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Means of Communicating Innovations. A Case Study for the Analysis and Assessment of Nanotechnology's Futuristic Visions[1]

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Abstract

Communications about the future potentials of current innovation processes of nanotechnology are often accompanied by visionary scenarios anticipating future applications of nanotechnological products. The analysis and evaluation of the mediality of such scenarios has for some time been an important research topic of both sociological expectation- and Leitbild-research as well as, more recently, the vision assessment of German technology assessment. However, problems arise in these research traditions when they analyze and evaluate the mediality of highly-futuristic visions whose speculative contents correspond neither to current trends in nanotechnological research and product development nor clearly to strategies and interests of the actors of innovation processes. Based on a case study on the mediality of visionary images of nanomachines used in medical journals, popular science magazines, business press and daily and weekly newspapers, my article shows that highly-futuristic scenarios can by all means be analyzed and evaluated as means of communication which facilitate communication between scientific, economic and mass medial discourses about future potentials of nanotechnology. The use of these futuristic and visionary scenarios for communicating nanotechnology's futures influences discourse-specific assessments of the innovative potentials of current nanotechnological product developments. To enable an analysis and evaluation of the mediality of highly-speculative visions which are not directly related to practical affairs, my article extends the theoretical and methodological instrument of the current vision assessment program. I suggest a systems-theoretical reorientation of vision assessment which is currently dominated by actor theoretical models.

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1 Introduction

Nanotechnology is a highly visionary topic. The most significant nanotechnological developments are expected to occur in the coming decades. Scenarios anticipating future applications of nanotechnological products—e.g. innovative drug delivery systems in medicine or smart devices designed for the mobile lifestyle—are communicated at the interfaces between politics, science, economy and the mass media.[2] As sociological research on future expectations (e.g. Brown/Mikael 2003; Rip 2005; van Lente 1993), technological 'Leitbilder,' or guiding visions (Mambrey/Tepper 2000, Dierkes et al. 1996; Wyatt 2000), and the vision assessment of German technology assessment of nanotechnology (Grunwald 2004; Coenen 2004; Paschen et al. 2004) have shown, the visions are suitable as *means of communication* in innovation processes. The relevant actors use these means of communication not only to discuss the perceived goals, developments and uses of nanotechnology, but also to consider the opportunities and risks posed by such developments. Problems arise, however, when the mentioned studies try to analyze and evaluate the mediality of *widely distributed* and *futuristic* visions—e.g. visions of surgical nanorobots and mini-submarines in the human body—whose feasibility is not suggested by current scientific-technological research and development and contradicts the interests of most scientific and economic actors.

Scenarios depicting speculative and futuristic visions are often used outside of concrete agendas—e.g. agendas of research policy or corporate product development—in the narrow sense. Articles from a broad range of publication-domains—popular science magazines, daily and weekly newspapers, the business press and even scientific journals—use such visionary scenarios for the representation of future potentials of current nanotechnological research and development—for instance, the designing of novel nanoparticles for drug carriers. When one interprets the scenarios' contents literally, the futuristic visions of nanorobots and mini-submarines have virtually nothing to do with actual innovation processes in nanomedicine. These visions seem rather to take on metaphorical or imaginative mediating functions in communication processes which—as my article will show—cannot be adequately explained with the actor-theoretical models which are used most frequently by sociology of expectations and Leitbild research. Paradoxically, this also applies to the new German vision assessment of nanotechnology. In contrast to Leitbild research, vision assessment's programmatic goal is to be applicable for the *analysis*, *evaluation* and *management* of the use of explicitly "futuristic visions" (Grunwald 2004: 1-6).

Due to their actor-theoretical orientation, these studies are interested in which actors make use of certain visions in certain contexts as media for communicating futures in order to influence current innovation proc-

[2] Nanotechnological visions are thematically quite versatile, since nanotechnology is situated at the crossroads between established technologies such as material sciences, bioengineering, information, and communication technologies. Due to its multi-disciplinary nature, nanotechnology is expected to lead to continual improvements (incremental innovations) in the various branches via new convergences between the individual scientific and technological disciplines and branches. At the same time, such convergences between, for example, nanotechnology, micro technology, biotechnology, and information technology are expected to make completely new products (radical innovations) possible. The source material on future expectations of nanotechnology as a converging technology is rich and diverse; cf. the following two reports by interdisciplinary expert groups Roco/Bainbridge (2002); European Commission (2004). For more on Science & Technology Studies (STS) on the visions of nanotechnology, see e.g Selin 2002; Fogelberg/Glimell 2003; Nordmann 2004; Schummer 2004; Hessenbruch 2004; Milburn 2004.

esses. Specifically, the actors' intentions, strategies, and goals are taken into consideration. From the analytical perspective of these studies, the correlation between the visionary topics of future scenarios and current developments, strategies, and interests in certain areas of science, economy, research policy, or even in the mass media are a main criterion for the evaluation of the visions' medial effectiveness. The actor-theoretical orientation thereby shapes the analytical categorization of the visions. If a correlation between visionary descriptions of the future and current reality cannot be reconstructed, from this perspective—as I will explain using the example of the German vision assessment of nanotechnology—the mediality of visions cannot be adequately analyzed and evaluated. Speculative-futuristic visions, insofar as they are said to play a role in communication processes at all, are assessed as being 'merely' rhetorical stylistic tools of the mass media: On the one hand, they can awaken the interest of the viewers; on the other hand, they can mislead the viewers' understanding of the future potentials of nanotechnology (i.e. Selin 2002: 15; Paschen et al. 2004: 268).

According to my research, such evaluations do not explain the *specific* mediality of *futuristic* visions. My hypothesis claims that speculative and futuristic visions can function as means of communication due to their weak, or better: 'vague' and 'unclear,' references to current nanotechnological research and product development. Such visions offer 'structural interfaces' (in Luhmann's sense) which enable e.g. scientific, economic and mass medial discourses specific and—due to the discourses' different modes for processing meaning—also contrary interpretations of their contents. The visions function as *media*, stimulating *communications* which are based on the discourses' internal processing of the *disconcerting* interpretations of other discourses.[3]

A vision assessment which is oriented towards a systems-theoretical interpretation of the mediality of future descriptions would not examine future scenarios of nanotechnology to determine which actors' intentions and goals the scenarios' contents are related to in a 'literal' sense. Such an assessment would analyse *how*, within which framework (for example in which *discursive formations),* and on the basis of which forms (for example *discourse-specific references* to visionary topics) certain scenarios function

[3] This hypothesis is oriented towards Niklas Luhmann's interpretation of the function of *descriptions of the future* in current and future-related negotiation processes (e.g. Luhmann 1992a; see also Luhmann 1982). Luhmann uses the concept of *media* in his writings in various forms. In my study, I apply a media-concept based on his definition of 'media' and the differentiation between 'media' and 'form' in *Die Kunst der Gesellschaft* (The Art of Society; c.f. Luhmann 1995a: 165-214). The systems-theoretical conception of *communication* corresponds to a specific characteristic of the discourses, namely the difference of discourse-perspectives. Although discourses do not intervene in each other during communication, they can specifically incite one another to come to decisions which influence actions (compare i.e. Luhmann 1992b). Based on the actor-theory concept of 'boundary objects' in Star and Griesemer's further development of the 'Sociology of Translations,' such future visions constitute 'communicative spaces' which enable the circulation and transfer of different meanings and interests between previously unconnected actors and networks (see Star/Griesemer 1999; Callon et al. 1986). Viewed from the concept of 'communicative difference' (e.g. Nassehi 2003) in the systems theory, these 'communicative spaces' do not allow the *transfer* of knowledge between discourses, but rather communication which is based on *discourse-specific processings* of disconcerting information. For a discussion on the communication models of information transfer between contexts versus context-specific processings of disconcerting information in studies on science and technology communication, cf. for example Japp 1997; Bucchi 2004.

as means for communicating future potentials of current nanotechnological research and development.[4]

Based on the results of a case study on visionary images of nanomachines in communication processes between scientific, economic, and mass medial discourses, the aim of my article is to examine the 'additional value' of a combined systems-theoretical and discourse-analytical approach for an assessment of the mediality of highly-futuristic visions. Following this introductory chapter is a short presentation of the interpretation of visions as *means* of communication and *strategic* instruments in actor-theory oriented studies on expectations and guiding visions (Leitbilder) in innovation processes (Chapter 2). The new German program of vision assessment and its preliminary empirical results in technology assessment on nanotechnology serve in my study as an exemplary point of departure. At this point, it will become clear that categorizing the visions analytically according to their chronological periodization and 'epistemic status' (truth-factor, feasibility) leads to fundamental problems for the evaluation of the mediality of futuristic visions as well as for the development of normative recommendations for the management of the use of these visions (Chapters 3 and 4). Starting with two exemplary nanotechnological future scenarios, I explain the relevance of a theoretical-methodological extension of the current vision assessment program (Chapter 5). Using the case study on the mediality of visionary images of nanomachines, I introduce my approach of an analysis and evaluation of the mediality of visions (Chapter 6). Finally, I point out the implications of the systems-theoretical interpretation of the communicative function of descriptions of the future for an extension and modification of the vision assessment program (Chapter 7).

2 Visions as Media and Strategies

Sociological research on the dynamics of future expectations in innovation processes have examined the medial effects of expectations within development agendas or in the complex processes of socio-technological implementation in case studies on other future technologies—for example information technology and genetic engineering (e.g. Konrad 2004; Brown et al. 2000). Such studies on the performativity of expectations were able to reconstructively provide information about the effects of visions on innovation processes—for example, hopes and fears about genetic engineering—which can be made useful for the technology assessment of nanotechnology (e.g. Brown 2003; Michael 2000; Rip 2005; Meyer/Kuushi 2004). Comparable to these studies, German technology assessment, which is oriented towards technical-sociological Leitbild-research, has started to attach great importance to the analysis and evaluation of nanotechnological visions, as they are considered to have a significant impact on nanoscientific and nanotechnological development strategies and to influence the implementation of nanotechnology in society (e.g. Paschen et al. 2004).

The medial role of guiding visions (Leitbilder) as constitutive for the societal implementation of new technologies has been investigated by Leitbild-research for some time now. It is the programmatic intention to place emphasis on the necessity of researching Leitbilder and visions, since visions

[4] The functionality of this combination of a *formation analytical* discourse theory—oriented towards Michel Foucault's discourse concept (Foucault 1972)—and a *systems theoretical* interpretation of communication processes is explained empirically in Chapter 6.2 of this article. For studies on key terms, metaphors and images as mediators between discourses which are based on similar theoretical and methodological approaches, compare, for example Leyesdorff/Hellsten 2005; Maasen/Weingart 2000.

and Leitbilder are considered effective means of designing and evaluating technology (e.g. Mambrey et al. 1995: 16, Dierkes et al. 1996). In this context, the terms 'Leitbild' and 'visions' are used synonymously for the most part and are to be read in a pragmatized sense, namely "in the sense of general and future-oriented conceptions of desirable and attainable lines of technical development or normative development goals" (Dierkes et al. 1996: 23). Here, the term 'vision' is limited to the description of that which is not yet reality but should or could be realized in the future. This notion of 'vision,' often underlying political rhetoric or business programs, semantically resembles terms such as 'plan,' 'notion,' or 'intention' (Schnettler 2004: 212-213). Thus, it is hardly separable from intentional distribution and implementation strategies of agents acting as 'visionaries.'[5]

The analytical perspective of these studies is based on actor-theory. Visions are viewed as means used by certain actors as *strategic* instruments for the implementation of their interests. According to Leitbild research, Leitbilder and visions should have important formative effects precisely in the early stages of technological development and innovation processes (e.g. Mambrey et al. 1995: 20). In the examination of the mediality of visions, some approaches of Leitbild-research are—in addition to their actor-theoretical perspective—oriented towards systems-theoretical interpretations of the functionality of communication media. They view Leitbilder and visions as *media* that enable "structural interfaces" (in Luhmann's sense) between functional systems of society. Leitbilder are thereby said to function as mediators in and between the various systems (ibid.: 47). Based on this reference to systems-theory, such studies conclude that for the explanation of the mediality of Leitbilder, not the "truths" of the visions, but rather their "simple effectiveness" (ibid.: 31) is of importance. However, the simultaneous actor-theoretical interpretation of Leitbilder and visions as *strategic instruments* of actors creates problems for the analysis and evaluation of speculative and futuristic visions which are not directly related to practical affairs. These visions cannot necessarily be interpreted as strategically utilizable instruments in communication processes; however, they seem to function in another form as means of communication.

3 The Program of Vision Assessment

The demand for a specific *vision* assessment in technology assessment is—according to the connotations of 'visions' as planning instruments and distribution strategies—based on the concept that visions, by reason of their being a *means of strategy*, can influence processes of development and the socio-technological implementation of innovations. Likewise, by reason of their being a *means of communication*, they can form a common platform of understanding among the actors participating in the development and application of new technologies. Thus it is understandable why the research perspective of "vision assessment"—including the investigation of futuristic visions—is considered important for the technology assessment of future technologies (Grunwald 2004; Grin/Grunwald 2000): in its function as a prospective tool, the examination of visions and the observation of the acceptance of particular visions should make it possible for technology assessment to assess future possibilities

[5] According to Schnettler, this secularized notion of 'vision' is most wide-spread in everyday life today. In contrast to religious visions, visions today distinguish themselves through their intentional production, communicative distribution and reference to implementation (Schnettler 2004: 212-215). These visions do not refer to ideals; they attempt to describe possibilities.

and risks posed by a new technology. It might thus be possible to prepare oneself in advance for new regulatory demands. With regard to its formative intentions, technology assessment could use visions as means of communication between the various actors—the engineers and technical experts, the investors, and the public—involved in the development and utilization of new technologies in order to support and encourage the desired innovative processes by means of the mediating dialogue between these actors.[6]

In his talk on *Vision Assessment as a New Element of the Technology Futures Analysis Toolbox,* Armin Grunwald of the *Institute for Technology Assessment and Systems Analysis (ITAS)* in Karlsruhe emphasizes a renewed relevance of investigating visions in the field of technology assessment which has become particularly evident in the debates surrounding nanotechnology (Grunwald 2004). Following Grunwald, "futuristic visions," which today dominate public media debates, are produced and distributed in committees and workshops led by research-policy and investment experts, especially in US research-policy (ibid.: 1-2).[7] According to Grunwald, vision assessment dealing especially with *futuristic* visions therefore requires that previous approaches of Leitbild-research be extended analytically and methodologically (ibid.: 9).

In order to achieve this requirement, Grunwald has developed a program which provides the following *procedural steps*: the first step is a "vision analysis" involving a mapped categorization of the occurring visions. The second step is a "vision evaluation," assessing visions according to their epistemic status and normative content. The results of these first two steps serve as the basis for a third step, "vision management," which Grunwald describes as "a rational management of visions" (ibid.: 9-10; cf. also Grunwald 2006: 73-75). This renewed conception of vision assessment should enable the development of criteria for a participative controlling of technological development by means of an accompanying and constructive technology assessment.

Grunwald defines vision assessment as a further development of Leitbild-oriented approaches in technology assessment and distinguishes it from the use of visions in venture management. Compared to technical Leitbilder and guiding visions used in venture management, which are designed within the context of concrete technological developments and as depictions of the future relevant for practical affairs, the visions Grunwald attempts to analyze are characterized by their long-term status and strongly speculative elements. These visions thus function as a 'nexus' between Leitbilder and science fiction stories (Grunwald 2004: 2, 4; cf. also Coenen 2004: 82-85). By positioning the futuristic visions in question between technical Leitbilder relevant for practical affairs and speculative scenarios of science fiction literature, Grunwald bases his program of vision assessment on a relatively 'open' concept of 'vision,' comprising a combination of various types of knowledge (scientific facts, futuristic utopia, science-fiction scenarios, or social, economic and technological knowledge or skills etc.). Accordingly, visions are understood to be hybrids between various forms of knowledge (e.g. natural science, industry and business, popular culture etc.). Because this vision concept also includes very speculative future scenarios, it opens up the pragmatized vision term of Leitbild-research, which could be characterized by its closeness to a

[6] For more on the differentiation between prospective and formative functions of technology assessments, cf. the overview by Grunwald 2002.

[7] Grunwald refers to convergences between the visions of US research policy and those of the Bill Joy debates in the mass media. See e.g. NSTC 1999; Roco/Bainbridge 2002; Joy 2000a.

plan or intention striving for realization.[8] However, the strategic intentions of Leitbild research have been retained in 'vision management.' The formative intention, on the other hand, subsequently connects the vision term again with its connotation as a realizable 'plan.'

Grunwald's vision assessment claims to be applicable for the analysis, evaluation and formation of Leitbild-like and futuristic visions. However, as one can see from the first results of an application of his program, it is precisely the formative intention of vision assessment which is based on actor-theory and the literal interpretation of the visions' contents which produce problems for the explanation of the mediality of speculative and futuristic visions whose analysis and evaluation Grunwald's vision assessment aims to enable.

4 Truth and Feasibility of Nanotechnological Visions

The remarks on "nanotechnological visions" in the report of the technology assessment project "Nanotechnology" from the *Office for Technology Assessment of the German Parliament* (*TAB*) in Berlin can be interpreted as an exemplary and preliminary result of the vision assessment of nanotechnology as postulated by Grunwald (Paschen et al. 2004: 257-274).[9] In this report the necessity of a "critical examination" of nanotechnological visions is recommended since it is "an important contribution to the rational and relevant discussion about the future of nanotechnology" (ibid. 20). Through critical analysis, vision assessment could serve to identify exaggerated expectations and fears that might later become obstacles for innovation (ibid.). The analysis of *widely distributed* and *futuristic* visions is considered particularly relevant for this task. For technology assessment, "the question may be raised regarding an appropriate method of dealing with nanofuturism" (Coenen 2004: 79).

On an *analytical level*, answering this question suggests—comparable to the first two steps in Grunwald's programmatic concept—first a *categorization* and then an *evaluation* of the visions. In the TA report, these two steps are carried out simultaneously during the development of differentiating criteria. Nanotechnological visions are divided into *optimistic and pessimistic*, *unrealistic (utopian) and realistic* as well as *short-term and long-term* visions. In comparison to the utopian visions, realistic visions, as the report states, are based on "contemporary scientific findings" and "do not contradict the known natural laws" and the "structural conditions of the imagined development." "Long-term visions encompass time frames upwards from one and a half decades, short-term visions relate to the next fifteen years at the most" (Paschen et al. 2004: 257). The visions' *classifying* differences, based on their chronological periodization, are connected to *evaluating* differences according to their epistemic status and the ethical desirability of their contents.

The *empirical basis* of the report are visions which are currently being debated by the European mass media, i.e. in Germany, which for the most part originated in the American context. These dominant nanotechnological visions are divided into *two visionary discourses*: The *first* discourse includes realistic short-term and long-term

[8] For example, the visions of science fiction do not lay claim to feasibility. Science fiction authors use the future as a 'space' for thought experiments in order to play through possibilities other than current socio-technical constellations (cf. already Schwonke 1972: 61). Milburn's analysis, for example, refers to the elimination of the differences and the increasing convergences between visions of science-fiction literature and future visions of nanotechnological engineers (Milburn 2004).

[9] The following quotes from German sources have been translated.

visions in research policy, academic science, and industry which were developed in the *National Nanotechnology Initiative* workshops *(NNI)* (ibid. 19-20). Short-term realistic visions from the milieu of the *NNI* include the development of synthetic inner organs, technological substitutes for sensory organs, improvement in the reliability of electronic systems by increasing the precision of manufacture, as well as textiles with innovative functions and qualities (ibid: 263). Long-term visions are the images of new possibilities for telepresence, new ways of easing the aging process and of improving human capabilities, innovative goal-oriented medications, and invisible artifacts for surveillance purposes (ibid: 264; cf. Roco/Bainbridge 2002; Roco/Tomellini 2002). The *second* discourse is accordingly dominated by futuristic and utopian long-term visions from the milieu of K. Eric Drexler's *Foresight Institute* in California (Paschen et al. 2004: 19-20). A particularly good example of the sort of optimistic, unrealistic visions to be found in this "strongly futuristic" utopian discourse are the visions of future nano-machines, suggested by Drexler in *Engines of Creation* (1986). These so-called assemblers could—if one is willing to believe Drexler—someday produce practically all macroscopic materials and products by molecular manufacturing (Paschen et al 2004: 268-269). Considered as unrealistic as these visions are those based on Drexler's assembler images—for example, the pessimistic visions created by Bill Joy which foresee the fall of man by nanomachines or nanorobots gone out of control (ibid: 273).[10]

The *recommendations* in the TA report for dealing with visions, i.e. "vision management," resulting from these procedural steps remain ambivalent: on the one hand, optimistic long-term visions could, in comparison to short-term, product-related visions, better serve to awaken an interest for nanotechnology in the areas of academic science, politics, and industry as well as among the public. In addition, this type of vision would be suitable for assessing the future societal and technical implications of implementing nanotechnology and for initiating a related dialogue between the participating actors. On the other hand, there is a danger of promoting goals that are too ambitious and could thus end in disappointment. The popularization of optimistic futuristic visions also necessarily conveys their opposites, that is, the popularization of pessimistic horror visions (ibid. 20, 319; cf. Coenen 2004: 89).

Vision assessment is thus stuck in a *normative* and *strategic dilemma*: on the one hand, futuristic and speculative long-term visions are especially suitable for vision management since—in comparison to short-term realistic visions—they draw attention to future potentials of nanotechnology in forums of science, politics, economy, mass media, etc. simultaneously. On the other hand, their use seems very problematic when viewed from a normative perspective, since these future scenarios are not oriented towards the criterion of scientific fact (epistemic status) and feasibility. An outline of a feasible plan is impossible from this perspective in the case of futuristic long-term visions, and thus, these visions can hardly function as guiding visions (Leitbilder) for the actors taking part in the innovation processes. Therefore, an evaluation of the normative desirability of anticipated societal implications of nanotechnological futures, which seems to be relevant for practical affairs, cannot seriously be derived from these visions. The essential categorization criterion for vision assessment is

[10] This vision was the subject of a debate staged in Germany in mid-2000 in the *Frankfurter Allgemeine Zeitung*, a daily newspaper which had reprinted Bill Joy's article *Why the future doesn't need us*, originally published in *Wired Magazine* (Joy 2000a, 2000b). A synopsis of the debate is found in Schirrmacher 2001.

thus the chronologically oriented distinction between short-term visions with little meaning and long-term visions with greater meaning. From a normative perspective, however, this greater meaning manifests itself as ambivalent for prospective and formative technology assessment.[11]

The ambivalence of the recommendation can be interpreted as a result of the coupling of a *mapped categorization* according to the chronological periodization, a *content-related evaluation* of visions according to their epistemic status, and the actor-theory based *formative intention* of technology assessment. Vision assessment—in opening up the term 'vision' used in Leitbild-research—also entitles speculative and futuristic visions, such as those of science fiction, to a meaningful function as media in communication processes. Thus, current scientific and technological conditions, as well as the vision's derived chances of feasibility based on these conditions, cannot function as the main evaluation criterion. The assessment of visions according to their reality or truth factor does not say anything about their mediality in communication processes. Thus, vision assessment should analyze and evaluate the mediality of widely distributed and futuristic visions *regardless* of the feasibility of the visions' contents. Furthermore, the relevance of visions for strategic-intentional formations of communication processes should not be used as a criterion of vision analyses and evaluation.

[11] A survey of experts from various scientific and industrial backgrounds also confirmed that the chronological periodizations of nanotechnological visions of the future correspond to assessments of the visions' feasibility or speculative content. See the results of the study commissioned by the German *Federal Ministry of Education and Research* (*Bundesministerium für Bildung und Forschung*, BMBF) entitled *Nanotechnologie pro Gesundheit 2003* (Farkas/Mohnfeld 2004).

5 Futuristic and Realistic Scenarios

The relevance of an extension of vision assessment's theoretical and methodological instrument for the examination of widely distributed futuristic visions can be explained via the comparison of two types of scenarios depicting nanotechnological visions which are often used in different publication-domains (i.e. news media, popular and specialty science). Such scenarios can appear to be 'unrealistic.' They include highly futuristic visions based on long-term developments like those featuring self-sufficient medical nanorobots or mini-submarines which transport medication purposefully to the focus of an illness inside the body and carry out surgical interventions directly inside arteries or cells (see Figure 1). The visions depicted in the scenarios can also be short-term, e.g. scenes which seem relatively 'realistic,' portraying the possible integration and use of nanotechnological products in future daily life, such as biocompatible hip joints, bicycle helmets that maintain contact with cyclists' employers, and fabrics that are coated to resist stains (see Figure 2).

Both types of scenarios attempt to represent the future potentials of current nanotechnological research and product development. Both of the depicted future scenarios show familiar artifacts and modes of application, i.e. the use of a laptop in a sidewalk café, vehicles in city traffic, a spaceship or space station, red blood cells, a tube which resembles the interior of a human artery, etc.

The depicted future innovations of the *everyday scenario* (Figure 2) are directly related to nanotechnological product innovations which are expected to be realized short-term. These innovations of the future should enable improved microsystems via new nanotechnologically produced coatings and materials.

Figure 1: A medical nanorobot in an artery
(Courtesy of Julian Baum / SPL / Agentur Focus.)

The scenario was developed by the magazine *Pictures of the Future* of the Siemens Corporation (Aschenbenner 2003). The anticipated product innovations refer directly to the lines of nanotechnological product developments in the company's own field (cf. Eberl 2002; Jopp 2003: 71, 134, 145; Ilfrich 2004: 213). Due to the close link between the depicted future innovations and current innovation processes, one could automatically interpret these visions as being strategically utilizable Leitbild-like mediators in communication processes—for example in corporate development agendas or in mediations between science and the public.[12] The references to the future are mediated in the scenario via the explanatory captions about the familiar artifacts and modes of application.

In contrast to this scenario, the arrangement of the artifacts and modes of application in the *nanorobot scenario* (Figure 1) emphasizes the nov-

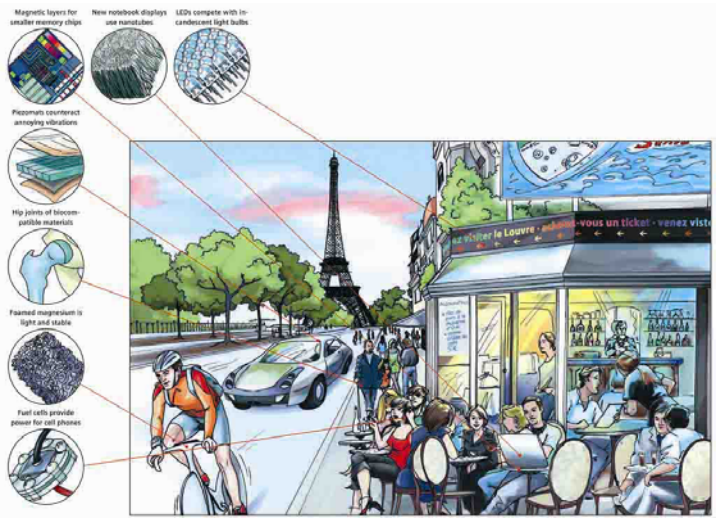

Figure 2: Nanotechnology in future everyday life.
(Courtesy of *Pictures of the Future,* Siemens AG, Munich.)

[12] These are the Siemens Corporation research-sector's declared intentions for the development of such scenarios (Eberl 2001). The same scenario is also found, with slight modifications, in an informational brochure published for the general public—e. g. school children—by the BMBF (BMBF 2004: 28-29).

elty and speculativeness of the depicted future innovations without the use of explanatory captions. These and similar scenarios of medical nanorobots and mini-submarines are found in the most diverse publications, for instance in investment guides (e.g. Beckmann/Lenz 2002), in popular science magazines (e.g. Drexler 2001), in the daily press (e.g. Haas 2003), or in medical specialist journals (e.g. Jordan 2001).[13] As compared to the everyday scenario, the nanorobot scenario does not refer to actual, current nanotechnological innovation processes. Press reports, for example, describe research projects on the development of molecular propulsion systems—which in the future should allegedly enable targeted drug carrying against the bloodstream—as a way of constructing motors for nanorobots or mini-submarines. In reality, however, research projects for the development of complex nanomachines—as they are depicted in the nanorobot scenario—hardly exist (cf. i.e. Lindinger 2003; Traufetter 2000: 169; Hardy 1999). Although—compared to the everyday scenario—the nanorobot scenario also depicts by all means familiar artifacts—for example the space-ship—and modes of application—surgical interventions in the human body's interior—the overall picture comes across as being *unfamiliar* and *in need of interpretation*. The artifacts and their modes of application are placed in environments in which they have not previously been found or observed.[14] Because the image places the artifact in use in the environment of a human artery, the artifact must be very small indeed. Thus it could be a visionary representation of a nanotechnologically enabled medical product innovation—e.g. a miniaturized surgical microsystem. Various other—even contrary—interpretations of the scenario would also be possible, depending on one's point of view.

Due to their need for interpretation and the multitude of possible interpretations of the images' contents, depending on one's perspective, such futuristic nanorobot-scenarios can hardly be interpreted as Leitbilder in innovation processes. However, it is also insufficient to interpret such futuristic scenarios as merely strategic instruments which can be utilized by the actors for the intentional and goal-oriented communication of future potentials to influence innovation processes. Surely, unrealistic as well as realistic futuristic visions could be used for the strategic goal of convincing the public of the unforeseeable potentials of nanotechnology. This strategy has been used by American research politics, for example (cf. Paschen et al. 2004: 264). This, however, does not explain the *medial* functionality of *futuristic* visions.

How can we analyze and evaluate the *specific* mediality of such futuristic and speculative scenarios? As the following presentation of my case study on the mediality of such futuristic scenarios will show, such scenarios are used quite often in popular science magazines, in business press as well as in daily and weekly newspapers, and occasionally even in medical specialty journals for the depiction of future potentials of nanotechnology. They serve not only as illustrations for texts; moreover, statements in the texts refer *argumentatively* to the visionary themes represented by the scenarios. Futuristic scenarios—for example the nanorobot scenario—facilitate linkings between precisely those arguments which can be analytically attributed to statements of various discourses. It seems that it is precisely the futuristic scenarios' 'vague' and 'unclear' references and thus their openness for vari-

[13] Most of the images portraying such scenarios derive from the "Nanomedicine Art Gallery" organized by Robert A. Freitas on the homepage of the American *Foresight Institute* (Freitas 2004).

[14] Depictions of spaceships in the human body are only known from science fiction movies (i.e. *Fantastic Voyage* from 1966, based on the Isaac Asimov novel).

ous interpretations which makes these images so suitable to serve as mediators in communications about futures.

6 Futuristic Visions as Means of Communication (Case Study)

6.1 The Distribution of Futuristic Nanorobot-Scenarios

Since approximately 2000, articles in German *daily and weekly newspapers* regularly cite a certain German research project as an explanatory example for the innovative potentials of current medical nanotechnological research and development: the development of a new technique for the treatment of brain tumors by the biologist and medical doctor Andreas Jordan of the Berlin clinic *Charité* (e.g. Traufetter 2000; Pantle 2000; Wüsthof 2002; Lindinger 2004). Jordan, in cooperation with the *Center for Biomedical Nanotechnology* (CBN) and the *Institute for New Materials* (INM) in Saarbrücken, succeeded in 'killing' cancer cells in brain tumors by heating iron oxide-containing nanoparticles in a magnetic field. Jordan and his team used the 'Magnetic Fluid Hyperthermia' (MFH) method and the 'magnetic field applicator' therapy system developed by the *MagForce Applications GmbH* and *MFH Hyperthermiesysteme GmbH* companies (e.g. Jordan 2001; MFH 2003; Ärzte Zeitung 2003). Jordan's success in cancer research is presented by the press as being possible preliminary stages for the development of complex nanomachines, which in the distant future will merely need to be injected into the bloodstream and which will then be able to find their own way—as 'intelligent' drugs—to the respective illness focus in the body. Since the end of the 1990's, such futuristic visions have been illustrated in the press primarily with visionary images (such as Figure 1) which are supposed to depict so-called medical nanorobots performing surgical operations or mini-submarines transporting drugs in the human bloodstream (e.g. Haas 2003, Traufetter 2000). These visionary images are clearly futuristic and, due to their highly-speculative contents, do not refer to actual *Charité* research or to other studies on drug delivery systems. Since the reports about Jordan's success are documents from daily and weekly newspapers, it stands to reason that such visionary images serve primarily to 'sensationalize' the presentation of information in the mass media.

The analysis of documents on Jordan's cancer therapy procedure in *medical specialty journals* led me to a surprising result, however: Jordan himself uses an almost identical futuristic image of a nanorobot in the human body as that which is used in daily and weekly newspapers—for instance, in an article in *Der Onkologe (The Oncologist)* (Jordan 2001). In this article, he attempts to convey the innovative significance of his Hyperthermia-technique with nanoscaled iron oxide particles for tumor therapy. "At first glance," Jordan argues, "the overall impression is that nanotechnology merely conveys visions ..., for instance, the 'nanorobots' or other endovascular *devices* especially for applications in medicine ... but they appear more concrete when you look more closely and concentrate on the partial solutions and production approaches, which are already being implemented, e.g., using the nanoparticles and nano carrier systems" (Jordan 2001: 1080). Jordan utilizes the image *argumentatively* to distance his own research, on the one hand, from previous research in his field on the other. At the same time, his use of the visionary image distinguishes the short-term anticipated successes of his own research from the futurism of the visions depicted in the nanorobot image (Jordan 2001: 1074-1080; see Lösch 2004a: 198; Lösch 2004b).

Similarly, since approximately 2000, the same and similar visionary images of nanorobots and mini-submarines, often accompanied by line-graphs,

have been used by the *business press* to represent the rise and fall of nanotech companies or the market value of nanotech shares. According to a report about nanotech investment options, "many a researcher is dreaming of the implementation of nanomachines which are invisible to the human eye. … With this vision, one removes oneself definitively from the substance of typical conversations with an investment advisor" (Knob 2000: C5). A similar report states: "at least ten years will pass before the first complex nanomachines will appear on the market. … Nanotech turnovers will skyrocket until 2010 …. Nanophase is one of the very few nano-companies on the stock market which actually specializes in the manufacturing of particles …. The share is highly speculative, but due to marketable products, it's a good deal" (Freise/Janich 2002: 22-24). The visions of nanorobots and mini-submarines are described in the texts, depending on the current economic situation, as either a long-term objective of medical research of particular interest to investors or as examples of the futuristic ideas of nano-research which are not expected to produce marketable products (e.g. Grotelüschen 2001; Freise/Janich 2002; Waters 2003).

Based on these *starting observations*, I posed the following questions for the case study: How can I explain the argumentative use of the same futuristic scenarios in the various domains of publication? Do the visionary images in the documents have a medial function which enables interfaces between different types of argumentation? Are these argumentations characteristic of statements in prototypical scientific, economic and mass medial discourses? Can the images be evaluated as media which motivate communications between the various discourses about the future potentials of nanotechnology?

6.2 Discourse-Specific Evaluations of the Visions

During the overall analysis of the documents from the publication domains 'daily and weekly newspapers,' 'business press,' 'popular science magazines,' and 'medical specialty journals' published between the mid 1990's and the end of 2004 (research period), I was able to *analytically* differentiate—even within the documents of one domain—three clearly distinguishable *types of statements*. All of these statements place certain themes of the visionary images *in relation* to discourse-specific evaluations of current research and development in medical micro- and nanotechnology (for the analyzed text sample and the relevance criteria of document selection, see the *appendix*).

Depending on the focus of the articles, but also depending on the lines of arguments within the articles, the texts refer to the visionary images in three different forms:

1. Based on current research and development, either the *fictionality* or the *feasibility* of future nanorobots and mini-submarines is stressed.

2. Nanorobots and micro-submarines are described either as being anticipated *incremental enhancements* of current pharmaceutical drug carrier research or as *radical innovations* which will replace previous micro-surgical technologies.

3. Nanorobots and mini-submarines are described as being either results of the *progressive miniaturization* of traditional surgical technologies or as products of a *wholly new nanotechnological design* of molecules.

Orientation towards the systems-theoretical *differentiation* between social systems and their codes and programs (e.g. Luhmann 1995b; 2000) allows me to attribute exactly those image references in the texts that—

according to the distinction 'truth/untruth'—question the *feasibility* of the represented vision to statements of scientific discourses. Image references concerning the *marketabilty* of the pictured future product—according to the distinction 'market value/no market value'—are classified as statements of economic discourses. Finally, those image references referring to the *novelty* of the depicted nanotechnological artifact—according to the 'new information/old non-information' distinction—are attributed to statements of mass medial discourses. All references or ascriptions of meaning to the images' contents during the investigation period again can be categorized into *three* different *semantic fields*: science fiction, medicine, and technology. Scientific discourses refer to the relationship between science and fiction. Economic discourses consider the relationship between incremental enhancements and radical innovations in medicine. Last but not least, mass medial discourses refer to the correlation between familiar microtechnological miniaturizations and a novel nanotechnological design of molecules (see Table 1).

Table 1: Discourse-Specific Image References

Discourse	Topic	Semantic field
Science	Feasibility	Science vs. Fiction
Economy	Marketability	Incremental enhancements vs. radical innovations in medicine
Mass media	Novelty	Miniaturization of technology vs. molecular construction

This table and analytical model of discourse-specific image references shows how the representations in the visionary images during the research period are used by *analytically* differentiated scientific, economic and mass medial discourses for the evaluation of future potentials of current research and development in the field of medical nanotechnology.

During the following course of examination, I raised the question whether and how the *effects* and *results* of reciprocal communication between scientific, economic and mass medial discourses could be *empirically* analyzed with the help of this analytical model: Which trends or modifications of the discourse-specific references to the visionary images can we observe within the research period (mid-1990's until the end of 2004)? Do such modifications correlate to observable reassessments of the depicted visions—for instance the fictionality instead of the feasibility in scientific discourses?

6.3 Discourse-Specific Reassessments over Time

Within the research period, *three temporal periods* with corresponding formations of communicative effects can be distinguished. In these periods, the specific evaluations of the future potentials of current nanomedical research and development in scientific, economic and mass medial discourses modify themselves. These modifications in each of the discourses correspond to changes in the discourse-specific image references (see Table 2).[15]

[15] For a more extensive representation of this temporal reconstruction, see Lösch (2006). The temporal reconstruction of

The textual *contexts* of the visionary images in the three periods can be described as follows:

The *first period* (end of 1990s until mid-2000) is characterized by a mood of 'starting up' in science and economy. The first possibilities of the transition from basic research to industrial application become apparent. The articles usually begin with a description of futuristic visions of nanorobots and micro-submarines which, in the course of the article, are contrasted by the description of market-oriented research plans on nanoparticles in the field of drug targeting. Starting in early 2000, an example of promising research which is often cited is the—already mentioned—research of Jordan on brain tumor treatment at the Berlin Clinic *Charité* (cf. e.g. Müller 1998; Kotthaus 1999; Traufetter 2000; Pantle 2000).

Table 2: Periodization of the Image-Communication

Period	Topic
Start up (late 1990s to mid-2000)	Future nanorobots
Problematization (mid-2000 to late 2001)	Market damaging nanorobots
Fictionalization (starting approx. 2002)	Metaphorical nanorobots

The *second period* (mid 2000 to late 2001) is characterized by a disenchantment of economic expectations. Industrial nanotechnological breakthroughs were not realized as fast as one had expected. With the market-crash of the IT-branch, the problematization of nanotechnology is adopted as possible hype and mere fad. At the same time, as a result of the Bill Joy debate caused by the publication of his pessimistic vision *Why the Future Doesn't Need Us* (Joy 2000b) in the *Frankfurter Allgemeine Zeitung,* the articles problematize the possible negative effects of futuristic visions for the public's—including also potential investors'—view of nanotechnology (cf. e.g. Knop 2000; Jung 2001; Vasek 2000).

Although previously low sales increases of nanotech companies were often brought up at the beginning of the *third period* (starting in 2002), it can be characterized by an increasing hope for the progress of nanoparticle research and the production of marketable products enabled by new nanoparticles (cf. e.g. Knop 2003; Waters 2003). The progress of the experiments with nanoparticles for tumor therapy at the *Charité* clinic and product developments by companies in the field of drug targeting, for example *Capsolution AG,* are viewed as evidence for an increasing development of marketable products in the pharmaceutical industry (cf. e.g. Wüsthof 2002; Freise/Janich 2002). Nanoparticles are dubbed "*huge* market conquerors" (Knop 2003). At the same time, the effect of the thriller *Prey* by author Michael Crichton, in which he depicts the catastrophic scenario of a swarm of nanorobots gone wild, is controversial with regard to the public's conception of nanotechnology (cf. e.g. Crichton 2002; Saxl 2002; Heckl 2002). In this phase, the debate between K. Eric Drexler and Richard Smalley over the feasibility of the pro-

these image-communications is based on results of the discourse analyses of documents from popular science magazines, business press and German daily and weekly newspapers. I also reconstructed the table of discourse-specific image references (see Table 1) in documents from medical journals. However, the examination of these specialty science documents over the short investigation period of my case study showed no significantly differentiable 'temporal' periods of image communication (as in Table 2). This result can be explained, among other things, by the weak sensitivity of specialty science publications to events, for example in comparison to the press.

Quotations 1: Exemplary image-references of scientific discourses

Start up and problematization periods: *"Nano-technicians will shrink diagnoses and repair instruments down to molecular size. … The nanorobots will react immediately to diseases in the earliest stage … The micro-submarine has already been launched as a prototype. … It is still uncertain what kind of operating power these machines will use … Nanotechnology is no longer merely a utopia—reality is already catching up to science fiction novels … Scientists are exploring the nanoworld, step by step" (Traufetter 2000: 169-171).*

Fictionalization period: *"Science Fiction: A mini-robot travels through the bloodstream" (Knob 2003: 39). "Nanorobots are injected into a blood vessel via syringe. There, they remove arterial blockages. These helpful machines exist only in fantasy" (Haas 2003: 28).*

duction of nano-assemblers also reaches its peak. Molecular nano-assemblers, and also all complex nanomachines, are increasingly being classified as fictional visions (cf. e.g. Baum 2003; Haas 2003).

The same or similar visionary images of nanorobots (such as Figure 1) and mini-submarines are used in the articles in all three periods.[16] The types of statements in the texts which I attributed analytically to the *three discourses* place their specific evaluations of current innovation processes of nanotechnology in relation to themes of the depicted visions. These relations correspond in each period to discourse-specific semantics (see Table 1). But these relations *vary* over the course of time, changing between the two sides of the semantics' dichotomies.

1. In the start up and problematization periods (from the end of 1990s until the end of 2001) *scientific discourses* interpret the visionary images of nanomachines as being representations of future innovations whose feasibility is said to be dependent on scientific-technological advancements, i.e. the nanotechnological development of suitable propulsion systems for miniaturized micro-machines. In the fictionalization period (starting roughly in 2002), the references of scientific discourses instead emphasize the fictionality of such visions (see Quotations 1).
2. This modification of image references in scientific discourses over the course of time can be interpreted as a reaction to the problematization of a market-damaging effect of nanorobot visions in *economic discourses* (starting roughly in mid-2000) which holds the popularization of futuristic visions of nanorobots and mini-submarines responsible for investors' lack of interest. In contrast to current incremental innovations via nanoparticle products in the pharmaceutical area, these visions are said to represent nanotechnology as being a radical innovation whose future marketability is allegedly too uncertain and thus incites no interest among investors. In the fictionalization period (starting approx. in 2002) this assessment in economic discourses finally switches to an interpretation of nanotechnological developments in general as being hopeful steps on the way to radical and marketable innovations of the future (see Quotations 2).
3. In the start up period (from late 1990s until mid-2000) *mass medial discourses* evaluate the visionary images as being representations of future microsystems which assume an absolutely novel molecular design of atoms and molecules.

[16] For the Start Up Period see e.g. Müller 1998; Traufetter 2000; for the Problematization Period e.g. Knop 2000; Jung 2001; Drexler 2001; for the Fictionalization Period e.g. Freise/Janich 2002; Knop 2003; Haas 2003.

Quotations 2: Exemplary image-references of economic discourses

Problematization period: *"Many a researcher is dreaming of the implementation of nanomachines which are invisible to the human eye and which can self-replicate to build new machines. … With this vision, one removes oneself definitively from the substance of typical conversations with an investment advisor" (Knob 2000: C5). "With these visions, 'nano' became a media sensation… Visionaries are talking about the possibilities. Engineers need feasible concepts… Therefore, visions are bad-advertizing for the area of research" (Vasek 2000: 18). "It's not hard to produce particles, the procedure has been known for generations. … After many years of basic research, scientists are on the verge of cashing in on their knowledge. They are founding companies and rushing the first products onto the market" (Jung 2001: 98).*

Fictionalization period: *"Nanotechnology will revolutionize industry and produce a billion-dollar market … The market forecasts for the nano-future are impressive… Like the internet, nanotechnology will likely enter almost every sector … In the pharmaceutical industry, molecular-design researchers are promising shorter development periods and higher effectiveness of medications. But nanotechnology also offers new opportunities for the administration of drugs. 'Medications can be directed via nanotechnological encapsulation directly to the focus of the disease'" (Freise/Janich 2002: 22-24).*

In the fictionalization period (starting roughly in 2002) their evaluation change to an interpretation of the visions as being representative and metaphorical depictions of nanoparticle-products in the areas of medicine and pharmaceutical drug targeting—enabled by a totally new molecular construction. Only a short time before, in mid-2000, mass medial discourses discuss the exact same research and product developments in the medical and pharmaceutical sectors as the tried and true miniaturization of pharmaceutical ingredients, but did not connect them to visions of nano-robots and mini-submarines (see Quotations 3).

In contrast to the aim of constructing complex nanomachines—such as nanorobots and mini-submarines—which should be enabled through molecular design and the ongoing miniaturization of microsystems, pharmaceutical research with nanoparticles for drug carrier systems is one of the main current areas of nanotechnological research and development, which has already produced marketable products. The shifting of scientific as well as mass medial image references enables economic discourses to interpret nanoparticles as radical but at the same time marketable innovations with high future potentials in the fictionalization period.

7 Conclusion and Discussion

7.1 Systems-Theoretical Interpretation of the Results

Viewed over the course of time we recognize fundamental reassessments of the discourse-specific evaluations of the future potentials of current developments of nanotechnology for medical and pharmaceutical fields. These reassessments are empirically observable based on the shifting of image references in the three discourses to the topics of futuristic scenarios. I interpret the temporal shifting as being the *result* of communications between the discourses. This conclusion is based on the observation that the reassessment of the future potentials in each of the discourses—for example in economic discourses—react to the reassessments in each of the other discourses—for instance, in scientific and mass medial discourses. I have determined a *specific* mediality of the analyzed futuristic scenarios within the communication processes which would not have been analyzable using a literal interpretation of the visions' contents and themes and by searching for the 'hidden' strategic interests of

Quotations 3: Exemplary image-references of mass medial discourses

Start up period: *"Nanotechnology is more than the shrinking of gearwheels and computer chips, it is a whole new way of thinking … Can human beings produce an artificial world in which atoms and molecules can be used like building blocks? … Is it possible to program these nanomachines so that they can build and copy themselves as often as is required?" (Müller 1998: 52).*

Problematization period: *"Such successes [in the development of medications; A.L.], however, are based on the miniaturization of ingredients … This contradicts the definitions of nanotechnology as the building of complex structures using the very smallest elements" (Knob 2000).*

Fictionalization period: *"Physicians are dreaming of nanorobots which cruise through our bloodstreams on their own … In 1959, the American physicist Richard P. Feynman described … the idea of being able to directly manipulate atoms and molecules one day. This vision has since become reality … Some nanoparticles have … completely new qualities. However, it is precisely this which gives nanotechnology its appeal, because when one has mastered the laws of the nanoworld, one can create new things" (Haas 2003: 28).*

the actors behind the use of the visionary images.

Niklas Luhmann has stated that current descriptions of the future can be interpreted as indications for the general frameworks and forms of future-configuring decisions within communication processes between social subsystems. Future conditions are dependent on decisions made in the present (Luhmann 1992a: 136, see also Luhmann 1982). The futuristic scenarios, in this sense, serve as the *common* and *shared* media in communication processes. As I mentioned in the Introduction of this article, the systems-theoretical communication concept defines communication as the system-specific processing of *disconcerting* information. From this theoretical perspective, communication between discourses can be described as follows: Discourse-specific interpretations of the scenarios' contents and themes—for example in a scientific discourse—disconcert other discourses—for example, economic discourses. This prompts the other discourses to modify their discourse-specific evaluations of the innovative potentials of current research and development. The observable effects of these reassessments are modifications of their own references to the visionary images.

In his communication theory, Luhmann distinguishes between *three dimensions of meaning*: According to this differentiation, visions extend the current symbolic system in the *material dimension* in light of unfamiliar futures. Via unfamiliar connections between symbols and reality, these visions encourage different ways of thinking. They accelerate interpretation efforts and contribute to the development of expectations—both discourse-specific as well as via the creation of convergences between the discourses. In the *social dimension*, the visions enable the stabilization of certain formations of assessments of future options within the communications between the discourses. In the *temporal dimension*, however, such fixations turn out to be only temporary. Realities which do not turn out as anticipated make accompanying adjustments of once-fixed assessments necessary. These ongoing adjustments are facilitated by the scenarios' polysemy and need for interpretation (Luhmann 1992a: 137-141).

7.2 Implications for the Vision Assessment Program

I will now explain the relevance of my case study's results and their systems-theoretical interpretation for the vision assessment of future technologies. With my case study I supplied evidence for the idea that the visions function as means of communication between discourses not due to a 'mediation'—in the sense of a transfer of knowledge—but rather due to their ability to

link various interpretations of their contents as well as their discourse-specific processing. The visionary images of the case study enable scientific, economic, as well as mass medial assessments of current developments in regard to possible development options of the future. The discussion of *the same* visionary images from scientific, economic and mass medial points of view facilitates communication between otherwise incompatible evaluations of innovation potentials via scientific, economic and mass medial discourses. In other words, the images bridge the gaps between different 'worlds' of society.

The *norm* for the evaluation of the medial effectiveness of the depicted futuristic visions in the case study cannot be the realization of future innovations as they are anticipated by the visions. As shown in my case study, visions can function as media in communications which are relevant for formatting the future. Whether and how certain visions function in this way can only be assessed based on *temporal reconstructions* of self-modifying correlations between discourse-perspective references to visions and discourse-specific evaluations of the potentials of current innovation processes. In this sense, the occurrence of the communication itself is the norm for the evaluation of the medial effectiveness of visions.

For the procedural steps of the current program of vision assessment (compare Chapter 3), my results call for the following modifications: On the *vision analysis* level, the systems-theory oriented analysis of the mediality of visions enables inferences as to how certain evaluations of future potentials are stabilized between discourses within communication processes (*social dimension*). In addition, my analysis shows how these formations of discourse-specific evaluations can again be destabilized over the course of subsequent communication processes in the face of progressing current developments of technological innovations (*temporal dimension*). How and to what extent a specific vision functions as a means of communication can be examined based on the variety of linkings between anticipated futures and present realities which a specific vision makes possible for the involved discourses (*material dimension*).

Instead of a normative *vision evaluation*, my approach enables a functional evaluation of the mediality of the visions in communication processes. The medial effectiveness of the visions eludes a 'direct' strategic *vision management*, which is suggested by the actor-theory orientation and the formative intention of the current vision assessment program. Intervention into the communication processes via vision management is, however, 'indirectly' made possible: Through the questioning of certain references of discourses—e.g of science, economy, and mass media—to the visions' contents and themes, discourse-specific productions of meaning can be recursively influenced. But one will not be able to predict and plan the concrete effects of this influence of discourse-specific evaluations of future potentials. The effects of such interventions, however, have been observed in the case study based on how, for example, economic discourses process the disconcerting references to the visions' contents and themes of other discourses, for example scientific and mass medial. These insights into the communicative function of futuristic visions must now be made utilizable for vision management.

The relevance of my systems-theoretical and discourse-analytical *extension* of the theoretical-methodological instrument of the vision assessment program is not limited to the analysis and evaluation of speculative and futuristic visions, however. This approach could also be used for the analysis of the mediality of realistic and present-related scenarios (such as Figure 2). The relevance of my exten-

sion of the vision assessment program, however, emerges significantly for the analysis of the mediality of futuristic-speculative scenarios.

8 Appendix

The case study is a part of the project *Spaces of Medical Micro- and Nanotechnology: Case Studies in the Sociology of Knowledge on how Technological Innovations are Negotiated and Mediated.* The overall project examines the mediating role of visions—especially in their pictorial form—in communications of scientific, economic, and mass medial discourses about the future potential of current research and development in medical micro- and nanotechnology.

In the relevant documents of the presented case study, the nanorobot-image of this article (Figure 1) appears along with three very similar images of nanorobots and mini-submarines (see Table 3; relevance criterion of document selection: current nanomedical research and development are coupled with future visions of 'nanomachines').

Table 3: Distribution of the visionary images in relevant documents

Publication domains	Documents of the case study	Images of nanomachines (4 images)	Documents of the overall project
Science (specialist journals and popular science magazines)	35	17	81
Economy (newspapers and magazines)	10	7	34
Mass Media (daily and weekly newspapers)	38	21	121
Total	83	45	236

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