NAVIGATING IN NANOSPACE

Presentation of an integrated roadmap

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NAVIGATING IN NANOSPACE

PRESENTATION OF AN INTEGRATED ROADMAP

INTRODUCTION

A lot of nanoproducts are currently for sale on the market and a lot more nanotechnologies are being developed. Society has high expectations. Will nanotechnologies offer a solution to modern society’s great challenges, such as the environment, health and quality of life? Meanwhile, research into nanotechnology is being conducted in a heterogeneous way. There are more and more specializations, responsibilities are fragmented and various interests are at play. In short, there is a need to streamline efforts in this field. But how? This is the main question in the research project 'Nanotechnologies for tomorrow's society' (NanoSoc).

The NanoSoc project consists of four interactive exercises:

1. First, both nanoresearchers and citizens started working with words and colors to try and imagine different nanofutures, based on divergent and confrontational visions.
2. Next, panels of scientists and citizens imagined themselves living in these nanofutures, asking themselves what it would be like.
3. Subsequently, stakeholder organizations tried, by means of a forum, to find out how social needs and concerns can find their way onto the research agenda; the main issue dealt with the organization of co-responsibility.
4. Finally, a method was tested to draw up a roadmap for nanotechnology research. Such a roadmap need not have the ambition to predict the future, an impossible task in this early stage of the research. However, in order to adequately prepare for the future, it should assist nanoresearchers in:
   - matching public challenges with available expertise and vice versa;
   - assessing alternative research paths on their feasibility (scientific effectiveness) and desirability (quality of life);
   - orchestrating all the knowledge and perspectives in a timely manner.

In many ways, the 'NanoSoc' project is an experiment.

- It focuses on a technology that is still in its early stages. In those early stages of research, many questions remain to be answered. What applications should we realize first? How will we handle risks that are hard to assess? How will nanotechnology reflect on society in the future? How will people respond to certain developments? Especially in light of these uncertainties, it is important to look for procedures that can help us put together well-founded research agendas for nanotechnology.
The cooperation between social scientists and nanoscientists also forms part of the experiment, as their research cultures clash now and then. When this happens, mutual confidence will become very important, but first it will have to steadily grow.

On several occasions, nanoscientists have exchanged ideas with *outsiders*. On those occasions, it was never really clear beforehand what both parties could expect from one another. That too is part of the excitement.

There is a great deal of duality in the opinions of laymen, as well as of nanoscientists, regarding developments in the nanotechnology field. This is a remarkable finding by NanoSoc and, at first sight, does not offer a clear indication of the direction new technologies should take. In the eyes of many, ambivalence creates a drag on technological innovation. Yet that does not make it necessarily true. The question is whether those mixed feelings, when given the chance to explicitly come to the surface, could lead nanoresearchers to innovative ideas. That is exactly what we have tried to ascertain with NanoSoc. Therefore, discussion forums were organized, in particular to clarify the argumentation behind these ambivalent reactions. This brochure is an account of what we have learned from that exercise.

First, a method is presented, by which a group of nanoresearchers and stakeholders made a roadmap for research into nanotechnologies. This roadmap is only the tip of an iceberg, permanently fed by images of nanofutures in society (see the chapter about our citizens’ panels) and by reflections on the research system and its policy framework (see the chapter about our stakeholder forum). This iceberg floats on a sea of political, social and philosophical considerations, relevant when contemplating a responsible management of nanoscience and nanotechnology (see the last chapter).

**THE TIP OF THE ICEBERG. DEVELOPING AN INTEGRATED ROADMAP**

**BASIC PRINCIPLES OF A COMMON ROADMAP EXERCISE**

Scientific and technological roadmaps originated in the eighties in an industrial context, but are still used today by promoters of technical and scientific developments. By means of roadmaps, they give their opinion on technologies they find desirable, feasible and economically interesting. They list the steps that should be taken in the field of research and development in order to realize the technology.

One of the more famous roadmaps is the *International Technology Roadmap for Semiconductors*, ITRS in short. This roadmap was an important guideline in micro-electronics for forty years. It can be summarized in one algorithm, Moore’s law, which states that the complexity of computer chips will continue to rise exponentially, while the size and costs will decrease proportionally.

Roadmaps are predictions for the future, yet always connected to an action plan to attain that future. In other words, they outline what is attractive, enviable and possible. Regularly, authors of such roadmaps start off with extrapolations based on scientific knowledge and socio-economic trends. Of course, these are never "objective" predictions. After all, roadmaps are the result of the perception and imagination of authors, and therefore reflect their views and interests.
Roadmaps support communication and decision-making in the field of research. Putting together a roadmap is a strategically important learning process which contributes to streamlining the multitude of actions and interactions necessary for research and technological developments. Moreover, a roadmap that is used to share visions on the future, is a useful tool to kindle the curiosity of sponsors.

ELEMENTS IN FAVOR OF A CUSTOM-MADE APPROACH

The ITRS roadmap was unique in the history of technology. Few roadmaps were so unambiguous and have served as a guideline for innovation for such a long time, especially in the microelectronics sector. Now that micro- is evolving into nanoelectronics, and more and more disciplines are converging (nano, bio, info, cogno), such a straightforward roadmap is no longer conceivable.

At one point, miniaturization will come to a halt and completely new features and applications for technological systems will have to be found. To get a better idea of such a road to innovation, simply continuing on the same technological trends will not suffice. Socio-economic considerations will also help to determine the direction in which these new technologies will evolve. In other words, roadmap designers should not only pay attention to what is technically possible or economically beneficial. They will also have to take into account social challenges, expectations and concerns of the general public, and concrete usage situations in which new technologies play a role.

In any case, this will lead to a multitude of scenarios for the future, as there are no longer clear trends to be extrapolated with a reasonable certainty. Working with different scenarios does have a disadvantage. The roadmaps will be less powerful. The number of options will also increase, making it more difficult to get all the different players on one line. That is why the predictive force of these roadmaps is smaller, they are in other words more preliminary.

BASIC PRINCIPLES OF AN "INTEGRATED ROADMAP"

As an alternative to existing roadmap exercises, some authors suggest an "integrated roadmap" (Erdmann, Behrendt, 2006; Fleischer et al., 2005). When putting an integrated roadmap together:

- the perspective shifts from technological feasibility to social challenges;
- a diverse group of people participates;
- unintended side effects of new technologies are taken into account;
- not one, but several futures are considered.

According to Fleischer and his colleagues, an integrated roadmap will create a more balanced communication regarding innovations. Although existing or expected advantages are often emphasized, traditional roadmaps sometimes "forget" to mention what is gained and what is lost, who the winners are and who the losers are, or they consider this information to be irrelevant. This can give outsiders the feeling that facts are being brushed up or represented in a dishonest way, causing suspicion. In the worst case, they reject the new technology. In other words, unbalanced communication is only grist to the mill of doomsayers and people with a rich imagination.
The German philosopher Alfred Nordmann\(^1\) puts forward the following recommendation when making a roadmap:

> I tend to be very critical towards roadmapping exercises because they are too future-oriented and thus import all the problems associated also with our ignorance regarding the future which are especially large in the case of a technology that is defined only in terms of its potentials.

> I would recommend instead an approach that seeks to match an awareness of publically recognized problems to existing capabilities. "Roadmapping" would then be an exercise of identifying the missing steps and trying to evaluate the difficulties they pose. These evaluations could include reflections on limits of knowledge and could incorporate concerns of citizens.

> There is a particular variant of this, which might be called a portfolio exercise. Gather together a typical roadmapping-team and invite people to come up with imagined technical applications to solve some problem. Then, take these idea-sketches/prototypes to various people/groups and ask for their assessments. (Other) researchers might comment on their feasibility, consumer groups on their desirability etc. (if it concerns the ageing population, include members of that group, gerontologists, etc.)

> The exercise might lead to a refinement, revision, substitution, rejection of these prototypical ideas and then perhaps also to a sense of a "roadmap" that would take us there. I don’t know whether this has been tried before, so it might be a good initiative for your project.\(^1\)

By way of experiment, the NanoSoc team has organized its own roadmap exercise. This exercise is just the tip of an iceberg, and its design and execution was based on ideas, questions and concerns that had been put forward during earlier interactive exercises with citizens and stakeholders (see chapter "The Iceberg").

Our roadmap exercise is meant in the first place as a communication and learning process. It wants to teach the actors involved – scientists and civil society – how to deal with normative and scientific uncertainties linked to technological innovation. Since this learning exercise actually precedes strategic choices made in research organizations, it is meant to support those choices. The aim of the roadmap exercise is to help the actors involved in learning how to spot possible alternatives and choices, understand and evaluate them, and gather the necessary knowledge and viewpoints in time to prepare for the future.

\(^1\) Prof Dr Alfred Nordmann is a member of the scientific committee of the NanoSoc project
The NanoSoc exercise distinguishes itself in the following ways from commonly used roadmap exercises:

- **Common roadmap**
  - plots one course for the future;
  - derives ideas from the hierarchy of research institutions and the trusted research network;
  - tries to predict the future;

- **NanoSoc roadmap**
  - helps to see alternatives early in the process;
  - also derives ideas from other segments of society;
  - helps to prepare for the future;

The NanoSoc roadmap exercise is based on the following principles:

1. On the one hand, we use social problems and challenges as a starting point, and on the other hand we work with experts that can offer a solution to those problems and challenges, especially researchers at the imec and the University of Antwerp.

2. Alternative routes are examined. In order to find those alternatives, we involve relevant people from outside the knowledge institutions and traditional partners, who will add their insights, experiences and expertise. Although assessing and weighing these alternative routes is a process of trial and error leading to a multitude of opinions and disagreements, the exercise will enable us to better evaluate the feasibility and desirability of the different futures scenarios, making it worth the effort.

3. Further developing a certain route is not a matter of describing a factual (future) history. After all, we cannot predict the future. It is a tool to create a reality in a systematic and well-founded manner, step by step. At the same time, it is also a tool to orchestrate the efforts of all the actors involved – both promoters and (future) users. Therefore, it should not be understood as a strictly linear exercise. Reverting back to an earlier phase can be useful and/or necessary. A roadmap can indicate what questions or problems (uncertainties) are up for discussion, in what stage of the research and development, and which actors can contribute. A roadmap can structure the input of relevant players in
an "iterative" process, it can describe the necessary actions and required skills, and make sure that action is taken and skills are developed in a timely manner. In this aspect, the roadmap is a tool to prepare us for the future.

OUR STEPS

The development of an integrated roadmap takes place in several steps.

1. Match public challenges with available expertises and vice versa;
2. Assess the feasibility (scientific effectiveness) and desirability (quality of life) of alternative research paths;
3. Conceive a research path by orchestrating expertises and perspectives in time;

STEP 1: MATCH PUBLIC CHALLENGES WITH AVAILABLE EXPERTISES AND VICE VERSA

From the outset, the NanoSoc team made two choices. On the one hand, it chose as "publically recognized goal" two challenges already mentioned by the World Health Organization, namely neurodegenerative illnesses in elderly people and asthma in children in urban areas. As "main technological approach", the team chose biotransducers\(^2\), because imec as well as the University of Antwerp, both partners in the NanoSoc project, have a lot of in-house expertise in this matter. Choosing partners and disciplines when making a roadmap, is important because it determines the alternative roads to explore. Therefore, the first exploratory discussion has to be broad from the start or broadened along the way when the need for more knowledge arises.

The central research question?

How can biotransducers contribute to combating these conditions in the next fifteen years?

Which possible research paths are relevant and what knowledge, both within imec and the University of Antwerp, can be used for this?

\(^2\) Biomedical transducers are systems that have at least a biosensing functionality (detecting a biomedical signal), but can also comprise a bioacting functionality (activating a biomedical signal) controlled by the biosensor.
Participants in the exercise were stakeholders and experts from the social and environmental sector on the one hand, and researches from imec and the University of Antwerp on the other, with different backgrounds in the field of bio/nano/cogno/info.

Researchers at imec and the University of Antwerp plotted several possible research paths for neurodegenerative illnesses and asthma in children. They were asked to indicate where they saw crossovers with their own expertise. Afterwards, the NanoSoc team has complemented and elaborated their (very fragmented) contributions into more coherent proposals for possible technology routes. For this purpose, the team had to gather missing knowledge, especially medical knowledge and knowledge related to social consequences.

Result

For each field of application, three proposals were made for possible research paths. See diagrams below:

**Asthma 1: detection in environment and warning**

<table>
<thead>
<tr>
<th>Background</th>
<th>Aim</th>
<th>Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asthma can be caused by high concentrations of dust/particles in the environment (inside/outside); Part of asthma treatment = avoiding risk factors;</td>
<td>Simultaneous detection of individual chemicals, compounds, particles in the environment; Warning or action if certain level is exceeded;</td>
<td>From &quot;single sensor based system&quot; to &quot;multiple or array sensor based system&quot;; Research into intelligent nose (spec combination of detectors) + signal processing; Bacteria and cells as possible sensor - can react in a very sensitive and specific manner; genetic modification to stimulate desired qualities; Compatible with home use/self calibration;</td>
</tr>
</tbody>
</table>
## Asthma 2: test for diagnosis and follow-up

<table>
<thead>
<tr>
<th>Background</th>
<th>Aim</th>
<th>Route</th>
</tr>
</thead>
</table>
| • Measuring biomarkers for infection reactions in the long is an invasive and expensive method;  
  • Routine application not very suitable for children; | • Developing non-invasive, reproducible test that continuously gives information on airway infection to enable early intervention; | • Focusing on analysis of, for example, NO in exhaled air;  
  • (Functionalized) nanostructures for sensitive, selective, fast detection of gas and bio molecules; |

## Asthma 3: combination of both routes

<table>
<thead>
<tr>
<th>Background</th>
<th>Aim</th>
<th>Route</th>
</tr>
</thead>
</table>
| • Determining a good environment is difficult;  
  • Discontinuous measurements give only limited information; | • A continuous monitoring system that enables:  
  • linking information of the environment to personal information;  
  • better standardization (better information about impact);  
  • taking information of the environment into account when diagnosing/treating; | • Route 1 + Route 2; |
### Neurodegenerative illnesses 1: medication with increased efficiency

**Background**
- Existing medicines fight symptoms but lose their effectiveness over time;
- Need for in vitro research to study the behavior of neural networks over a longer period of time;

**Aim**
- Search for medication with increased efficiency;

**Route**
- Bio-electronic in vitro platform for lab tests;
- Studying bio-compatibility (neuron survival) on this platform;
- Designing relevant assays (tests) to study the effects of the potential medicines on neurons;
- Optimizing medicines based on these assays;
- Studying influence of admission mechanism;

### Neurodegenerative illnesses 2: closed loop monitoring and feedback

**Background**
- Current stimulation systems have no feedback possibility;
- Ratio desired effect vs. undesired side effects is not adequately monitored today;
- Spatial selectivity is small (cause of side effects);

**Aim**
- Improving monitoring of effectiveness of the treatment (stimulation) and adapting the stimulation;

**Route**
- Designing implant with appropriate electrode topology;
- Designing electronics for stimulation and monitoring;
- Study action-reaction in in vivo experiments;
- Developing control strategy (therapy);
STEP 2: ASSESS THE FEASIBILITY AND DESIRABILITY OF ALTERNATIVE RESEARCH PATHS

Researchers at imec and the University of Antwerp, medical experts, stakeholders and Technology Assessment experts discussed these research paths together, supervised by a facilitator.

They first investigated the feasibility of the research paths: what kind of uncertainties and difficulties would result from the development of these paths.

The result was an inventory of uncertainties:

a) Strategic uncertainties:
   - What are the underlying human and social views (on future patients, the welfare state, the line between illness and health)?
   - What should we aspire to (regarding quality of life, innovation, economy, equality, environmental care)?
   - What target groups are we aiming for (people requiring help, high-risk groups, age brackets)?
   - What time perspective will we use (regarding scientific research, workable technological concept, regulating embedding in society)?

b) Knowledge gaps:
   - What scientific research is required (e.g. system criteria, alternatives, risks, specific biomarkers, detector sensibility, characterizing chemical aspects)?
o What socio-scientific insights are missing (regarding the organization of healthcare, doctor/patient relation, impact of risk research on the cost price)?

c) What design rules can we conceive for using the technology, e.g. in light of the implementation in the healthcare sector?

d) What are the conditions to embed the technology in an adequately social way? What institutional, legal and cultural changes are necessary?

Secondly, the participants compared the research paths (within each field of application), basing themselves on the knowledge gaps and uncertainties listed in the previous step. In addition, it was investigated what the opportunities and risks are, the pros and cons and the desirability of every research path. In this step, it becomes clear which participants (researchers and stakeholders) prefer which path and for what reason.

This resulted in the following points of interest:
STEP 3: CONCEIVE A RESEARCH PATH BY ORCHESTRATING KNOWLEDGE AND PERSPECTIVES IN A TIMELY MANNER

In a last step, the NanoSoc team developed a roadmap approach for conceiving a research path. To that end, the team chose one research path for each case, based on discussions about feasibility and desirability by the participants in the previous steps: for neurodegenerative illnesses, it was "electrical stimulation in the brain with feedback" and for asthma in children, it was "linking data from the environment to monitoring the individual".

The following is a schematic representation and a description of the three suggested phases in the roadmap approach:
During every phase, this roadmap links scientific-technical expertise to social issues arising at that time. This way, the roadmap contributes to a more holistic approach of research and technological development. After all, that was one of the main concerns of the participants in the stakeholder forum.
PHASE 1: MATCH RESEARCH QUESTIONS TO STRATEGIC TARGETS AND TARGET GROUPS

In a first phase, researchers map relevant problems in their field of knowledge (= 1. electrical stimulation in the brain with feedback for neurodegenerative diseases and 2. combined monitoring of environment and people regarding asthma in children). At the same time, the social context in which the technologies will be embedded, is explored. This creates a counterweight against overspecializing and fragmenting, phenomena inherent to scientific research. Organizing a “multidisciplinary science fair” where representatives of social and natural sciences can dialogue with each other, could be very useful. That is why the human factor needs to be taken into account as well when outlining the costs.

- Vision on sickness and health?
- Research organizations involved?
- Map of patients?
- Existing prevention, diagnosis, therapy?
- Research funds?
- Cost?

<table>
<thead>
<tr>
<th>Technological/Scientific problems</th>
<th>Societal context</th>
<th>Experimental route 1</th>
<th>Knowledge gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research questions</td>
<td>Strategic choices</td>
<td>Technological option 1</td>
<td>Social framework</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Experimental route 2</td>
<td>Knowledge gaps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Technological option 2</td>
<td>Social framework</td>
</tr>
</tbody>
</table>
After this broad exploration, researchers define a set of initial research questions. Preferably, this exercise is linked to a reflection on strategic choices from the start. What are the goals with regard to scientific quality, quality of life, innovation, economy, equality and environment? At what target groups will the technology be aimed? More insights in the social context in which the development and implementation of technology routes occur, help to better substantiate the strategic choices.

- Targets: health care, innovation, economy, profit, ...?
- Target groups: patient types, age brackets, income levels, ...?
PHASE 2: OUTLINE OF EXPERIMENTAL TRAJECTORIES

Depending on the strategic choices, initial experimental research trajectories will emerge, as will a number of alternative technology routes. Each of those routes is based on variant technological options. For instance: some of those technologies might be less invasive, others more invasive; or in some cases, the system might have most of the control, and in other cases the patient; or there is the choice between stimulation in closed loop or not. These alternative technology routes can be judged based on what users in the healthcare sector find important (e.g. reversibility, separating data for research and diagnosis, respecting privacy, awareness of behavioral changes, etc.).

It is good for users and civil society to hear in all openness what the different choices comprise and how they meet different design demands.
PHASE 3: TEST AND VALIDATE THE PROPOSED TECHNOLOGY ROUTES

In a last phase, researchers conduct experiments, using prototype technology. Those experiments show what lacunas in scientific and socio-scientific knowledge are yet to be filled. These lacunas are closely linked to the way in which the technology will later be embedded in society. Therefore, it is necessary to examine both dimensions simultaneously.

Solving these knowledge lacunas is the task of specialists in the field of exact sciences and social sciences. The results of their research will be discussed with the relevant actors, i.e. technology promoters and future users. This knowledge will enable both sides to take action in order to firmly embed the technology in society.

Ultimately, it is the government’s task, together with civil society, to provide the intended technology routes with an organizational, cultural and legal framework. On public discussion forums, they will present their proposals so that research institutions and companies can get an idea of their margin of maneuver.

Knowledge gaps
- Risk of neural stimulation for the patient?
- Risks of unintended side-effects?
- Impact of continuous monitoring on patient wellbeing?
- Impact of doctor-patient relation on patient wellbeing?
- ...

Social Framework
- Freedom of choice?
- Solidarity vs. patient choice?
- Are there win-win situations?
- Legal framework?
- Distribution of responsibilities?
- ...

Technological/scientific problems
- Societal context
- Research questions
- Strategic choices

Experimental route 1
- Technological option 1
- Knowledge gaps
- Social framework

Experimental route 2
- Technological option 2
- Knowledge gaps
- Social framework
COMMENTS REGARDING THIS METHOD

This proposed method was submitted to two groups, each consisting of researchers at the University of Antwerp and imec. One group gathered at the University of Antwerp and dealt with the “asthma” case, while the other group gathered at imec and looked into the case of neurodegenerative diseases. Both groups were allowed to deliver criticism and suggestions regarding
- the logic of the consecutive phases (allowing iteration);
- the types of questions dealt with in each phase;
- the roles of the different actors during each phase.

We arranged the comments of both groups according to the three separate phases of the roadmap approach.

PHASE 1: MATCH RESEARCH QUESTIONS TO STRATEGIC TARGETS AND TARGET GROUPS

In this phase, the central idea is that the research strategy should be dependent on different socially relevant targets and needs (and not solely on technologically feasible and economically attractive targets).

An academic participant states that this principle goes against common research practice.

‘The start-up of a research project at imec or the University is driven by science and technology. We need not take into account the social aspects when applying for funds. As long as the project fits in the larger framework of patents and publications. For this reason, scientists do not bother to talk with citizens or pressure groups. This leads to situations such as the genetically modified poplars in Ghent or the GMOs in Europe. The scientific community never took the effort to explain what the pros and cons are. Social aspects should be involved early on in the process. It may already be too late.’

An academic researcher says:

‘You have so much interesting technology at imec, but it is not always clear to me what the possible applications are. Surely, you cannot develop a technology first and start looking for applications afterwards. Oh well, maybe that is the way of things, but it surely increases the risk of coming up with irrelevant applications.’

An imec researcher puts things into perspective:

‘You have to take into account the specific position of a research center such as imec. It serves as a bridge between the university and the industry. Imec is in trouble when a company refuses to take the market risk for a certain application, but also when a university pulls out early in the development process. “Someone” has to take over in that case, but who?’
Regarding the first phase of the roadmap design, many wonder if it is at all possible to reconcile research with socially relevant goals. First and foremost, a research group or institution has to be able to freely choose its research topics, only then can a roadmap exercise start with the right expectations. Moreover, socially relevant projects also have to be able to receive funding, which is not always self-evident.

**FREEDOM OF CHOICE**

First of all, in order to meet socially relevant challenges, a research group must have the liberty to look into the future, to anticipate knowledge already acquired. One has to have the opportunity to tap into a new knowledge and technology field and to exceed existing knowledge and technology fields, because only then will the margin of maneuver be wide enough to choose a certain field of application. In the "asthma" case, the idea of freedom of choice for researchers, was discussed as follows.

> 'On the one hand, there is a technological challenge. How can sensors be used to continuously and in real-time measure which pollutants are present in the (inhaled) air and how can those measurements be linked to monitoring exactly what those pollutants do to our (asthmatic) lungs? On the other hand, this problem of asthma could be turned into a socially relevant case, namely that of a police officer directing traffic and therefore being exposed to air pollution on a daily basis. Yet the research partners, who agree to tackle these technical and social challenges, must have a fair degree of maneuverability. When for instance a research group is dependent on assignments coming from companies developing common measuring devices, in the sense that this company outsources a particular research step to the research group, then chances are you have little room for choosing an innovative path. In that case your research will stick to known parameters regarding asthma, such as lung volume, and will perfect existing measuring methods, e.g. by miniaturization. However, real innovation means taking medical knowledge as the starting point. To make a diagnosis more accurate, you find other parameters, like changes in the lung structure. To measure this, you need new measuring technology. When a research group does not have the freedom to match new social challenges with new medical knowledge, then chances are you will only measure the same parameters with new techniques instead of other parameters with other techniques. The first is called optimization, the latter is innovation.'

The innovative approach is a sign of more maneuverability, but also gives rise to uncertainty. However, thanks to such a roadmap, the uncertainty can be (partly) lifted. By involving more partners than just the usual suspects from the own research institution or the traditional network, it becomes clearer what might be socially relevant and what is desirable.

> 'When you develop something, you have certain applications in mind, but by talking to stakeholders other options can open up.'
FINDING PROMOTERS

Finding a promoter for socially relevant projects is a second important factor for success. But these are typically projects that will take you on a long ride. During the start-up phase of projects looking for technological answers to tomorrow’s challenges, only prototypes are available. Neither the government, nor the private sector is interested in investing in research and development on such a long term. Imec for instance, is bound to five-year contracts with the Flemish government. The university works with four-year projects that have to conform to very precise targets. The seven-year projects that are being awarded to top researchers however, are not bound to any social justification. During the discussions, possible solutions to the financing problem were suggested.

"Scientists might try and rouse the interest of citizens and stakeholders in a socially relevant research project and then find a promoter (together) who can take the result to the market in the long run. A term of fifteen years can be agreed with the financer, on the condition that a concrete project proposal will be submitted much sooner, providing a subdivision in research phases and, linked to this, specially adapted evaluation criteria. That way, scientists can break free from traditional funding. Not only the government, but also other bodies can be a partner in this. In the United States for instance, private funds exist that would invest in something like this. Why don’t we talk to our health insurance funds, so they would not spend money solely on practicing medicine, but also on aiding relevant medical research?"

PHASE 2: OUTLINE OF EXPERIMENTAL TRAJECTORIES

INTERDISCIPLINARITY

The degree of creativity in finding possible technology routes for a certain target is mostly defined by a successful cooperation between multiple disciplines. Interdisciplinarity should be the first focus when looking for non-traditional partners for a roadmap exercise.

For instance in the "asthma" case:

"Creativity is the result of the interaction between technological possibilities, and clinical and social questions we would like to answer."

The participants agree that the step towards an interdisciplinary cooperation has to overcome some large hurdles, even within the own institution. These are some of the conditions that might promote the success of such a cooperation:

- it has to be a two-way cooperation;
- visibility as a potential partner is important;
- an open attitude and creating personal relations is required;
- the first talks will have to be held at an institutional level.
SOCIAL STAKEHOLDERS

Can designing possible technology routes benefit from communication with third parties, and who are those "third parties"? Some wonder if "society" is the same as "the market". In other words, is it enough to work with companies, who after all know what consumers want, in order to make a bridge to society? Or should researchers also communicate with other stakeholders such as civil society organizations and citizens?

When working together with civil society, you have to know very well why you do it. And you have to decide how you select stakeholders and citizens as partners, and based on which criteria. Regardless of how difficult this exercise is, the participating researchers recognized its value. Firstly, civil society can provide the necessary support for a project. Secondly, citizens can open the eyes of scientists regarding new options. In other words, they provide additional knowledge.

'It is important for a project to receive support. That is why we should check from the start whether we are asking the right questions. A project has to fit within a framework. This was not the case with the controversy about the ‘Lange Wapper’ bridge in Antwerp, so that everything that could go wrong, went wrong. Still, this phase cannot go on for too long. At a certain point, you have to get to work, because we can only learn by putting things into practice. At the end, concrete pilot projects have to be re-evaluated and receive feedback from society.'

When it is established who can sit down at the table and why, the question has to be asked how the interaction should take place. The discussion was mainly centered around the question "on which level" communication with "society" should be organized. One could decide to restrict the interaction and communication about research and development routes to the political level of Flanders. That way, a debate could be held on the purpose of imec in Flanders and we could ask the question: 'Does it make sense for society to invest so much money in imec?' The disadvantage is that discussions like that often get bogged down in abstract conversations about the link between research and society. Moreover, politicians are already dealing with these kinds of questions, as it should be in a parliamentary democracy. It could also be decided to organize the discussion with society at the level of individual research projects. Again, there are disadvantages to this method. Individual projects are very technical and often incomprehensible to laymen. Moreover, the responsibility of the individual company plays an important role, as it is up to the company to decide whether or not to market a product.

'Only those who decide to take something to the market, can be held responsible.'

According to the participants, the solution can be found on the intermediate level.

'The individual citizen never comes into contact with his political representative. In the same way, it is impossible to bring him into contact with the individual scientist.'
We could, however, consider "platforms" on which stakeholders and citizens discuss a combination of projects. A discussion like this does not always need to take place in plenum, but can occur occasionally, with one or more partners and in function of the current needs.

**PHASE 3: TEST AND VALIDATE THE PROPOSED TECHNOLOGY ROUTES**

After finally having gathered society's arguments and concerns, the question remains how to transfer them to the specialists and scientists who are (further) developing the technology routes. How do we enable society to modulate those routes technologically and socially? Who guarantees that third party surveys really have an impact? And if they do, how do you feed this back to those third parties?

In other words, how can we facilitate the exchange of information between researchers and civil society?

> 'At the end of the day, it means incorporating social relevance in the usual brainstorming sessions between scientists.'

One of the solutions could be a person or group facilitating the exchange of information between social players and technological specialists. The concept of an "integration manager", which already exists at the Flemish Institute for Biotechnology (VIB), can serve as a source of inspiration. This man or woman keeps track of the different activities in the research groups and looks for synergy advantages so that people can work together effectively.

*The integration manager’s tasks can comprise the following:*

1) Inform the roadmap designers of the social aspects that need to be analyzed from a technological point of view;

2) Indicate which social aspects are relevant, but cannot be helped with technology and therefore need to be picked up by other partners;

3) Given some degree of translation, communicate to society what the technologists have worked out and how they have taken into account society’s concerns;

4) Repeat this feedback loop, because developing and implementing a roadmap sometimes follows an unpredictable logic;

5) During a final discussion between social players and technologists, determine a preference regarding technology routes. That selection will then be submitted to the steering committee of the research institute, which will then make the final decision.

After phase 3, the steering committee selects the routes to be followed. Because of the preceding steps, the steering committee has an easier task in estimating how long those routes will take and what the (social) costs will be.
LEARNING MOMENTS

The journey is as important as the destination. This is especially true when drawing up an integrated roadmap.

The process preceding the actual selection of technology routes is an interesting communication and learning process, providing the participants with new perspectives that possibly go beyond the decisions that are eventually taken.

If the learning process goes well, the actors involved will realize that there are alternatives and choices when putting together roadmaps. In other words, the world is more complex than the participants thought when starting the process. They will also better understand that not everyone looks at technology in the same way, meaning tension areas are never far away. The question is how to make those tensions bearable without denying them or cancelling them out.

Such a learning process can also reveal that a lot of expertise is available, even outside the research institutions, and that different opinions and positions exist that are relevant to the conception and implementation of a roadmap. This way, a roadmap becomes a tool to adequately prepare oneself for an unknown nanofuture.

After this roadmap exercise, we compiled reactions from participating stakeholders and researchers, and from strategic research managers at imec and the University of Antwerp.

Did they believe that

1) such a roadmap exercise was useful to discover alternative routes and their social impact?
2) such a roadmap exercise taught us who has relevant knowledge and what players, besides the usual suspects of university partners, have interesting opinions on alternative technology routes?

LEARNING TO SEE ALTERNATIVES

The exercise encourages participants to leave the trodden paths and stimulates them to look at modern day challenges with a fresh perspective.

‘All participants left their own small cocoon. It was a very positive experience to bring together people with a multitude of backgrounds, both natural scientists and social scientists’ (nanoscientist, imec).

‘Unexpected perspectives emerged’ (nanoscientist, imec)

‘This exercise inspires us to broaden the range of technological options by better integrating knowledge.’ (nanoscientist, imec)

‘It is interesting to see how an initial route can be vague and open, but still be enough to kindle a discussion and evoke technological and non-technological reflections. During the discussion, the technology was constantly referred to: What is technologically possible? Should the technology change in certain aspects? From those alternatives, suddenly a new technological option emerged.’ (nanoscientist, imec)
Navigating in Nanospace,

'We, researchers, are used to working on a specific scientific problem that is, however, part of something bigger that we usually don’t even consider. In future, I will spend more time contemplating how I, as a layman, observe that bigger picture.' (nanoscientist, University of Antwerp)

'I was pleasantly surprised. Discussing concrete cases with stakeholders and people from different disciplines, surely offers opportunities. When you develop something, you have certain applications in mind, but by talking to stakeholders other options can open up.' (nanoscientist, University of Antwerp)

Someone says it is mainly the developer who benefits from an intensive exchange of knowledge:

'If we want to achieve revolutionary breakthroughs, in which technological innovations go hand in hand with social adaptations to technology, than this kind of forum is both useful and necessary. The imec project on neurodegenerative illnesses is a good example. Such long-term projects are often financed with public funds, making a broad survey justified and in fact compulsory. Although an exchange like this with other actors is no alternative for regulation, it can have an added value for developers, because they will make better products as a result.' (representative ecology movement)

On the other hand, the exercise helps civil society to gain a better insight in the social implications of the routes at hand.

'It was interesting to discover that different technological routes have a different social profile. This means you have a choice. What I mean is, scientists can base their actions on technological and scientific possibilities, as well as on information from society.' (representative of a health insurance fund)

Because there are more options to be considered, tensions can arise as more choices have to be made.

'Where nano and bio meet, uncertainty is common. How far can we go as scientists? It feels like today we are intervening in matters that were in God’s hands only yesterday. Science is starting to fight itself. Will we stop or continue and risk spoiling everything?' (nanoscientist, imec)

The stakeholders also feel that discussing alternatives is not only about expertise, but also about interests.

'The stakeholders were not defending their own interests, they were contributing knowledge together.'

(medical researcher, KU-Leuven)

'The subject went beyond our role as stakeholders.' (representative of a health insurance fund)

With the following nuance:

'In this stage, interests did not play a large role. That will be the case however, when the developments become more concrete.' (Technology Assessment expert)

When stakeholders are asked to help think about alternatives, they also want to be taken seriously. This is clearly shown by the next question:
'Are we expected to provide a support base for technology routes that have already been plotted? Or is there room to influence those routes?' (representative of a health insurance fund)

Or the reaction of a participant to the fact that the NanoSoc consortium had already set the social targets:

'Next time, civil society should feed its own targets into the process. Now, we feel as if we've been presented with a fait accompli.' (representative of an environmental organization)

Some believe that, as long as strategic and economic interests determine the context in which a roadmap exercise is conducted, the effectiveness of the discussion regarding social issues arising during the exercise, remains questionable.

'Can we deal with those issues in a sufficiently independent manner, in function of the main goal: Prevention and optimal treatment of asthma, for as many patients as possible and primarily for those who need it the most, even if they do not have the means to pay for it?' (representative 'Medicine For The People')

'As long as money, jobs, prestige and technology dictate future choices, a humane and thus rational technology development will not be reached! I think this context calls for real change.' (representative of a health insurance fund)

**CLARIFYING REQUIRED KNOWLEDGE AND DIFFERENT ATTITUDES**

It is important to bring enough expertise together at the first stage when designing possible routes. The aim is to converge knowledge of scientists, experts and stakeholders.

'This exercise teaches us that we have to expand the "ecosystem" of participants outside the circle of known industrial and medical partners. That way, a lot of information will enter the discussion.' (nanoscientist, imec)

'Due to a lack of knowledge during the first meeting, it was hard to find a focus for the asthma case. Are we going to aim the route towards the surroundings or the individual? Afterwards, medical practitioners were invited who were able to combine the different subroutes into one relevant route, focusing on the link between the individual and the surroundings.' (nanoscientist, University of Antwerp)

'It's about recognizing our own limitations and involving others as a solution for these limitations.' (nanoscientist, University of Antwerp)

'From the start, you have to keep the route "open" and steer towards cooperation, in order to include social concerns as well. The route for asthma was interesting because it was less clear and concrete at the beginning, making it possible to broaden it. At the end, a route has to transcend the research group. As researcher, you received so much input, that you don't have full control over it anymore.' (nanoscientist imec, nanoscientist University of Antwerp).
This so-called "ecosystem" has to be a complete system. When a technology route is aimed at applications in health care, the point of view of people suffering from the illness has to be taken into account also.

‘What suffering does someone with a neurodegenerative illness experience and what are his needs?’
(representative of a health insurance fund)

‘It is important that patients are consulted from the start during innovative projects that can change the modalities of health care. Patient associations are hands-on experts who know their needs very well. When researchers have to justify why they do or do not react to the concerns of these associations, technologies will enjoy a larger legitimacy and acceptance by the target group.’ (representative Flemish patient platform)

On the other hand, some participants criticize the limited participation of companies in the NanoSoc roadmap exercises, although these stakeholders are mostly well-represented in common roadmap processes.

‘In the NanoSoc exercise, companies representing the promoters of products, are often absent. Nevertheless, they are the ones who decide what technology will be dealt with. Now we are talking in a virtual world.’ (nanoscientist, imec)

With more companies participating in the exercise, the phase of industrial production on a large(r) scale would have probably been discussed more, together with its technical and social consequences.

‘The choice not to commercially work out a certain technology, may well be justified, but it has to be explicitly stated. Projects often stop suddenly when the funding dries up. That is why early research into the exploitation of technology would be justified.’ (representative of a company)

THE ICEBERG. A SERIES OF INTERACTIVE EXERCISES

In the NanoSoc project, developing an integrated roadmap is the last step in a whole series of interactive exercises that are detailed further in this report (see figure 1). The ideas and comments – of nanoscientists, citizens and civil society – brought forward in these exercises, were used in the roadmap exercise as a source of inspiration.

Before starting the interactive exercises, we defined three technology domains, because terms like "nanoscience" and "nanotechnology" are very abstract and ambiguous. The exact meaning of these terms is unclear. The line between what is and what is not nanoscience or -technology, is not clearly defined. Depending on their own research domains, scientists and technologists differ in opinion on this matter.
In any case, a lot of nanotechnologies exist. For this research project, we limited ourselves to three groups, or rather three domains: The construction and manipulation of nanoparticles and mesoporous materials (the case of "New materials"), connecting biological matter to micro- or nanoelectronics (the case of "Bio-on-chip"), and networking tiny computers, communicating wirelessly with each other while forming part of our body, our clothing and our surroundings (the case of "Smart environment").

Below, we will present (1) the different steps of the route, (2) the way in which the NanoSoc team has shaped these exercises, and (3) the results that were derived by the team. The figure below offers an overview to the reader.

![Figure 1: Overview of the different steps](image)

**DEVELOPING NANO-IMAGINARIES**

In both the first and the third step of the route (see figure 1), the NanoSoc team has encouraged the construction of visions or imaginations of possible futures in which nanotechnologies play a part. In the first step, a mixed company was involved, whereas in the third step, only nanoresearchers participated.

**NANO-IMAGINARIES?**

Promoters of nanotechnologies – nanoscientists, research managers, policy makers – are working, most of the time implicitly, with nano-imaginaries. Such imaginations always consist of facts and fiction. They contain fictive, utopian elements, but also take into account technical and scientific feasibility. They are not purely science-fiction, as they are not the product of the fantasy of SF authors, but of that of scientists who believe that their "imaginations" can become reality, precisely because they are working on it.
Navigating in Nanospace,

Nano-imaginaries help determine the direction of research choices. They not only describe the future, they also set out what that future should look like. They respond to the current expectations and concerns, make presumptions about future attitudes and about how social structures, like industry, education, labor market and legislation will look like. That way, they influence their listeners. They provide a wake-up call for possible financers, they stir the interest of the scientific community, they get attention from the media and they stimulate the political and public debate. As such, they help to streamline technical and scientific innovations in society.

The NanoSoc team decided to have a mixed company of nanoscientists, citizens and social experts construct nano-imaginaries. The aim is not to predict our future with nanotechnology, but to challenge common nano-imaginaries circulating in our society, nuance them, diversify them and put them up for discussion. Widespread visions on a future with nanotechnology are in other words enriched by the confrontation with "outsiders": people and social groups who are usually not involved in the decision-making regarding research and development.

By transforming those nano-imaginaries into stories, they become ideal communication platforms for discussions with the general public. Because stories are developed along plotlines and happen in a concrete historical and social context, they make expectations about a desired or non-desired future tangible. Debating with several players about such a story, can develop our collective ability to

- think critically about promises and about so-called inevitable trends in prevailing visions;
- make abstract technologies concrete by placing them in a specific user context;
- get an idea of how the prevailing visions influence scientists and the broader public;
- confront different visions on the (causal) connection between technological and social changes.

**APPRAOCH**

The **first step on our route** (see figure 1) was the joint construction of nano-imaginaries. For each type of application, three imaginations were drawn up. The three domains can be summarized as "bio-on-chip", "new materials" and "smart environment". Except nanoresearchers and citizens with a keen interest in science and technique, others took part who, during their professional activities, come into contact with new technologies (politicians, civil servants, journalists, artists, social scientists). The NanoSoc team has deliberately chosen this diversity to allow a multitude of knowledge and experiences to penetrate the stories. In this regard, sociologist Ulrich Beck (1992) argues to reunite two types of knowledge that have been separated from one another in the course of technologic evolution. On the one hand, there is laboratory knowledge – complex, specialized and depending on the experiment – and on the other hand, there is knowledge based on daily experiences and cultural symbols. According to Beck, we should try

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\text{‘to play off the prejudice of laboratory knowledge against the prejudice of the daily conscience, and vice versa.’}
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First, the participants were invited individually to give their vision on nanotechnological developments in the form of short stories. The essence of these stories was subsequently poured into a catalogue of statements or assertions

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The 9 stories can be found in the NanoSoc brochure ‘Nanotechnologie gewikt en gewogen’, www.nanosoc.be.
on nanotechnological futures by the NanoSoc team. In a next step, the participants – again individually and in writing – could indicate how much they agreed with these statements and substantiate their opinion. Based on these opinions, the team has deducted a series of "drivers" or factors that, according to the participants, influence the direction of technological development (see figure 4). In a final round – no longer anonymous, but interactive – the participants spent a day and a half working with these "drivers" to arrive at a plot, which later could be turned into a fluent, flowing story line by a professional writer. In preparation, the participants thought about possible scenes, characters, time and place.

Figure 2: Elements of nano-imaginaries (case of bio-on-chip)
Navigating in Nanospace,

Figure 3: Participants are drawing the elements of nano-imaginaries

An Inc. truth
- Economically very attractive
- Negative influence on man and environment
- Exploring uncertainties

No more sales
- Economically not attractive
- Positive influence on man and environment
- Exploring uncertainties

Oops, the air is polluted
- Economically very attractive
- Negative influence on man and environment
- Neglecting uncertainties

Figure 4: Titles of three stories and there constituent drivers (case of "New materials")
Only nanoresearchers participated in the third step of the route (see figure 1). Again, they worked together to construct nano-imaginaries based on drawings. This exercise was not planned at the beginning of the NanoSoc project. It was added afterwards because some nanoresearchers indicated that, during the first interactive exercise, they did not have the opportunity to express themselves freely enough on how they saw a possible future with nanotechnology. After all, during that first exercise, their task was to adjust the input of non-scientists based on their own technical and scientific knowledge. Nanoscientists were given the opportunity afterwards to let their imagination run free in a separate exercise, not only in technical and scientific terms, but also based on their own normative points of view. In other words, nanoresearchers no longer had to differentiate between their role as a scientist and as a citizen during this exercise.

OPENINGS...

VISIONS

The NanoSoc team investigated in what way "official" visions – visions that are already going around in policy documents, literature, the media and the press – are being picked up by NanoSoc participants.

First, the NanoSoc participants summed up almost the entire range of nanoapplications that were found in all sorts of public documents.
For the case of "New materials", participants brought up the most diverse applications, ranging from ICT, health, food and agriculture, construction, textile, energy and the environment. This diversity is no surprise, because manipulating matter on a nanoscale can indeed lead to new developments in a broad range of fields.

In the case of "Bio-on-chip", the link was made between nanoelectronics and biological organisms. Participants mentioned different systems, devices and preparations for diagnosing, treating and monitoring in the field of health and the environment. It is striking that the NanoSoc participants paid relatively little attention to enhancement, applications aimed at improving human performance. Except in the field of sports and labor, enhancement was never mentioned.

For the case of "Smart environment", the participants came up with omnipresent and integrated devices, communicating with each other and anticipating the needs of the users. For example, a "smart" fridge ensures that its content is replenished automatically and according to the preferences of the user. Using a PDA (Personal Digital Assistant), students receive custom education, and devoted travelers can choose a personalized itinerary. Smart clothes take care of our physical and mental condition and communicate health problems to our (virtual) doctors through so-called body area networks.

It is remarkable however that participants paid little or no attention to the rather "spectacular" applications. In the stories, military applications were hardly mentioned, nor were the famous nanobots: tiny robots or factories that can build new structures "atom by atom". This is remarkable because nanoresearch in the United States is heavily financed by the military, influencing the focus of nanoresearch worldwide. The fact that nanobots are hardly discussed, is also a surprise because these robots often feature in discussions between researchers. One example is the discussion between Smalley and Drexler, two prominent American nanoresearchers, about the so-
called gray goo scenario in which out-of-control nanobots destroy everything in their path. This scenario also plays an important role in what Mihail C. Roco calls the "original nanotechnology vision" (Roco & Bainbridge, 2002). Also remarkable, is how little attention is paid to products and systems leading to an improvement of human performance, though this has always been an important item of discussion between American and European policymakers (Nordmann, 2002; Roco & Bainbridge, 2002).

When naming nanotechnological applications, there are no significant differences between the groups – nanoscientists, social experts, interested citizens. This could indicate that dominant visions are picked up (or not picked up) by these groups in a similar way.

**CHALLENGES AND CONCERNS**

On the one hand, we expect new technologies to offer an answer to challenges and problems; on the other hand, the introduction of new technologies always goes hand in hand with intended and unintended changes in society that may give rise to concerns among the population.

For promoters of nanoscience and -technology, the most important challenge is often an economic one. Technological innovation is seen as a necessary condition to economic innovation and has to maintain or strengthen our international competitiveness. It is striking that NanoSoc participants, during the construction of their imaginations, barely give an explicit mention of these economic motives. On the other hand, they do not deny the economic importance of nanotechnological innovation. Do they find this argument so obvious, and therefore not suitable for discussion? Or do they believe that economic interests are not necessarily incompatible with responding to social needs?

Within a European context, it is not enough nowadays to merely indicate the economic arguments for technological innovation. The problems with genetically modified crops are a good example of this. Through its science and innovation policy, the EU encourages the research communities to focus their efforts on typical "European" problems, like the ageing population, energy and pollution. Still, NanoSoc participants mentioned much more precise arguments in favor of nanotech. Health and the quality of care provision are the central challenges in the case of "Bio-on-chip". The environmental issue is receiving a lot of attention in the case of “New materials”, especially the high costs due the diminished natural resources and energy sources. Comfort seems the most important challenge in the case of the “Smart environment”. Devices and systems are becoming more user-friendly and people are outsourcing routine household and labor tasks. Other important matters emerge as well as central challenges, like social justice and security of food stocks.

Besides the fact that nanotechnologies can offer a solution for certain problems, participants use their stories to highlight social changes that might lead to discussion and controversy. In their publications, technology promoters often mention the possible effect of nanotech on health, the environment, and the labor market. However, when developing their nano-imaginaries, the participants expressed even more concerns regarding nature (durability, environmental risks, life span of products, energy consumption), the economy (jobs, costs of goods and services, commercialization), and society as a whole (meaning of social relations, gap poor/rich, cultural changes, values and standards, relationship man/machine). Moreover, a lot of participants are concerned about the fact that they have little to say in the development and use of new technologies.
The concerns mentioned are shared by all groups of participants, nanoscientists, social experts and interested citizens.

**DIVERSITY**

The individual stories (first round) gave rise to statements which have been judged by the participants (second round) and translated in "driving factors". Those factors in turn lead to collectively made stories (third round) that were written together. As this process continued, the multitude of visions and appreciations expressed by the participants grew, as did the complexity of their imaginations.

During the first round, the stories are generally positive. It was expected that new technologies would live up to their promises and would be reliable. The social changes often linked to the introduction of new technology, are found to be largely more positive than negative.

Already during the second round, the participants judged the technological and social possibilities of new technologies to be less uniformly positive. Also, more social issues and concerns were put up for discussion. The differences in opinion between participants became more frequent.

Compared to the anonymous, short stories from the first round, which were often anecdotal, the stories that were composed in group were much more elaborate. They show more dimensions of a future society with nanotechnology, there is more differentiation and ranking in the events, in the prevailing values, in the social positions and the roles of characters, and the institutions with which those characters come into contact. The stories illustrate that the potential of new technologies can have very different results, depending on the concrete context in which they are developed and depending on the way in which they are embedded in society.

**... AND CLOSURES**

Some myths are very persistent. For example, the idea that the general public has a mainly negative attitude toward new technologies, or the myth that nanoresearchers are blind to the dangers of nano. Anonymous surveys, conducted before constructing the stories, show that nanoresearchers, citizens and social experts do not have systematically different views on nanotechnology. In general, they envisage the same applications and they have the similar expectations and concerns. Even after comparing the results of the first step (with a mixed group of participants) and the third step (only with nanoresearchers), the NanoSoc team was unable to find clear differences. As the discussions continued, the tone and appreciation, as well as the attention paid to complex interactions between technology and society, became more subtle.

Nanoscientists and citizens did however respond differently to the final tone in the stories. According to some nanoscientists, the stories were generally too negative. They attribute this to the fact that citizens were involved when making them. Some scientists even wonder whether the participation of citizens is desirable. 'After all, are we scientists not citizens as well, and don't we know as well what "citizens" want?'

Moreover, they also feel that involving citizens holds certain risks. They fear that the stories might have a negative impact on the public opinion, and therefore on the available research budgets. Chances are that such criticism on the final negative tone of the stories will affect the legitimacy of the constructed stories as effective platforms for a public debate. However, "negative" reactions are part of the collective learning process NanoSoc represents. One
Navigating in Nanospace, can wonder whether the scientific community’s concerns about the negative attitude of some media and citizens regarding nano are not partly justified. Besides, are these concerns not proof that scientists are involved in the public debate about their research field and that they want to reflect about this? Controversy about the tone of future stories, can be very informative. It can help researchers to think about their identity as scientists in light of the developments in their field of technology. That is also an essential step in NanoSoc’s learning process, even though this step is not free from conflict.

According to some people, only social issues, specific to the nano field, are relevant. It is true that the promises and concerns regarding nanotechnology, are being denounced in a rather general manner. This is also true for discussions regarding nuclear power, biotechnology or other emerging technologies (Swierstra & Rip, 2007). Still, a finding like this, should not be allowed to kill the discussion. Whoever puts this claim forward, is soon no longer inclined to critically reflect on the expectations and concerns that exist regarding nano.

Doesn’t this statement exactly show that our questions and concerns have remained unanswered so far, and that perhaps it is time to do something about them? The fact that important social and ethical questions are at play here – questions that depending on the particular technology would certainly get a more specific meaning – might be enough to stop and think about them. Some social changes may well depend on specific user situations, and are not inherent to the development in the nanofield, still it should not imply that the research community can walk away from its responsibilities. The constructed nano-imaginaries made clear that it had little use to talk about nano in abstract terms. These stories are exactly intended to make the links between technology and practice tangible and debatable.

During the discussions, a recurring question was: ‘What does nanotechnology have to do with this?’ Several considerations can lie at the basis of this question. The question can express the expectation that nanoresearchers are only responsible for matters that are directly linked to nanotechnological developments. The question can also express frustration and the inability of the nanoresearchers who do not appreciate how they can integrate the new insights gathered during the NanoSoc exercises into their research activities. Asking this question however, must not lead to avoiding the debate. Only when we try to discover the motives and considerations behind this simple question, can we take the next step in the collective learning process around nano. It is an important goal of the NanoSoc project to formulate an answer to this question. The previously discussed integrated roadmap, aims to be the instigator of this answer.

**LEARNING MOMENTS**

What does this nano-exercise teach us about designing roadmaps?

When dealing with technological obstacles during the design of a roadmap, these obstacles cannot be viewed separately from the context in which technology is created or embedded. That context comprises science and innovation policies, risk management, legislation regarding right of ownership and user practices. Therefore, not only promoters of new technologies should ensure a better harmony between technological and social developments, it is our collective responsibility. If we want a better understanding of who can play what role, then we need to involve more social groups in the development of new technologies.

However, not all participants find a broad participation important. During discussions with some nanoresearchers, it became evident that they regarded the participation of citizens as a threat for the market success of their
technological findings. Most of the participating citizens however, found the exchange with researchers to be an opportunity, moreover because the exchange took place in an early stage of the technology development.

Of course, these appreciations are tied to different points of view and different interests. A researcher or promoter strongly identifies himself with his technology and really wants to put it on the market. Users worry more about which technologies will cater to their needs. They will compare different technological alternatives. As far as they are concerned, a solution need not even be nanotechnological. Even a non-technological approach may be considered as well. By involving user groups in the development of technologies, it is possible to leave the tunnel vision behind, to broaden the horizon and avoid too many prejudices.

We discovered that participants respond differently to the final stories. Promoters of new technologies sometimes find them too negative in tone, even threatening, whereas others want to leave room for these negative stories, next to the positive ones. Negative stories can help to detect the risks and weaknesses of particular technological developments. Moreover, because the future of nanotechnology depends on the way in which society anticipates uncertainties, certain "negative" stories may be a useful tool to make technology successful (Dupuy&Grinbaum, 2006; Punie et al., 2006).

CITIZENS VISITING THE NANO-IMAGINARIES

During the second step of the route (see figure 1), groups of citizens came together to talk. In each group, a case was discussed: new materials, bio-on-chip, and the "smart" environment. We wanted to ascertain how citizens think about nanotechnology. What do they find important? What is important to them when they come into contact with new technologies?

These citizens' panels are not representative for the whole of Flanders. This is impossible when you invite only sixty citizens. We tried to involve people from different areas and all ranks of society, leading to a diverse perspective which in turn results in diverse reflections.

In our current multicultural society, citizens clash with each other regularly. Moreover, our society changes very fast because of science and technology. Therefore, it is useful to voice our (possibly conflicting) opinions in this matter in an explicit way.

To better understand the arguments of our citizens' panels, we found inspiration in earlier research into the general public, e.g. regarding genetically modified crops and food. This teaches us that it is difficult to grasp the opinion of the general public when it comes to new technologies. Research into the mind of the general public indicates that most people are not necessarily conservative or respond negatively to technological and social changes, despite popular belief. When people are asked to give their opinion on such changes, their reaction is something between enthusiasm and skepticism (Claire Marris et al., 2002). Given these ambivalences, it is impossible to predict how the general public will respond to new technology. The usual sociological parameters, such as class, sex, age, education, religious or political background, no longer suffice. Flemish research into the reaction of the general public to genetic engineering (Jan Claeys et al., 2004) and American research into the acceptance of nanotechnology (DM Kahan et al., 2007) indicate that citizens are rather emotional at first in their response to new technology. Upon closer examination, those emotions are mainly an indication of the "mental" unpreparedness for the introduction of a new technology.
To find out what citizens deem important in light of emergent nanotechnologies, and what values are at play, we organized three workshops, each lasting two days (September – October 2007). Around twenty citizens with various social backgrounds were invited to each workshop. Together with a few nanoresearchers, these citizens "visited" the nano-imaginaries or the nanofutures described in the stories. They looked for answers to questions like: How does it feel to live in those new worlds? How does it feel to have children in these nanofutures, to work, to move about, to relax, get old or sick, have friends, organize the housekeeping?

It is not so easy to find out what people value most. Values are not directly observable. They only become evident from the way in which people act and communicate with one another. That is why groups of participants, together with a professional actor, have re-enacted scenes from the stories by means of role-playing. Both the "actors" and the "observers" were asked to reflect on what they saw, how they felt and what questions they had.

By travelling to an unknown future, citizens have reflected on the present. This is a little trick called alienation. Like returning from a long voyage, our participants looked at today’s society from another perspective. They wondered: 'What does this journey to a possible nanofuture teach us about the present? How does that future differ from today? What do we prefer and why? Which values are important to us today? Which values are open to change? Are there new values already being constructed today?'

In other words, we did not content ourselves with simple premises about how "the public" nowadays thinks about new technologies. The described method enabled us to make the complexity of the public attitude tangible, and to do justice to a broad range of different opinions.

For example, the discussions have shown that enthusiasm and skepticism toward emerging science and technology go hand in hand. Most of the time, citizens express both feelings simultaneously:

'Monitoring a disease results in a higher quality of life. After all, it creates the possibility to spend more time on other things.'

'However, it also makes us dependent, because we no longer trust our instincts.'

'Technology can become a part of ourselves, like the air that we breathe every day.'

'But I want to know who I am, without technology.'

'I don’t mind when a smart environment gets to know me. The system should have the freedom to learn how to combine data about me in a creative way, so it can surprise me from time to time.'

'But I want to know who made what kind of agreements with the system.'
"When you decide to have a chip implanted that will closely monitor your health, then this will prevent illnesses."

"But that way, your health might become an obsession, causing you to worry more."

"I don't appreciate it that people can always reach me on my mobile phone."

"But on the other hand, it gives me a sense of freedom."

We should probably interpret this ambivalent attitude towards emerging sciences and technologies as an expression of inner division, inherent to modern mankind. We want nothing more than to keep up with the times, yet at the same moment we desire to go back in time or ponder over it. Surrounded by all that material comfort and the one-sided economic mindset in our Western society, more and more people feel the need to question themselves and start living more consciously and more intensely. The growing appeal of psychiatric medication, of trainings such as "Mindfulness", of relaxation therapies, etc. is an indication of a looming unhappiness and a hard to define discomfort in our modern-day society.

As was once demonstrated in research with citizens on biotechnology (Claire Marris et al., 2001), discussions in our panels also show that this discomfort can be traced back to two basic attitudes: a sense of powerlessness and a lack of identity.

**SENSE OF POWERLESSNESS**

In a technological and fast-paced society, welcomed by most people who do not wish to turn their backs on it, it becomes gradually more difficult to remain in control. New technological developments go hand in hand with a loss of control.

"I find it strange that people somewhere far away are designing these programs. It is as if a higher power is controlling you, we are no longer in control."

"The more intelligent the system becomes, the stronger my desire to stay on top of it."

"I am afraid that we will no longer have a choice. This is not like choosing whether or not to buy a television."

**LACK OF IDENTITY**

The inner division mankind experiences today, is also linked to the fact that we are not always sure how to deal with these modern times. In most cases, we cannot fall back on religion, ideology or moral "routines" to judge the future. Emerging sciences and technologies are robbing moral of its evident functions. More and more often, people and organizations have new and tough decisions to make, for instance regarding genetics and bioelectronics, confronting them with new questions and dilemmas. This creates growing unrest about the power of those choices (P. Sloterdijk, 2006). On top of that, society seems to offer inadequate support to its citizens in their search for purpose in these modern times. We have to find out ourselves what is right or wrong. In many cases, modern-day man cannot even name his own values and standards. There is little opportunity for reflection.
and the problem is rarely addressed in a systematic way by politicians or social organizations, e.g. via public debates.

‘In the past, things just happened to you. You could say: I never knew that. But now, you have to make deliberate choices all of the time that can be right or wrong.’

‘To me this is very important: The idea that you are who you are, without technology. I think this is extremely important. But still I also find technology very comfortable.’

‘In a smart environment that takes over a lot of educational tasks, the parents are “off the hook” as it were. They do nothing, and therefore can do nothing wrong. The system will take over.’

The fact that citizens have such an ambivalent attitude toward nanotechnology, is due on the one hand to a sense of powerlessness, a loss of control, and on the other hand to a lack of authenticity and identity. In order to take hard decisions, you first have to know who you are or what is important to you, and that is the problem nowadays.

**IN SEARCH FOR CONTROL AND MORAL SUPPORT**

That is exactly why it is so important to get an insight in the arguments behind public opinions about new technology. Citizens will feel called upon to search for moral support and ways in which to (re)gain control.

Because the participants to these exercises have to travel to a concrete nanofuture, they were obliged not to think in abstract terms, but they had to express arguments and remarks, grafted onto the context of the stories.

How concrete was this exercise? Each story was a combination of different "drivers" and had a certain social and political context. Participants also had to re-enact the scenes from those stories. The contexts of those scenes were well-defined as well. The participants knew the characters and their mutual relationships, they knew the social environment of the characters and knew what kind of activities they conducted. When the participants gave their opinion on the way in which the characters from the nine stories dealt with nanotech, they compared this to their own reaction to existing technology.

In other words: In the exercise, the participants situated their review of nanotechnologies, just like they review technologies in the real world.

An exercise like this helps participants to explore both the social context in which technologies are embedded, and the way in which values and preferences get a concrete meaning in that specific context. This learning process can give more control and moral support to the participants, but also to nano-researchers and nano-engineers, regarding the actual nanotechnological developments.

Based on the situation, participants will always look for a new balance between values:

‘[In this situation] I would prefer the cold touch of technology instead of a warm contact with a person, in return for more autonomy.’
Suggestions were made how the technology could best be embedded in a specific user context, so it can comply with a certain value pattern:

‘The more feedback a technology gives to the user [in that situation], the better that user can organize his life independently.’

‘When monitoring with biosensors violates our privacy, people will tend to avoid social contacts.’

‘A bigger learning ability in a technological system, can challenge the user to be creative himself and to take the initiative.’

Participants will investigate common views on people and society in a very critical way:

‘Is it necessary that we can be reached, everywhere, always and in every way?’

‘Is a particular feeling of alienation and loss of control over one’s own life not unavoidable when further implementing biosensors and the smart environment?’

The stories encourage them to pay heed to changing values.

‘Can we call Facebook friends still "real" friends?’

‘In exchange for more comfort, people in a "smart environment" seem to be more inclined to give up their "data" privacy than their physical privacy.’

Participants also question the technological fix. In other words, do we really need a technological solution for everything:

‘Why should we focus on monitoring our body, instead of preventing pollution?’

‘Is recreating nature by some nanotechnology worth the investment, when in fact we are trying to copy what nature has given us for free in the past?’

... AND CLOSURES

By organizing citizens’ panels, we can discover what citizens find important when they are confronted with new technologies. A closer look shows that their expectations are more complex than we would think at first sight.

Technology developers and policy makers in the field of technology can benefit from systematically and continuously gaining an insight in that complexity, especially when they have to make choices, e.g. when designing a roadmap. This is the approach NanoSoc wants to use by means of citizens' panels. According to us, it is a realistic target.
However, expectations regarding citizens' panels are often so high that they become unrealistic. Unfortunately, this increases the skepticism toward citizens' panels so that we risk throwing away the baby with the bathwater.

**LOOKING FOR A SUPPORT BASE**

Some say that a citizens' panel with barely twenty participants is not representative. Behind that commend lies the disproportionate expectation that a citizens' panel could give a decisive answer to the question if there is a sufficient support base for a certain technology. Just like a democratic process in a representative democracy, the legitimacy of a technology is based on a representative make-up of these panels.

Although the arguments put forward in our citizens' panels may feed the political debate, they cannot replace it. The potential and the added value of the citizens' panels lie elsewhere. The success of citizens' panels should not be measured by the realization of a compromise, as is the case during political decision-making. Discussions with citizens can however teach those developing and embedding technology how, when planning social and technical development routes, they should handle and take into account all sorts of appraisals and appreciations.

**PREDICTING**

In some cases, citizens' panels are expected to decide on what consumers will want or think ten or twenty years from now. According to Sheila Jasanoff, American sociologist, such an expectation is proof of a lot of "hubris" (S.Jasanoff, 2006). It is like saying that we can precisely predict the costs and benefits of future technology by surveying citizens today. A public survey teaches us that citizens judge tomorrow's technologies by today's standards and values. But who can say with certainty that those standards will be the same ten or twenty years from now? Neither citizens nor social scientists can put themselves in the shoes of later generations and say what they will find important. Instead of trying to predict values, it is better to organize citizens' panels on a regular basis in an attempt to define what it is that people consider valuable.

**FORMING OPINIONS IN INDIVIDUALS**

The opposite is also true, namely that citizens' panels are often underappreciated or that the bar is not set high enough for them. Often citizens' panels are expected to be useful to help citizens be more aware of their lives and assist them in making conscious choices, e.g. when buying a food product or starting a new therapy. This may be an added value of citizens' panels, but should not be its main goal. In that case we would ignore the fact that a large part of the population is uncomfortable with the speed at which technology is evolving and with the accompanying loss of control and identity.

There is a collective need for reflection to make sense of these new technologies and be responsible for them. It is also a collective task to put this uneasiness on the public agenda.

**LEARNING MOMENTS**

New technologies put people before difficult choices. Citizens are confronted with this in a medical context, they have to give personal data in exchange for more comfort, or they lose part of their control over raising their
children. This leads to the feeling of losing solid ground. It is hard to decide what choice is the right one and people sometimes feel left to their own devices when making decisions.

Exercises with citizens' panels can help restore that solid ground. This has little to do with making certain individuals more empowered, but by making it comprehensible what is at stake when introducing new technology, e.g. nanotechnology.

By putting a new technology and its applications into a story, participants get a better idea of the applications, the society in which they are embedded and the values that play a role. A story about the future also helps us to get in touch with values that are subject to change.

Citizens' panels are experimental gardens in which users reflect and discuss the social implications of technology routes. What if we use biotransducers in children with asthma? What if we give brain implants to elderly people with neurodegenerative illnesses? Depending on the concrete situation, citizens will respond differently, and therefore technologists have to listen to those involved again and again. That way, citizens' panels can be a source of inspiration for developers and have an impact on the concrete planning of their research routes.

In light of emerging technologies, citizens' panels not only offer more insights and support, they also offer a counterweight for the growing fear of losing control. When regarded in this sense, citizens' panels are an exercise in collectively and publicly expressing values and responsibilities, and at the same time, they are an important source of inspiration to promoters of science and technology when making strategic choices.

THE STAKEHOLDER FORUM: ASSIGNING ROLES AND RESPONSIBILITIES

AAPPROACH

The proposed roadmap exercise entails a new procedure for fixing an agenda for nanoresearch. However, this exercise can only succeed insofar as the obtained results are actually put to use later on, that is to say if promoters of research learn something from it. The exercise is not an isolated event either, but is conducted in a specific context. Its success depends on a well-organized scientific undertaking. However, it is exactly this organization that is subject to major changes. Indeed, with the advent of new technologies, different domains – bio, nano, info, cogno – are becoming more and more intertwined. Experts from different disciplines will be prompted to work together. And this convergence of technologies will make us reassess our views on man and society. At the same time, research and development in the field of nanotechnology also create new opportunities for another kind of science and technology governance.

In our conversations with individual researchers at imec and the University of Antwerp, and during the subsequent stakeholder forum, we have repeatedly asked this central question: If we want to give social topics a prominent place on research agendas, how do we go about organizing that? Who is to assume which role or responsibility?

The forum was attended by members of some 30 organizations in very different domains of society: the social service sector, education, industrial and environmental sectors, consumer organizations, the human rights movement, policymakers and scientists. The goal was not to achieve a consensus between all participants in the end, but to allow everyone to gain a better insight into their own views on new developments. We can also divide
the participants of the stakeholder forum into "promoters" of nanoresearch on the one hand, having a direct influence on what is put on the research agendas of nanoscientists, the industry and policymakers, and "users" on the other hand, who will personally experience what the consequences of nanoresearch will be. Out of the 34 organizations represented, 22 can be categorized as users and 12 as promoters. All in all, 45 people sat around the table. The closing panel discussion saw about 100 people participate, several of whom had already participated in previous discussions.

OPENINGS...

A recurring theme in the reasoning of the stakeholder forum's participants is their call for a holistic approach of innovation. According to the participants, we have to look at the bigger picture of innovation. The cohesion between social and technological perspectives must always be made clear. This can be transposed into new platforms of consultation between representatives of technology and of society. Such consultation will only be able to succeed when the roles and responsibilities between the actors concerned are transparently divided.

COHESION BETWEEN SOCIAL AND TECHNOLOGICAL PERSPECTIVES

Depending on which phase a technological innovation route is currently going through (determining the research agenda, the actual research and development, use of a new technology), participants have quite differing interpretations of such a holistic view.

When the research agenda is set, the focus is on aligning research with society's very diverse needs. But, participants say, neither the government nor the market have succeeded in doing this in the past. That is why it is a good thing to keep investigating with a critical eye how social trends and new technologies become interlaced and possibly reinforce each other. We need only think of the growing attention paid to our bodies: For many people today, their body is the basis of their identity and 'enhancement technologies' are capitalizing on that. Or how about the interaction between our focus on autonomy and authenticity, and the technological possibilities to enable "remote care"? Merely extrapolating trends and offering a technological answer to them, however, can be dangerous. This might cause us to cross a critical line, into a situation where technology ultimately offers more disadvantages than advantages.

During actual research and development, participants say it is important for researchers and engineers to keep certain guiding principles in mind. The principle that a technology route has to be sustainable is one of them. One must have an eye for environmental and health risks, for instance, and try to follow the technology's entire life cycle closely, including the energy and resource consumption. Non-technological solutions to a problem must not be brushed aside without good reason. Furthermore, the followed course must be plotted in such a way that researchers can always go back and retrace their steps.

Being open to the complexity of the general public's reactions to emerging technologies can be another guiding principle. New scientific developments and technologies are bound to elicit ambivalent reactions from the general public. Rather than merely dismissing such reactions as 'emotional' and irrelevant, we ought to consider them as manifestations of introspection. Individuals and groups appear inclined to question themselves and their own values, when confronted with new evolutions. Technological development can take advantage of this introspective tendency in society.
After all, as the stakeholder forum's participants argue, the eventual usage of a technology must be considered as early on as possible during its development. For instance by questions such as: Can people handle that much knowledge about their medical future? What if an implant stimulates excessively? Who is accountable? Are we building in sufficient ‘practicing time’ for future users?

**CONSULTATION PLATFORMS**

A holistic view on technological innovation is only likely to flourish if society as a whole and the research networks and research organizations in particular, make room for it. According to the forum's participants, this implies today, at these different levels, a critical inquiry into the stereotypical roles and responsibilities taken up or delegated by the parties concerned.

**SOCIETY**

Currently it is the market and the government through funding and licensing, who decide which direction technological research will follow. The stakeholder forum's participants wonder whether these classic players alone will be enough in the future. Participants have more faith in consultation platforms situated between both levels, where researchers and stakeholders/citizens debate about the new technologies.

'A highly integrated consultation body is important. Consultation between scientists and target audiences today is all but nonexistent. People are always going on about technological innovation. Why not innovate the forms of consultation? How do you bring people together again?' (forum)

'Our visit to imec made clear that they are five to seven years ahead when it comes to the introduction of innovative technologies in society. Researchers and the industry are already making choices now, without any patient participation. That is a problem.' (forum)

'Besides a dialogue with representative stakeholders, citizens must play a role as well. It must be possible to create forums for citizens, where people can voice in simple terms what they want, how they want to exist and how they want to organize their lives.' (forum)

'The solution is maintaining dialogue and gradual innovation. Of course one can draft a long-term plan or roadmap, but the process must be kept transparent and constant assessment and feedback from users is vital.' (imec, interview)

**RESEARCH NETWORKS**
Participants say that corporations and research groups should describe more clearly who is responsible for which part of the development and use of a technology.

Solid management of such research networks should shed some light on questions such as: 'How are the mandates divided? Who is expected to do what? How do we make clear to other partners what the consequences of our actions are?'

A transparent division of responsibilities can help set clear agendas that are efficiently tailored to one another. This is the only way for collective responsibility for an application to be organized properly.

‘Who will take the responsibility to guide the evolution toward 'remote healthcare'? Who will still want to do that? Is it even necessary to have someone be ultimately responsible in case something goes awry? Healthcare is gradually evolving into team care.’ (forum)

‘I think that we need to define everyone’s responsibilities very clearly right from the start. All cards need to be put on the table: economic, toxicological and institutional. Based on that overall picture you can assign responsibilities.’ (forum)

For the purpose of increased transparency regarding responsibilities, it is probably advisable for a research group or organization to aim for a higher degree of independence from the networks of which it is a member. Such independence can be financial, but also in relation to expanding one’s own room for possibly blazing a new trail in research and development.

‘Are we not faced with the problem of research being organized mostly top-down? More research funds coming from the outside always means more top-down research.’

‘This is precisely why research structures have to change. Responsibilities must be organized both top-down and bottom-up. This is the only way for the corporate culture to change.’ (forum)

‘It is vital that we do not all go in the same direction. I think we have to try something new from time to time. Today there is more and more clustering and everyone keeps going down the trodden paths. This entails quite a few risks.’ (forum)
THE RESEARCH INSTITUTE

Individual scientists speak of an area of tension between the feeling that they are partially responsible for new developments on the one hand and their inability to fully assume that responsibility on the other hand.

‘Research is like a highway. Once you are on it, the wheels are set in motion and you start developing. I would prefer to see people reflect a little more on their own research. Am I myself convinced of this research project I am working on? Now, this seems a foregone conclusion from the start.’ (forum)

‘Quite a few experts do reflect, but not necessarily about their work. There is too little time for reflection.’ (forum)

‘If we, scientists, are told what to do, we are unhappy. Citizens would not put up with it either if you were to say: “Here you go, this is the technology. Now just use it!”’ (imec, interview)

‘On the other hand I do think about the implications. Many things have a high fun factor. I just don’t see the immediate need for it.’ (imec, interview)

‘I am not responsible if an application is abused, but you put your personal values in technology and as such into society. This is not a neutral activity.’ (interview, University of Antwerp)

‘There is a responsibility for scientists to make all these nice things work in all their complications. So I feel responsible about those chips and if people make nasty stories about it, I feel attacked because that’s what I do, that’s my work and I don’t like it when people have fancy or dark ideas about that.’ (imec, interview)

‘I reckon some people don’t have the patience to wait and see whether or not something is of use to the outside world. You can try to debate the issue for a little while, but once the decision is made high up, there is not much left to do about it.’ (imec, interview)

Building in the time to slow down, take a step back and reflect in the research organization is not necessarily counterproductive. On the contrary, it can even boost innovation, especially when this reflection happens in an early stage of development.

‘If the social issues are brought up at the beginning and influence the researchers’ drive, you will probably see a different situation.’ (forum)

‘Creative debate in an early phase is vital. Most scientists really are willing to discuss the social scope of their research.’ (forum)

‘It may be interesting to reflect on the subject together with outsiders, in order to generate new ideas and better understand the question at hand. It may very well be that the question is not what we presume.’ (imec, interview)
'I love discussions, because discussions open up our minds. Diversity is an asset, because at the end of the journey it might enable us to come up with better solutions.' (interview, University of Antwerp)

The importance of a corporate culture growing organically through internal discussion and reflection is not to be underestimated. As a matter of fact, according to sociologist Scott Lash (U. Beck et al., 1994) this culture is gaining ground, parallel to an increasing pluralism. This drives scientists in research institutes to look for like-minded people, when it comes to beliefs and lifestyles. They do not only do this within the walls of their own facility, but also in the ever increasing exchanges in research networks. This way, Lash argues, research institutes in today's society are becoming "deeply cultural in nature". In other words, the importance of discussing views and values in such organizations is on the rise.

'I would personally find some satisfaction in knowing that our institution is consciously considering social issues. Some researchers should be called to account and be presented with a strategy. But all the while society at large should also be occupied with these issues.' (interview, imec)

... AND CLOSURES

A holistic approach, as championed in the stakeholder forum, is only as viable as the research network is transparent. In other words, it needs to be clear who assumes which role and responsibility. A holistic approach basically implies that a very diverse group of individuals all rally behind the accumulated knowledge and the possible applications, as well as behind the same picture of the future. This requires for research networks to be managed transparently.

The growing complexity of technological innovation can be an obstacle here, however. Current knowledge allows researchers to intervene ever more profoundly in man and society, which raises the question of how far down the road one can still estimate the implications of all these actions. In light of this evolution, research networks must consider issues such as responsibility, liability and accountability in a new way.

'We must not forget that there are countless nanoparticles that we do not control. The air we breathe is teeming with nanoparticles as it is, and as materials will become more advanced, wear and tear will lead to more and more nanoparticles in the air. The challenge is to measure these particles, because today there is a big gap between what we can measure and what is actually present.' (forum)

Knowledge centers will operate more and more in networks managing many risks. Will the current organizational principles still stand then? Back when consequences and risks of new technologies were fairly easy to estimate, the roles and responsibilities could be divided neatly and easily. In doing this, the principle of 'functional differentiation' was adhered to. The knowledge value chain was split up into a cluster of monofunctional entities, at the same time enabling an increase in scale. The successive tasks involved in the development of knowledge and technology were split up and neatly divided among separate entities (corporations, universities, research institutes). In this kind of organizational model the individual partners did not have to keep an overall view of the bigger picture and they could dedicate their activities exclusively to their own expertise.
"Pharmaceutical companies set the technological needs. How they arrive at formulating those needs, we don’t know. How they determine their roadmaps, we don’t know either. They don’t share their strategy with us. They are in contact with patient organizations, though, but they don’t share this information with us.‘ (Interview, imec)

But what if scientific and technological developments are increasingly open-ended in nature, with regard to both the promises that were made and the possible adverse effects? What if it keeps getting harder to determine which effects will manifest themselves where and when? Can the current networks still be held responsible for collectively accumulated knowledge in such situations? Sociologist Ulrich Beck (1992) sees the rise of a dynamic he calls "organized irresponsibility". All partners are inclined to attribute responsibility for unexpected – adverse – effects outside their own organization. They deny, renounce and place the ball in someone else’s court.

Our interviews show that certain nanoscientists subscribe to this dynamic. The following kind of statements might nip the debate about responsible management of nanotechnology in the bud.

‘As a scientist you stick to the scientific work and what happens next, is not your responsibility. That is the responsibility of the company and the company will say: "Well, it’s not ours, it’s the consumers! Because if they don’t want, they don’t have to buy it.”‘ (interview, University of Antwerp)

‘Supplying academic output and creating industrial leverage, those are our performance criteria. Realizing these goals leaves little room, or time, for researchers themselves to reflect.’ (imec, interview)

‘Here is just one example. At imec, we think about the way a doctor can accumulate as much data about his patient as possible in an efficient way. What we don’t consider, however, unless maybe during coffee breaks, is what insurance companies can do with that information. Let’s say that my insurance company allows me to drink two beers a day and they find out I’ve been having three. Will they then pull out when I get a heart attack?’ (imec, interview)

‘Through cooperation with the industry we are in fact considering socially relevant issues. But we don’t actively look for social meaning to attribute to our research.’ (interview, University of Antwerp)

‘Sociologists are supposed to better understand how society works, they should give feedback to the scientists, an interaction is needed, and the information flow should go in both directions. I have my personal perception about how society reacts, but I can be wrong. I’m sure there is plenty of literature in this field.’ (imec, interview)
'Don’t place the ball in our court. Except for scientific research, people should be paid to think about that – say, the interface at VIB for instance. (interview, nanoscientist, Catholic University of Leuven)

'Researchers spend little time thinking about such things and I don’t encourage them to. I may sound like a cold-hearted manager, but you know, corporations don’t ask us to, and we really have no business engaging in such considerations. What’s more, I think corporations should engage in this exercise themselves. As a corporation you should know that people, when constantly monitored and unsure as to what will happen with the data, might just reject the technology.' (imec, interview)

LEARNING MOMENTS

The stakeholder forum and the preliminary talks with scientists have yielded a number of meaningful suggestions for preparing a roadmap.

LESSON 1: ALWAYS KEEP IN MIND THE OVERALL PICTURE OF INNOVATION

Translated to phase 1 of the roadmap, where the relevant scientific, technological and social problems are explored, this lesson is about how we must not extrapolate technological or social trends too lightly. Some trends, in spite of initially improving the well-being of users, can end up having the opposite effect and ultimately meet with negative reactions. For instance, a ten percent increase in the use of ICT is great, but what does this mean for the power supply, for waste management or time spent at the home computer? At a certain point the trend reaches an absolute threshold where new problems crop up. It is vital to subject such trends to critical review when preparing a roadmap.

In phase 2 of the roadmap, technological routes are presented and goals and target audiences are considered. The guiding principles that were discussed during the forum can come into play here. "Taking into account citizens' identity and self-image" or a principle like "sustainability" can give something to go on when goals are picked and target audiences need to be defined.

In phase 3 alternative technological routes are compared and judged on the basis of their implications on society. Moreover, draft rules are tested against specific user situations. The stakeholder forum has shown that the eventual use of a technology should be considered from the early stages of its development onward. The roadmap should, especially in this phase, also provide the option to retrace one’s steps to the previous phase, so as to provide an answer to the users’ need for some "practicing time".
LESSON 2: A HOLISTIC APPROACH REQUIRES (RADICAL) INSTITUTIONAL AND ORGANIZATIONAL INITIATIVES

Flanders ought to organize platforms for each technological domain, where scientists, citizens and civil society are constantly talking to each other. After all, a roadmap needs ongoing dialogue, combined with only gradual innovation. This is the only way to enable feedback and assessment throughout the process.

In order to increase an integrated roadmap’s chances of success, research networks need to undergo changes as well. Research groups or organizations could aim for more elbowroom in the networks of which they are a member. Well-harmonized research agendas are also a must, because this allows for the transparent division of roles and responsibilities.

Imec, at any rate, feels this need because the disciplines keep on converging and because this research institute attaches significant importance to providing constant feedback to its partners:

'Cooperation is needed between biotechnologists, computer scientists, sociologists and the like. Convergence and interdisciplinarity should ensure the exchange of the specialized knowledge present. Sharing intellectual property is a new phenomenon. Corporations used to conduct research themselves and even when outsourcing it, the results would still remain their exclusive property. These last few years, however, we see an evolution toward corporate models where broad, often multidisciplinary, generic problems are solved by a group of companies who share the costs, often in association with research centers. Imec’s cooperation model is an international pioneer and textbook example in this field. The impact of research results in this field on other industrial sectors is massive. The chip, for example, is now at the heart of all electronic devices. Such research therefore deserves sufficient attention, in order to create tomorrow’s smart, people-friendly environment.' (Imec/IWT leaflet about the smart environment, 2003)

Finally, the research institute had better not disregard the importance of an organically growing culture of discussion and reflection in research environments. Anticipating this can not only yield valuable ideas for preparing a roadmap, but can also help an institution create a distinct profile, positioning itself in society.
Nanotechnologies bring the promise of major solutions to present-day problems and challenges. Hopes are high, but there is also doubt - both among promoters of these developments and among the public at large. The most doubt is cast on what exactly constitutes proper nanoscience and nanotechnology management. Science and technology "management" is the set of rules, procedures and practices governing science and technology's progress and general direction.

Nanotechnology promoters start doubting when it comes to reconciling their strategic research plans with an uncertain future, or when they find that there are still many gaps in the knowledge that is needed to realize the innovations put forward.

The public's concern is not so much with the scientific and technological side of things, but rather with a lack of confidence in the way the promoters involved actually manage and guide technological development. Doubts voiced by the public should therefore not be dismissed too lightly as emotional reactions or as merely poor knowledge of the subject. It is precisely this kind of doubt that should prompt better management of research and development.

Research managers in companies and public research institutes have already voiced their concerns regarding the Flemish innovation policy in the past (L.Goorden, 2004). They have raised the following questions:

1) How do we cope with the growing complexity and uncertainty that go hand in hand with innovations in science and technology? Various disciplines and kinds of expertise meet on the nanolevel and work together toward a common goal, but everyone looks at the same reality from a different perspective. Technological innovation is becoming more complex, so consultation between the actors involved is needed now more than ever. This raises the question of whether the government should intervene as moderator and translator, steering cooperation in the right direction.

2) What is the public value of the research, in which we are all, both private companies and the government, investing? By 2010, Flanders wants to spend three percent of its GNP on research and development\(^4\). But will technological innovation also mean progress for society? Do we not need a strategy, a vision for the future describing which challenges should be dealt with first in the Flemish research? And will the companies acting from a profit and shareholder perspective consider participation in such research a win-win situation?

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\(^4\) In 2002 the Council of Europe decided in Barcelona that by 2010, every European Member State was to allocate at least three percent of its GNP to research and development. Two thirds of the investments have to be privately funded. Flanders subscribed to this objective in 2003 with the launch of the ‘Innovation Pact’.
3) Lastly, will there be a sufficient support base for the technological innovations already in the pipeline? Recent controversy about launching technologies such as biotech or GMOs leads to caution and doubt. Maybe science and technology should occupy a far more prominent place in public and political debates. And should we not focus a lot more on educating the public about new technologies?

In essence, these doubts boil down to three key questions:

- what are the knowledge and procedures needed to cope with the ever-growing complexity of technological innovation?
- what are the criteria we can use to justify how priorities are set in research and development?
- how will the general public’s attitude toward new technologies evolve?

What research managers are really wondering is whether management of knowledge on the nanolevel is not too focused on certainties which may have applied in the past, but are now slowly becoming outdated. In other words, is the innovation policy regarding nanotechnology based on the wrong assumptions?

**SCIENTIFIC UNCERTAINTY**

Up until now the main assumption has been that innovation policy is founded on a thorough scientific understanding of man and nature. More knowledge helps researchers to predict and assess the risks and effects of technological developments. However, research also indicates that structures and systems on a nanoscale not only exhibit unexpected and surprisingly useful properties; they also contain new risks that are difficult to anticipate. Human knowledge is growing. Problems created in the past can be exposed and assessed more accurately today. Still there is no unequivocal connection between the growth of our knowledge and the fundamental understanding we gather of ourselves and the world around us. More specifically, our capacity to intervene technologically on a nanoscale in man and nature is growing, but at the same time we find that we do not have the same capacity to predict and control the effects of our interventions. Today we might have an idea of what we know, but we are not sure how much we do not know.

**STRATEGIC UNCERTAINTY**

The accumulation of knowledge today – ranging from basic research to technological applications – is considered to be a linear process that eventually always leads to benefits for society. A government can accelerate this process through its research policy, in order to reap the benefits of new technology faster, or slow it down, such as when unexpected problems occur. The process itself, however, seems to follow an internal logic that always leads to progress for society, one way or another.

Yet pollution and global warming, along with the consequences of modern production and consumption, prove that the introduction of technical/scientific inventions is not necessarily good, or at least not only good, for society. The practice of research, too, indicates that science and technology are shaped and guided by a multitude of choices and decisions, made by networks of knowledge centers, policy bodies and corporations. As it is about choices, those choices can be influenced. In other words, sound nanotechnology management can follow different directions.
Navigating in Nanospace,

NORMATIVE UNCERTAINTY

It is usually taken for granted that public consensus on science and technology can be realized. As long as we communicate efficiently, as long as we educate people sufficiently, interact with them and gain their trust, their values and their standards will adapt and they will embrace the new technologies. How can we reconcile this with the ongoing controversy about new developments? Examples abound: Genetically modified crops and foods, nuclear technology, designer babies, stem cell research, animal cloning, brain implants, synthetically made organisms, cerebral computer interfaces, and so on. Ambivalent reactions to the introduction of new technologies will become the norm rather than the exception in days to come. Or as it is worded in Paul Haggis' acclaimed motion picture 'Crash': 'Modern life is so fast-paced that we cannot avoid crashing into each other'.

In this climate of increasing uncertainty – be it scientific, strategic or normative – we need to find a different approach to dealing with doubts. European policy makers and scientists are already making a case for collective "experiments", "in society's laboratory", where we learn to cope with increasing uncertainty together. In establishing this NanoSoc project, we went and gathered information in the United States, where the Centers for Nanotechnology in Society (CNS) too are interested in an improved anticipation of uncertainties. Rather than deny them, we need to prepare for unforeseen twists and turns along the way.

NANOSOC FOR THE BENEFIT OF ANTICIPATORY GOVERNANCE

American sociologist Sheila Jasanoff (2006) argues that science and technology promoters have two ways to deal with insecurities, characteristic of emerging science and technology. The first and formerly the most common way is based on what she describes as hubris – pride goes before a fall, you might say. This attitude is based on the assumption that there is an objective and definite basis for making decisions about science and technology.

1. The "hubristic" answer to scientific and technological complexity or ignorance is a set of methods designed to obtain a "precise and quantitative calculation" of future risks. One presumes to be able to predict the odds of negative effects and what the extent of such effects will be.

2. When faced with strategic uncertainty, or uncertainty about priorities and the general direction of the research, trust is placed in methods predicting the "most likely future" as accurately as possible.

3. In light of normative uncertainty, or uncertainty about how values and standards evolve, the strategy of calculating in detail the costs and benefits of a technological change will prevail. It is in this context also implicitly expected that an objective assessment and a cost-benefit analysis will lead to a consensus among stakeholders.

Such a presumptuous attitude trivializes any and all uncertainties. According to Jasanoff it is better not to strive toward "sure" decisions, but rather toward "solid" decisions in science and technology. Solid is to be
interpreted as able to withstand some adversity and to be sufficiently substantiated so as not to topple over at the slightest gust of wind. Jasanoff promotes a policy that prepares for unexpected events, such as when new knowledge arises or new values and interests come into play.

Such anticipatory governance of science and technology is founded on the following principles:

1. If it turns out that we are unable to calculate all risks exactly, we had better not put all our eggs in one basket.

2. Because the future is unknown, we ought to focus our attention on today's research and technology choices. The visions underlying these choices will help determine what tomorrow will look like.

3. Since, in our rapidly changing and ever more complex society, reaching a consensus on new technologies is turning out to be a utopian dream, we had better consider the wide variety of perspectives before making decisions about science and technology.

In a word, nanoscience pushes us toward humility and sound management, anticipating what might come. This way, uncertainties are not denied and decent preparations for the future are made.

According to our American colleagues of the Center for Nanotechnology in Society at Arizona State University, such anticipatory governance in nanoscience requires three key competences (D.Barben et al., 2008).

SEEING ALTERNATIVES

A first competence is the art of seeing and understanding the available scientific and technological alternatives. Not putting all one's eggs in one basket means that one investigates (as) many options (as possible) when drafting a research plan. This is a gradual learning process, which takes time and money and is therefore best organized collectively with science and technology promoters and potential users. After all, timely input and exchange of knowhow and experience yields a better understanding of possible alternatives. Developing knowhow in scientists is one thing, but many other competences are required to turn a discovery into a ready-to-use innovation.

IMAGINATION

A second competence is imagination, the power to conceive of a future where nanotechnology is in use. Scientific and technological innovation greatly benefits from circulating visions that are richer and more varied. After all, visions exert an influence on today's research decisions and therefore on tomorrow's way of living. Current visions of the future, featured in the media, popular science columns and policy documents, prove to be very one-sided and biased. In short, rather than pursuing knowledge about a future that cannot be predicted, we ought to spur imagination about possible versions of the future. Or as Einstein put it:

'Imagination is more important than knowledge. For knowledge is limited to all we know now and understand. While imagination embraces the entire world and all there will be to know and understand.'
Exercises in imagination will inspire scientists and engineers in their choices and will enable them to get a better understanding of how technological and social changes are intertwined.

**NAMING VALUES**

Finally, we need to learn to constantly keep recognizing and naming the ever-changing values and perspectives in the field of technology. Scientific and technological developments indeed evoke mixed feelings. Scientists do not have at their disposal a timeless checklist of our pattern of values, on the basis of which they could test the pros and cons of a new technology. Individuals and groups review their values constantly and in doing so they question themselves. This is why regular articulation of values is important, all the while keeping in mind cultural ties, plurality and flexibility through time.

**NANOSOC AS A JOINT AGENDA-FIXING EXPERIMENT**

NanoSoc is a joint experiment in support of anticipatory governance in Flanders. This project endorses the basic philosophy set out in the European report titled *Converging Technologies: Shaping the Future of European Societies* (A. Nordmann, 2002).

According to the report’s authors, it is not the government’s task to impose an agenda, a vision or predetermined goals on nanoscientists and nanotechnologists. Nevertheless it can be useful to experiment with new procedures of setting the research and development agenda. Those could start from the following questions. What do citizens want? What does society want? Can a combination of knowledge and technologies fulfill these needs?

Encouraging social innovations can be a way to promote technological development. How do we improve elderly people’s ability to live independently? How can we make travel more efficient and environmentally friendly in the future? How can we eradicate malaria? What can improve certain patients’ quality of life?

Setting the research and development agenda this way, will guarantee that information, for instance about roadmaps, can be exchanged in two directions. This contrasts sharply with the way such communication is carried out today, that is to say unilaterally from the experts to politics and society.

In such experiments it pays off to elicit so-called “informed differences of opinion”, rather than terminate the debate prematurely. This is the only way to see the wide variety of possible futures where people use nanotechnology. Differences of opinion in society should not be considered as obstacles for innovation, but as a source of inspiration for the selection of socially relevant technologies. That way, agenda-setting experiments can also be turned into exercises in reformulating a region’s (Flanders’ or Europe’s) own identity.

Such experiments with interactive agenda-fixing processes – including NanoSoc – are based on an optimistic presupposition: Society can influence technology routes. We are, however, not sure of this and in reality the impact of society depends on the whims of politics and other interests. But can this not be said for any experiment? An uncertain outcome?
When mapping out a policy for science and technology, policymakers will undoubtedly encounter uncertainties. The challenge is to deal with unintended and unexpected consequences of scientific and technological developments in an efficient manner. This tightrope exercise has on occasion led to very contradictory governance strategies in Flanders.

The Eighties

In the eighties, Flanders goes through a radical change, shifting from traditional industry to high-tech activities. This process is accompanied by major uncertainty about the direction in which certain things are evolving. In reaction to this uncertainty, Flemish policymakers take refuge in a centralized top-down policy. Public funds are to support research in areas that offer the promise of new applications, such as microelectronics and biotechnology. This approach results from a linear vision on innovation, based on the assumption that funded basic research will automatically lead to technological development and ultimately to new product launches. Giving researchers the means to follow their scientific intuition in certain broad domains is the fastest and most efficient way to realize new discoveries. Implicitly it is assumed, however, that government or society have no control over the direction in which science and technology are evolving. Technical and scientific developments can merely be sped up or slowed down, but not adjusted.

It is around the same time that the concept of technology assessment is first found in Flemish policy documents. Technology assessment is a scientific and communicative activity, meant to shape the public and political opinion about social aspects of science and technology. Because it was assumed that scientific and technological routes evolved independently, technology assessment in Flanders was initially focused mostly on the end point of such routes. What are the possible risks and consequences of this? In this approach it is presupposed that one can reliably predict the consequences of new technologies and that politicians will also base their policies on this scientific information, e.g. to develop a risk policy in time. This allows for negative consequences to be prevented or at least controlled.

It does not take very long for this top-down approach to meet its limitations. Funds intended to support basic research have not automatically yielded technological innovation. An "innovation paradox" occurs. Flanders, and by extension Europe, excelled in fostering knowledge, but was unable to market it by way of products. Funding priority research domains with government money was no more than a lottery.

The idea of focusing technology assessment on early predictions of negative consequences, in order to try to avoid them, was now being undermined as well, because this approach passes over the fact that new technologies are (sometimes) accompanied by radical changes in society that cannot be predicted. Finally, if one would be able to predict, this information would not have had a significant impact on scientific decisions, because the technology assessment research occurred in social sciences, institutionally separated from both scientific research and politics.
THE NINETIES

As a reaction to this, in the nineties the focus of Flanders' research and technology policy shifts to a bottom-up approach. Policymakers no longer guide research programs in certain technological research domains, but encourage "spontaneous" partnerships, forged "organically" between science and technology promoters (universities, research institutes and corporations). Technology assessment is still being used, but according to a policy document drafted in this period 'it should not slow down or compromise the creativity of the innovation process'. From now on the TA-exercise is performed in close collaboration with the research management of publically financed research and technology institutions such as VIB, VITO, IWT or SCK. Dedicated technology assessment cells are established for this purpose.
The fact that the TA-exercise is now also done in places where research and development are actually being conducted entails the advantage that scientists and engineers themselves are now invited to think critically about their research practices and choices. However, practice has taught that this reflection soon turns into merely taking possible risks and market potential into account. Checking with society what their expectations and concerns are is, however, not possible given the 'closed' institutional environment in which research into new technologies is being conducted. Furthermore, in this period in Flanders there is no systematic public debate on science and technology whatsoever.

EARLY 2000

To correct this issue, technology assessment is moved to the 'Institution for Society and Technology' (IST), a new institution that will be advising the Flemish Parliament. The idea is to enrich the social debate on new technologies, since discussions on GMOs, cell phone radiation, nuclear technology and the like are bogged down by disputes about potential risks, while more fundamental questions about values, visions and interests are not addressed. The IST is expected to provide these arguments, in order to foster both the public debate and discussions in the Flemish hemicycle, and to attain a political compromise on these issues. The institution has partially succeeded in this task. The repertory of arguments in the governance debate is effectively broadening and becoming more diverse. Yet controversy persists and stalemates, such as between proponents and opponents of GMOs and cellular towers, are multiplying. Moreover, the institution continues to operate outside of the research environment and therefore its technology assessment system has but a limited impact on science and technology development itself.

NANOSOC (2006-2010)

The NanoSoc project is a collective experiment for the sound management of nanotechnologies and wants to learn from previous experiences with innovation governance and technology assessment. In order to do this it takes lessons from the development that technology assessment has gone through in Flanders and in other countries. Equally important in the coming about of NanoSoc are the recent shifts of focus in the Flemish innovation policy, intended to improve dealing with the unpredictability of technical and scientific developments.
WHAT CAN WE LEARN FROM THE EIGHTIES?

Guiding basic research using a top-down approach in certain fields and the expectation that this allegedly linear process automatically results in technological innovations has yielded very few convincing results. Technology assessment research to predict the effects of the process on society was hardly more successful.

After all, this governance approach is founded on the major misconception that technological development follows a natural inherent logic. Proponents of this approach gloss over the fact that certain imaginations or visions regarding man, nature and society always underlie the production of knowledge. Visions dictate, however subconsciously, where research is going. Or as science philosopher Dupuy (2007) said it:

'Men dream science before doing it and these dreams, which can take the form of science fiction, have a causal effect on the world and transform the human condition'.

Articulating such visions of the future and bringing them up for discussion can be enough to perforate the fiction of a linear development and to start employing more deliberately fostered knowledge for specific innovations.

In a recent memorandum on Flemish innovation policy entitled 'Innovatie' (K.Debackere, 2008) a case is made to fill this void. It is argued that the innovation policy must also encourage public imagination about social innovations, in the field of care, labor, mobility and the like. The ideas generated by such reflection will motivate scientists, according to the memorandum, to "widen" their innovation routes, which in turn facilitates the introduction of innovation into society (Lever 9).

This ambition fits in with a recent movement in technology assessment thinking in Great-Britain. The so-called Upstream Public Engagement strives to widen and diversify the social considerations that help shape science and technology in an early stage of research and development. Ideally, this approach strives to obtain a situation

'where scientific 'excellence' is automatically taken to include reflection and wider engagement on social and ethical dimensions' (Wilsdon et al. 2005a).

WHAT CAN WE LEARN FROM THE NINETIES?

In the nineties the idea was rightly abandoned that a government could or should impose top-down research agendas to scientists. From now on, government would stimulate spontaneous partnerships and create room within research & development itself for reflection on one’s own choices (=technology assessment). Only in this period there was a lack of public reflection or debate about what constitutes socially relevant choices. It just so happens that this is the very information researchers need as inspiration for their research choices.

In the aforementioned memorandum 'Innovatie' (K.Debackere, 2008) a case is made for ideas that exist in society about relevant research to be taken into account in selecting research projects. It is suggested, for example, to start including "relevance" besides scientific excellence in the list of criteria for judging and financing basic research in universities and other knowledge centers. Research is "relevant" if it is founded on
Navigating in Nanospace, a clear need, where the term "need" is to be understood as encompassing more than purely economic needs ('Breakthrough 2.3.').

This ambition can be reconciled with another variation of technology assessment, which originated in the United States. The so-called Real Time Technology Assessment or RTTA stresses the reflexive capacity of researchers and aims

\[\text{to build into the R&D enterprise itself a reflexive capacity that encourages more effective communication among potential stakeholders, elicits more knowledge of evolving stakeholder capabilities, preferences and values, and allows modulation of innovation paths and outcomes in response to ongoing analysis and discourse} \] (Guston and Sarewitz, 2002).

WHAT CAN WE LEARN FROM 2000 AND BEYOND?

Political consultations are basically geared toward finding a compromise for all parties involved. Since 2000, technology assessment is expected to aid policymakers in achieving this goal. However in this logic, with the creation of conferences for citizens and forums for stakeholders, technology assessment would sometimes come too late, when debate is already corrupted and nobody can see a way out. This entails the risk of narrowing the use of technology assessment to damage control.

It looks as if citizens will continue to respond to new technologies with increasingly mixed feelings. If a new technology is launched, groups of citizens will feel forced time and again to reassess their values and their identity. In that light there needs to be room for different opinions early on in the research and the debate must not be nipped in the bud for the sake of political compromise.

An extract from the 'Innovatie' memorandum stresses the importance of an early, open debate and wants to involve multiple actors from society in this debate, not just the traditional promoters of innovation processes (Lever 4).

Getting (future) users involved at a stage where the technology is still "under construction" is key in the so-called Constructive Technology Assessment, another variation on technology assessment, developed in the eighties by Arie Rip (1997). In his approach he makes a case for decent follow-up and analysis of interactions between science and society, between promoters and users of a technology. Based on what one takes away from that, one will be able to influence these interactions more effectively.
CONCLUSION

The advent of nanotechnology will have a profound impact on our lives. Thanks to tiny computers monitoring us round the clock and making our houses, offices, shops, streets, railway stations, airports and the like ever ‘smarter’, our living comfort and safety will increase. Tiny nanorobots will trace diseased cells early on and repair them, enabling us to live longer and healthier lives. Various kinds of technological enhancements will allow our bodies and our brains to function ever more efficiently. And new nanomaterials have some spectacular new characteristics in store. At the same time we are faced with important social and ethical questions: As our ability to intervene in our environment and our own bodies with nanotechnology increases, we lack the knowledge to assess all the implications of such interventions.

So a lot is at stake here. Radical technological and social changes must be steered in the right direction. Many people put their hopes on the government to fulfill this task. How will the government align its innovation policy with these new challenges?

In the past, government influence on technological advancement was rather limited. Public debate about new technology would usually only get going after a long, drawn-out controversy. Examples of social conflict abound, be it about genetically modified crops and foods or about nuclear technology, radiation from cell phones and their towers, and so on. At that stage, it is already too late. After all, the technology is ready to be commercialized. The only option a government then has left is to be on the defensive and fight out disputes behind the lines about the risks involved in using the technology. Indeed, governments can then still opt for a strict approval and risk management policy, but in doing this it is still lagging behind the facts.

THE IMPORTANCE OF GOVERNMENT ATTENTION TO NEW-FOUND TECHNOLOGIES

The time is right for a different approach. There are signs that governments are starting to pay more attention to the early stages in nanotechnology research and want to encourage a responsible development of nanotechnology more upstream in the innovation chain. The European Commission, for instance, today propagates a behavior code for nanoscientists and research institutes. This code mentions several principles to help scientists conduct nanoresearch in a socially sound and responsible manner.

Government attention to the early stages of a technology’s development is a good thing. Indeed, this creates room for democratic input regarding the direction that new technologies with important social implications are taking. But there must not be any misunderstandings about this.

Governments should not impose specific research goals on the research community from above and then expect it to align its research activities with those goals. Not only would this curtail the creativity of scientists and potential user groups, such an approach would also be a sign of hubris.

After all, imposing a research goal leads to the assumption that a public body – rather than the market or researchers themselves – is in a position to determine how science is to go about tackling the major challenges of
our time. It is most doubtful that a government would be capable of making accurate predictions of nanotechnology's possible applications, or that they could manage to estimate with some degree of accuracy what the risks would be down the road. Let alone that they would manage to perform effective cost-benefit analyses for nanotechnology's future. In an ever more complex society, the assumption that we can get a grip on our future using current insights, is a false hope that is built on sand. This holds true not only for policymakers, but for everyone who has to make research policy decisions, including research communities.

Nevertheless, the innovation policy's attention to the early stages of research and technological development is very pertinent. Governments however do need to look for a method that shows less hubris, an approach that differs from 'predicting' and 'directing' from above. Coming up with procedures that will allow us to 'anticipate' the future efficiently will then be more practicable.

**ANTICIPATING**

Anticipating then means: working together – scientists, policymakers and stakeholder groups alike – in order to be well-prepared for the as of yet unknown questions and consequences that will accompany the eventual introduction of nanotechnology. The words together and prepare are key here.

Getting prepared is something that must be done jointly, given the many uncertainties cropping up along research and technology routes. Constant exchange of perspectives, experiences and knowhow is needed, between researchers on the one hand and the social groups concerned on the other hand. Furthermore, what is especially needed is a good orchestration of all these ideas.

And just like when preparing for an exam, we need to start studying early enough and particularly also allocate time to review what we have learned, so that our preparation for successful innovation will amount to a gradual buildup of knowledge. This includes the option to revert to previous steps, based on new knowledge presenting itself. Or as one nanoresearcher puts it:

*The solution is to maintain constant communication, while only gradually innovating. Of course one can draft a long-term plan or roadmap, but constant assessment and feedback from a committee of users is essential. And this entire process must be made transparent for the general public.‘*

This statement instantly sheds a new light on the role of the government. Encouraging anticipatory exercises such as NanoSoc – collective experiments at times when the planning for new research comes up for discussion or when roadmaps for new technology routes are being outlined – thus becomes an important task for policymakers.
LESSONS LEARNED FROM NANOSOC

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<td>'In the field where bio and nano converge, it becomes apparent that we can intervene where previously only God could. There is plenty of uncertainty, we are unsure as to how far we can go. Contrasting trends are emerging: Should we stop before we wreck everything, or march on?'</td>
<td>Nanoscientist</td>
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<tr>
<td>'Technology can become a part of me, like the air I breathe day in, day out, but I want to know that I am who I am without the technology.'</td>
<td>Citizens</td>
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<td>'It is interesting to see how an initial route is still vague and open-ended and yet there is already sufficient fuel to fire up the discussion of both technological and social issues. The discussion constantly goes back to the technology: What is technologically feasible, should the technology change in some ways... alternative ideas are voiced and discussed and suddenly, a new technological possibility is born.'</td>
<td>Nanoscientist</td>
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One result of NanoSoc stands out: The thinking about new developments in the field where bio and nano meet is riddled with immense duality and ambivalence. This holds true for both laymen and nanoscientists. This does not have to be an obstacle for innovation, though. If mixed feelings are allowed to surface, then they might inspire nanoresearchers to consider new ideas.

At the center of it all, in light of ambivalences and uncertainties, is the question of how to favor and optimize a sound development of nanotechnology. NanoSoc as an interactive exercise in research planning starts from the idea that these uncertainties must not be denied, but instead must be identified, while new creative ways are to be sought to deal with them appropriately. This exercise results in three lessons.

LESSON 1: MOBILIZING IMAGINATION IN SOCIETY

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<td>'It must be possible to create forums for citizens, where people can voice in simple terms what they want, how they want to exist and how they want to organize their lives.'</td>
<td>Participant in stakeholder forum</td>
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The nanoscale creates high expectations: A multitude of technological possibilities can contribute to meeting various needs of society. The direction these developments will take and which trends will prevail cannot be
foretold. This raises the question of where in research the priorities should lie. We lack a guiding light by which to set the course.

Keeping in mind the idea that people dream science before actually realizing it, NanoSoc has embraced the following principle: In a situation of major strategic uncertainty, put the focus on mobilizing and fostering society's imagination.

The NanoSoc exercise has therefore appealed to the imagination of people of very diverse backgrounds. They have come up with stories for the future application of nanotechnology, imaginary worlds one can visit and where one can take imaginary action without real consequences. This leads to looking at the real world with other, critical eyes – focusing on what is really important in life and therefore is to be preserved by nanotechnology in the future; and assessing habits that on second thought, looking back on one's imaginary journey, just might be traded in for something more attractive. Such an imaginary exercise can also reveal to what extent the visions currently circulating in the research community can withstand a perspective from the outside world.

Stories also carry the entire social context in which new technologies are embedded. This gives a good insight into the way social and technological changes are interrelated, which in turn can spur imagination about social innovations. New ways to organize care, mobility and labor, among other things, are cropping up and people are starting to consider the different practices and standards of these new ways.

Such an approach also fits in with a key issue in the Flemish innovation policy. The recent memorandum 'Innovatie' (K.Debackere, 2008) mentions the suggestion of the government also remunerating experiments pertaining to 'social innovation' – combined with technological innovation.

**LESSON 2: INVEST IN PUBLIC ARTICULATION OF VALUES**

It is very difficult to predict with any real accuracy the future costs and benefits of new technologies. In a fast-paced, ever-evolving multicultural society every emerging technology will lead to other values and interests coming into play. And what subsequent generations will deem important or not, remains unknown to us.

However, it is possible to assess at regular intervals and through public forums what exactly is at stake when a new technology emerges, and what certain groups stand to gain or to lose. In other words: If the costs and benefits of a new technology cannot be calculated objectively, then put the focus on public and regular articulation of values.

Technology developers can turn this to their advantage.

>'When you develop something, you have certain applications in mind, but by talking to stakeholders other options can open up.' (nanoscientist)

>'It may be interesting to reflect on the subject together, in order to generate new ideas and to better identify the question. It may very well be that the question is not what we presume.' (nanoscientist)
Society, too, stands to gain from this method, at least if the stakeholders involved are taken seriously, for this is a necessary condition for the success of such forums.

‘Are we expected to provide a support base for technology routes that have already been plotted? Or is there room for us to influence those routes?’ (participant in stakeholder forum)

Here too the Flemish innovation policy is creating more room. The authors of the VIA memorandum (K.Debackere, 2008) make a case for the involvement of more groups from society rather than just the technology promoters in outlining innovation routes. This idea is implemented by Flemish minister for Innovation, Ingrid Lieten, by establishing so-called 'experimental gardens' where users and technology developers can confer (for instance about technological innovation in care and mobility). Furthermore she attaches importance to the continued concrete development of strategic research priorities proposed by the Flemish Science Council, in association with a broad group of stakeholders from society, not just technology promoters.

LESSON 3: DO NOT PUT ALL YOUR EGGS IN ONE BASKET

Investing in research into risks and potential negative effects of a technology route is important. However, the complexity of future generations of nanoproducts will grow and it will become increasingly difficult to assess future implications when choosing one technology route over another. In this situation, the saying 'do not put all your eggs in one basket' can provide the answer. It is probably a sign of wise and cautious governance to allocate time and means to the parallel exploration of alternative routes.

'It is important that not all of us always continue down the same chosen path. I think we sometimes need to do something new.' (nanoscientist)

'Research is like a highway. Once you are on it, the wheels are set in motion and you start developing. I would prefer to see people reflect a little more on their own research.' (nanoscientist)

The NanoSoc roadmap exercise encourages participants to abandon the trodden paths and look at today's challenges from a fresh perspective.

‘Perspectives emerged that we never expected.’ (nanoscientist)

'This exercise inspired us to broaden the range of technological options.' (nanoscientist)

One important condition is that researchers, given the uncertainty that goes hand in hand with learning to discover alternatives, are given the freedom to go down new paths. Sufficient trust between partners in the research network is then conductive to this freedom. And trust can only grow if the partnership model allows for a transparent division of roles, responsibilities and research agendas.

The way the research is financed is important as well. For example, after the exercise nanoresearchers would come up with the following idea:
‘Try getting groups of citizens and stakeholders to support a socially relevant research project. Then start looking for a financing partner willing to invest in the concept and launch the product on the market.’ (nanoscientist)

Regarding this, the VIA memorandum also contains an interesting suggestion: It is put forward that public financing of basic research at universities and other knowledge centers could be made dependent, it too, on the selection criterion 'relevance for society' in addition to 'scientific excellence'. Such an initiative can incite researchers to reflect on and experiment with alternative research and technology routes.

IN CONCLUSION

The NanoSoc project might best be summarized as an answer to the following question that a nanoresearcher is facing:

‘On the one hand you see that a fraction of the world’s population determines progress, and the rest follows. On the other hand, a form of democracy should be possible in science as well, because most people are wise. The big question is: How do you do that? It’s so complicated.’

We should interpret this question as an appeal to continue working on the NanoSoc experiment, as a collective and interactive way to determine sensible research agendas.


