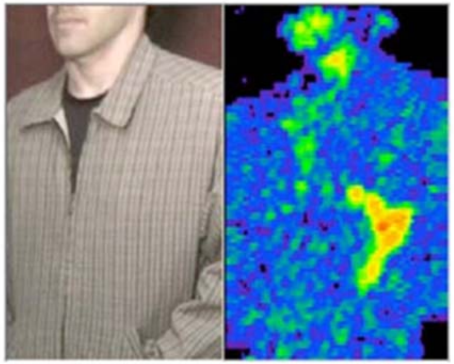
2. “Terahertz Imaging”

Task 4.1 | WD4.1
Fraunhofer INT – 065

Description

In the electromagnetic spectrum, terahertz radiation is located between microwaves and infrared radiation and spans the frequency range of 0,3 to 10 THz. Many organic materials, such as **plastics, cloth or paper, are transparent for terahertz radiation**. Therefore, terahertz imaging can be used for **detecting hidden objects** underneath a person’s clothing, in luggage or packages.

Furthermore, many organic molecules show characteristic absorption and reflection spectra in the terahertz range. Therefore, terahertz radiation can also be used for a spectroscopic **identification of security relevant substances**, such as drugs or explosives.



Source: UML

Relevance

In future, terahertz imaging could **improve airport security checks**. Compared to today’s full-body scanners, terahertz imaging would allow higher resolutions than millimeter-wave systems (30 to 300 GHz), and could be more accepted than backscatter X-ray systems concerning health concerns.

Expectations

The technology readiness level of terahertz imaging is medium. The complexity of terahertz systems, the low efficiency of terahertz sources, and high costs have prevented a widespread use of terahertz imaging systems.

Current research and development activities might lead to first commercial terahertz imaging systems for security applications in the next five to ten years.

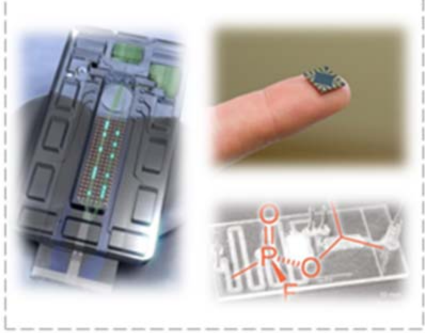
1. “Lab-on-chip Technology”

Task 4.1 | WD4.1
ISDEFE-09

Description

Devices that **integrate multiple laboratory** functions on a **single chip**. They allow the handling of extremely small fluid volumes down to less than picoliters. They are used in a **wide** array of biomedical and other analytical **applications** including rapid pathogen detection, clinical diagnosis, forensic science, electrophoresis, flow cytometry, blood chemistry analysis, protein and DNA analysis. This devices can be fabricated from many types of material (polymers, glass, or silicon, or combinations of these materials.). **Lab-on-chip technologies** are enabling **portable handheld technologies**, which are at the nanoscale, to run parallel or simultaneous hazard recognition systems.

Other applications including food safety, environmental control, point of care, drugs discovery, etc.



Relevance

The lab-on-chip technology reduces a process that typically takes 20 manual steps in a traditional [clinical] laboratory down to just two, and as such it can be carried out by anybody who receives some basic training. Unlike lab-on-chip-based diagnostics, it does not require expert personnel. This technology offer all the advantages of traditional molecular analysis with none of the disadvantages. **Benefits**: Fast, small volumes of samples, low power, automated measurement, robustness, user friendly interface, portability and disposability, cheap materials, better process control, lower fabrication cost in mass production, safer platform for chemical, radioactive or biological studies.

Threats: Novelty, is a novel technology and therefore not yet fully development, the design and manufacture of these systems is extremely difficult.

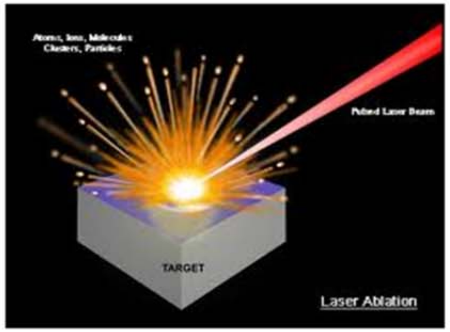
Expectations

The lasted technologies for the prototyping of devices, including replication and direct machining methods of fabrication, and the new approaches for fluid control and manipulation will allow obtain early diagnostic tools with better sensitivity, specification and reliability, wich could improve the effectiveness of in –vivo and in-vitro diagnostic.

The majority of this market is monopolized by large companies but that will be expected to change as smaller companies with more innovative technologies enter in this area.

2. “Lasers for remote detection of Chemical and Biological agents”

Task 4.1 | WD4.1
ISDEFE-10



Description

Unambiguous chemical or biological agent detection at hundreds of meters for low concentrations values will be possible. Active sensors for remote identification of chemical or biological agents are based on atmospheric spectroscopy (agent absorption characteristics).

Relevance

Applications: protection of sites and infrastructure.
Due to laser frequency and density power, safety issues (eye damage hazard) still not solved. Probability of finding traces of CB agents and explosives on an object and how does that correspond to a real threat still not sufficient but increase in laser power and access to many wavelengths in the mid and far IR bands will allow unambiguous identification at low concentrations.
For prospective activity, civil and military laboratories are currently involved in the development of innovative solutions: France (ONERA, Laboratoire Verres et Céramiques), Germany (Fraunhofer, IPHT Jena…).
At an industrial level the following companies have already existing know-how in components and lasers developments: Denmark (NKT Photonics), UK (Fianium), Fr (Leucos, Thales RT and III-V lab), Switzerland (Univ. de Neuchâtel, Alpes Laser), Sweden.

Expectations

- Optical Parametric Oscillator (OPO) lasers: tunability range increase, linewidth narrowing, spectral control techniques and fast tunability techniques compatible with security and military needs.
- Supercontinuum laser: spectrum broadening and spectral power increase that are necessary for military applications.
- QCW QCL for mid/far IR: extend the spectrum at smaller wavelength (l<4 µm) to increase the output power while mitigating temperature problems
- Transition metal lasers for SWIR (l <3 µm) and mid-IR: produce higher output power (> 1W).