

## **1b. Title of research proposal**

New Technologies as Social Experiments: Conditions for Morally Responsible Experimentation

## **1c. Summary of research proposal**

Technologies like biotechnology, nanotechnology and nuclear energy technology not only bring large social benefits but also introduce potentially catastrophic hazards. Many of the conventional approaches to risk governance are not directly applicable to these fields due to high levels of uncertainty and ignorance about potential hazards. To overcome this problem, the proposed research conceptualizes technology as a form of social experimentation and investigates the conditions under which such social experiments are morally acceptable. In this perspective, introduction of technology into society is not seen as a one-off decision but rather as an ongoing social experiment. On the basis of a conceptualization of technology as social experimentation, conditions for responsible experimentation are proposed and applied to three technological domains: nanotechnology, biotechnology, and nuclear technology. All these domains are characterized by a combination of large potential benefits, potential catastrophic hazards and high levels of uncertainty. On the basis of an evaluation of these domain applications, the conditions for responsible experimentation will be revised and refined. The conditions will also be compared with proposals in the literature on management under uncertainty and ignorance and on the regulation of new emerging technologies. The resulting conditions for responsible experimentation are relevant for national, European and international policy with respect to new technologies. The proposal will also help to find new ground in the stalemate between proponents and opponents of new technologies who both start from the assumption that the introduction of technology into society is a one-off decision while radically disagreeing on what normative and evidential grounds these decisions should be made. Lastly, by applying the notion of social experimentation the proposed research develops a new paradigm for ethical analyses of new technologies, which recognizes that uncertainty and ignorance cannot be fully reduced before new technologies enter society.

## **1.d Keywords**

Technology as social experiment, philosophy and ethics of risk, engineering ethics, philosophy of technology, emerging technologies

## **1e. Host institution (if known)**

Delft University of Technology, Faculty of Technology, Policy and Management, the Philosophy section

## **2a. Description of the proposed research**

### **A. Research topic**

#### **A1) Problem formulation**

Emerging technologies like nanotechnology and biotechnology and complex technologies like nuclear energy technology have the potential to bring large social and economic benefits. At the same time, these technologies may create large and catastrophic hazards. These technologies are, moreover, characterized by high uncertainty and ignorance, so that potential hazards cannot be reliably expressed in risks as traditional approaches to risk management and governance suppose. As a consequence there is an urgent need, both socially and scientifically, for a new approach for dealing with the hazards of these technologies. This proposal sets out to develop such a new approach by conceptualizing technology as a social experiment. The **overall aim** of the proposed research is to explore under what conditions such experiments are morally acceptable.

The proposed project will develop a coherent conceptualization of technology as a form of social experimentation. This conceptualization will be used to develop a set of conditions under which social experiments with technology may be deemed morally acceptable. These conditions will then be specified and applied to three technological domains: nanotechnology, biotechnology and nuclear energy technology. On the basis of these applications, the conditions for responsible experimentation will be revised and refined. Finally,

the implications for the regulation and governance of technological hazards will be investigated.

The **research question** is:

*What conditions for responsible experimentation can be formulated on the basis of a conceptualization of technology as social experimentation and its application to three technological domains (nanotechnology, biotechnology and nuclear energy technology) and what are the implications for the regulation and governance of technological hazards?*

## **A2) Theoretical background**

The notion of *hazard* is often used to indicate that a technology, or its use, can cause damage or otherwise undesirable effects. The term *risk* can be seen as a specification of the term hazard. An often-used definition of risk is the product of the probability of an undesirable event and the impact of that event. To express a hazard in a risk requires knowledge of the potential consequences of a technology, the impact of those consequences and the probability of their occurrence. Particularly with new technologies like nanotechnology and biotechnology, such knowledge is usually lacking. *Uncertainty* refers to the situation in which we know what might go wrong, but lack the knowledge to express a hazard in a risk. *Ignorance* refers to the situation in which we do not even know what could go wrong, resulting in unknown hazards.

In some cases, potential hazards cannot be expressed in risks because their occurrence depends on the behaviour of, for example, users or operators. Such situations may be characterized as *indeterminate* because the causal chains potentially leading to a hazard are open and depend on the actions of some relevant actor.<sup>1</sup> The impossibility of expressing hazards in risks may also be due to *ambiguity*. Ambiguity refers to the fact that different interpretations or meanings may be given to the measurement, characterization, aggregation and evaluation of hazards. More specifically, normative ambiguity refers to disagreement about the relevant (moral) values and their relative importance (Renn 2005).

<b>Hazard</b>	Possibility that a technology causes undesirable effects
<b>Risk</b>	Specification of a hazard, usually in terms of probabilities and consequences
<b>Uncertainty</b>	Situation in which hazards are known but cannot be expressed as risks due to a lack of knowledge
<b>Ignorance</b>	Situation in which hazards are unknown
<b>Indeterminacy</b>	Consequences (hazards) are causally open, for example because they depend on user or operator behaviour
<b>Ambiguity</b>	Situation in which there are different disagreeing perspectives on the nature and the (un)desirability of a hazard

**Table 1: Central notions**

Most current approaches in ethics, law and policy-making for judging the acceptability of hazards are based on the notion of risk. The ethical literature on risk has established that the moral acceptability of risks does not only depend on their magnitude but also on considerations like voluntariness, the balance and distribution of benefits and risks, and the availability of alternatives (Shrader-Frechette 1991; Hansson 2003; Harris, Pritchard, and Rabins 2008; Asveld and Roeser 2009; Hansson 2009). However, these considerations cannot be applied straightforwardly in cases of uncertainty and ignorance. How can we judge whether the balance of benefits and

<sup>1</sup> In some cases it might be possible to predict or model human behavior reliably, so that despite indeterminacy risks can be established. Even then, indeterminacy is a relevant category because it introduces an element of human choice and hence of moral responsibility. This is relevant for the conditions under which social experiments are morally acceptable (see also project 3).

hazards is positive when benefits and hazards are uncertain or even unknown?

The main moral and legal principle that is currently proposed for dealing with situations of uncertainty is the *precautionary principle*, which basically says that in situations of uncertainty in which there is a real possibility of hazards, precautionary measures should be taken (Sandin 1999; Commission of the European Communities 2000). The precautionary principle is, however, hotly debated and has led to political controversy between the USA and Europe, for example about genetically modified organisms. Also philosophers and legal scholars disagree about the usefulness of the principle. Some believe that the principle is basically a form of practical rationality or prudence (Andorno 2004; Hansson 2009). Others believe that the principle is incoherent: the principle forbids the precautionary measures it requires because very often those measures also have potentially large negative (economic) effects (Sunstein 2005; Peterson 2006).

There is also no agreement on what exactly the precautionary principle implies for new technologies. With respect to nanotechnologies, it has been suggested that the principle implies that the risks of new nanotechnological products should be established before they enter the market (Health Council of the Netherlands 2006; Weckert and Moor 2007). Although this seems a sensible strategy, it is based on the wrong assumption that risks can be fully and reliably established *before* new technologies enter society. This is often impossible due to long-term cumulative and interaction effects, and recursive non-linear systems dynamics that cannot be accounted for in the laboratory. Moreover, laboratory and field tests are often not representative of real-life circumstances and, finally, some hazards may be entirely overlooked due to ignorance (Krohn and Weyer 1994).

As a result of the above, society has become the laboratory for technical experiments, which raises serious ethical and social questions about the acceptability of such experiments (Felt et al. 2007). However, remarkably little work has been done to address such ethical and social issues. Martin and Schinzinger (2005) have proposed to apply the *principle of informed consent* to technology as social experimentation. Informed consent implies that it is only acceptable to use humans as experimental subjects if they have voluntarily agreed to engage in the experiment after being fully informed about all potential hazards (and the expected benefits). For medical experiments, informed consent is usually legally required; for other experiments it might not be legally required but it is still generally considered an important moral yardstick (Whitbeck 1998).

Applying the principle of informed consent to social experiments in technology raises the question of whether it makes sense to ask people to consent to unknown hazards (Van de Poel 2009). Consenting to an experiment with unknown hazards seems to entail accepting all hazards that emerge from the experiment. It is hard to see how people could rationally accept such experimental conditions. But if they do not give their informed consent (which seems the only rational thing to do), any social experiment involving ignorance would be unacceptable. This raises serious questions about the adequacy of the principle of informed consent in situations of ignorance. In addition, it has been suggested that the principle might be too strict (Hansson 2004). In bioethics, the principle of informed consent has also been criticised for neglecting other ethical concerns like justice (e.g. Fisher 2007).

Instead of directly trying to apply the principle of informed consent, it might be better to focus on the underlying moral concern on which the principle is based, i.e. moral autonomy, and to explore under what conditions the moral autonomy of the public that is subject to social experiments is guaranteed. Moreover, conditions for acceptable experimentation should not be restricted to this concern, but should also take into account the ethical requirements that have been formulated for standard experiments and which include respect for persons, beneficence and justice (see e.g. Belmont Report 1979). Table 2 lists a preliminary set of conditions that have been identified in previous research.

1. Absence of other reasonable means for gaining knowledge about hazards
2. Monitoring
3. Possibility to stop the experiment
4. Consciously scaling up, so that relevant operating experience is available
5. Containment of hazards as far as reasonably possible
6. Reasonable to expect social benefits from the experiment
7. Experimental subjects are informed about potential hazards, uncertainties, ignorance and expected benefits
8. Approved by democratically legitimised bodies
9. Experimental subjects can influence the setup, carrying out and stopping of the experiment
10. Vulnerable experimental subjects are either not subject to the experiment or are additionally protected
11. A fair distribution of potential hazards and benefits among different groups and among different generations

**Table 2: Possible conditions for responsible experimentation (Van de Poel 2009; Jacobs, Van de Poel, and Osseweijer forthcoming)**

The perspective of technology as social experimentation also raises interesting conceptual issues. In the traditional view, the properties of new technologies are largely fixed in the laboratory and do not significantly change after they have been introduced into society; the new perspective sees the properties of technology as the emergent outcome of the co-evolution of technology and society. Also the moral frameworks with which we judge emerging beneficial and harmful properties may co-evolve during the experiment (Grunwald 2007; Swierstra and Rip 2007; Swierstra et al. 2009). This normative ambiguity adds a further layer of complexity to the question of when such experiments are acceptable.

### **A3) Significance**

Dealing with uncertainty and ignorance is one of the main challenges for the ethics of technology (Sollie and Düwell 2009). All too often, ethical analyses of technologies take the properties and consequences of specific technologies as given. When uncertainty and ignorance are addressed, it is often through the notion of risk. However, establishing risks requires reliable knowledge of probabilities and consequences of potential undesirable events and such knowledge is usually lacking for emerging technologies like nanotechnology and biotechnology and for complex technologies like nuclear energy technology. Addressing the role of uncertainty and ignorance in ethical analyses of new technologies beyond the notion of risk is therefore crucial for the further development of the ethics of technology. Approaches based on the precautionary principle (see A.2) or approaches that focus on techno-moral scenarios (e.g. Swierstra, Stemerding, and Boenink 2009) provide interesting alternatives but they still focus on the anticipation of consequences. Such approaches suppose that uncertainty and ignorance about technological hazards can be sufficiently reduced *before* new technologies are introduced into society. For emerging and complex technologies, this assumption is unrealistic not only because of practical and epistemological limitations but also because the properties and the consequences of these technologies are the emergent outcome of the co-evolution of technology and society and, hence, are sometimes unexpected and unpredictable. What is missing is an approach that recognizes that uncertainty and ignorance are partly irreducible and, in as far as they can be reduced, such reduction is an ongoing process. The proposed research fills this lacuna through a conceptualization of technology as a form of social experimentation. In doing so, it develops a new paradigm for dealing with the hazards of technologies. Several authors have recognized the importance of the notion of technology as social experiment (Krohn and Weyer 1994; Sarewitz and Woodhouse 2003; Martin and Schinzinger 2005; Felt et al. 2007). The notion of social experiment has also been successfully applied to several domains and cases including urban studies (Park 1929; Gieryn 2006), waste facilities (Herbold 1995), genetically modified crops (Levidow and Carr 2007), engineering research laboratories (Fisher and Lightner 2009), ecological design (Gross 2010) and sunscreens with nanoparticles (Jacobs, Van de Poel, and Osseweijer forthcoming). However, a full conceptualization of the notion and thinking through of all the implications of the concept are still missing. Moreover, hardly any work has been done on investigating the conditions under which such experiments are *morally acceptable*. This project will systematically develop a set of conditions for morally responsible social experiments in order to contribute to a new approach to the ethics of new technologies.

The project is also socially significant. Large investments have been made in emerging technologies like nanotechnology and biotechnology and in nuclear energy technology because they promise large social benefits. In the meantime, there are large potential hazards and high uncertainty and ignorance. Current regulation and governance, which are usually based on the notion of risk, cannot adequately deal with these challenges and have resulted in a stalemate between opponents and proponents of new technologies: opponents require safe technologies beyond doubt; proponents only want to consider risks that have been scientifically proven. The proposed approach has the potential to overcome this stalemate and to reduce the social costs of the introduction of new technologies by developing a new perspective on the regulation and governance of hazards, in which the introduction of new technologies is not viewed as a one-off decision but rather as an ongoing experiment. (See further: section 2b on research impact).

**B. Approach**

**B1) Key objectives and subprojects**

The research question is:

*What conditions for responsible experimentation can be formulated on the basis of a conceptualization of technology as social experimentation and its application to three technological domains (nanotechnology, biotechnology and nuclear energy technology) and what are the implications for the regulation and governance of technological hazards?*

The **key objectives** of the project are:

1. To develop a coherent conceptualization of technology as a form of social experimentation;
2. To develop a set of general conditions under which social experiments with technology may be considered morally acceptable;
3. To specify and apply these conditions to three technological domains: nanotechnology, biotechnology and nuclear energy technology;
4. To evaluate these applications and to revise and refine the initial set of conditions on the basis of these evaluations;
5. To investigate the implications for the regulation and governance of technological hazards.

These objectives correspond with the five proposed **subprojects** as follows:

<b>Key objective 1 and 2</b>	Project 1: Conceptual and moral analysis of technology as social experiment
<b>Key objective 3 and 4</b>	Project 2: Nuclear energy technology as social experiment Project 3: Biotechnology as social experiment Project 4: Nanotechnology as social experiment
<b>Key objective 5</b>	Project 5: Regulation and governance of technological hazards

**Table 3: Relation between key objectives and projects**

A conceptualization of technology as social experiment and a first proposal for conditions for responsible experimentation will be developed in project 1. In projects 2-4, these conditions will be specified for, and applied to specific technologies in three domains: nanotechnology, biotechnology and nuclear energy technology. This application will iteratively result in a revision of the proposed conditions or in the formulation of additional conditions. Project 5 investigates the implications for regulation and governance.

## **B2) Approach and Methods**

The project will combine conceptual, normative (moral) and empirical investigations. In project 1, a *conceptualization* of technology as a form of social experimentation will be developed. Project 1 also includes a *normative* investigation of conditions for responsible experimentation. A first set of conditions has already been formulated (see Table 2, above). This set of conditions will be further developed and refined in project 1.

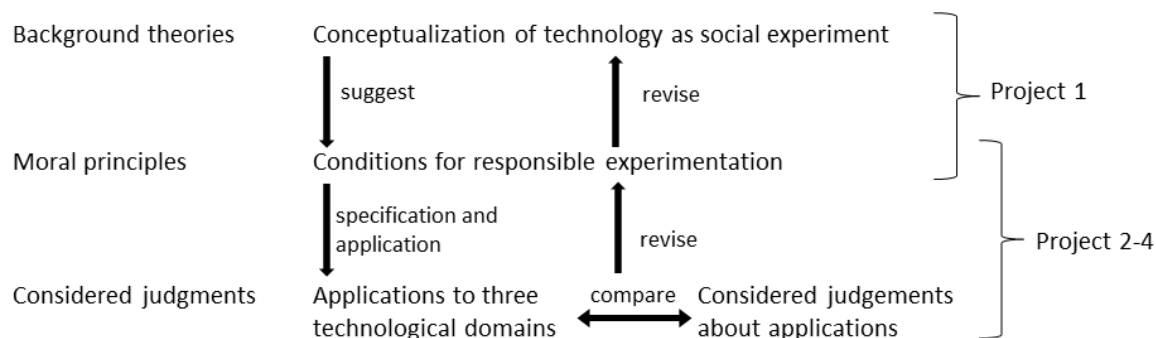
In projects 2-4, the conditions for responsible experimentation will be investigated for three technological domains: nanotechnology, biotechnology and nuclear energy technology. These domains have been chosen because they are all characterized by high uncertainty, ignorance and hazards that are potentially catastrophic, while at the same time technological developments in these domains promise large social benefits. The approach in projects 2-4 may be characterized by what has been called *empirical ethics* (Musschenga 2005). Empirical ethics involves, for example, empirical investigations into how decisions are now made in current practices and the practicality and effects of ethical guidelines and principles. It can also involve empirical investigations about the moral opinions, values and reasoning patterns of the people involved. Unlike descriptive ethics, empirical ethics is not purely descriptive in nature. It also involves normative investigations. It may, for example, judge existing practices with respect to their moral acceptability or it may specify abstract moral principles for specific circumstances. Empirical ethics approaches are especially suited to make ethics more context-sensitive.

For the proposed project, a context-sensitive approach is important for two distinct reasons. First, the set of conditions for responsible experimentation developed in project 1 will need to be further specified for the three technological domains, and possibly for specific technologies or specific applications in these domains, in order to be operative (cf. Beauchamp 2003). A specification substantively qualifies the initial norm by adding context-specific information 'describing what the action or end is or where, when, why, how, by what means, by whom, or to whom the action is to be done or the end is to be pursued' (Richardson 1997: 73).

Second, the justification of the conditions for responsible experimentation does not only depend on general and abstract moral concerns, like moral autonomy, but also on how these principles work out in practice and the degree to which they cohere with the considered judgements of people in the relevant practices. The approach to justification that the project will adopt is coherentist. More specifically, the project will apply the wide reflective equilibrium approach to ethics that has been developed by Rawls and Daniels (Daniels 1979, 1996; Rawls 1999 [1971]; Rawls 2001). This approach aims at making coherent three types of moral beliefs: 1) considered moral judgments, 2) moral principles, and 3) background theories. The background theories include ethical theories, but also other relevant theories.

Figure 1 indicates how these three levels of moral judgment will function in the proposed project. As Figure 1 shows, project 1 will especially focus on the upper two levels and their coherence. Projects 2-4 focus on the lower two levels by focusing on specific technological domains. These projects apply a three-step methodology to the domains studied:

1. The specification of the general conditions for responsible experimentation for the specific technological domain;
2. The application of these principles to the technological domains;
3. An evaluation based on a comparison of the application of the principles with considered judgments about these domain applications.



**Figure 1: Levels of moral judgement**

In each of the subprojects 2-4, the conditions for responsible experimentation will be specified for and applied to two more specific cases. In each domain, one case will be selected in which application is expected to be relatively straightforward. This will be a case that is characterized by uncertainty and ignorance but in which indeterminacy and ambiguity do not play a role, so that the conditions can probably be specified and applied without major problems (cf. Table 1, above). Possible cases include the food safety of GM crops and potential health hazards of nanoparticles (see Table 4, below). The main aim of this first case is to see whether the proposed conditions for responsible experimentation can indeed be specified and applied to specific cases in the three selected technological domains.

A second round will involve more difficult cases that raise challenges or specific moral issues that the initial set of conditions for responsible experimentation may not be able to deal with. One may, for example, think of the following challenges:

- Cases in which potential hazards apply to future generations that cannot give their informed consent to the experiment or cannot otherwise be involved. An example is the hazards of nuclear waste.
- Cases that involve indeterminacy because the occurrence of hazards (partly) depends on the behavior of users or other actors. An example is genetically modified (GM) herbicide-resistant crops, in which the hazards depend on how these crops are cultivated by farmers.
- Cases in which there is not only uncertainty and ignorance but also normative (moral) ambiguity or disagreement about what is desirable. An example is the possibility of human enhancement by nanotechnology.

	'Simple' case	Challenging case	Challenge
<b>Nuclear energy</b>	Early introduction of nuclear energy	Nuclear waste	Future generations
<b>Biotechnology</b>	GM crops (food safety)	Herbicide-resistant GM crops	Indeterminacy
<b>Nanotechnology</b>	Nanoparticles	Human enhancement	Normative ambiguity

**Table 4: Possible cases for projects 2-4.**

Projects 2-4 thus involve more than a straightforward application of the conditions for responsible experimentation to the three technological domains. First, specification of the conditions for each of the domains is not a deductive process but requires context-sensitive ethical analysis (cf. Beauchamp 2003). Second, each project involves an evaluation of the applications, which also requires ethical judgement. Third, each project addresses one specific theoretical challenge for formulating conditions for responsible experimentation (see Table 4).

In addition to the domain applications, the conditions for responsible experimentation will be revised and refined by comparing them with the view of experts and stakeholders as part of **Project 5**. This comparison will be based on two sources:

1. A literature study of regulatory challenges and dilemmas raised by governance under uncertainty and ignorance and of strategies for dealing with these;
2. A session in the Group Decision Room (GDR) at the Faculty of Technology, Policy and Management, TU Delft with relevant experts and stakeholders.

The GDR is an electronic environment for group brainstorming, discussion and casting votes. A session in the GDR will be organized halfway through the project involving experts in (risk) regulation and governance, policy makers and advisors, engineers and scientists, companies and relevant Non-Governmental Organizations (NGOs). For the setup and analysis of this session use will be made of an approach for tracing the considered judgments, principles and background theories of the people involved that has been developed and successfully applied in earlier research (Zwart et al. 2006; Doorn 2010; van de Poel and Zwart 2010).

The chosen overall approach makes it possible to balance attention for general moral and philosophical principles and issues with the effects of those principles in actual practices and the considered judgements of the stakeholders involved. This helps to avoid the possibility that specific moral issues arising from actual practices are overlooked by only focusing on general moral principles. At the same time, the approach provides a general conceptual framework and approach for the diversity of domain applications that are undertaken as part of the project.

### **C. Innovation**

The topic and approach are innovative in several respects. First, the notion of technology as social experimentation provides a new approach for dealing with the hazards of technology. Current approaches focus on expressing hazards scientifically as risks and conceive of the introduction of new technologies as one-off decisions. The new perspective proposed here sees them rather as ongoing experiments and so opens a whole array of new questions and issues. Second, the research focuses on the *moral* acceptability of social experiments. While several authors have recognized that the notion of technology as social experimentation raises important moral issues (e.g. Martin and Schinzinger 2005; Felt et al. 2007), these issues have not yet been systematically investigated. Neither has there been any systematic research into the conditions under which such experiments are morally acceptable. This knowledge lacuna will be addressed in the project. Third, the research is innovative in addressing the implications of the notion of social experimentation for regulation and governance of technological hazards. Although there is rather extensive literature on governance under scientific uncertainty or ignorance (e.g. Collingridge 1980; Cohen 1985; Wildavsky 1988; Funtowicz and Ravetz 1990), this literature does not yet incorporate the notion of social experimentation.

### **D. Research projects**

As indicated in Table 3, five subprojects will be carried out. The research questions for each of these projects are:

1. How to conceptualize technology as social experimentation, and what are the conditions for responsible experimentation? (Project 1)
2. What conditions for responsible experimentation can be formulated with respect to nuclear energy technology, in particular for experiments involving future generations? (Project 2)
3. What conditions for responsible experimentation can be formulated with respect to biotechnology, in particular for experiments under indeterminacy? (Project 3)
4. What conditions for responsible experimentation can be formulated with respect to nanotechnology, in particular for experiments under normative ambiguity? (Project 4)

5. What are the implications of the conditions for responsible experimentation for the governance and regulation of technological hazards? (Project 5)

**Project 1: Conceptual and moral analysis of technology as social experiment (applicant)**

The key objectives of this project are to develop a coherent conceptualisation of technology as social experimentation and to develop a set of general conditions for responsible experimentation.

Project 1 will start by developing a general characterisation of technology as social experiment. In a next phase, this will be followed by a full-fledged conceptualisation of technology as social experiment involving three kinds of investigations. First, a comparison will be made between standard experiments in science and engineering and the notion of technology as a form of social experimentation building on the existing philosophical literature on scientific experiments (e.g. Hacking 1983; Radder 2003). Social experiments are different from standard experiments in at least three respects. Firstly, they take place outside the lab and involve more and other human subjects than standard experiments, in particular users and bystanders. Secondly, they are not always explicitly carried out or recognized as experiments, so that data gathering or monitoring is sometimes absent. Thirdly, they are less controllable, which makes it more difficult to control experimental conditions and to contain hazards. Social experiments may be difficult to terminate or they may have irreversible consequences. Despite these differences, they may have a similar (potential) role in the gathering of knowledge or in the empirical cycle or the design cycle as standard experiments in science and engineering (cf. De Groot 1969; Eekels and Roozenburg 1991). These and other relevant differences and similarities will be mapped. Second, different notions of ignorance and of related notions like uncertainty, ambiguity and indeterminacy will be distinguished (cf. Table 1 above) (e.g. Ravetz 1987; Smithson 1989; Funtowicz and Ravetz 1990; Wynne 1992; Bammer and Smithson 2009; Sollie 2009; Gross 2010). It will then be investigated which of these notions are necessary or sufficient to speak of technology as a form of social experimentation. Different types of experiments will be distinguished, like 'experiments under ignorance' or 'experiments under ambiguity.' Such distinctions are useful because they relate to different conditions under which social experiments are morally acceptable. Third, it will be investigated to what extent technology as social experimentation can be understood in terms of the co-evolution of technology, society and morality (see e.g. Rip and Kemp 1998; Nowotny, Scott, and Gibbons 2001; Swierstra et al. 2009; Swierstra, Stemerding, and Boenink 2009) and whether the properties of technologies in this perspective may be said to be emergent, and if so what kind of emergence is involved (e.g. Kroes 2009; O'Connor and Wong 2009).

In addition to this, project 1 will develop a first set of conditions for responsible social experimentation on the basis of three resources. First, an investigation will be made of ethical requirements that have been proposed for experiments with human subjects in relevant scientific disciplines, in particular in medical science (e.g. Faden, Beauchamp, and King 1986; McNeill 1993; Emanuel, Wendler, and Grady 2000; Emanuel et al. 2003; Fisher 2007). Second, conditions will be based on the literature about the moral acceptability of technological risks (e.g. Shrader-Frechette 1991; Hansson 2003; Harris, Pritchard, and Rabins 2008; Asveld and Roeser 2009; Hansson 2009). Third, the literature on the management of technology in society and management under ignorance or uncertainty will be investigated (Collingridge 1980; Wildavsky 1988; Collingridge 1992; Rip, Misa, and Schot 1995; Schot and Rip 1997; Gross 2010). This literature explicates conditions relating to monitoring, learning, reflectivity, reversibility, flexibility and the like. The initial set of conditions will be revised on the basis of results from the other projects. Lastly, project 1 will develop a conceptualisation and specification of the notion of moral autonomy that is relevant for social experiments. This will involve a questioning of the notion of 'informed consent' under conditions of uncertainty and ignorance. Attention will be paid both to individual and more collective forms of moral autonomy, as social experiments may involve large numbers of people and moral autonomy may be better understood in terms of democratic control rather than as individual informed consent.

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## **Project 2: Nuclear energy technology as social experiment (PhD student)**

The key objective of this project is to apply the notion of technology as social experimentation, and correlative conditions for responsible experimentation, to the domain of nuclear energy technologies. The project will result in a specification of the conditions for responsible experimentation for the domain of nuclear energy technology, the application of the specified conditions to two cases and suggested revisions for the general set of conditions for responsible experimentation based on an evaluation of these applications, in particular in relation to the challenge of dealing with hazards for future generations.

Nuclear energy technology is historically one of the first examples of a technology that is characterised by a combination of large social and economic promises and expectations, the potential of catastrophic hazards, and high uncertainty. The technology is not only interesting from a historical perspective; concern about greenhouse warming and the depletion of fossil fuels has brought the nuclear option high on the agenda again. This project will focus on two more specific cases: the introduction of nuclear energy in the 1960s and 1970s and the hazards of nuclear waste.

For several reasons, it is interesting to analyse the introduction of nuclear energy in the 1960s and 1970s as a social experiment. First, nuclear energy provided the context for the development of what is known as probabilistic risk assessment (PRA) (Keller and Modarres 2005). At the time, risks of nuclear reactors could neither be based on a full-fledged theory of reactor operation nor on historical accident data. The famous Rasmussen study therefore estimated the risks of nuclear power on the basis of event trees and fault trees (US NRC 1975). To each event in an event or fault tree a probability value was attached, for example on the basis of component failure data. Next, the probability of specific accident scenarios was calculated. Although PRA has proved to be an important approach to risk assessment and safety design, it has also become clear that PRA cannot take away the large uncertainty with respect to nuclear hazards (Union of Concerned Scientists 1977; Lewis et al. 1978). Moreover, PRA as such cannot avoid ignorance about possible disaster scenarios without extensive operational experience.

Second, licensing of new nuclear reactors in the USA, and elsewhere, was characterised by a succession of newly arising safety issues (Okrent 1981). This complicated the licensing process and led to adaptations in reactor design. The emergence of new safety issues was not anticipated at the time, although it is exactly what one would expect from the perspective of technology as social experimentation. Third, in the USA nuclear energy boomed in the sixties to fail in the seventies; since 1978, no new reactor has been built in the USA. While the reasons for this failure are complex, it can at least in part be attributed to the rapid up-scaling of nuclear energy technology at the time. Between 1964 and 1974, the annually ordered nuclear capacity in the USA was larger than the total nuclear capacity installed in all years before (Bupp and Derian 1978). The mean capacity per nuclear plant ordered quickly rose, from about 636 MW in 1963 to 1141 MW in 1972 (Bupp and Derian 1978: 73). At no time between 1963 and 1972 was any plant in operation as large as the smallest being ordered (Jasper 1990: 49). Due to this rapid scaling-up of nuclear plants, there was scant operating experience on which the design of new reactors could be based. From the viewpoint of responsible social experimentation, this rapid up-scaling was certainly unwise.

The second case will focus on the hazards of nuclear waste. With currently available technologies, nuclear waste will remain radiotoxic for an estimated period between 5,000 and 200,000 years, depending on the exact nuclear fuel cycle employed (Taebi and Kloosterman 2008). A new technology that is under development, Partition and Transmutation (P&T), may reduce this period to 500-1000 years. In all these cases, nuclear waste will generate a potential hazard for future generations. Although technologies have been developed to contain the hazards, like geological repositories, and estimates of the risks for future generations have been made, it is also clear that large uncertainties are involved (e.g. Shrader-Frechette 1993; Macfarlane and Ewing 2006). These uncertainties do not only arise from lack of knowledge about chemical and physical processes but are also due to the fact that it is hard, if not impossible, to predict how people in the far future will deal with geological repositories. The latter involves not only uncertainty and ignorance but also indeterminacy (cf. Table

1, above). Nuclear waste may therefore be understood as a social experiment involving future generations. A crucial question is under what conditions such experiments are morally acceptable given that future generations cannot give (or withhold) their informed consent or cannot otherwise be involved in decisions about the acceptability and setup of the experiment.

### **Project 3: Biotechnology as social experiment (PhD student)**

The key objective of this project is to apply the notion of technology as social experimentation, and correlative conditions for responsible experimentation, to the domain of biotechnology. The project will result in a specification of the conditions for responsible experimentation for the domain of biotechnology, the application of the specified conditions to two cases and suggested revisions for the general set of conditions for responsible experimentation based on an evaluation of these applications, in particular in relation to the challenge of dealing with indeterminate hazards.

Biotechnology has raised a range of ethical concerns including issues of food safety, animal welfare, environmental and ecological hazards, international justice and social consequences, patenting and intellectual property issues and issues relating to 'playing God' and intervening in nature (e.g. Dyson and Harris 1994; Sherlock and Morrey 2002; Morris 2006; Thompson 2007). The few authors that have implemented the perspective of biotechnology as a form of social experimentation to analyse such ethical issues (Levidow and Carr 2007) have not paid attention to the conditions under which such experiments are morally acceptable.

The subproject will focus on food biotechnology, an application of biotechnology where controversies have arisen partly because of uncertainty about potential hazards. The experimental nature of food biotechnology has increasingly been recognized in governance and regulation. The OECD, for example, wrote in a report about the safety of recombinant DNA applications: "Development of organisms for agricultural or environmental applications should be conducted in a stepwise fashion, moving, where appropriate, from the laboratory to the growth chamber and greenhouse, to limited field testing and finally, to large-scale field testing" (OECD 1986: 43). Initially, however, this step-wise approach did not consider the commercial stage, i.e. the actual introduction into society, as part of the experiment (Levidow and Carr 2007). This has changed in some countries in response to remaining uncertainty and public distrust. So, for example EU Directive 2001/18 on the deliberate release into the environment of genetically modified organisms requires post-market monitoring of possible hazards, and labeling and traceability at all stages. First approvals for release are limited to a period of ten years. All these requirements fit into the notion of biotechnology as a form of social experimentation.<sup>2</sup>

Two possible case studies for project 3 are food safety concerns of GM crops and herbicide-resistant crops. GM crops have raised food safety concerns with respect to such issues as toxicity, carcinogenicity, food allergies, antibiotic resistance, and effects on food quality and nutrition (e.g. Cummins 2002). Standard toxicity tests and risk assessments are hard to apply to whole foods (Kuiper et al. 2001; Atherton 2002). This was one of the reasons why the notion of 'substantial equivalence' was developed (OECD 1993, 1996). This notion implies that if a GM crop is not substantially different from its traditional counterpart it is assumed to be safe for food consumption. For the respects in which it is substantially different an additional risk assessment is required. The notion of substantial equivalence has been criticized by consumer groups and some scientists (e.g. Millstone, Brunner, and Mayer 1999). As a result the notion has been reassessed and, especially in Europe, substantial equivalence per se is no longer an argument to avoid additional risk assessments (Levidow, Murphy, and Carr 2007). Such risk assessments have themselves been criticized and cannot, anyway, take away all uncertainty and ignorance. It would therefore be interesting to apply the perspective of social experimentation to food safety issues raised by GM crops. This might also shed new light on currently debated issues like post-market monitoring of GM food and the need for labeling GM ingredients in food.

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<sup>2</sup> This perspective has been far less recognized in the US. There are in fact large differences between how the US and European countries have come to regulate biotechnology, resulting in conflicts between the EU and US in the World Trade Organisation (WTO). See also (Jasanoff 2005; Asveld 2007).

With respect to herbicide-resistant crops, three types of possible hazard have raised concern: 1) the possibility of weed becoming herbicide-resistant, 2) a reduction in farmland biodiversity and 3) mixture of GM and non-GM crops (Levidow and Carr 2007). The latter is important to sustain the possibility of traditional and organic agriculture alongside GM crops. The occurrence of these hazards is to an important degree dependent on how farmers use herbicide-resistant crops in combination with certain herbicides. This is thus not just a case of uncertainty or ignorance but also of indeterminacy. Initially this challenge was tackled by farm-scale evaluations which were designed to make more realistic assumptions about how farmers use GM crops and herbicides. Increasingly, however, such tests got a prescriptive flavor: they were used to prescribe farmers methods of using GM crops and herbicides rather than just describing their actual practices (Levidow and Carr 2007). The move to prescriptive testing appears to be an attempt to redistribute responsibility from biotechnology firms to farmers. This raises the ethical question whether, and if so under what conditions, such redistributions are morally acceptable (cf. Pols 2010). Or, phrased more generally, under what conditions are experiments under indeterminacy acceptable?

#### **Project 4: Nanotechnology as social experiment (PhD student)**

The key objective of this project is to apply the notion of technology as social experimentation, and correlative conditions for responsible experimentation, to the domain of nanotechnology. The project will result in a specification of the conditions for responsible experimentation for the domain of nanotechnology, the application of the specified conditions to two cases and suggested revisions for the general set of conditions for responsible experimentation based on an evaluation of these applications, in particular in relation to the challenge of dealing with hazards under normative ambiguity.

Nanotechnology has attracted a lot of ethical concern and attention in the last few years. Several studies have taken stock of potential ethical issues that are raised by nanotechnology (Roco and Bainbridge 2001; The Royal Society and The Royal Academy of Engineering 2004; Brune et al. 2006; Hunt and Mehta 2006; Schummer and Baird 2006; Allhoff et al. 2007). This includes environmental and health issues, the potential hazards of nanoparticles, privacy and control threats, human enhancement, and issues of equity, global justice and distribution of benefits and risks, including patenting and property rights.

Compared to biotechnology, discussion about the moral challenges of nanotechnology is still in its infancy. Moreover, it is as yet only partially clear what ethical issues nanotechnology will exactly raise (Van de Poel 2008). Nevertheless, it is possible to list some potential issues and hazards. The Health Council of the Netherlands (2006) has categorized the various issues raised by nanotechnologies according to a taxonomy proposed in Renn (2005):

- 'Simple' risk problems, in which probabilities and impacts can be scientifically determined;
- Complexity-induced risk problems, in which relevant scientific data is available but there is major scientific dissent about complex dose-effect relations;
- Uncertainty-induced risk problems, in which there is a lack of knowledge or even ignorance of possible hazards so that they cannot be expressed as risks;
- Ambiguity-induced risk problems, in which there are different disagreeing perspectives on the nature and the (un)desirability of the hazards.

One case will be selected from the uncertainty and one from the ambiguity category. The first will consider an application of nanoparticles. The hazards of nanoparticles are difficult to express in risks due to potential long delay times of harmful effects and interaction effects. In an earlier paper, conditions for responsible experimentation have been applied to the case of titanium dioxide nanoparticles in sunscreens (Jacobs, Van de Poel, and Osseweijer forthcoming). We were able to show that while conditions for responsible experimentation are currently not met, there are good opportunities to meet such conditions once the experimental nature of the technology is recognized.

The ambiguous case will focus on human enhancement. The potential of human enhancement by

nanotechnology and other converging technologies has already spurred fierce ethical debate (see e.g. Savulescu and Bostrom 2009).<sup>3</sup> There is no agreement on the desirability of human enhancement. Moreover, the current ethical debates are often disconnected from actual technological developments and what is technically feasible (Nordmann 2007). The notion of technology as social experimentation may help to reconnect discussions about the desirability of human enhancement to actual technological developments. The main challenge will be to develop conditions for responsible experimentation in the light of normative ambiguity.

#### **Project 5: Regulation and governance of technological hazards (postdoc)**

The key objective of this project is to investigate the implications of adopting a conceptualization of technological development as a social experiment for the regulation and governance of hazards. The project will consist of three phases. In phase 1, a literature study will be carried out on dilemmas of regulation under uncertainty and ignorance, and on strategies for dealing with these dilemmas and challenges. In phase 2, the conditions for responsible experimentation that have been proposed in the other projects will be evaluated for their feasibility and adequacy by comparing them with the strategies proposed in the literature and with the opinions of experts and stakeholders. In phase 3, the implications for hazard regulation and governance will be investigated.

The first phase starts with the identification of regulatory dilemmas raised by uncertainty and ignorance (cf. Smithson 1989: 300-301). One is the so-called Collingridge dilemma that states that in the early phases of technological development technologies are still malleable but knowledge of relevant social effects is usually lacking, yet in later phases relevant social effects (and hazards) will become clear but then technologies are often so well embedded that they are hard to change (Collingridge 1980). Two general governance strategies may be distinguished to deal with the Collingridge and comparable dilemmas: anticipation and resilience (Wildavsky 1988). Anticipation tries to foresee possible hazards and to avoid them. Anticipation does not necessarily require the expression of hazards in quantifiable risks. Also application of the precautionary principle to possible hazards or the sketching of different possible scenarios may be considered anticipatory strategies. Resilience emphasizes the ability to deal with surprises and unexpected outcomes. It does not focus on foresight but on the adaptive and reactive potential of the 'receiving system.' In general, a combination of anticipation and resilience may be most desirable although both strategies may be difficult to combine. A number of authors have proposed and discussed more specific strategies and models for governance and regulation of potential hazards of new technologies under uncertainty and ignorance (e.g. Stern and Feinberg 1996; Kirwan, Hale, and Hopkins 2002; Renn 2005; Renn and Roco 2006; Marchant, Sylvester, and Abbott 2008; Kasperson 2009; Mandel 2009). Such strategies typically stress the importance of monitoring, adaptability of regulations, the involvement of different stakeholders and 'soft' regulation like codes of conduct and other forms of self-regulation, in addition to traditional regulatory instruments. Such alternative strategies will be investigated in the first phase for their ability to deal with the experimental nature of technology.

The second phase of project 5 will research the proposed conditions for responsible experimentation that have been developed in the other subprojects for their regulatory practicality and their ability to deal with the challenges and dilemmas identified in the first part of project 5. The conditions will also be compared with the approaches and models for the regulation and governance of technological hazards that have been proposed in the literature. In addition, they will be compared with the considered judgements of experts and stakeholders. To this end, a session in the Group Decision Room (GDR) will be organised with experts in (risk) regulation and governance, policy makers and advisors, engineers and scientists, companies and relevant NGOs.

The third phase will be carried out after the final revision of the conditions for responsible experimentation for the entire project and it will investigate the consequences for governance and regulation of hazards of the proposed conditions. This will include the formulation of recommendations and the communication of these to

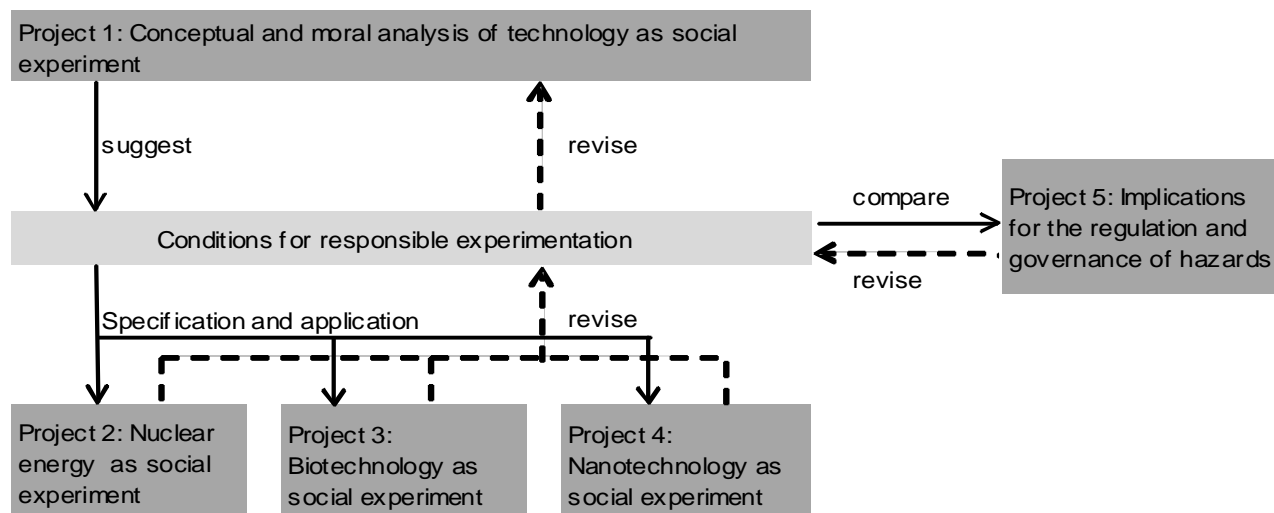
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<sup>3</sup> The term 'converging technologies' refers to the NIBC technologies: nanotechnology, information technology, biotechnology and cognitive science, which are believed to increasingly converge in certain applications, like enhancement.

relevant stakeholders like policy makers.

**Relation and interaction between the subprojects**

In project 1, a characterisation and conceptualisation of technology as social experimentation will be developed and a first set of conditions for responsible experimentation will be developed. These will then be specified for and applied to three technological domains in projects 2-4. Each of these projects focuses on one specific domain (nuclear energy technology, biotechnology and nanotechnology) and will involve two more specific case studies (cf. Table 4, above). These applications will be evaluated and this will likely result in proposed revisions in the initial set of conditions. Whereas in projects 2-4, the conditions for responsible experimentation are assessed through an application to specific technological domains, in project 5 they are assessed by comparing them with governance strategies proposed in the literature and the considered judgements of experts and stakeholders. Figure 2 illustrates the relations and interactions between the projects. The central notion around which the interaction of the subprojects is organised is “the conditions of responsible experimentation”, the development of which is the overall aim of the project.



**Figure 2: Relations and interactions between the subprojects**

**E. Plan of work**

The plan of work is outlined in Figure 3 (see next page). The work plan has been carefully drafted to optimise interaction between the subprojects. Project 1, which will be carried out by the applicant is crucial for overall progress. The time schedule on which the subprojects 2-5 can deliver the results can diverge from the ideal schedule without endangering the overall progress and success of the project. Projects 2-4 will in principle be carried out by PhD students while project 5, on the subject of governance and regulation, will be carried out by a postdoc. Depending on the available candidates, one or more of the projects 2-4 may also be carried out as a 3-year postdoc project rather than 4-year PhD project as currently planned. The project team will meet monthly to discuss progress made, literature of common interest, to exchange results and relevant data and to make comparisons between the studied technological domains.

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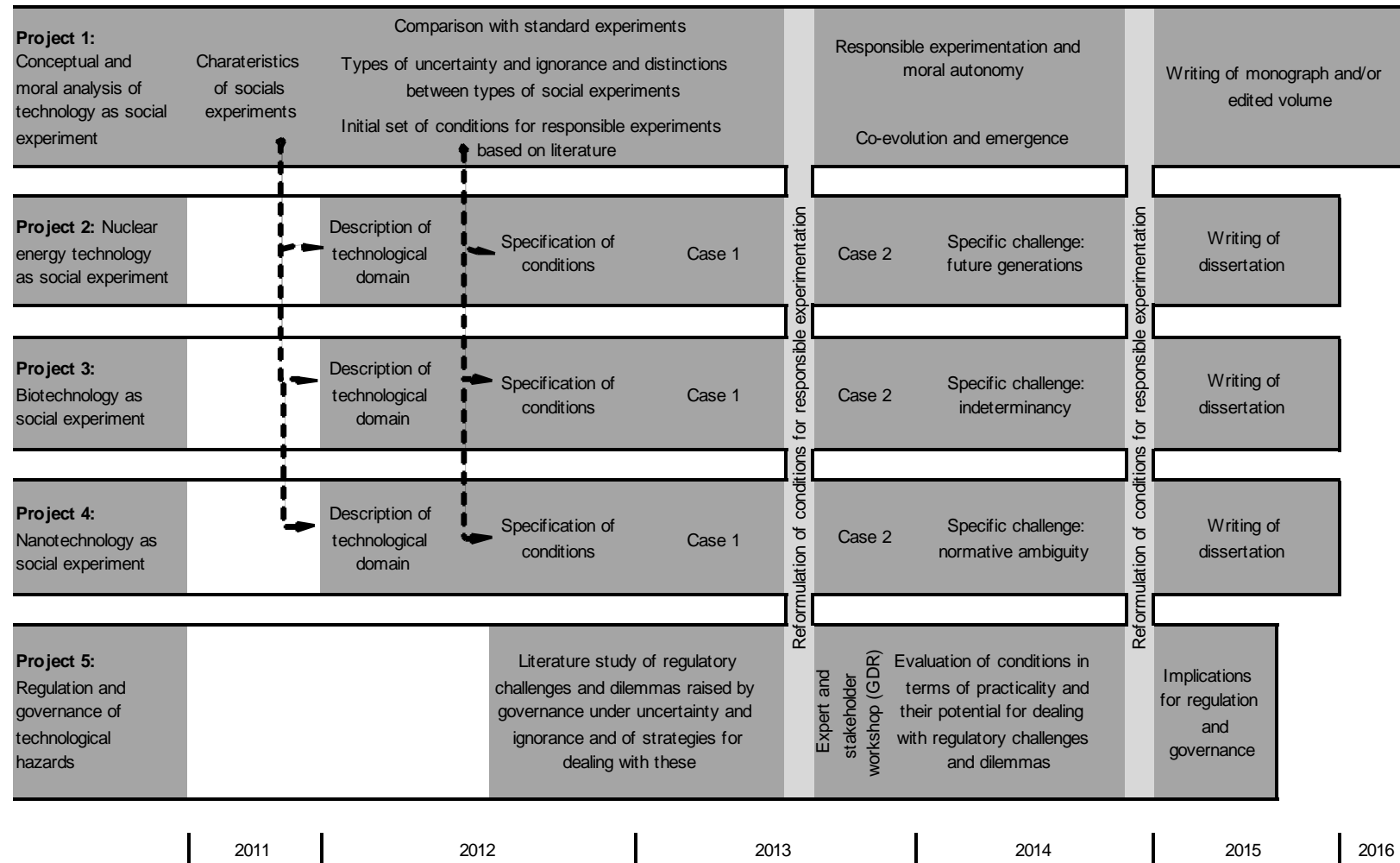


Figure 3: Work plan

### **Host institute and collaboration**

The research will be carried out at the Philosophy Section, of the Values and Technology Department, in the Faculty of Technology, Policy and Management at the TU Delft in the Netherlands. The Philosophy Section consists of about thirty people and is an internationally renowned research group in the philosophy of technology; it achieved the highest score on all assessment criteria during the last philosophy research assessment in the Netherlands.

The Values and Technology Department also consists of the Safety Science Section and the Law & Technology Section, which both have relevant expertise for this project. Expert researchers from these Sections may advise on the supervisory committees for the subprojects. The TU Delft is home to internationally renowned research groups in nanotechnology (Kavli Institute), biotechnology (Kluijver Laboratory) and nuclear energy technology (Reactor Institute Delft), with which excellent contacts exist and with which the applicant has successfully cooperated before.

Furthermore, the research will be embedded in the 3TU.Centre for Ethics and Technology, in which the philosophy sections of the technical universities in Delft, Eindhoven and Twente cooperate ([www.ethicsandtechnology.eu](http://www.ethicsandtechnology.eu)). The centre has many international contacts which will be helpful to establish international collaborations. The centre also offers a PhD program in Ethics & Technology that will be followed by the PhD students.

### **2b. Research impact**

*[Following the prescribed format, this section only describes the social impact; for scientific impact, see sections A3 and C above].*

The introduction of new technologies into society regularly raises controversy, often resulting in a stalemate. Opponents and skeptics require proof that new technologies are safe beyond doubt before they enter society. Proponents urge for 'science-based regulation': only risks firmly grounded in scientific evidence are to be regulated. Given the uncertainty that surrounds new technology, this results in disagreement about which technologies and applications are acceptable and which are not. Still, many opponents and proponents see the introduction of new technology as a one-off decision. The discussion is framed in terms of when it is acceptable to introduce a technology into society, and is based on the assumption that once a technology has been introduced it can be treated as acceptable without further monitoring unexpected hazards.

My research proposal challenges this assumption and instead sees the introduction of technology into society as an ongoing experiment. Rather than focusing on whether it is acceptable to introduce a technology at a certain moment in time, the proposal focuses on the conditions under which such ongoing experiments are acceptable and when they should be stopped or redesigned. This perspective might provide common ground between proponents and opponents of new technologies by shifting the discussion away from what can now be proven about the hazards of such technologies (which is actually very limited) to an emphasis on progressive insight and, eventually, to the question of what are acceptable ways of dealing with new technology in society.

The new perspective is also relevant for regulation and governance of technological hazards. These do not yet take into account the experimental nature of new technology, as for example noted by the European

#### Expert

Group on Science and Governance established by the European Commission (Felt et al. 2007). Doing so might in fact substantially reduce the social costs of introducing technologies into society. On the one hand, the new perspective is likely to result in less controversy and public resistance, so reducing the costs of non-adoption. Non-adoption has huge costs, partly due to the large R&D investments in new technologies (amounting to billions of Euros worldwide only in the case of nanotechnology), and partly due to a loss of economic and social opportunities. At the same time, focusing on the experimental nature of new technologies and the need for responsible experimentation, including monitoring and learning, is likely to result in earlier detection of initially unknown hazards and in better hazard management, so reducing both the impact and probability of hazards, and the accompanying social costs. Asbestos, which has resulted in tens of thousands of deaths worldwide, is a good example of the potential magnitude of such social costs. It took decades before the first signs of the danger of asbestos were translated into effective ways of dealing with the hazard; doing so earlier and more effectively would probably have saved thousands of lives (Harremoës et al. 2001). The new policy and legal frameworks for dealing with hazards that can result from this proposal may drastically reduce such social costs.

The following target groups may make use of the results of this project:

- Policy makers and policy advisors. This includes relevant governmental ministries and bodies. At the European level, this may, for example, include people from the DG (Directorate-General) Research, DG Environment and DG for Health and Consumers.
- Engineers and scientists, especially from the three studied technological domains (nanotechnology, biotechnology, nuclear technology). All these domains are represented by internationally esteemed research groups at the TU Delft, with which contacts exist. Also other international research groups may be contacted.
- Companies in three studied technological domains (nanotechnology, biotechnology, nuclear technology). It may especially be useful to approach their departments for corporate social responsibility (CSR), branch organizations, or consultancy firms that advice on CSR (like DHV).
- Non-governmental organizations (NGOs) like consumer groups and environmental groups that take an interest in new technology. This may include organizations like Friends of the Earth, Consumers International and the ETC group, which has called for a moratorium on nanotechnology (ETC Group 2003).

As part of the final phase of project 5, special attention will be paid to formulating conclusions and recommendations to the mentioned target groups in accessible language. Apart from scientific publications, the entire project also aims at professional publications in relevant media. To ensure the social relevance of the project and the results, not only the mentioned target groups will be involved, but also experts, especially in hazards regulation and governance. This will especially be done through a GDR session and an international workshop.

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