SMART

Specific Support Action

Materials for a Safe Europe

Security Workshop, October 2006

Imprint

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SMART stands for ‘Foresight Action for Knowledge Based Multifunctional Materials Technology’. It is a Specific Support Action (SSA) of the European Commission within FP6. SMART started in April 2005 and will analyse, within 2 years, the most relevant research fields in materials science.

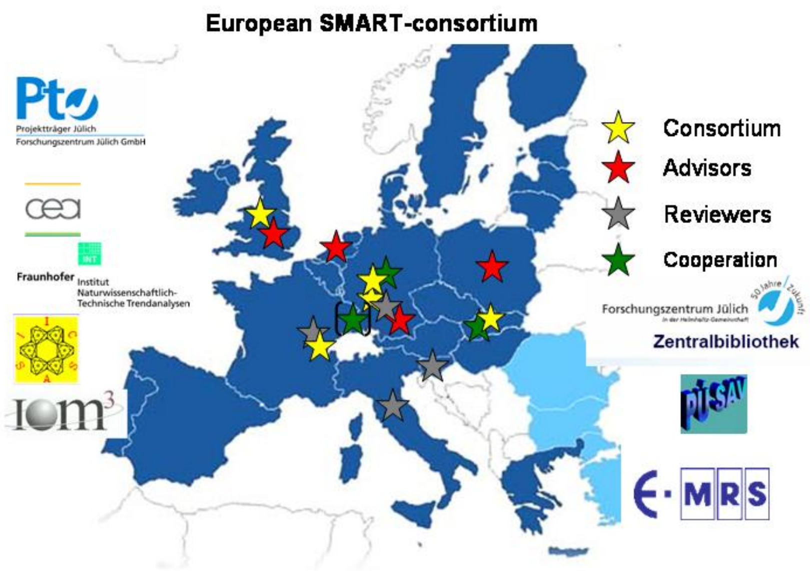
SMART objectives are:

- Improvement of European R&D-Position
- Improving public awareness especially of tax payers
- Enabling the further development of ERA.

These objectives are being achieved by:

- Identification of materials research hot spots for the future
- Mapping of European materials research activities
- Development of roadmaps
- Analysing foresight studies
- International benchmarking.

The following diagram shows the members of the SMART consortium.



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1.

EXECUTIVE SUMMARY

A welcoming address to a roadmap on *Materials for Security* was given by Dr Bernd Hunger of the Federal Ministry of Education and Research, Germany.

A group of invited experts from the broad field of Security attended the workshop to add their contributions to a draft roadmap that had previously been prepared.

Several presentations were given to bring the attendees up to date with the latest developments in materials needed to provide improved detection and protection.

Typical roadmapping procedures were then followed to 'foresight' the future in this sector. The barriers preventing progress were then examined, before consideration was given to what should be done to overcome the barriers.

From the inputs of the contributors, an updated roadmap for *Materials for Security* has been prepared, which will be shown to a wider audience in order to achieve a consensus of opinion.

2.

CONTRIBUTORS

The following people attended a meeting at Materialica, Munich, Germany on 11th and 12th October 2006 to formulate the a roadmap in Materials for Security:

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3.

METHODOLOGY

The methodology used for this roadmap is summarised in Appendix 8.1, following the procedures typically used for other roadmaps that have been produced.

Experts, in groups of around six, are asked to provide their thoughts and opinions for the four main stages of the roadmapping process:

- Where are we now?
- Where do we want to be?
- What is stopping us getting there?
- What needs to be done to overcome the barriers?

For each stage, large hexagon *Post-its* are used to gather each input. These are then clustered under common topics as a spokesman from each group presents their findings. This draws comments from the rest of the participants and generally arrives at a consensus of opinion.

Using adhesive stickers, priorities are given to what are considered the most important issues for the second stage of the roadmapping process, enabling a key priority list to be established for subsequent steps.

The final outcome is a list of priority items that need action in order to enable the industry to progress in a more dynamic and competitive manner.

As with other roadmaps, once this first edition is produced, comments are sought from others in the field, so that ownership comes from the entire community.

4.

CURRENT SITUATION

The SMART consortium had previously produced a draft roadmap for Materials for Security, and the meeting at Materialica, Munich was called to refine that roadmap.

The first phase of a roadmapping process is to consider 'Where are we now?'.

A number of recent publications had been found that were relevant to the future trends in materials for security. By way of introduction, these are summarised in Appendix 8.2.

Presentations on current advances in the sector were given by the following:

Dr Dušan Galusek, Trencin University and Slovak Academy of Sciences, Slovakia, who spoke about Ceramic Armour. His slides are reproduced in Appendix 8.3.

He began by showing how through history armour is a step behind what is the threat, and there is a need to protect vulnerable parts of the body. Today's threats are anti-personnel and against vehicles, with protection needed for vital parts, whether it is vulnerable parts of a person's body or the parts of a vehicle that can immobilize it if damaged.

There are requirements for armour materials which respond by resisting a change in shape from an applied load. This means the material must have high elastic modulii and a high value of Y compared with the ballistic threat materials, and low density ceramics are the materials of choice. The advantages and drawbacks of ceramic and composite armour were discussed, identifying developments to reduce the affected area to a few centimetres and offering protection against repeated impact on adjacent surfaces, and damaged parts must be easily replaced. Recent developments with metal matrix composites (a combination of ceramics and metal powders) to make lighter weight materials, and the use of nanoparticles was highlighted.

The advantages of light improved ballistic armour (LIBA from Mofet Etzion Ltd) were considered, along with the need for traditional bullet-proof glass to be replaced with another transparent material which is harder than the threat. There are some improvements, but there is a real challenge for better crystalline materials for transparent armour.

There are no new materials in sight that satisfy current requirements and it is necessary to modify what is already available. This means:

- usage of nano-structures ceramic materials
- new concepts and combinations of metals, hard metals, high tech fibres and elastomers
- new constructions of armour sandwiches
- transparent armour concepts.

Professor Dr Stefan Kaskel, TU Dresden, Germany spoke about bullet proof ceramics, where the search is for harder but lighter weight materials that can be used for armoured vehicles or personnel protection.

Water security was also discussed, particularly regarding the use of porous materials capable of removing contaminants.

Security glass for automobiles, and both commercial and residential properties were also considered, to provide added impact strength from polymer nanocomposites, liquid crystal based switchable glass, and reflective security glass. Chalcogenide glasses are also finding increasing use in security cameras.

Ferro and pyroelectric materials are being used in new IR sensors. Other sensors being developed are for chemicals and explosives.

Holography and pigments for security applications were also discussed with emphasis on forgery proof bank notes. Patterning of luminescent nanocomposites to provide hidden messaging, that is impossible to copy, is also being developed. Printing transparent dispersions is now possible and will provide novel security applications in the future.

Jeremy Plimmer, Product and Image Security Foundations, UK, spoke about security aspects of packaging and anti-counterfeit products. With fraud soaring in most countries, new technologies are being used to prevent counterfeiting. For banknotes holographic techniques are coming under increasing attack from counterfeiters, and in addition multiple holographic features confuse the public which results in unreliable authentification. A new Nanogravure™ technology is aimed to supersede holography with its nanotechnology-based imaging method enabling the creation of a portrait or object-based feature with a highly unusual visual appearance, which incorporates a wide range of forensic features.

He also talked about the developments for increasing sophistication being used in technology for prevention of fraud with respect to driving licences and national ID cards/passports.;

Further information on the topic may be found via jeremy.plimmer@aol.com.

Mark Benecke, IFRC, German, has an international reputation as a forensic anthropologist / biologist. He spoke at length about the difficulties of identification presented in the aftermath of the Twin Towers tragedy. In his talk, he also showed how entomology provides clues about corpses and how it is being increasingly used in forensic science.

He explained how Hitler's skull and teeth had been identified.

As the author of a number of books, his web site is particularly interesting (www.benecke.com).

5.

FUTURE DIRECTION

For the second stage of the roadmapping procedure, “Where do we want to be?”, the technique was to ask those present to split into groups and brainstorm their vision of what would happen in the future in this sector.

To stimulate further thought, the following questions were posed:

- What is our vision for the future?
- What should we be doing to maximise benefit for the UK?
- Are we doing something now that we should put more effort into?
- Are we doing something currently that we should drop?
- What is going to make a real impact on our activities?
- What new areas should we be working in?
- Are there opportunities for creating spin-out companies?

The ideas from the participants are shown in Appendix 8.4, and are reproduced in the following diagram (Figure 1), with dots (●) indicating the level of priority judged by the team.

Figure 1: Future Direction
(● indicates priority level)

SENSORS	~ Monitoring of complex systems – smart devices ●●●●●●●● **(1)** ~ Biological sensors (self-growing) ●●●●● **(4)** ~ Research into cheap and rapid detection systems particularly against chemical warfare ●●●● **(5)** ~ Sensor development ●●●● **(6)** ~ Terahertz as part of multi-spectral detection system ●●●● **(7)** ~ Air purity / condition / toxicity ●●●● **(8)** ~ Monitoring of sensors (how do we sensor a sensor?) ●●●● **(9)** ~ Miniaturised DNA scanner – lab-on-a-chip ●●● **(16)** ~ Detection of toxic compounds ●●● **(17)** ~ Broad threat identification ● ~ Continuous monitoring / air including negation in public use buildings ● ~ Own house security ~ More reliable sensor systems ~ Can perspiration be used as a direct means of identification
MATERIALS - TECHNOLOGY	~ Simulation of new molecular structures with specific properties ●●●● **(10)** ~ Protection against chemicals ●●●● **(11)** ~ A non-destructive test for armour ●●●● **(12)** ~ Nanotechnology – unbiased – open, more active marketing ●●● **(18)** ~ Low maintenance systems that operate once in a life time with reliability ●● ~ Steel is still very relevant – do not forget traditional materials ● ~ Design a material to have specific properties rather than vice versa ● ~ M Gravity production technologies (space…) ● ~ Production technologies – improve, invent ~ Light to energy without loss (direct) ~ Machine like a microwave oven that would disintegrate all rubbish to dust
PACKAGING	~ Self-disintegrating packaging
FUNDING	~ Specific funding
IDENTIFICATION	~ Use of materials that personalise your property – can use a type of lacquer ~ Use of personal data by aircraft boarding personnel
PROTECTION	~ Copying from nature ●●●●● **(3)** ~ Secure personal privacy ●●●● **(13)**

	~ Customised modular armour ●●● **(19)** ~ Fire protection for houses ●●● **(20)** ~ Dual use of low cost COTS protection equipment ●●● **(21)** ~ Armour for personal protection both individual and public transport ●●● **(22)** ~ Privacy windows ● ~ Armour processes for large / complex structures ● ~ A non-destructive test for armour ● ~ Cheap ceramic armour ● ~ Immediate communications (emergency) ● ~ Porous materials for shock wave energy dampening ● ~ Protective clothing for older people ● ~ New production or manufacturing technologies to make affordable armour ~ Reactive anti-fall clothing ~ Cloaking technology (Star Trek invisibility) ~ Secure clothing (knife / bullet proof) ~ Personal force field ~ Person recognising house ~ Multipurpose armour (active / passive / stealth, light weight
SOCIETAL	~ Interdisciplinary research ●●●●●●●● **(2)** ~ Transferable integrity of person for life use ●●●● **(14)** ~ Real equal opportunities worldwide ●●● **(23)** ~ Problem with drawing the line between safety and privacy ●●● **(24)** ~ Secure EU borders ●● ~ Not 1984 ● ~ Check out scanner to be used for automatic checking of bank notes ● ~ Rapid threat identification ~ Drug addiction ~ Listen to the voice of the customer ~ Too much emphasis on safety and security
ISSUES	~ Public building security (malls, stations, stadiums) ●●●● **(15)** ~ Secure utilities ●

The main priorities raised are shown in the following diagram:

Main priorities for future direction in Materials for Security	
SENSORS	Monitoring of complex systems – smart devices **(1)** Biological sensors (self-growing) **(4)** Research into cheap and rapid detection systems particularly against chemical warfare **(5)** Sensor development **(6)** Terahertz as part of multi-spectral detection system **(7)** Air purity / condition / toxicity **(8)** Monitoring of sensors (how do we sensor a sensor?) **(9)**

	Miniaturised DNA scanner – lab-on-a-chip **(16)** Detection of toxic compounds **(17)**
MATERIALS – TECHNOLOGY	Simulation of new molecular structures with specific properties **(10)** Protection against chemicals **(11)** A non-destructive test for armour **(12)** Nanotechnology – unbiased – open, more active marketing **(18)**
PROTECTION	Copying from nature **(3)** Secure personal privacy **(13)** Customised modular armour **(19)** Fire protection for houses **(20)** Dual use of low cost COTS protection equipment **(21)** Armour for personal protection both individual and public transport **(22)**
SOCIETAL & ISSUES	Interdisciplinary research **(2)** Transferable integrity of person for life use **(14)** Real equal opportunities worldwide **(23)** Problem with drawing the line between safety and privacy **(24)** Public building security (malls, stations, stadiums) **(15)**

These top priorities were discussed by the groups during the next phase of the roadmapping procedure: looking at the barriers to achieving the vision and what needs to be done to overcome those barriers.

6.

BARRIERS TO PROGRESS AND POSSIBLE SOLUTIONS

Having arrived at a consensus of the future direction for Materials for Security, the next stage was to determine *"What is stopping us getting there?"* and deciding *"What needs to be done to overcome the barriers?"*. For this stage yellow Post-it hexagons were used to identify the barriers.

Typical questions asked were:

- Do we have the skilled people we need?
- What are the gaps in our technology?
- Is funding likely to be adequate?
- Do we have the necessary infrastructure?
- What is inhibiting manufacture?
- Are patents inhibiting progress?

Actions needed to overcome the barriers (shown in blue) are also included in the following table (Figure 2), and are taken from the hexagons shown in Appendix 8.4. The priorities are those indicated by participants in the Workshop.

Figure 2: Barriers and Possible Solutions

SENSORS

(1) Monitoring of complex systems – smart devices

Barriers	Solutions
Lack of multi-technology sensors (different physical phenomena and data fusion). Increase in sensitivity of sensor materials required e.g. artificial nose. Need deployable lab-on-a-chip systems. Need better reliability and monitoring.	Better coordination of activities in sensors. Provide self-healing and self-checking systems. Application of combinatorial materials science, including high throughput screening.

(4) Biological sensors (self-growing)

Barriers	Solutions
No bio-based multi-spectral BC sensors. Lack of understanding of information extracts and processing in living biological systems Interdisciplinary research – integrate biological.	Directed research programme needed.

(5) Research into cheap and rapid detection systems particularly against chemical warfare
(6) More sensor development
(8) Air purity / condition / toxicity
(17) Detection of toxic compounds

Barriers	Solutions
Low cost, cheap sensors not available.	Strive for cheaper production methods.

A barrier is re-use and re-cycling. Strategy for decision making not formulated. Lack of fundamental understanding. Engineering of multiple opportunities. Communication of benefits lacking	Further miniaturisation will be available through nanotechnology. Global approach required. Interdisciplinary research needed (including non-scientists). Drawing attention of research too 'weakly' represented but important items. Provide good case studies to highlight benefits of sensors; and educate the general public.

(7) Terahertz as part of multi-spectral detection system	
Barriers	**Solutions**
Lack of knowledge about its affects on the human body. Lack of adequate materials. There are no suitable manufacturing technologies.	More basic research work on sensors emitters

(9) Monitoring of sensors (how do we sensor a sensor?)	
Barriers	**Solutions**
Standards are missing.	Must provide.

(16) Miniaturised DNA scanner – lab-on-a-chip	
Barriers	**Solutions**
Not currently available.	Research programme needed.

MATERIALS - TECHNOLOGY

(10) Simulation of new molecular structures with specific properties	
Barriers	**Solutions**
Basic understanding of simulation. Synthesis of simulation materials. Lack of understanding of correlation between material and structural parameters and its function.	Fundamental research and simulation. More high throughput data acquisition. Controlled organisation of materials by a tool.

(11) Protection against chemicals	
Barriers	**Solutions**
Proper clarification on threats from chemicals. Focus more on major threats, not on everything. There are no threat levels. Removal of threat. Lack of anti-agents.	Lightweight materials that protect against radiation are needed. Sensor reaction and selection. Provide barriers and filtering.

(12) A non-destructive test for armour	
Barriers	**Solutions**
None available.	Difficult.

(18) Nanotechnology – unbiased – open, more active marketing	
Barriers	**Solutions**
Risk of nanomaterials. No effective protection against nano.	Risk can be controlled and is likely to be small.

PROTECTION

(3) Copying from nature	
Barriers	**Solutions**
Identifying appropriate mechanisms. Understanding natural mechanisms. Processing materials. Real time monitoring and reaction.	Interdisciplinarity. Open research structures.

(13) Secure personal privacy	
Barriers	**Solutions**
Cost. Perception. Lack of transparency of benefits and threats. Public perception resistance. Acceptance. Changing nature of the threat.	Transparency. Education – distribution of information. Develop scenarios. More work on sensors.

(19) Customised modular armour (22) Armour for personal protection both individual and public transport	
Barriers	**Solutions**
Cheap lightweight personal armour. No force field available! Non-visible body armour.	Research effort required.

(21) Dual use of low cost COTS protection equipment	
Barriers	**Solutions**
Availability of dual use and COTS. Identification of threat.	Programmable sensor.

ISSUES - SOCIETAL

(2) Interdisciplinary research (24) Problem with drawing the line between safety and privacy	
Barriers	**Solutions**
Communication barriers among people (taxonomy, approach, technological terms. No genuine interdisciplinary research existing yet.	Purposeful installation of interdisciplinary teams with explicit funding.

(14) Transferable integrity of person for life use	
Barriers	**Solutions**
High impact of misuse of 'ultimate' ID-proof. High risk of misuse of 'ultimate' identity proof.	More effort needed.

(15) Public building security (malls, stations, stadiums)	
Barriers	**Solutions**
Public building security versus costs, personal freedom, adequate guidance and training. Current visual appearance of building security.	Needs to be cheaper and less obtrusive.

(23) Real equal opportunities worldwide	
Barriers	**Solutions**
Competition without economic hindrance. Equal opportunities versus economy, place of birth, etc – too optimistic. Discipline languages. Structure of research in establishments. Acceptance of other ways of looking.	New structures. Communication.

7.

ACTIONS / RECOMMENDATIONS

From the barriers identified, and the solutions to overcoming the barriers, the following points are highlighted:

SENSORS

For detection and protection, there are many examples of effective systems in nature. Especially for sensors, nature has numerous examples of detection at extremely low levels. Nanotechnology and lab-on-a-chip techniques will enable fast and more sensitive detection systems, and biological sensors should receive some focus. Self-healing and self-checking detection systems are needed, and standards for sensors should be established.

However, it is felt that work on sensors in most of Europe is particularly fragmented and interdisciplinary, and would benefit from greater collaboration between those working on different types of sensors.

Generally, cheaper and more reliable sensors will be developed, but major steps forward could be achieved through terahertz technology and through the development of rapid, miniaturised means of detecting DNA.

MATERIALS

There is a lack of understanding of the correlation between material and structural parameters, and simulation work would be beneficial.

It is likely that nanotechnology will help provide materials development leading to better ways of protection and materials for detection. This will have a particular impact on lighter weight and stronger materials, as well as providing improvements in barrier properties.

PROTECTION

A better understanding of natural mechanisms would give an insight into what has evolved in nature.

There is a need for lighter weight and more easily wearable armour (or clothes generally) that offer protection from piercing, chemicals, impacts, radiation, etc.

SOCIETAL AND OTHER ISSUES

There needs to be more focus on major threats rather than trying to detect or protect everything.

There are issues such as public building security versus costs and personal freedom, where security can be seen as intrusive, expensive, and spoiling the look of a building. \designers should take this into account.

The following diagram incorporates the thoughts of those contributing to the workshop as well as the original draft roadmap.

SMART
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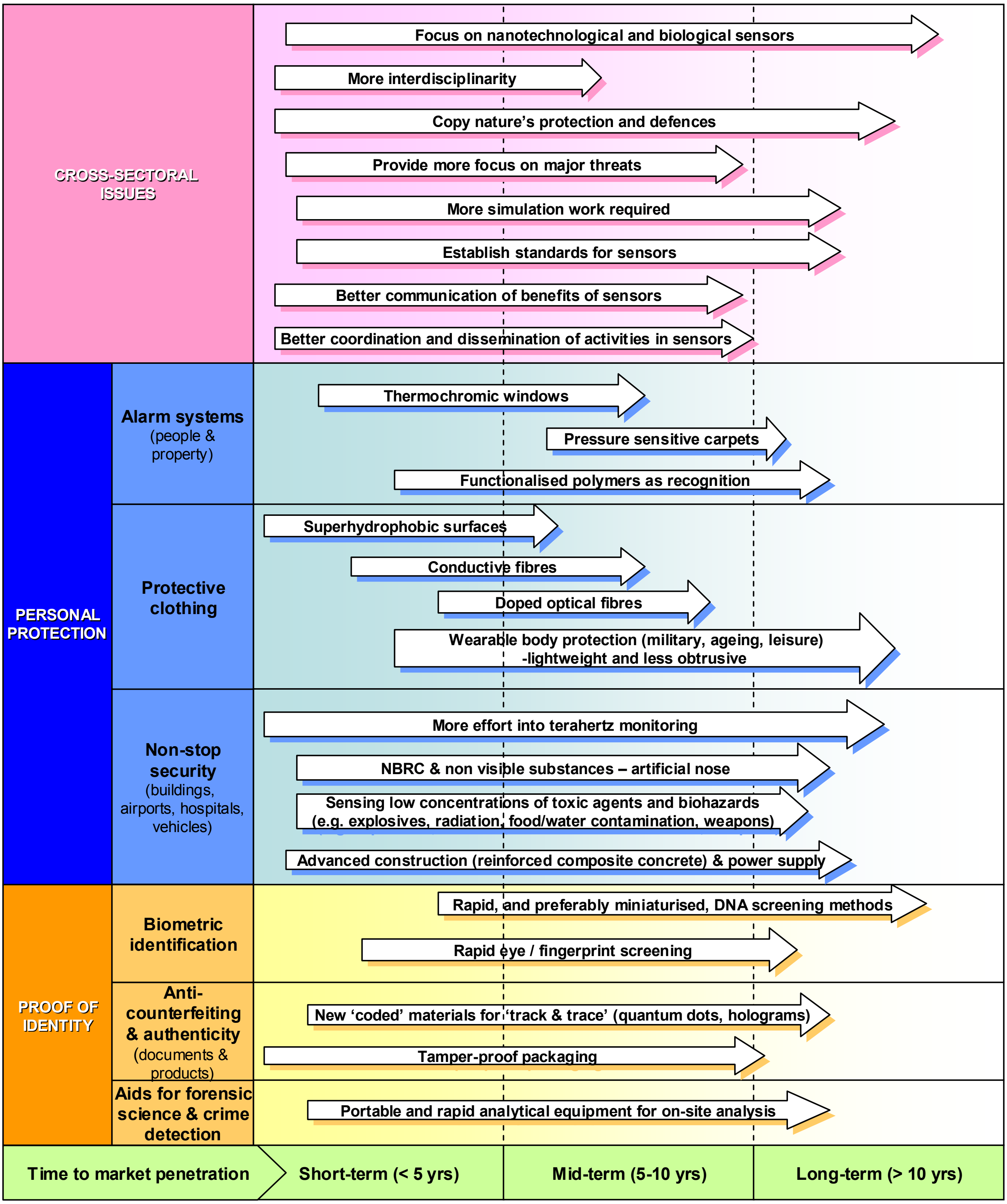
ROADMAP IN MATERIALS FOR SECURITY



This workshop is not the final phase of the roadmap. The views of the wider community will be sought, and as with other roadmaps the report should be re-visited annually to discuss changes and progress.

8.

APPENDICES

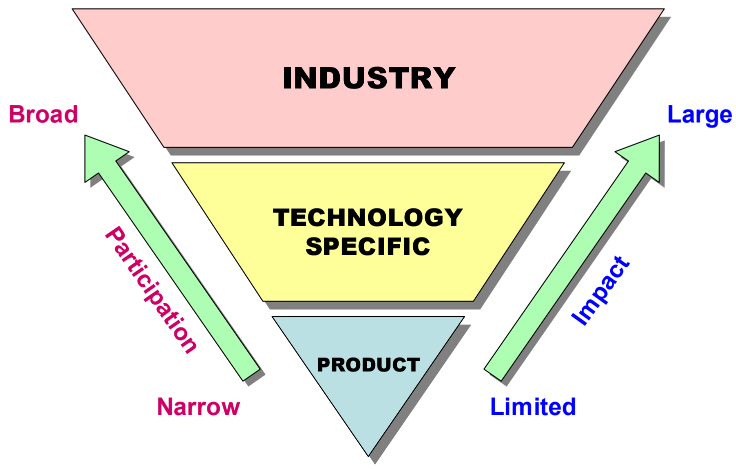
8.1 Methodology for Roadmapping

What is Roadmapping?

Based on a Foresight model, roadmapping is a high-level planning tool to help both project management and strategic planning in any technically-based establishment, whether in academia or industry.

Motorola first coined the word roadmapping in the seventies, but only recently has it been widely adopted by both individual companies and industry sectors as an essential part of their future growth. Figure (i) summarises the types of roadmaps that have already been produced. They can be for industries such as “glass” and “petroleum”, or for specific technologies such as nanomaterials, biocatalysis, etc. Some roadmaps have been produced just for single product areas.

Figure (i): Types of roadmaps

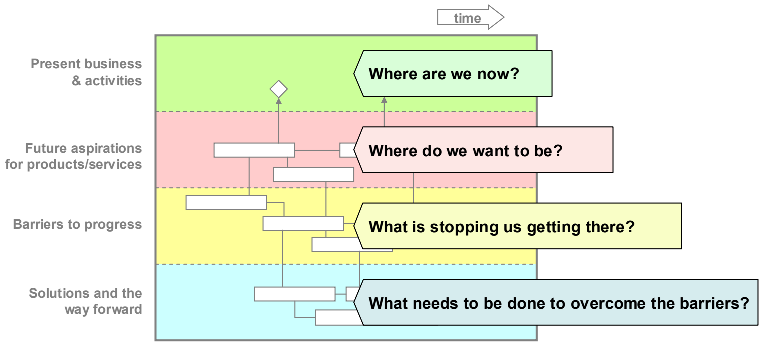


How are the Roadmaps produced?

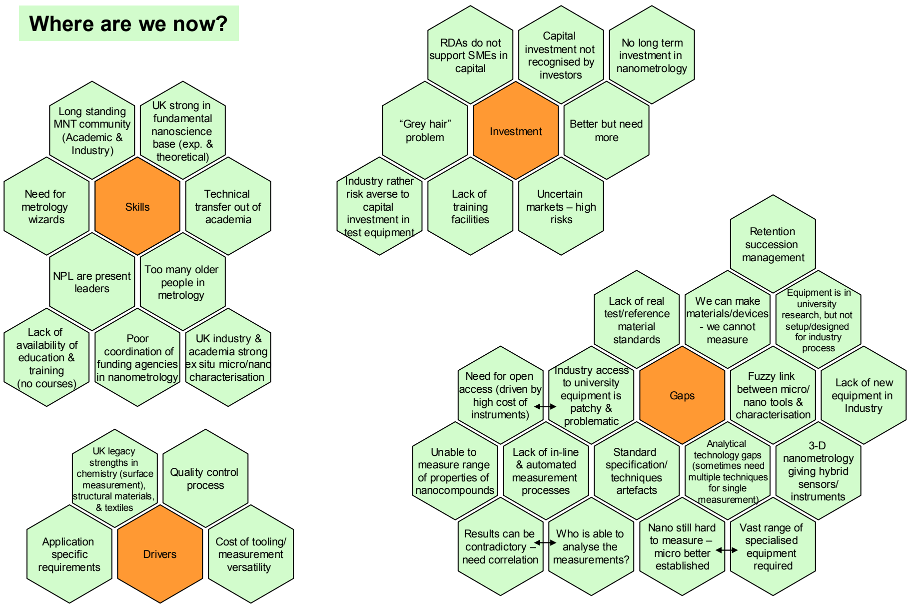
The process gathers together groups of commercial as well as technical experts, and takes them through the four stages that are shown in Figure (ii). The participants need to have sufficient information about the markets and the business to say where the topic under consideration is at the present time. The first step is to agree what the present situation is, and then to move on to provide a vision of where they see things going in the future - where they want to be during the next 20 years.

The third stage is to determine what the barriers to achieving the objectives and goals are. Finally decisions and proposals need to be made to enable the barriers to be overcome. These are arranged over a timescale, with short-term (0 to 3 years), medium-term (3 to 10 years), and long-term (> 10 years) goals.

Figure (ii): Stages in the Roadmapping exercise



Hexagon shaped *Post-its* (colour coded for each stage) are used to gather the participants' thoughts for each step. These are then grouped into topics, and a typical example is shown in Figure (iii). When a consensus is reached regarding the conclusions, "dot" stickers are added to indicate the main priority items.



Such roadmaps provide a collective opinion about the future strategy, with agreed objectives.

As soon as the roadmap has been completed, it can be sent out to other interested parties for their additions and comments.

Roadmaps are "live" documents and should be updated on a regular basis.

8.2 Background information on 'Materials for Security'

There are a number of roadmaps, foresight exercises and strategy documents that refer to the use of new materials for improvements in the general area of security, but few go into any detail. There are, however, a number relating to web based security, but these are not discussed here.

The following summaries highlight the main ones:

A EUROPEAN TECHNOLOGY PLATFORM FOR SUSTAINABLE CHEMISTRY – MATERIALS TECHNOLOGY – SUSCHEM

SusChem, the European Technology Platform for Sustainable Chemistry has produced (2005) a strategic research agenda, in draft form (http://www.suschem.org/media.php?mId=2678). Development priorities are listed as:


1st SRA draft
20 June 2005
SusChem
A European Technology Platform for
SUSTAINABLE CHEMISTRY
Materials Technology
Towards a Strategic Research Agenda
Draft
Draft 20 June 2005

- Fundamental understanding of structure property relationships
- Computational materials science
- Development of analytical techniques
- From laboratory synthesis to large scale manufacturing.

There is a strong focus on citizen protection, with the drivers being given as:

- Accidents
- Terrorist attacks
- Sudden climate changes
- Catastrophes causing extensive personal and material damage.

Two requirements for citizen protection are:

- Develop new intelligent technologies to protect the civil population
- Provide new ways of predicting and avoiding them

which can be achieved through provision of

- Sensors for explosives, toxic agents and biohazards at low concentration
- Materials for personal protection and/or buildings e.g. hospitals, airports, and vehicles
- Functional textiles that recognise and destroy toxic agents or administer the right counter-agents.

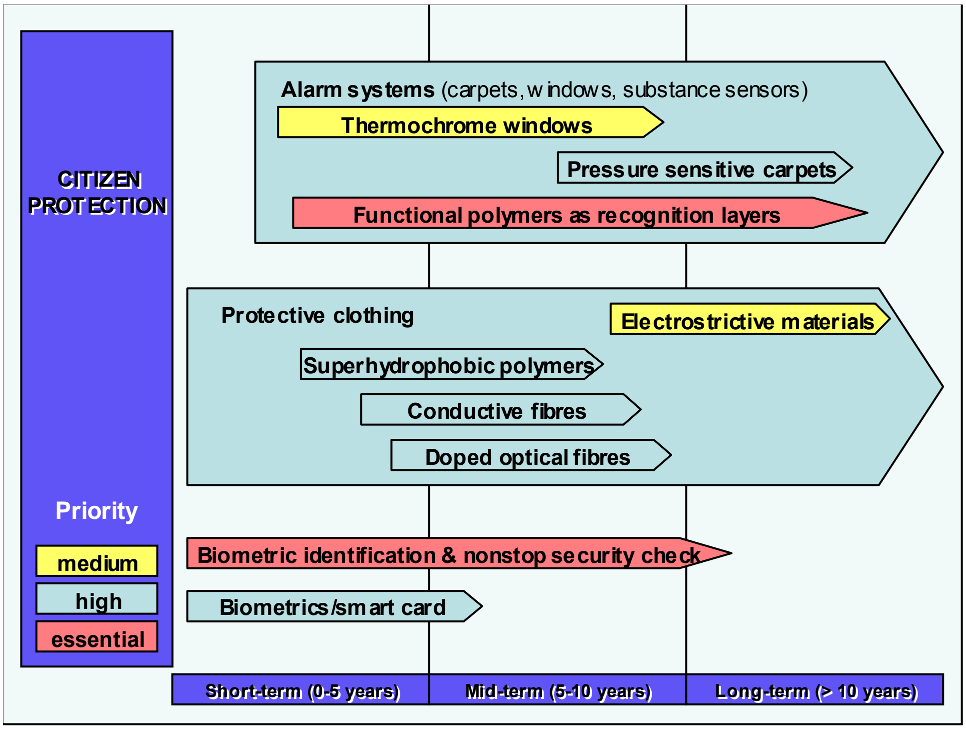
There is emphasis on nanotechnology which can help to create cheap, sensitive and reliable multi-sensing systems for monitoring cleanliness of water, air or soil. The report specifically mentions nanotechnology contributing to the following for citizen protection:

- Sensors for cheap and accurate tests
  - Explosives
  - Radiation
  - Weapons of mass destruction
  - Food / water contamination
- Smart materials for protecting homes, offices, and first responders
- Biomedical research for revolutionary treatments for chemical / biological attacks and trauma
- Remediation technologies for healing the effects of environmental change
- Development of non-stop checks in airports.

Also in the section on nanotechnology, lighter weight composites are described along with new functional coatings (e.g. on vehicles that reduce air resistance or water resistance).

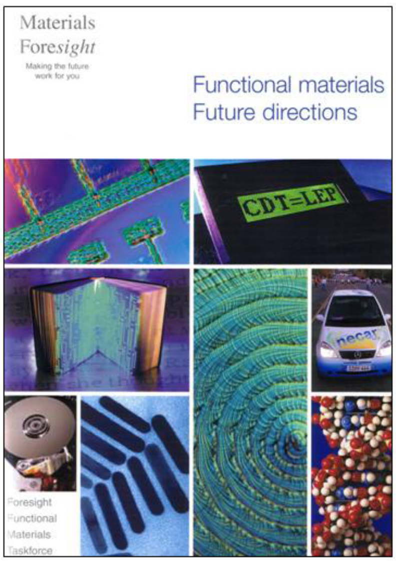
Following the Twin Towers attacks, the report states that the US Government has awarded $28 billion to state and local governments to protect the Unites States through the Department of Homeland Security (DHS) Appropriations Act.

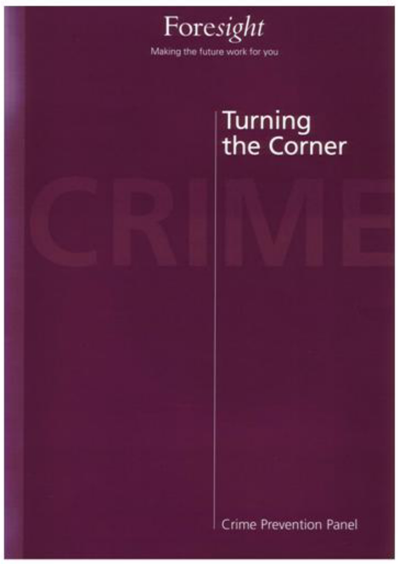
The following ‘Products Roadmap for Citizen Protection’ is reproduced here:



The SusChem Materials Technology report is by far the most detailed report on security, but there are others that have been more general or mention the importance of new materials for safety and protection.

There have been two reports from the UK government’s Foresight exercise directed at crime prevention and functional materials:





FORESIGHT MATERIALS PANEL: FUNCTIONAL MATERIALS – FUTURE DIRECTIONS

In 2003 the Materials Panel for the UK Government's Foresight exercise produced a booklet entitled *Functional Materials – Future Directions* (http://www.iom3.org/foresight/Functional%20mats%20web.pdf). It called for immediate action in terms of increased resources for:

- Electronic polymers
- Fuel cell materials
- Semiconductor spintronics
- DDNA nanofabrication
- Direct write printable materials
- Terahertz technology
- Magnetic materials
- III-V nitrides
- Ferroelectrics.

Under terahertz technology the following applications were listed, some of which relate to citizen protection:

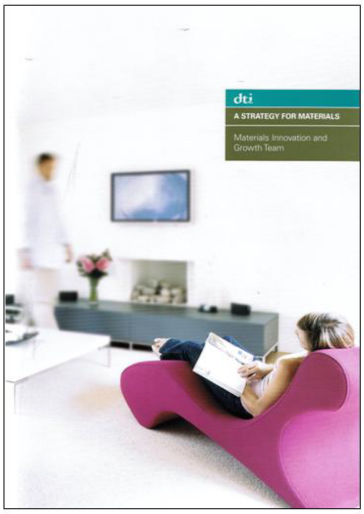
- Security scanning
- Postal scanning
- Biological weapons detection
- Landmine detection
- Collision avoidance radar
- Dental imaging
- Pharmaceutical applications
- Semiconductor imaging
- Pollution monitoring
- Telecommunications.

FORESIGHT CRIME PREVENTION PANEL: TURNING THE CORNER

In December 2000, the Crime Prevention Panel for the UK's Foresight programme produced a report (http://www.crimereduction.gov.uk/crimereductionprogramme17.htm) which gave their recommendations:

1. Establish a dedicated funding stream to focus science & technology on crime reduction
2. Establish a national e-crime strategy
3. Review the wider impact of the Criminal Justice System
4. Thinking on crime reduction is incorporated into mainstream of central Government and business decision making
5. Develop a programme to address crime at all stages of a product's life cycle.

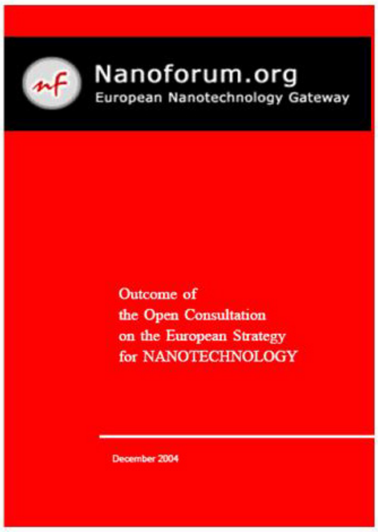
No detail was given regarding future developments in the field of materials.



UK DEPARTMENT OF TRADE & INDUSTRY – A STRATEGY FOR MATERIALS

In March 2006, the UK's Department of Trade & Industry published a report directed at future innovation and growth in the materials sector (http://www.dti.gov.uk/files/file25250.pdf?pubpdfdload=06%2F651). There is a small section on security and defence, which states that a priority need is research, development and modelling of materials and technologies for sensing and diagnostic applications. This was highlighted as a key theme, not just for applications in security, both personal and 'homeland', but in all aspects of our lives such as energy, transportation, healthcare, the built environment, and communications and IT. Opportunities are given as the development of materials for sensors and systems that rapidly scan luggage and travellers, and for sensors in clothing and baggage that facilitate detection of dangerous substances. There is mention of the fact that defence applications have long been a driving force for new civil technology.

EUROPEAN STRATEGY FOR NANOTECHNOLOGY



The European Nanotechnology Gateway (http://www.nanoforum.org) prepared the European Strategy for Nanotechnology and subsequently (December 2004) published the outcome of extensive open consultation with a great many groups.

There is scant reference to security and defence other than that the infrastructure for defence and security should focus on:

- The topic of smart dust
- Quantum computing / security / one EU reference laboratory.

EuMaT – ROADMAP OF THE EUROPEAN TECHNOLOGY PLATFORM FOR ADVANCED ENGINEERING MATERIALS AND TECHNOLOGIES

EuMaT, has produced a report, issued in June 2006 (http://www.mpa-lifetech.de/eumat/(bu1oi3ed0syi33bq5b4rb33r)/downloads/EuMaT_Roadmap_ver27b_Kj_08062006.pdf), aimed at providing R&D priorities for advanced engineering materials and technologies. The overall performance targets are given as:

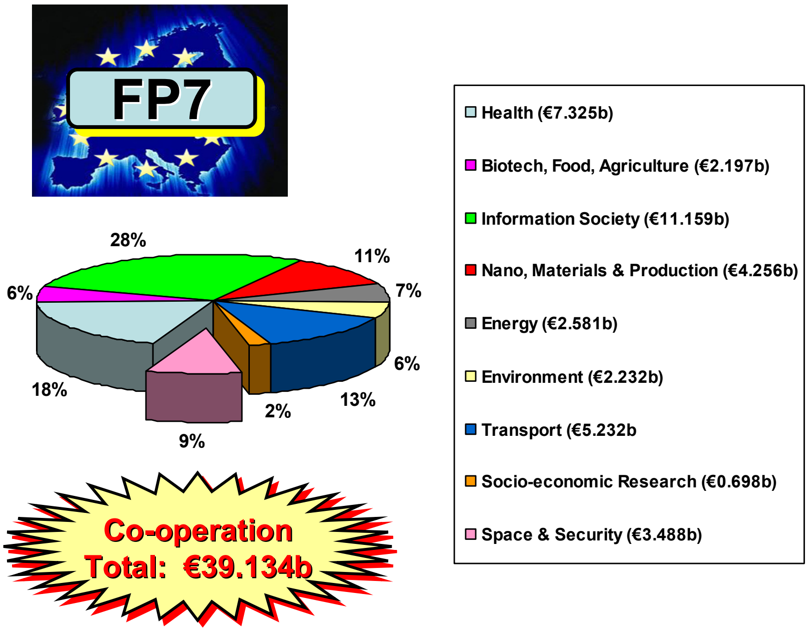
- Help reduce life cycle costs of process equipment and infrastructure by 30% and energy consumption by 50% (more efficient materials)
- Increase productivity of assets by reducing downtime by 25% (more reliable materials)
- Protect the environment by containing processes (e.g. by recycling 95% of metallic and 70% on average of other advanced engineering materials at the end of their useful life)
- Capture existing knowledge and efficiently train a future workforce and develop capability and capacity to develop new generation materials.

Security and defence are only briefly mentioned in the report and this is in reference to the FP7 framework priorities. The priority items are:

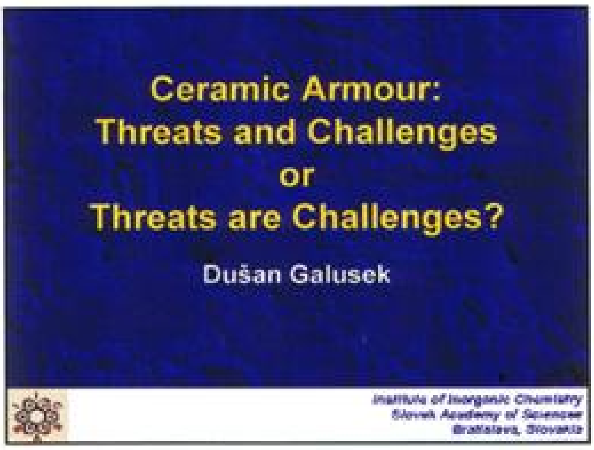
1. Health
2. Food, Agriculture and Biotechnology
3. Information and Communication Technologies
4. Nanosciences, Nanotechnologies, Materials and new Production Technologies
5. Energy
6. Environment (including Climate Change)
7. Transport (including Aeronautics)
8. Socio-Economic Sciences and the Humanities
9. Security and Space.

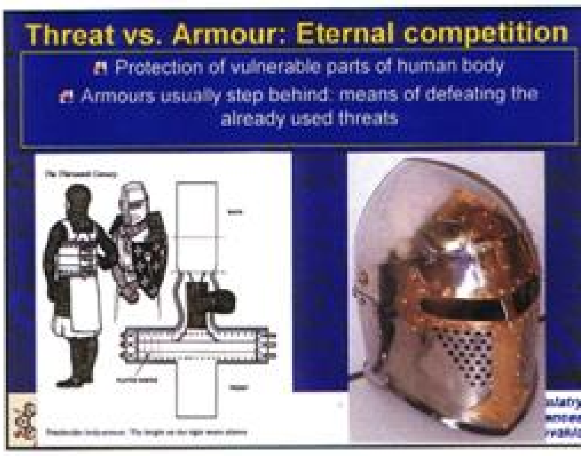
EuMaT stakeholders are also listed and ‘civil society’ is included and described as users and consumers.

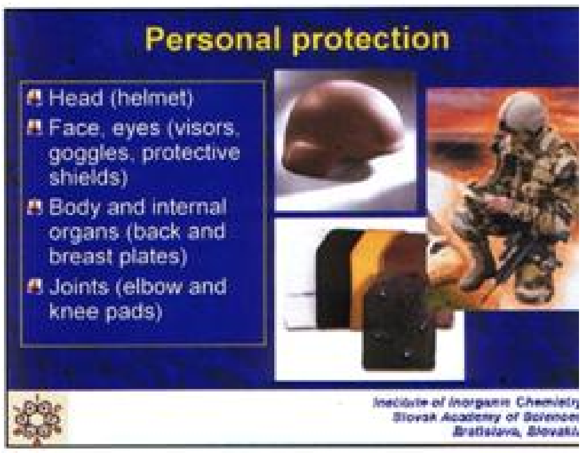
Clearly security is important in more than just the ninth priority, and is especially relevant to nanotechnology as has been described earlier. The latest figures for proposed spending in these priority areas are shown below:

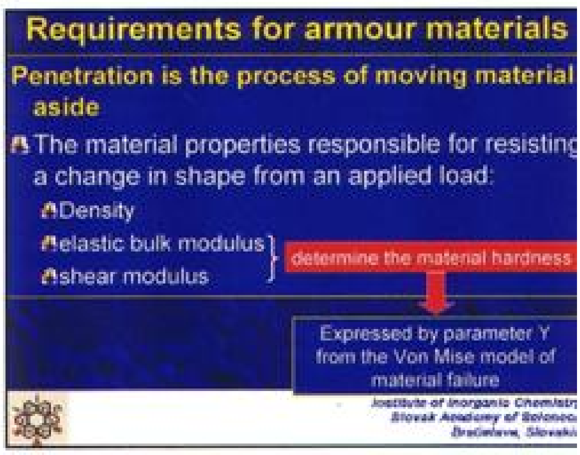


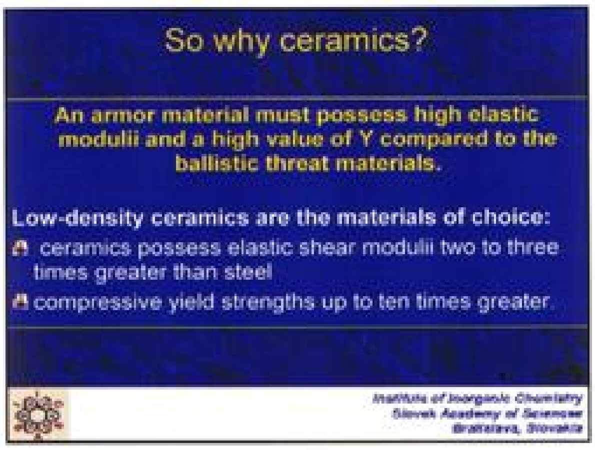
8.3 Presentation on Ceramic Armour










So why ceramics?
An armor material must possess high elastic modulii and a high value of Y compared to the ballistic threat materials.
Low-density ceramics are the materials of choice:
ceramics possess elastic shear modulii two to three times greater than steel
compressive yield strengths up to ten times greater.
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Slovak Academy of Sciences
Bratislava, Slovakia


Ceramic & Composite Armor: Principle
Conventional steel armour:
absorbs impact energy by ductile deformation
Ceramic & Composite Armor:
hit-on the strike (top) surface: deformation to the projectile, increasing its cross section
reduces kinetic energy of the bullet by its fragmentization and by shattering the tile's hard surface
the residual energy of the smaller fragments is absorbed by plastic or elastic deformation within the backing of the armor tile.
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Ceramic & Composite Armor: Advantage
A typical composite protection tile weighs half the weight of steel plate and provides the same level of protection.
The lower the weight, the thicker the ceramic armor.
The thicker the ceramic armor, the larger the area the load is spread over the backup plate.
The thicker the armor, the more erosion of the projectile during penetration.
The more the erosion, the less mass and kinetic energy of the projectile.
The less the projectile mass and kinetic energy,the easier to stop with the backup plate.
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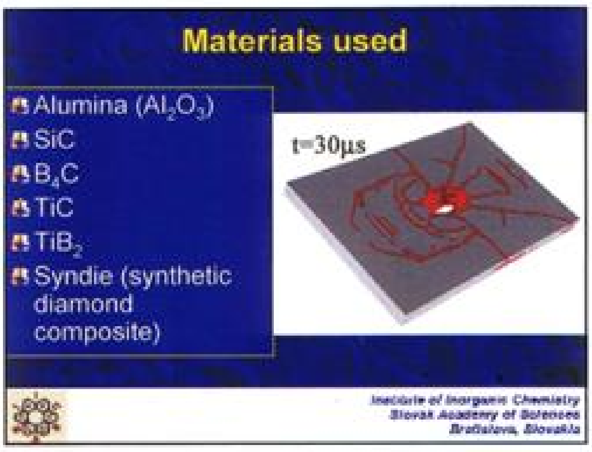
Materials used
Alumina (Al_2O_3)
SiC
B_4C
TiC
TiB_2
Syndie (synthetic diamond composite)
t=30µs
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Ceramic & Composite Armor: Drawbacks
ceramic element does not retain the same physical properties after disintegration
limited capability to protect against multiple hits
Single shot
Double shot
Encapsulated TiB_2 Experiment (N.L. Rupert, ARL ~1997)
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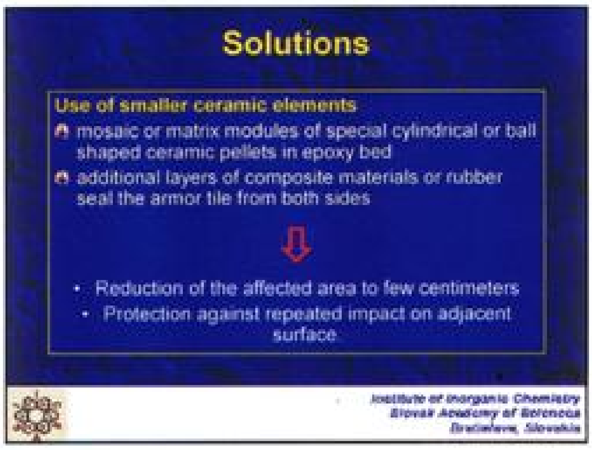
Solutions
Use of smaller ceramic elements
mosaic or matrix modules of special cylindrical or ball shaped ceramic pellets in epoxy bed
additional layers of composite materials or rubber seal the armor tile from both sides
Reduction of the affected area to few centimeters
Protection against repeated impact on adjacent surface
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Composite armours
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Slovak Academy of Sciences
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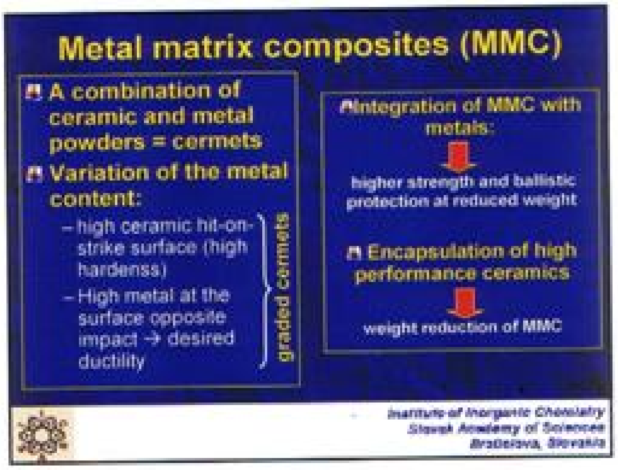
Metal matrix composites (MMC)
A combination of ceramic and metal powders = cermets
Variation of the metal content:
– high ceramic hit-on-strike surface (high hardenss)
– High metal at the surface opposite impact → desired ductility
graded cermets
Integration of MMC with metals:
higher strength and ballistic protection at reduced weight
Encapsulation of high performance ceramics
weight reduction of MMC
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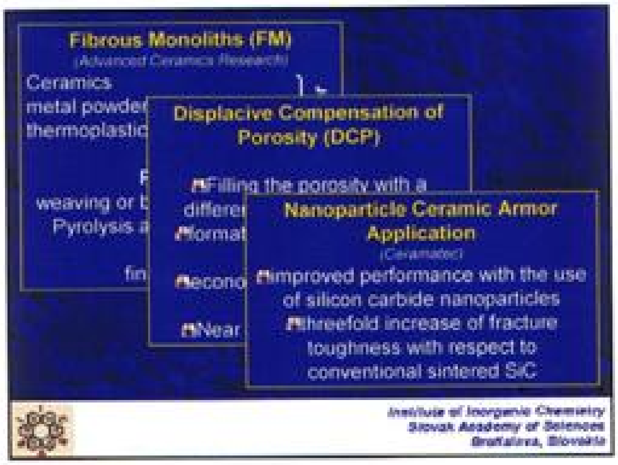
Fibrous Monoliths (FM)
(Advanced Ceramics Research)
Ceramics
Displacive Compensation of Porosity (DCP)
Filling the porosity with a
Nanoparticle Ceramic Armor Application
(Ceramatec)
improved performance with the use of silicon carbide nanoparticles
threefold increase of fracture toughness with respect to conventional sintered SiC
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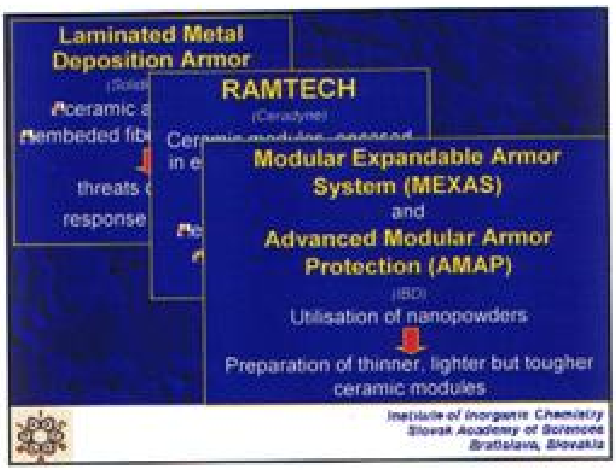
Laminated Metal Deposition Armor
RAMTECH
(Ceradyne)
Modular Expandable Armor System (MEXAS)
and
Advanced Modular Armor Protection (AMAP)
(IBD)
Utilisation of nanopowders
Preparation of thinner, lighter but tougher ceramic modules
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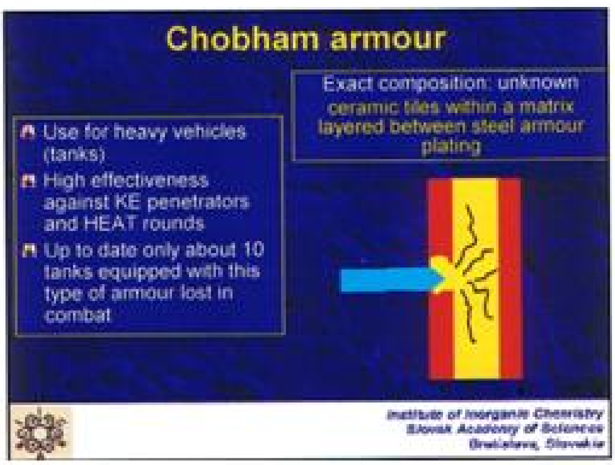
Chobham armour
Exact composition: unknown
ceramic tiles within a matrix layered between steel armour plating
Use for heavy vehicles (tanks)
High effectiveness against KE penetrators and HEAT rounds
Up to date only about 10 tanks equipped with this type of armour lost in combat
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Exote
(Exote Armor Technology)
titanium-carbide metal matrix
metal or composite base liner
claimed to break even the hardest AP bullets
Excellent multi-hit resistance


Light Improved Ballistic Armor (LIBA)
(Mofet Etzion Ltd.)
ballistic protection against small arms up to 14.5mm AP caliber projectiles and 20mm fragments
half the weight of comparable steel protection
exceptional multi-impact and shock resistance properties
Retains flexibility
Easy to replace
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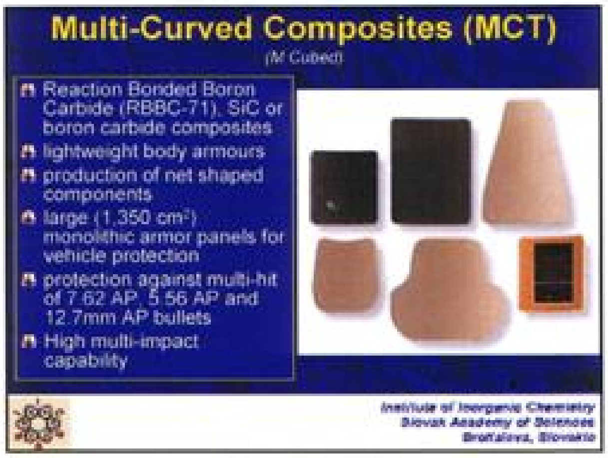
Light Improved Ballistic Armor (LIBA)
(Mofet Etzion Ltd.)
Concept:
different sizes and shapes of ceramic pellets
various types of advanced ceramic materials
embedded in an elastomeric matrix
attached to a composite fiber, metal base
stand alone solutions possible


Multi-Curved Composites (MCT)
(M Cubed)
Reaction Bonded Boron Carbide (RBBC-71), SiC or boron carbide composites
lightweight body armours
production of net shaped components
large (1,350 cm²) monolithic armor panels for vehicle protection
protection against multi-hit of 7.62 AP, 5.56 AP and 12.7mm AP bullets
High multi-impact capability
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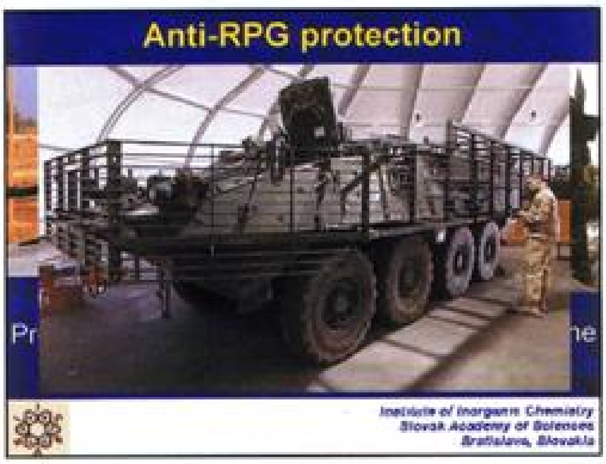
Anti-RPG protection
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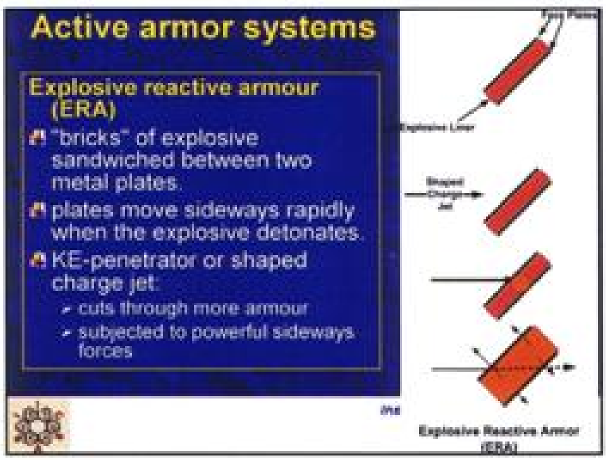
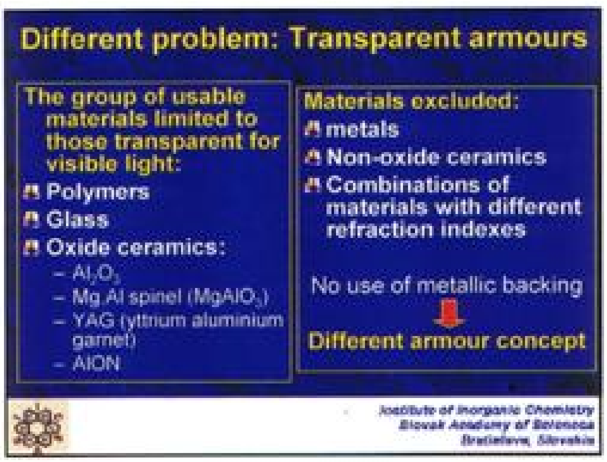

Active armor systems
Explosive reactive armour (ERA)
"bricks" of explosive sandwiched between two metal plates.
plates move sideways rapidly when the explosive detonates.
KE-penetrator or shaped charge jet:
cuts through more armour
subjected to powerful sideways forces
Explosive Reactive Armor (ERA)


Different problem: Transparent armours
The group of usable materials limited to those transparent for visible light:
Polymers
Glass
Oxide ceramics:
– Al2O3
– Mg Al spinel (MgAlO4)
– YAG (yttrium aluminium garnet)
– AlON
Materials excluded:
metals
Non-oxide ceramics
Combinations of materials with different refraction indexes
No use of metallic backing
Different armour concept
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Bratislava, Slovakia


Traditional transparent armours: "bulletproof glass"
Polycarbonate backing
Hardened float glass
Polymer film
Scratch resistant layer
Impact
Protection against soft core small caliber ammunition
Limited protection against AP WC-core bullets:
Glass softer than the threat
Unacceptable increase of thickness and weight
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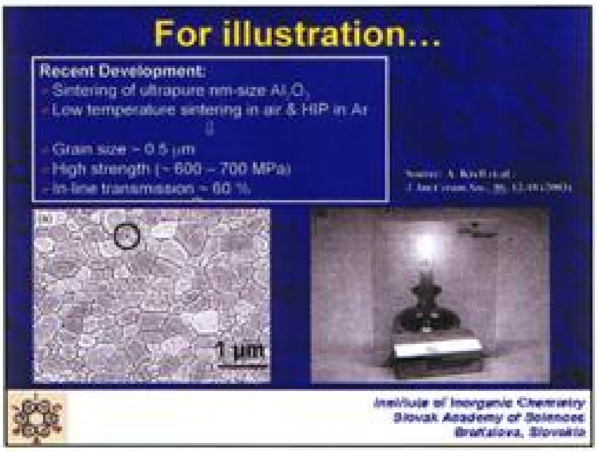
Proposed solutions
Replacement of glass with another transparent harder-than-the threat materials:
BUT
Spinel and YAG:
Good transparency
Lower hardness
Poor ballistic performance
Polycrystalline alumina:
Limited transparency
High hardness and ballistic performance
AlON:
Good transparency
High hardness and ballistic performance
Very expensive
Sapphire monocrystal
Very good transparency
High hardness
Questionable ballistic performance
There exists no dream material up to date


For illustration...
Recent Development:
Sintering of ultrapure nm-size Al_2O_3
Low temperature sintering in air & HIP in Ar
Grain size ~ 0.5 μm
High strength (~ 600 – 700 MPa)
In-line transmission ~ 60 %
1 μm
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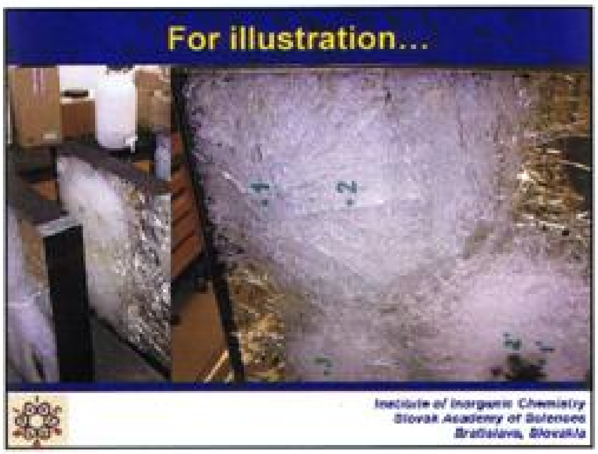
For illustration...
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Sapphire single crystal: A solution?
Original WC projectile
Al_2O_3: h = 14 mm, HV = 13 GPa
Al_2O_3: h = 8 mm, HV = 15 GPa
Al_2O_3: h = 14 mm, HV = 18 GPa
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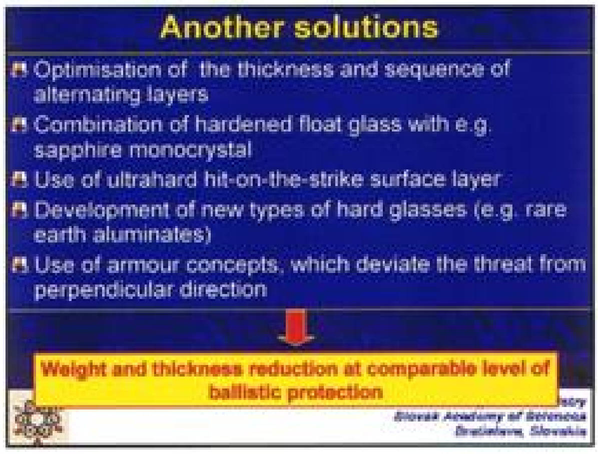
Another solutions
Optimisation of the thickness and sequence of alternating layers
Combination of hardened float glass with e.g. sapphire monocrystal
Use of ultrahard hit-on-the-strike surface layer
Development of new types of hard glasses (e.g. rare earth aluminates)
Use of armour concepts, which deviate the threat from perpendicular direction
Weight and thickness reduction at comparable level of ballistic protection
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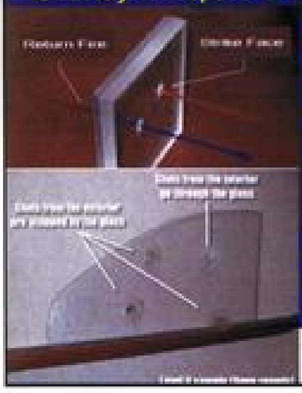
Some interesting bits:
OneWay Transparent Armor (Labock Industries)



- free shooting from inside out
- stopping projectiles coming from outside
- Level II and III protection
- less weight than comparable armor glass

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Conclusions

- Ceramics remain irreplaceable component of both personal and equipment's ballistic protection
- Not stand-alone material:
- Combination with metals, fibers, and polymers is vital for superior ballistic performance
- Challenge: transparent armour

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Hints for R&D in the future

- No on principle new materials in sight
- We must do with what we have:
  - ✓ Use of nano-structured ceramic materials
  - ✓ New concepts and combinations with metals, hard metals, high-tech fibers and elastomers
  - ✓ New constructions of armour sandwiches
  - ✓ Transparent armour concepts
- Improvement of fundamental understanding of materials' failure under conditions of dynamic loading

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Developments in practical armour concepts:

- Higher modularity ("armour on demand")
- Easy replacement of damaged parts
- Combination of active and passive protection

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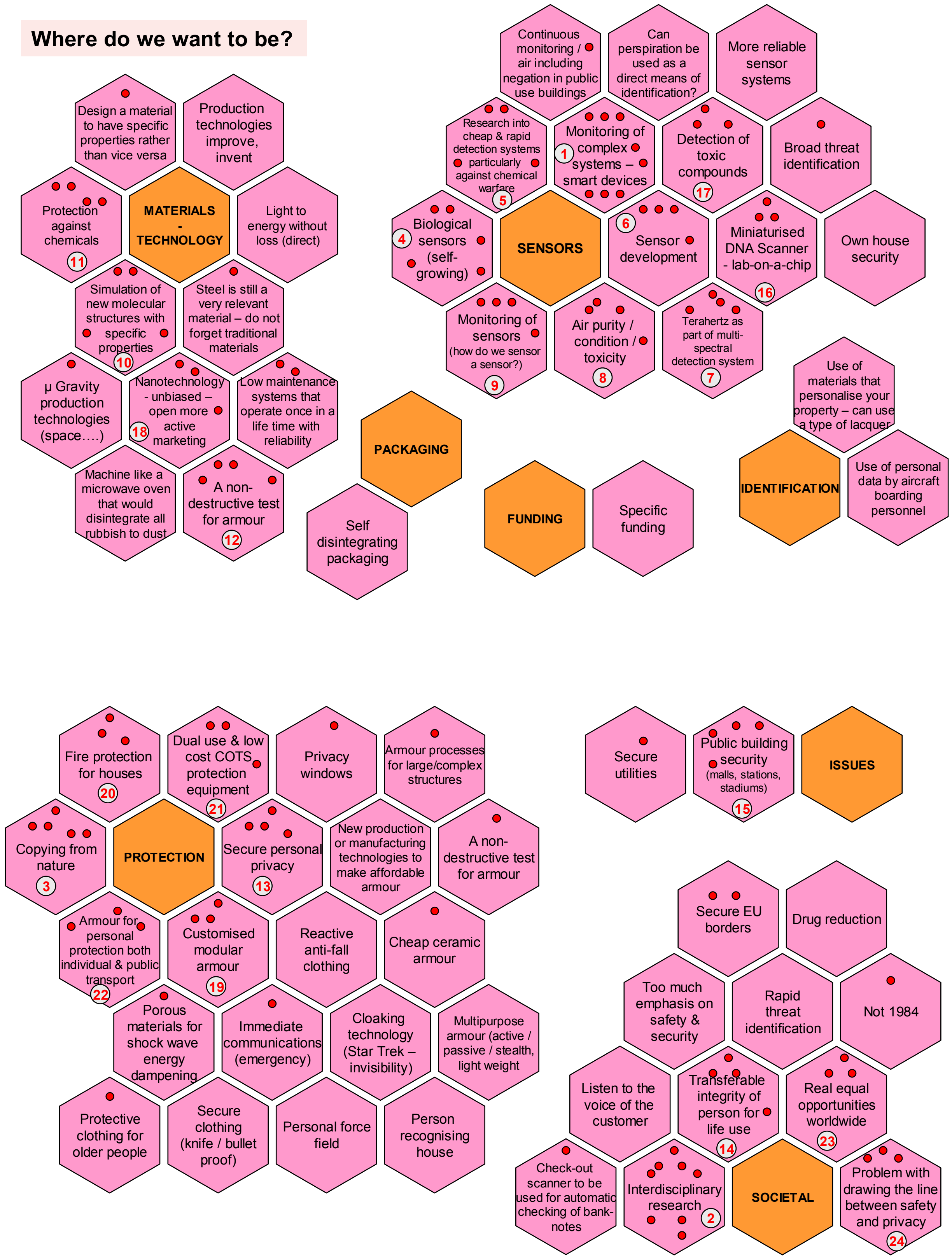
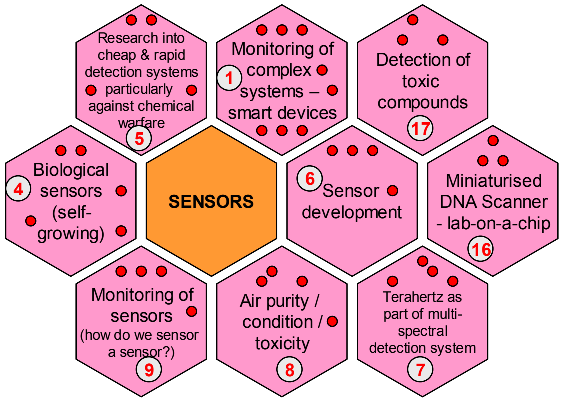
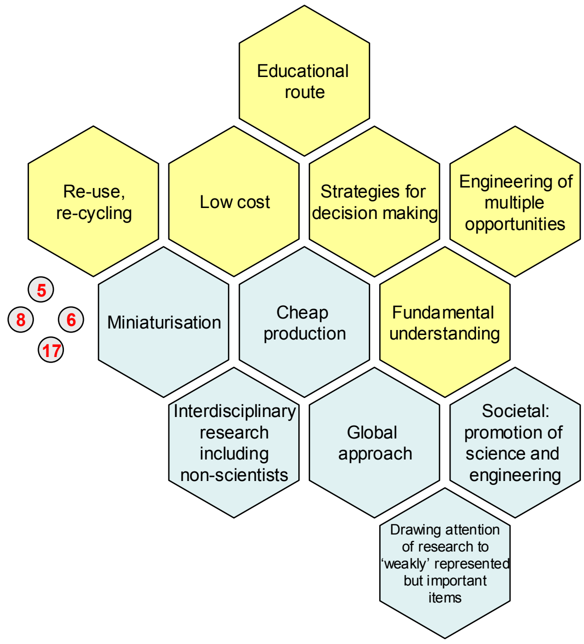
8.4 Results of Brainstorming with Hexagons

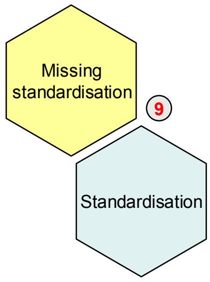


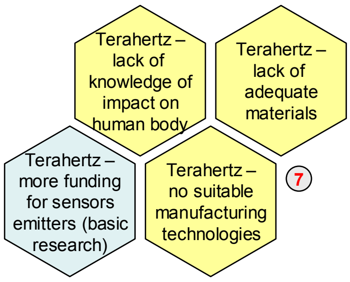


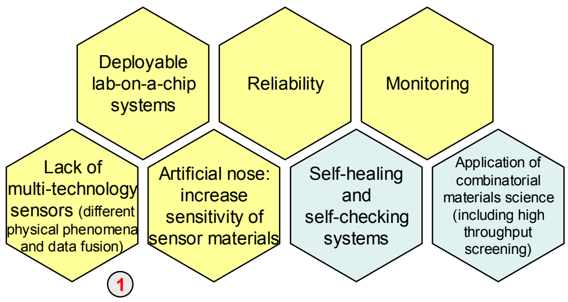
What is stopping us getting there?

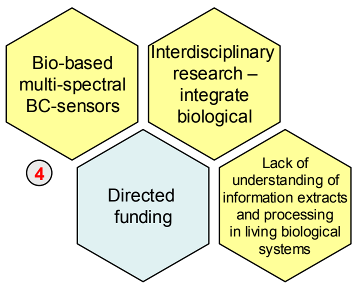
What do we do to overcome the barriers?

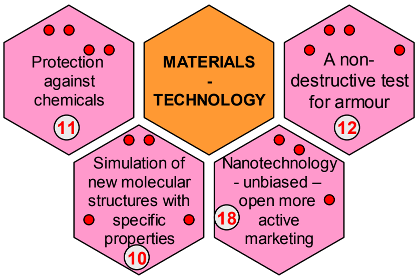






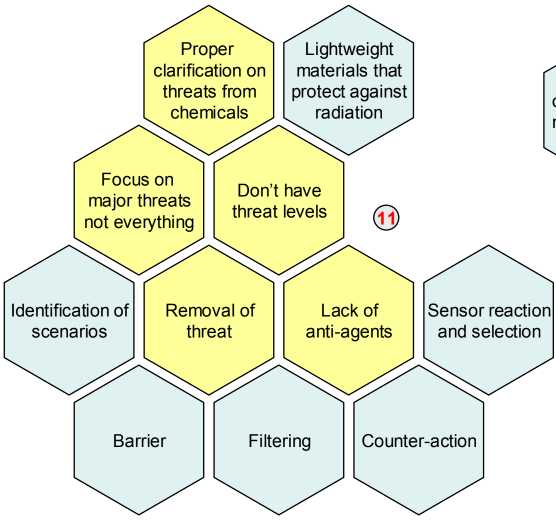


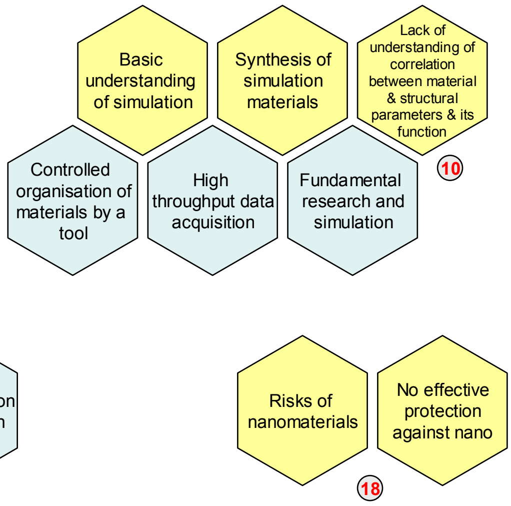




What is stopping us getting there?

What do we do to overcome the barriers?






What is stopping us getting there?
What do we do to overcome the barriers?
Fire protection for houses
20
Dual use & low cost COTS protection equipment
21
Copying from nature
3
PROTECTION
Secure personal privacy
13
Armour for personal protection both individual & public transport
22
Customised modular armour
19
Identifying appropriate mechanisms
Understanding natural mechanisms
3
Processing materials
Open research structures
Real time monitoring and reaction
Interdisciplinarity
Perception
Lack of transparency of benefits and threats
Public perception resistance
Cost
Transparency
Acceptance
Education – distribution of information
Changing nature of threat
Develop scenarios
Sensors
13
Availability of dual use and COTS
21
Programmable sensor
Identification of threat
Cheap lightweight personal armour
No force field
22
19
Non-visible body armour


Public building security (malls, stations, stadiums)
15
ISSUES
What is stopping us getting there?
What do we do to overcome the barriers?
Transferable integrity of person for life use
14
Real equal opportunities worldwide
23
Interdisciplinary research
2
SOCIETAL
Problem with drawing the line between safety and privacy
24
23
Competition without economic hindrance
Equal opportunity vs. economy, place of birth…→ too optimistic
New structures
Structure of research in establishments
Discipline languages
14
High impact of misuse of 'ultimate' ID-proof
High risk of misuse of 'ultimate' identify proof
Communication
Acceptance of other ways of looking
2
24
Communication barriers among people (taxonomy, approach, technological terms,..)
No genuine interdisciplinary research existing yet
Purposeful installation of interdisciplinary teams→explicit funding
Public building security vs. costs, personal freedom, adequate guidance, training
15
Building security – visual appearance