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Editorial
Next Generation Technologies

This second issue completes the first entire volume of the STI Studies. Additionally, the volume includes the first special issue of our journal. When we launched the journal in summer 2005, it was still an exciting question whether we would be able to attract a reasonable number of good papers. A total of thirteen articles published this year, however, shows that there is need of a peer reviewed online journal addressing social research on science, technology, and innovation. Admittedly, we are sometimes struggling to complete an issue in time. Coping with the reviewers' recommendations and stipulations is time consuming and causes delays on the side of the authors. But we have committed ourselves to take the peer review process seriously. Thanks to responsible and thorough reviewers the peer review has turned out to be a valuable and well functioning instrument for achieving high quality but at the same time resulted in several rejections and many “revise and resubmit” decisions.

The issue contains three papers which deal with next generation technologies – and apply different strands of sociological theory as well. In his contribution *Stefan Kaufmann* explores the transformation of the military in the information age, especially the decentralization of the organization, which is triggered by the utilization of smart technology and the networking of electronically equipped units. *Andreas Lösch* shows in his paper, how highly futuristic visions of nanotechnology can serve as a means for the facilitation of communication between different actors involved, even if they cannot be directly related to strategic interests. Finally, *Johannes Weyer* deals with the question of governance of hybrid systems, since smart technology allows for the creation of new systems' designs, e.g. in form of the combination of central and decentralized control, which now is on the agenda in modern aviation.

All these case studies try to take a look into the future of modern societies, which obviously will be shaped by a new type of technology, that can be labelled "next generation technology" – not only because it differs clearly from currently used technology, but also because it allows to create new types of social organizations, where the "social" and the "technical" meet and interact in an unexpected way.

Future issues of STI Studies will continue to explore these paths.

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Land Warrior. The Reconfiguration of the Soldier in the "Age of Information"

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Abstract

The U.S. Army is currently working on the development of a new hybrid type of infantryman. Land Warrior is the name for the project which aims at equipping the dismounted soldiers with wearable computers, head-up display, permanent online connection and other technical components. The idea is to link up the dismounted soldier to an information and communications network spanning the whole field of operation. This project sets the stage for the introduction of a completely new type of soldier. It aims not merely at securing a new armament technology, but the complete technical and disciplinary reconfiguration of the soldier. The project transfers to the micro-level of the soldier the whole set of expectations which the military command units and advisers have in mind as a consequence of the epochal changeover to the "Information Age". The change introduced by information technology, so the argument goes, brings with it new kinds of opponents and dangers, but also new opportunities for military strategy. It transforms the entire fabric of geo-political and armament technology. Thus it brings the need for a change of the rationality of organisation of the military: founded on the plan of a "Network-centric warfare", there is to be a programmatic re-structuring which extends right from the ideas of warfare to the design of the individual soldier. The combination of two research perspectives is used as a heuristical guideline for the empirical presentation. Fundamental assumptions of actor-network theory, and the idea that technical expectations can be seen as far-reaching "prospective structures", lead the gaze to the decisive significance of the main expectation, that of standing at the threshold of the information age. And they bring into sharper focus the idea of network-centric warfare as a programmatic analysis, which translates the technical developments into social demands made on organisational structures, procedures and cultures; and which, conversely, interprets the military definitions of situation, strategic and tactical, as a technological challenge. Drawing on Foucault's analysis of forms of governance and its further extension within governmentality studies, this not only allows a systematic treatment of the reconfiguration of the soldier which this process of change entails, it also shows how thorough-going and far-reaching are the transformations of the soldier-subject which are envisioned. And the recourse to the Foucauldian perspective at the same time shows us how a network-type coordination of action, encouraging decentrality and self-organisation, implicitly requires for its precondition a specific kind of subjectivity structured by processes of power.

1 Introduction: the Thesis of "The Postmodern Military"[1]

Land Warrior is the term given to the project of reconfiguring the soldier in a socio-technical sense by equipping him with wearable computers, head-up display, permanent online connection, and other components. Land Warrior is not merely a technical innovation along the usual lines of development in armament technology. It is much rather the innovation of a new type of soldier. A soldier-type whose formation can be seen as both a promise and a requirement, an effect and the basis, of a new military order: "Today, we are on the threshold of a new era, and we must proceed into it decisively. Today the Industrial Age is superseded by the Information Age, the Third Wave, hard on the heels of the agrarian and industrial eras. Our present Army is well-configured to fight and win in the late Industrial Age, and we can handle Agrarian-Age foes as well. We have begun to move into Third Wave Warfare, to evolve a new force for a new century – Force XXI […] Force XXI will represent a new way of thinking for a new wave of warfare." (Office of Chief of Staff of the U.S. Army, 1994; quoted in *Der Derian* 2001: 16-17).

This quote reflects a far-reaching conviction of the military strategic thinking of today. The US army leaders are taking the "Information Age" as the starting point for their situation report. Information is determining the forms of production and civilisation. The information age is producing new opponents, and at the same time it is determining the direction for one's own "evolution". This diagnosis of having arrived at the threshold of an epoch, with the new threat situation, and the state of one's own forces – all these are now to be thought of as grouped together, as one unit – such is the pivotal concept for the military situation report. The horizon of expectations, from this sense of standing at the threshold of the information age, is here translated into a programme of restructuring the military apparatus, and this finds expression at the micro-level as the reconfiguration of the soldier. *Land Warrior* is the dismounted soldier who set up for action in the setting of this new age.

Considering the case of Land Warrior, one finds a great significance in the general observation of the actor-network theory that the development of technology – be it the individual artifacts or entire technologies – always entails the design of a complete "setting", the design of "assemblies of human and non-human actants where the competences and performances are distributed" (Akrich/Latour 1992: 259). In such "settings" – in French *dispositifs* (ibid) – the roles of humans and non-humans are distributed, role expectations are formulated, moral norms are translated into technical functions and technical regulations, possible courses of action are shut off or opened up. In the Land Warrior project, these translations and attributions are linked to the idea of the dispositive, known from the tradition of Foucault theory. Foucault applied the term "Dispositives of power" (1978) to describe the lines of force, rationalities of governance, the practical knowledge, procedures and installations, which have been directed to the fashioning of specific subjects since the 18th century.[2] And this shows us the

[1] This study was made possible by a research grant from the *Deutsche Forschungsgemeinschaft*. I would like to express my thanks to Prof. Dr. Gerhard Tröster, of the Electronics Institute at the Zurich ETH, and Mr. Riccardo Sibilia, of the *Zentrum für Wissenschaft und Technologie* of *Armasuisse*, for providing information about the technical components of Wearable Computing and the Land Warrior Project.

[2] Like other theorists who are interested in the long-term structural changes of subject-formation, and who especially look at the transition from traditional to modern societies, Foucault saw in the military one of the central institutions in which the

right context for understanding the human-to-machine integration which the Land Warrior project is aiming at. Here it is not merely a case of "prescription, proscription, affordances, allowances" (Akrich/Latour 1992: 261), for example when one wishes to integrate such items as cat-flaps, street kerbing, key-rings, safety belts, and door-closers into the human activities in programmes of action (Latour 1992, 1996: 15-83). As will be shown here, Land Warrior instead aims at something of quite a different order, a comprehensive reconfiguration of technical competencies and military disciplining. The principle here is that one does not just control this or that action, but strives to work on the general capacities and overall arrangement or dispositions of people and machines. The rationality and full range of this reconfiguration only become clear when one sees the possibilities for action which Land Warrior opens up, as a part of a more comprehensive programme of action. And this is: to manage warfare in the Information Age. Or to put it more precisely: to re-program the military so as to make it fit for warfare in the Information Age.

In order to make clear the basic reasoning, the calculation of the economy of force, which is driving the Land Warrior project forward, one has first to outline the processes of transformation affecting the international balance of force, within the frame of which the reconfiguration of the military and the soldiers is taking place. Taking up the key idea of a transition to a "postmodern military", which has now become so prominent in military sociology, one finds that there are four lines which can be identified, to describe the way this change is manifesting.[3]

Firstly, the military field of operation is governed by the perception of a new kind of threat situation. The whole set of military thinking and acting is no longer primarily focussed on the nuclear threat and on a conventional opponent. The activities of warfare and coercion by non-government agents have developed to the point where they represent a challenge to the military of Western societies. And the brief of the military is redefined accordingly. It is no longer just a case of warfare against conventional opponents. Now the opponent can also be a criminal, a drug-baron or a terrorist. As a result the brief includes numerous operations of a non-military nature: "peacekeeping", "humanitarian assistance", "counterdrug" or "counterterrorism" (cf. CJCS 2000: 7).

Secondly, there is the influence of a general change of culture which can be seen in the forming of the armed forces. There is thus the need for an adjustment to civil social developments, and a number of cultural commonplaces, dominated by masculine groupings, are undermined, for example when women are integrated in the battle-forces.

Thirdly, there is a new approach to the organisational structure which shows the armed forces in a new light. The thesis of a "postmodern military" identifies a gradual erosion of hierarchies, and the fixed boundaries between types of weaponry, and between battle

generally valid forms of governance found their model expression. Thus Max Weber (1976: 686) for example described the military as the "womb" of all discipline. And Norbert Elias (1976: espec. 263-283) also present a treatment of the structural homology, mirror-imaging and partial identity of the different practices, mechanisms, technologies and guidelines of civil and military social disciplining and subject formation.

[3] Cf. the volume by Moskos/Williams/Segal (2000), which has now become a standard reference, in which the U.S. military is introduced as the paradigm of a "postmodern military" (Moskos 2000), and then following this model the individual aspects of the change are listed in sequence for 12 further Western nations. For the international reception of the concept cf. also Boëne (2003), and for its adoption by German military sociology the omnibus volume by Kümmel/Collmer (2002).

and service troops. Thus the military programme of a "Network-centric warfare" (cf. Cebrowski/Garstka 1998; Alberts/Garstka/Stein 1999; Alberts/Hayes 2003) is found to relate expressly to the revised new context of the current type of new enterprise, where one works with de-centralised organisation, flat hierarchies, modular and task-oriented co-operation, virtual teamwork, lean production, and precise logistics. The military network concept, in an analogous way, sees the possibility of operating with flexible, task-specific procedures, and units put together in an ad hoc way. The military has to view itself, in fact, as a "network-centric enterprise" (Alberts/Garstka/Stein 1999: 89).

Fourthly, the forces of globalisation, with the loss of state sovereignties that they entail, are having their effect on the constitution of armed forces. The missions are increasingly carried out at the request of international instances, in co-ordination with other armed forces, in an arrangement with non-state organisations; indeed the troops themselves are often made up of international, and not always military, forces.

The basic forces guiding the reorganisation of the military can be determined by a reference to the thesis of the postmodern military. However, the term "postmodern military" suggests an observation of the transformation process in the military field made within a given, static typology. The typology defines observed trends of the change as factual elements of a new type of organisation, instead of analysing the process of its (potential) constitution. What is ignored by this form of analysis is a fact which immediately springs to mind when one has the perspective of discursive analysis: the expectations, plans, programmes and projects which are formulated, drafted and set in motion by the advisors, officer units, programme leaders, project developers, – they are all clearly bound and tied up to technological factors. The first point here is that right at the outset the military views itself as in the midst of a transition not to the "postmodern", but to the "Information Age", and naturally it then sets about handling the central components of its transformation process accordingly, from this starting diagnosis.[4]

It is this aspect which we will now take up as the fifth line of influence: technology defining the scope of military reorganisation and ultimately that of the new dismounted soldier. It will be presented in three stages in the following sections. (2) Firstly one needs to clearly establish what it means if the expectations for future development are centred on information and the information age. (3) Following this course of approach, we show how the expectations are linked to the planned idea of a network-centric warfare which attempts to combine a technological transformation with a reconfiguration of military organisational structure and organisational culture. (4) Finally the project of the reconfiguration of the soldier will be studied in its following aspects: (4.1) technical,

[4] As evidence for the thesis that it is the expectation of an information age, and not the thesis of postmodernism, which does in fact guide military thought, one can adduce this example of a statistical sampling. A search for key terms which was run on the Internet pages of the U.S. military and military-related institutions came up with the following results, for "Information Age" and "Postmodern". The journal "Parameters" issued by the U.S. Army War College (<http://carlisle-www.army.mil/usawc/Parameters/>) gave 72 and 28 hits resp.; the webpage of the Strategic Studies Institute (<www.strategicstudiesinstitute.army.mil/>) gave 207 and 10 hits resp.; and that of the Rand-Corporation (<www.rand.org/>) 200 and 28 hits respectively. While these webpages mainly refer to publications of strategic advisors, planners and think-tank experts, on the website of the U.S. Army (<www.army.mil>) one finds a great variety of different articles – from official guidelines, to troop reports, to military news. Here there was a hit count of 9,520 and 17 resp. (data gathered on 20.12.2005).

(4.2) skill-related, (4.3) ethical-normative and (4.4) that of disciplinary space. Unlike in the case we mentioned of a typological attribution, here by applying the concepts of expectation, programme and project, emphasis will be placed on the dynamic and mobilising character of the transformation.

2 Expectations: the Military in the Information Age

One can say that it is now freely accepted in (technology-related) sociology, that expectations about possible future technologies direct and guide the actions of social actors, that arrangements are made for certain future developments.[5] The descriptions of the society-structuring factor of expectations for future technology, are strongly coloured by this idea of "prospective structure" (Lente/Rip 1998). "Expectations allocate roles for selves, others and (future) artefacts. When these roles are adopted, a new social order emerges on the basis of collective projections of the future." (ibid 203) The idea that expectations about technical developments are particularly liable to actually becoming a deciding force of structuration, is supported by the fact that the talk of an inevitable technological progress can be considered as a central "ideograph" for the modern era, and conversely, technical progress can be viewed as the classic feature of modernity (Lente 2000). Since the progress in what is technologically feasible appears to be an evident fact, the step from the prediction of a development – often coming across as tantamount to a promise – to the necessity of it happening, is readily made (ibid). The predictions of a future technology generally press for action. It is precisely these two factors, a strong and effective will to fashion structures, and a great keenness to describe future expectations as necessary requirements, which one can observe in the present transformations of the military. One can track the way the idea of the "Information Age" inspires the successive unfolding of socio-technical structures, on three levels of social aggregation: it presents general guidelines of armament technology, it defines the frame of military organisational alignment, and also the frame for the restructuring of the soldier. Now we will deal first with the general guidelines of strategic armament.

The concept of the information age is linked to a set of expectations which are concerned primarily with the macro-societal level, predicting a far-reaching change in all fields of society. The main reference for the military experts, the "forethinkers", is the work of futurologist Alvin Toffler. "Third wave" is the metaphor used by Toffler (1980) to describe a third wave of epochal change, which is to bring a change in civilisation comparable to that caused by the transition to the agrarian economy, and to the industrial revolution. Toffler's diagnosis is translated in the military field as a diagnosis identifying a "Revolution in Military Affairs", a conceptional standard which has already been given an acronym: RMA (cf. Hundley 1999; Sloan 2002; Cohen 2004). This reference to an epochal transition, the mention of a revolution, is used to support the radicalness of the change demanded in the military field, its urgency and its wide scope. Mobilise and get ready for a constant change, so runs the military programme. "In today's world, change has become the norm, not the exception", this is how Frank Fernandez, director of DARPA (Defense Advanced Research Projects Agency), describes the state of affairs (quoted from *Der Derian* 2001: 102). The rhetoric of looking to the future, of

[5] For the role played by future expectations about the development of specific technologies, in ideals, metaphors, science fiction, political agendas, cf. Dierkes/Hoffmann/Marz 1992; Mambrey/Pateau/Tepper 1995; Brown/Rappert/Webster 2000; Konrad 2004; Uerz 2004.

radical and permanent change, becomes ubiquitous when one speaks of RMA. In 1994 the army refers to it as "new force", "new century", a "new way of thinking" and "Force XXI". Later on one finds such concepts as "Army after next" and "Future army", presented as guidelines for a change of organisation. And in 1996 the future-oriented programme *Joint Vision 2010* is issued, addressing all the armed forces; followed four years later by *Joint Vision 2020* (cf. CJCS 1996, 2000).

The talk of RMA suggests some far-reaching technocratic visions. Regarding armament technology, it lays stress on the dynamics of technical development, especially information and communications technology, which is said to do away with the existing base of military power. No longer does military strike-power result primarily from the potency of weapons, but rather from a superior co-ordination of information and communications technology. The expectation transits seamlessly into requirement: "The future is, as Toffler says, that unless you tame technology, we will encounter future shock. We're not only taming technology, we are turning technology into not future shock, but future security." (defence minister William Cohen 1997, quoted from *Der Derian* 2001: 113) The RMA caused by information technology is going to come anyway, so the logic goes, one just has to keep abreast of it, at the forefront of it. It is certainly clear that efforts in the field of armament are concentrating on information technologies under the head of "digitization". Two technocratic visions are linked to this: that of the "transparent battlespace", and that of the "precision strike" (cf. Sloan 2002: 4-9). Surveillance using satellites, planes and low-flying unmanned aircraft will – so the prediction goes – make all that can be visible, visible, using radar as well as thermal and optical imaging. And parallel to this, in the field of Command and Control, there will be sufficient executive power to fight everything that can be observed. Warfare in the "Information Age" means that one no longer tries to gain military strength by individual, superior weapons systems, but rather by using information and communications technology to network them, by "intelligent munitions" and new surveillance technologies. Certainly such visions are an advantage in the struggle for budgets and funding: information technologies hold out the promise of delivering more performance at less expenditure (Adams 1998: 93-101, 122-137; Sloan 2002: 46-48).[6]

In this way the military use of the term Information Age draws on a basic principle of the sociological thesis of an information society: "By information society one evidently means a recommendation and a program of

[6] At this point it would be appropriate to add a note about the current state of the literature. Most of the publications on the subject of this military transformation originate from the military sector itself, and the military sociological research, too, is almost everywhere (this applies especially to the USA) institutionally and financially tied to military organisations, and accordingly application-oriented (cf. Caforio/ Nuciari 2003). Hence we find that mixtures of diagnosis and advice are the rule. The present study is based on a comprehensive analysis of materials about RMA, especially the numerous publications of the "think tanks" such as the RAND-Corporation or the Command and Control Research Programme; further, the leading journals in the field of military studies have been systematically evaluated, and here as a primary reference one can name *Parameters*, the Quarterly of the US Army War College. Regarding the change in training, the published studies of the U.S. Army Research Institute for the Behavioral and Social Sciences have provided a detailed insight into the transformatory processes, while a description of their broader outlines can also be found in the texts of military sociology. The present article is based to a large extent on a kind of reading "against the grain" of the central programmatic writings, i.e. advisory texts and instructions as well as the findings of military sociology literature. Such an approach in this context was only used by the quoted writings of Der Derian (2001) and Dillon (2002).

action which one wants to impose upon a government." (Stichweh 1998: 438) It is our perception that this thread occurs throughout the entire sociological works: from the one performed on behalf of the Japanese government which introduced the term into the political debate towards the end of the 1960's, up to the now well-known study by Simon Nora and Alain Minc which was ordered by the French government in the year 1980, and finally up to Al Gore's programme of information-superhighways (cf. ibid: 434-439; Konrad 2004: 41-49). The military prognosis participates in widespread visions of how controllable and manageable technical and social progress will be, and takes up the idea of a transition from industrial warfare to war in the information age, translating it into the technocratic vision of a transition from *mass destruction to precision warfare* (cf. Adams, 1998: 292-304; *Der Derian* 2001: xv-vxii). The expectations bound up with the information age first structure the military apparatus in two ways: they prescribe the focus for armament technology, and they exert an extremely mobilising effect by setting the mood for extensive processes of change.

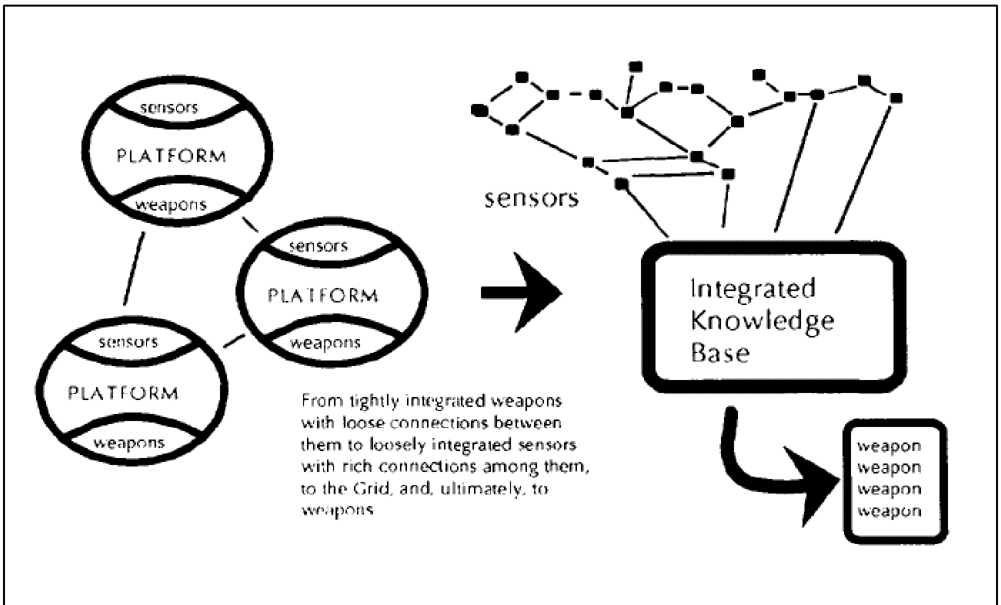
3 Programme of Action: the Network as Prospective Structure

Finally, the idea of a network-centric warfare leads from a general mobilisation to the actual, concrete programme of transformation. The concept was introduced into the debate on RMA by vice-admiral Arthur K. Cebrowski with his co-author John J. Garstka, in 1998, and rose to become the programmatic guideline for the restructuring of the American armed forces. As the "father of network-centric warfare" (DoD 2001), Cebrowski was eventually appointed director of the Office of Force Transformation, which was formed in November 2001 with the task of coordinating and promoting the structural change of the armed forces.

The entire programme of network-centric warfare aims at a comprehensive transformation: "Initiating a whole-scale re-thinking of the very basis of military organization, doctrine, force requirements, procurement policies, training and operational concepts." (Dillon 2002: 73) The idea derives its effective energy and plausibility from a variety of heterogeneous sources. The factors and procedures of structuring the organisation, are geared to the new organisational rationality governing enterprises in the economic field, as we have indicated earlier. And the idea gains further plausibility from the reference to the type of organisation of the new opponents, who are after all themselves, too, operating in the networked rather than the hierarchical style (Arquilla/Ronfeldt 2001). Furthermore, it draws its powers of persuasion from considerations of complexity theory, which draw parallels between natural events as interpreted by chaos theory and the nature of warfare, and explaining the societal concept of self-organisation as a strategy for managing complexity (Alberts/Czerwinski 1997; Czerwinski 1998). Finally – and this is the point which is to be outlined in what follows – the concept of network-centric warfare draws its rationale from the translation of cultural forms which have emerged from the development of the Internet, into the setting of warfare.

The immediate reasoning, however, is that networking is considered to be the key to an increase in military strike-power. The director of the Command and Control Research Program David Alberts and his co-authors put it like this: "We define NCW as an information-superiority-enabled concept of operations that generates increased combat power by networking sensors, decision makers, and shooters to achieve shared awareness, increased speed of command, higher tempo of operations, greater lethality, increased survivability, and a degree of self-synchronization." (1999: 2) In harmony with this idea, as one of the central initiatives in this transformation, the U.S. Defense Department has been working on setting up a Global Information Grid (GIG) (Libicki 2000). The GIG is considered to be an "Internet-like network for D[epartment]O[f]D[efense]-related operations" (GAO 2004: 3), a military Internet in which everything is connected, the entire command and control systems, all the weapons platforms, all the soldiers down to the individual footsoldier, together with other services, from weather to the secret service. A projected date for the basic installation is 2020, and 21 mill. $ have been set aside for the period to 2010 alone.

This military Internet is the technical means to implement the new organisational structures, procedures and social behavioural forms – or to put it more precisely: the means to initiate the "coevolution of organization, doctrine, and technology in the warfighting ecosystem" (Alberts/Garstka/ Stein 1999: 3). The Internet, or an Internet-type design of information management, is conceived as the catalyst for a completely new structuring of social roles, an entirely new organisational culture. On the basis of the GIG, information management is to be shifted from a "platform-centric" to a "network-centric" design, and operated in a way akin to the Internet. And this is a trend which is diametrically opposed to the present military communications methods. Martin Libicki (1999: 23) presents these ideas graphically in the following sketch (Fig. 1).



No longer are we to have the scenario where the individual battle groups have access to specific means of surveillance, and the gathered information is then made mutually available to each of them. This is how the conventional form of military information management is set up. The new method now is to have the sensor data entered into a common network, and then distributed and made retrievable via this network, in collated, processed, stored and administered form. The "networking of sensors, decision-makers and shooters" thus means doing away with the exclusive power of certain specific platforms to hold specific pieces of information. The flow of information is to be decoupled from the traditional functional and hierarchical differentiation. Hierarchies, monopolies, the asymmetrical control of information, are brought into a kind of marketplace allocation. The information flow is decoupled from the hierarchy of command. The powers of information management are shifted from the sender to the user. No longer do those who provide the information decide to whom it is to be given, for whom it might be of use. They simply enter it into the network. Potential users decide what they want to do with it (Libicki 1999: 71-93; Alberts/Garstka/Stein 2000: 65-68; Albert/Hayes 2003: 74-82). This is exactly what is meant by "shared awareness": the distribution of information takes place not through "stovepipe monopolies" but via the GIG, which consists of "eclectic, adaptable marketplaces" (Alberts/Hayes 2003: 218).

Even more far-reaching is the proposal to radically change the function of command. One heuristic approach to successful philosophies of command, from the 20th century, lays out a series of six steps: passing from a manner of proceeding which is regulated in a detailed fashion and centrally controlled, to operational forms which are decentrally controlled by general rules and intentions only (Alberts/Hayes 2003: 18-26). Equipped with network technology, one might expect that one could potentially operate using all types of procedure. But, say the protagonists of network-centric warfare, the optimum in "speed of command" und "tempo of operations" can only be attained using the latter type of procedure which we have just mentioned: "Self-synchronization is perhaps the ultimate in achieving increased tempo and responsiveness." (Alberts/Garstka/Stein 1999: 175) Self-synchronisation means short-circuiting the feedback-loops of observation, orientation, decision, action, which are spread out over various functioning units, and hence also the traditional chain of command itself: even before a command is issued, the subordinate instance has grasped the situation and anticipated the change needed (cf. Wesenstein/Belenky/Balkin 2005: 95-97). The central entity to which the actors orient themselves is no longer the command, but the picture of the overall situation, which is circulating in the network.

Military publications have drawn a lot from thinkers of the "cyberpunk culture" described in Wired Magazine (cf. *Der Derian* 2001: 17-18). Here again it is not the technocratic vision of central control, central management, which is given priority, not the technical engineering metaphor of the network. Rather it is biological evolution and self-organisation which are seen to enable the management of unpredicted events by a co-ordination of scattered knowledge, by organisation using bottom-up processes (cf. Wyatt 2000: 118-120). The tendency is for the network to overlay the chain of command: "Unlocking the full power of the network also involves our ability to affect the nature of the decisions that are inherently made by the network, or made collectively, rather than being made by an individual entity." (Alberts/Garstka/Stein 1999: 105). Collectivist principles are no longer opposed; they are incorporated as a productive force. The collective takes centre-stage, the power of position is replaced by the effective powers of relatedness. Functions are no longer hoarded at command posts, now the motto is rather "Power to the Edge". (Alberts/Hayes 2003: 180-181)

Following on from the focus on network structures, other factors of expectation of the information society come into play, beside those with the stress on the potential for technocratic regulation and control. When the protagonists of network-centric warfare refer to an information society, they are evidently inspired by media theory and inter-cultural flow, for example when they refer in an appreciative way to the forms of a "distributed social order" (Faßler 2001), and this with a view to reconstituting the military itself as just such a network organisation.

4 Land Warrior: The Soldier as Socio-Technological Project

The new rationality of organisation, and the new organisational culture which is emerging along with it, call for a redesigning of the soldiers themselves. Within the compass of network-based military operations, new models of leadership are developed, and the infantryman, the simple dismounted soldier, is also thought of in a new way. The defining character of what goes to make up a soldier is in a process of change.

This change can be described schematically as having four aspects, with reference to a general analysis of forms of government, meaning the forms of governance and self-formation (cf. Foucault 1986: 37-39; Dean 1999: 20-39).

Firstly, forms of governance always work with specific techniques, with a certain kind of expertise and know-how, together with procedures, instruments and strategies, to shape specific subjects. From this standpoint, the predominant feature which characterises the dismounted soldier is that he is conceived as a socio-technical venture at the height of the information age. Here the techniques of subject-formation lead to a technical hard core.

Secondly, the techniques of governing are always informed by a specific knowledge, a specific rationality. They refer back to an underlying thought-structure, which determines what can be taken as realisable, what can actually be done. For the new soldier, it is the appeal to the network idea itself which is the basis for determining what the soldier has to learn, in what direction, by what methods he should be shaped, by what skills he should be distinguished.

Thirdly, the techniques of administration present a set of duties, of rules, of expectations, by means of which the subjects are bound and defined. Subjectivity is based on an ethical dimension, it is not conceivable without some ethical foundation. And in the context of the network-based reconfiguration of the soldier the question presents itself with fresh urgency, as to what should be the professional culture, the soldierly ethos, the thing which marks the soldier apart from all other subjects.

Fourthly, every form of administration contains a *telos* or aim, which means it at once brings into play a kind of utopia or utopian ideal. Governing is based on programmatic formulations and ideas which work on the assumption that subjects can be fashioned in the desired manner. And yet at the same time, every programmatic approach draws its energy from the fact that programme and reality do not match up completely. We will now take a closer look at this *telos* of governance, which presents a kind of utopian ideal, in order to show the special form of disciplinary space which is set up in operations following the network paradigm.

4.1 The Soldier as Information-Technology Venture

During a conference organised for the Pentagon by the Oak Ridge National Laboratory in 2001, the purpose of which was to formulate proposals for the visions and plans outlining the development of the soldier of the future, General Paul Gorman of the *Institute for Defense Analysis and Science Board* described the general situation of the infantryman as follows:

"The soldier of today is thrust far forward. He is the point of the Army spear. It is very lethal and very lonely out there. The soldier of tomorrow will never be alone and he will advance on his enemy shielded by dominant information. His leaders will be able to say this to him: ‘Soldier, you are the master of your battlespace. You will shape the fight. The network will enable you to see all that can be seen. You will out-think, out-maneuver and out-shoot your enemy. The Force is with you. You are one with the Force.'" (NSD 2001, Composite Vision: 2)

The mobilisation of the future, the playing off of the present against a predicted technical development to come, characterises the forming of the soldier. Gorman's diagnosis of the present situation hints at the fact that the dismounted soldier was a neglected figure in the military thought of the Cold War. There was no place reserved for him on the highly modernised battlefield, an area possibly even contaminated by tactical atomic weaponry. The only form one could still imagine the infantry taking was in the guise of robots. And it was only the new threat scenarios which brought the infantry back into view. Generally the miscarried operation in Somalia of 1993 – which as "Black Hawk Down" has already been turned into a notorious media event – has been styled as the starting-point for considering a complete overhauling of the infantry (Adams 1998: 60-80, 108-111).

The ultimate soldier of whom Gorman speaks was first presented as the "Land-Warrior" in 1994. The "Land-Warrior" was going to be an integration of the dismounted soldier into the information network covering the entire field of battle, by means of wearable computer, permanent radio contact, global positioning system, headgear with integrated speaker, microphone and optical display, laser rangefinders, day/night cameras and other technical devices. The overall idea of network-centric warfare is based on the feasibility of technically linking up the infantryman to the tactical situation picture, to keep him permanently online. The infantryman should not merely be fitted out with new pieces of equipment. Rather he is projected as an integral unity of man and machine (Sterk 1997: 69; Schaprian/Rather 1997).

Land Warrior is a project in which three general expectations for the research into wearable computers are spelled out in military terms (Baumeler 2005: 10-15). Firstly, what the traditional soldier could learn of just by a kind of vague sensing, will be achieved by automated *context sensitivity*: sensors integrated into the uniform and distributed at other locations are to recognise surroundings which are contaminated chemically, atomically or biologically, and trigger automatic warnings. And also the vague sensing of the opponent, and his concealed or nocturnal movements, is to be replaced by an exact technical viewing, such as by thermal-imaging devices. In addition to all this, the network provides the soldier with an *augmented reality*. From getting help with a foreign language, to the map showing the location of friend and foe, he is to be provided with every possible kind of supplementary information. He can veritably immerse himself in this augmented reality, where information is shown to him via a see-through display, imaged directly into the optical field, for example in the form of distance lines, prohibited areas, or targets. (NSD 2001, composite vision: 20; Wehrtechnischer Report 2003: 31-35). Finally, the Land Warrior is to be given the capacity for *autonomous and proactive action*. The system should for example automatically recognise the soldiers' positions and send out corresponding reports. Bodily functions (pulse, temperature) are to be automatically monitored and any irregularities reported. Nano-technologies, which are planned for the successor of the Land Warrior – the Objective Force Warrior, – are to open up even more far-reaching possibilities: textiles which actively regulate the microclimate, and which register any loss of blood and then automatically tighten, and which can recognise the surroundings and adapt to them like a chameleon (Erwin 2003; Rötzer 2003; Shachtman 2004).

Here, the technique of shaping the soldier consists in using this method of fitting of new technologies directly onto the body of the infantryman, to constantly push the duality of technical and social into more areas of action. The soldier becomes a hybrid actor, whose technical components are increasingly modified to take on qualities which are considered to be specifically human – such as behaviour which is specific to a situation and the ability to learn during "proactive acting" (cf. Rammert/Schulz-Schaeffer 2002). For example the visual perception of the soldier’s surroundings, or his own bodily condition, changes from an exclusively social action to an action that is both human and mechanical; and the two can then be recombined in a modular way. In this manner the network-centric logic, of decoupling sensors, decision-makers and shooters, is transferred to the microlevel of the action of the individual soldier. Thus for example during the act of shooting, a kind of transference of media takes place in the unity of eye, firing sight, target-location and firing. Targets can be marked by having data sent in from the network. In this way it is possible for soldiers to take aim at a target which they merely see in virtual form. This also makes new shooting techniques possible: by using a video-sight, the eye can be lifted from the sight, the rifle moved out from cover and held above the head or pointed round a corner. The image from the video-sight is transferred to the head-mounted display, and so the target can be aimed at in this way. Supported by the network, new forms of combat interaction also become possible. Thus a soldier can request laser or GPS guided fire, by marking an objective with his laser. The soldier becomes the sensor for a shooter who does not have the target in his field of view (cf. NSD 2001, Panel 2: 4). The expected gain in flexibility, speed and coordination which this combination of man and machine offers, is immediately apparent.

The characteristic feature here is the projective, future-oriented nature of the scenario. The equipment appears to offer endless possibilities. And thus new projects are constantly invented. Even though the Land Warrior has not yet come into production, work is already being done on his successor.[7] With the technological shaping of the soldier a utopian telos of governance has already been brought into play: the human being as infinitely adaptable Cyborg. Such a vision is derived from the field of space travel in the early 60’s and the associated literary genre. According to the predictions, the human being will be able to survive in surroundings hostile to life, thanks to scientific progress (Spreen 1998: 7-12). Essentially Land Warrior is working on a technical heightening of the sensing-power of the soldiers. In the case of Future Force Warrior, the protective suit is itself to become "intelligent" as well, to recognise the surroundings, and assist the movement of the soldiers by "exoskeletal strength". What once applied to outer space, now gets transcribed to become a military programme in battlespace: the "subject"

[7] Equipped with a budget of 6 billion dollars, the original plan was to have about 10,000 such systems ready for deployment by the year 2000. However, today there is still no production-ready version 1.0 of the "Land Warrior". The planned introduction met with repeated delays because of technical problems. A report by the Government Accountability Office (GAO 2005: 91-92) states that in January 2005 the personal network area system, which contains the switches, wiring and interfaces which are meant to connect up the elements worn on the body, was still not ready. And also the software-based Joint Tactical Radio System, which was to ensure that all the radio equipment used in the tactical area would be compatible, was still at the development stage. A further problem was the enormous weight of the total kit, which depending on the kind of full set of equipment ranged from 86 to 100 pounds (Wehrtechnischer Report 2003: 31-38).

becomes the technological "project" (Flusser 1994).

4.2 Professional Skills: the Idea of the Multi-Skilled Warrior

In this new configuration, bottom-up processes and self-organisation become the central factor in military operations, especially at the tactical level; the Internet design of knowledge and information structuring, is thus transferred to the military organisational structure, inspired by media techniques. This is perceived as the only way to be in a position to deal with the dynamics and complexity of the new military tasks. But more than just equipping each soldier with new technical skills – "digital skills" being the appropriate term here (Schaab/ Dressel/Moses 2004; Baxter 2004) – they are to be given a broader set of overall capacities and competencies.

In harmony with this idea, the *Army Research Institute for the Behavioral and Social Sciences* (ARI) is working systematically to determine precise profiles of the new requirements, and is carefully examining the models for new forms of training. As a first stage, a research programme of the ARI is investigating how the new set of geostrategic tasks and the push for more technology affects the conditions of the soldiers' training and service. It has identified six basic changes (HRRO 2005: 2-4). The organisation is to be understood as a "learning environment" and no longer as an organisation with stable descriptions of official posts. It exhibits a "transformed Army culture", because "every soldier is trained and equipped to be a decision-maker". It is characterised by new communications methods, involving an enormous frequency of communications. These three points are now added at the top of the list of military criteria and requirements, and only afterwards do we find listed the old factors, such as action under stress and in situations of endangerment to life, as characteristic features of military operations. Thus, the research institute suggests, right at the recruiting stage other "KSA's" (Knowledge, Skills, and Attributes) have to be tested and promoted: the ability to adapt, the ability to communicate, and even cultural tolerance, these are given priority now. The training objectives here define a new type of soldier – this in turn attracts a different type of recruit, one who is far more educated, for the military. "Intelligence" is prescribed as the main precondition.

The essential purpose of the training, as proposed by the ARI, is found in the concept of the "Multi-Skilled Soldier", an aim which is clearly set apart as different from traditional training methods (Nelsen/Akman 2002). Traditionally there have been very clearly demarcated and separate descriptions of the individual occupations: this is termed Military Occupational Speciality (MOS). There is a very precise ruling about which skills a person fitting a particular MOS must have. The purpose of this system, which was introduced at the start of the 20th century in the sense of Taylorist job descriptions, is to enable a ready access to replacements. Should, say, a soldier of a mortar platoon, with job code MOS 11C20, be effectively put out of action, then he is simply replaced by another MOS 11C20. Naturally in this system it would still be possible for the soldier to gain further qualifications. But what has changed now is that in every training programme from the start, other wide-ranging skills from other departments are to be integrated. Both teamwork and independence are to be strengthened. The job boundaries are now seen as flexible, the jobs themselves in the midst of a flux. As a consequence of this, continued training is now the duty of every soldier. What is more, a quality which was previously considered suspect for all but the command levels, is now to be a standard requirement for every soldier: the creative problem-solving ability: "The focus of the training would be to instill in the soldier the mindset of adaptability, self-education, and problem solving as defining attributes." (ibid: 6)

Adaptability, self-education, problem solving are viewed as necessary skills for every soldier at the crest of military missions in the information age: "In one moment in time, our service members will be feeding and clothing displaced refugees – providing humanitarian assistance. In the next moment, they will be holding two warring tribes apart – conducting peacekeeping operations. Finally, they will be fighting a highly lethal mid-intensity battle. All on the same day, all within three blocks. It will be what we call the three block war." (Gen. Charles Krulak, cited in Alberts/Hayes 2003: 66) Krulak's oft-quoted idea of the "Three Block War" reflects the new situation in political security, the new perception of threat, here viewed from the perspective of tactical missions. The broadening of what one considers to be the military field of deployment becomes the basis for making new demands on the soldiers' abilities and performance. It is the ready canvas, on which the image of the soldiers' qualities and skills is drawn. The situation may call for an instant transition from negotiating good relations between national groups, to fighting the enemy. It affects both the inner attitude, and also the skills needed in, say, switching a display from foreign language assistance to enemy situation picture. In such situations, the command and obedience structures ingrained by practice, the specialisations and mechanical routines – the kind of discipline which Max Weber had in mind when he spoke of the "iron cage of obedience" – can no longer suffice to ensure an adequate service. The soldier has to adapt himself to a regime of fluid transformation and change: "The multifunctional warrior is now trained to think not what to think. At one time, the warrior was trained only for certain missions. We are now breaking down this linear environment. Task organization is becoming increasingly fluid." (NSD, 2001, panel 1: 7)

This fluid, transformatory regime, which the sociological diagnosis identifies as the central characteristic of the information age (cf. Castells 1996, Lash 2002), is now dictating the military plan of operations – it guides the profiling of the new soldier. While before the emphasis was laid on obedience, one now speaks of "empowerment". Network-centric warfare "involves the empowerment of individuals at the edge of an organization" (Alberts/Hayes 2003: 5). And Land Warrior is considered to be one of the decisive instruments for flattening the hierarchy and shifting the power of the organisation downwards (Adams 2000: 55). The spirit of a general is to be planted in every private. Thus Krulak (1999) could describe the new key figure emerging from this fluid regime, as the "strategic corporal".

4.3 Professional Culture: the Ethos of the "Land Warrior"

The protagonists of network-centric warfare orient themselves to the communal visions of Internet culture, they relate network culture to a culture of the collectivity. As a result, the key problem which every social network organisation has to face now becomes crucial: if self-organisation tends to replace the hierarchy, then trust becomes the central resource for cooperation (cf. Weyer 2000: 11-14). The *Joint Vision 2020* speaks of a spirit of "jointness", which is to hold the armed forces together, from the small group up to the highest levels transcending the separate armed forces, from soldier to leader. The theorists of *network-centric warfare* go on to assert that "interoperability" also holds sway in a "cognitive" and "social domain" (Alberts/Hayes 2003: 107-114); that means it would be based on deep emotional and normative ties. *Network-centric warfare* calls for a search for stronger forms of cohesion. And here the answer to the problem of building trust can indeed be found in the traditional military way of strengthening self-definition: the common ethos of the soldier. Not only should the qualities and skills of the soldier be developed, it is the ethical shaping of the soldier which becomes a central project of a future-oriented transformation process.

Considering effective ways to collect together all the "efforts on winning the Global War on Terrorism", the U.S. Army (2004: 15) named 16 concrete initiatives which were to be given priority. One of them was: "The soldier – develop flexible, adaptive and competent soldiers with a warrior ethos." Such a warrior ethos has been developed by a task force specially set up for this in the army's programme of transformation. The result is tantamount to a confession of faith: "A warrior's ethos. I am an American soldier. I will always place the mission first. I will never accept defeat. I will never quit. I will never leave a fallen comrade. I am an American Soldier. I live by this creed."[8] This ethos, which is firmly integrated at every step of training, is aimed not only at guiding the soldier's behaviour, it is intended primarily to promote a collective identity. To the question "What do you do for a living?", the soldier should no longer reply: radio-operator, cook or electrical engineer in the army, or suchlike, but: "I'm a warrior" (Burlas 2004). Besides this initiative, a plethora of discussions and programmes have arisen as to how this spirit of jointness is to be developed. Suggestions such as these emerge: to survey the "command climate", in order to assess the ability of officers to create trust (Jones 2003); to base the promotion system more firmly on the organisational unity rather than on individual careers (Smith/Corbin/Hellman 2001: 106-110); to experiment with an extension and prolonging of the basic training in order to strengthen the collective identity (Nelson/Akman 2002: 12).

This leads conceptually to a twofold contradiction in the constitution of the "postmodern" military, as the military sociologists have observed, which is bound to emerge in network-centric warfare. The first point is the contradiction between the attributes of a "warrior" and a "peacemaker", which for example finds expression in the dichotomy of "to be fit for action" vs. "empathy", of "decisiveness" vs. "expertise", of "obedience" vs. "cooperativeness" (Nuciari 2003: 75). And secondly, the contradiction between an organisation which, oriented to social and yet no less to technological qualification profiles, compares and equates the professional image of the soldier to that of other commercial activities, and yet attempts to distinguish an ethos specific to the profession, the state of being a soldier, from all other activities (ibid: 76-80). Both are to be strengthened at the same time: the warrior and the peacemaker, the obedient soldier and the independently responsible expert. Network-centric warfare makes of contradictory demands a feature of its programme. The new soldier is meant to be both peacemaker and warrior, he is to be capable of acting in an independently responsible, creative and adaptable way, while yet remaining ever obedient to orders, subject to the military collectivity and duty-bound to service of the nation.

When we look at the way these contradictions come into play, we find that there is an aligning of the network-centric military organisation to match the new opponents of the information age undermining the sovereignty of the modern state – from subversive political networks, up to new forms of organized crime and terrorists groups. For these too – according to the analysis of Arquilla/Ronfeldt (2001: 328-343) – replace organisational rigidity by a

[8] This "Soldier's Creed" in the concise version cited here can also be found as a videoclip (www.army.mil/warriorethos/).

greatly increased density of communications, which is achieved by a methodical use of new information and communications technologies, and by encouraging a communal approach with the use of narrations, values and doctrines. The term network was always associated by the national force-organisation with a kind of terror because networks are by nature organisations at the boundary of formal adhesion, at the edge of dissolution. It is not unusual for combatants to run off when they see things getting too risky. And networks are also seen as a terror because they operate constantly on the verge of transgressing rules. Indeed the network was ever the metaphor for the criminal, the underground, the radical. And it is precisely in this twofold manner of operating at the edge, that lies the radical nature and ambivalence of this endeavour to break through the bounds of the iron cage in which Weber saw the people of the modern era confined, by the mobilisation of the power of the Land Warrior (cf. Kaufmann 2005: 247-250).

4.4 The Soldier on the Screen: the Network as Control Room

Besides ethos and doctrine, network-centric warfare does of course hold one special medium for securing trust: the military Internet itself, this "Common Operational Picture" (COP). In these techniques of subject-forming, characteristic forms of visibility are set up, one establishes effective control instances for maintaining and using visibility. And in this very control space we find a further utopian aspect of the network-form of governance, expressed here in military terms.[9]

The essential element, around which the whole networked form of operation revolves, is the COP: "Shared battlespace awareness emerges when all relevant elements of the warfighting ecosystem are provided with access to the COP. This means that battlespace awareness must be viewed as a collective property (a type of collective consciousness)." (Alberts/Garstka/Stein 1999: 135) The network-based military operates with a "collective consciousness", in the form of media-technology. The link-up to the COP widens the perception. The individual infantryman still knows the situation of friend and foe, he has sensor-data available to him, he is in e-mail-contact with soldiers of neighbouring units and can call up assistance for his particular action over the network. But at the same time each individual soldier is given a "data-double". The infantryman will be constantly online, his movements will be registered and fed into the situation picture. He will have this picture presented to his own view on a head-up display, the whole time. Thus the soldier acts as his own observer, watching his actions as they are represented on the screen. The soldiers can become virtual commanders of themselves, because using the screen they are able to relate their own situation to the overall situation – and that means self-synchronisation. And they act always under the observation of the others for whom the same applies. The network becomes a generalised control space. The collective consciousness, which Durkheim has so effectively shown to be widely distributed and deeply anchored in many of the regulations, norms and instances of society, would here be represented by a kind of running media installation.

What the COP would mean here, is not so much a control by monitoring the execution of a plan, rather what happens is that the whole sequence of *command and control* – that means planning, reconnaissance, orientation, decision, command, surveillance – converges in one simultaneous process. The optimum in governance is

[9] Regarding the social dispersion of network-formed governance, see the outline by Kaufmann (2004). For the comparison to the supervisory technique of 360°-evaluation, which functions in a very similar way to the COP, see Bröckling (2003).

attained if the constant self-adaptation to the changing situation pictures can be kept up. "Leadership" no longer figures as a quality which is allocated to one person or one position, but as an emergent phenomenon that develops out of the situation (Albert/Hayes 2003: 184-186).

This *telos* of governance, where there is a constant optimisation and fine adjustment of one's own forces, does contain utopian factors for its operation.[10] Gorman's saying, "the network will enable you to see all that can be seen", relates to ideas of a "transparent battlefield", and many have imagined a "God's-eye view" circulating in the network. And this is exactly where one finds the technological utopia: God's insight is immediate, whereas soldiers have to rely on media, on data. Again, it is just at this point where the whole apparatus of information and communications technology, from the GIG to the display of the Land Warrior, comes into play, the whole process by which the reality is brought quite literally "in-formation", via media, via the readings which are worked on by "digital skills". To imagine that this whole machinery steps into a kind of pure media-space, because it runs friction-free, is utopian. This idea hides, for example, the dialectic that when one transfers the war almost entirely into another sphere, that of information, this leads to counter-movements.[11] And it hides the "frictions" – to use this Clausewitzian term – in one's own gear-wheels, which follow on from internal increases in complexity; for example when everyone is able to decide about targets.[12] Viewed in this light, one might conclude that network-centric warfare is a project of the type described by Daniel Defoe at the end of the 17th century: part of a phase of enthusiastic project-building, which takes it original model from the tower of Babel (cf. Klopotek 2004: 218-219). But of course this utopian undercurrent is linked to project-forms in the sense of contemporary management, which works with concrete objectives, with definite time-periods, with evaluations for individual intentions. The phase of enthusiastic project-building is the driving force behind efforts to realise network-centric projects. The expectations for such technological and social developments are relatively impervious to problems, setbacks, and the failure of individual projects, quite simply because they relate to nothing less than the threshold of a new era.

[10] It is precisely here where its strength lies: for example, although the implementation of Land Warrior has been delayed for years, the project is constantly being revised but never given up. And again the negative events experienced in the Iraq war – for example that strong forces of the Iraqi army were "overlooked" despite a superior surveillance, or that during the fast-moving mobile warfare in the first phase, it was not possible to set up information networks with corresponding swiftness – all this could be brushed aside while focussing on the future development to come. (cf. Scully 2004; Onley 2004; Grant 2005).

[11] One knows for example that NATO, relying on their high-tech reconnaissance in the Kosovo war, dropped some 3,000 precision bombs. They struck 550 targets: 50 tanks – and 500 decoys (Sloan 2002: 94-95). Camouflage and simulation is only a means of counteraction, and indeed the internal military critics never tire in pointing out the sensitivity of information technologies towards counterattacks (among many others: Mey/Krüger 2005: 32-33, 36).

[12] The army officer Robert Leonhard (2000: 156-157, 224-225) reports that during large-scale experiments with information-based operations, the use of munitions caused "logistical nightmares". Instead of fighting important targets in a focussed way – and thereby sparing munition as planned, – everything that the improved surveillance identified as a potential target was immediately fired at. Hence there is a constant discussion about the problem of "information flooding" on all levels, and linked with this, whether one can raise the standard of training accordingly, specially at the lower level (cf. among many others Mey/Krüger 2005: 34).

5 Conclusion

The military sociology, like the military programmatic theorists themselves, has for some time now been suggesting that a comprehensive transformation of the military field is currently in progress. A discourse analysis of the programmatic itself, such as the one being carried out here, reveals that in its central formulations it is founded on expectations, which have hardly been acknowledged by the military sociological analysis: primarily, the expectation of a radical technical change.

It was possible to take a three-tiered approach in describing this central role of the expectation of a technical change: there is the strategic-technical transformation which is inspired by the key-word "Information Age"; then the technical, organisational and operative transformation by applying the idea of network-centric warfare, which is clearly realized as and decidedly presented as a coevolutive project; while at the level of soldierly discipline the transformation crystallises out as the Land Warrior project.

In order to understand the mobilising force, the dynamics and range which the programmatic is developing on these three levels, we refer to two distinct research viewpoints with the theorems implicit in them. The idea of "prospective structures" gave some impression of the tremendous mobilising energy which the talk of a transition to the information age evokes in the military context. The term is linked to technocratic visions of monitoring and control, and suggests that in future the superior weapons systems will result from the technology of command and control and no longer from superior weapons platforms.

The idea of "prospective structures" draws on the actor-network theory, whose basic assumption is that technical change should always be expressed in sociotechnical terms, and against this background one can discover the logic linking together the key elements of the planned technical and social change of the military. The programmatic of a network-centric warfare can be read as a kind of applied actor-network theory, where a military Internet becomes the catalyst for a reconfiguration of the entire organisational fabric. And this leads to a new orientation for the organisational structure, the operational procedures, the information management and information culture. Here the network serves as the pivotal idea, guaranteeing the homologous alignment of the technical procedures and social roles, tasks and attitudes. The fact that the idea functions here more as a metaphor than a clearly defined concept, is precisely what lends it such power: it allows heterogeneous factors, those of decentralised, modular, flexible methods of co-ordination in the economic field, to be combined with tactical methods of battle and the communitary approaches of an alternative Internet culture. Interconnectivity and interoperability become key features, applying in equal measure to technical systems, sociotechnical units of action, the units of organisation, and also to individuals. Furthermore the idea of network-centric warfare, in both its technical and its social components, is viewed as providing the answer to the various geostrategic and tactical challenges which the "Information Age" presents.

This is most evident in the sociotechnical reconfiguration of the soldier, as envisaged by Land Warrior. By referring back to Foucault’s theory of subjectivation, which is taken up in current governmentality studies, we gained a viewpoint allowing a systematic approach to the change in the shaping of the soldier within this frame of a network-centric warfare. Firstly the soldier, and especially his senses, will be newly constituted as a sociotechnical hybrid. Secondly, it is not only the network of technical and human activities now being built onto the body which imposes new demands on the capacities and skills of the soldier. It is rather the overall functioning of a flexible and network-based organisation which makes up the rationality of the concept of the "multiskilled warrior", who is primarily designed for adaptability, self-education and problem-solving. Thirdly, the question of how to compensate for the loss of formal cohesion which characterises a network is answered by a strengthening of fundamental ethics. And the method for this involves learning from the new network-organised challengers with an almost mirror-like emulation. Fourthly, and this is the second answer to the loosening of formal cohesion, one feature of the Common Operational Picture is that a new form of control emerges, which no longer follows the old pattern of top-down control – the aim now is rather to secure a constant adaptation to the situation by means of a generalised self-control.

Thus we find that the reference to Foucault's idea, that one should identify the traces of power in the constitution of the subject, gains a double significance. It not only allowed a systematic analysis, at the level of subject-formation, of the perspective offered by actor-network theory, trying to find the conditions, mechanisms and contents of networks where the technical action potential and social action potential become compatible. It also demonstrates in an exemplary way just how much the network coordination form, with its independently acting, independently deciding, flexible subject, is the result of a power-based subjectivisation process. This is not a new discovery, but it does lend itself to a specially meaningful use in this military context.

As we have repeatedly stressed: here the main focus of interest has not been the theoretical or methodological aspects, but an examination of the basic sociotechnical orientation of the programmatic theorists, working to reconfigure the method of warfare, the military apparatus and above all the soldier, as a network-formation. It is well-known, for example from studies of organisation sociology, that there often lies a broad rift between such programmatic and the actual forms of operation and leadership. And not only where the internal structure is concerned: the question also arises whether it is really feasible to deal with terrorist networks and a partisan-type warfare with forces armed in this manner. On this point we merely indicated certain contradictory elements and the general utopian nature of the project.

But one should take the programmatic seriously. It ought to give sociologists pause for thought, when the very institution which, at the beginning of the modern era, had for many social theorists represented the model example of the new organisational and social type, and which is still now most strongly associated with a hierarchical structure, should now be found to be adopting quite a different organisational and disciplinary mode for its fundamental orientation. And not only this: until now it has hardly been considered in sociology how the entire field of national security is undergoing an extensive restructuring under the new head of "networking" (cf. Kaufmann 2006). In view of such considerations, the diagnosis of the "Rise of the Network Society" can be granted further plausibility.

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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-

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[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

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[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

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[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-

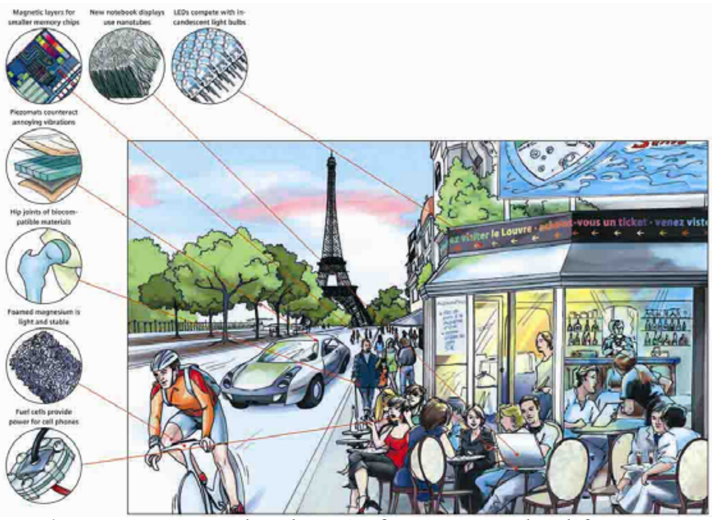

Figure 2: Nanotechnology in future everyday life.
(Courtesy of *Pictures of the Future,* Siemens AG, Munich.)

[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 nanoresearch 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

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.

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-

> **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 micromachines. 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 nanorobots 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 extension 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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Modes of Governance of Hybrid Systems. The Mid-Air Collision at Ueberlingen and the Impact of Smart Technology

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Abstract

The paper deals with hybrid systems, where human actors and non-human agents meet and interact. Different from most of the literature on autonomous technology, which mainly deals with the question of agency of non-humans, the paper puts forward the assumption that the release of smart technology may lead to a deconstruction of order or even a regime change, thus raising the question of how order emerges in hybrid systems. Discussing different sociological concepts, the paper identifies two modes of governance: central control and decentralized self-organization. However, smart technology allows implementing different system's architectures, some of which may go beyond this traditional distinction. Referring to a case study on collision avoidance in aviation (and especially the mid-air collision at Ueberlingen in 2002), the paper shows that hybrid systems create new opportunities, but entail new risks as well. The release of smart technology seems to intensify well-known problems of automation, especially when systems get out of control. Aviation is one of the societal fields, where experiments with new modes of governance currently take place that combine features of central control and decentralized self-organization.

1 Introduction: The problem of (social) order

Modern knowledge societies find themselves in a situation that may turn out as the threshold of a new era, which is constituted by a new relationship of man and machine, of technology and society. Smart agents are now being released in large numbers into the real world, which are stupid compared to human beings, but can generate "intelligent" behaviour if they are interconnected to large networks. Smart technical agents meet human actors more and more frequently, and they interact and coordinate their actions. Artificial societies emerge and mingle with human societies. Hybrid systems come into being which are constituted of human and non-human decision makers.

Sociology has reacted to this phenomenon in different ways: Bruno Latour and others raised the question of agency of non-humans and proposed a symmetric ontology (cf. Latour 1998). However, the primary focus of Latour has always been the claim that non-humans have to be accepted as equal ranked co-players, disregarding the question of the specific features of the interaction of humans and (smart, autonomous) non-humans in distributed systems – and whether it differs from other types of interaction. Other researchers in the fields of "artificial societies" (cf. Epstein/Axtell 1996, Macy 1998) and "socionics" (cf. Malsch 1997, Kron 2002) have tried to utilize their knowledge of human societies and to transfer it analogously to artificial societies in order to create more realistic designs of multi-agent systems that – conversely – help to better understand how social order emerges out of the interaction of utility maximizing agents. Despite of many insights about the functioning and especially the dynamics of distributed systems, the obvious shortcoming of this kind of research has been that it is not suited to explore the interaction of real humans and artificial agents.

Thus the question remains unresolved, how orderly structures emerge in hybrid systems, which consist of human actors and non-human agents. Referring to *human* societies, the term "social order" typically implies

- the existence of various self-interested actors (thus establishing the need to regulate the processes of interaction and exchange by some kind of rule-set),
- a mechanism of the generation of mutual expectations and trust as a base of cooperation, and finally
- the sedimentation of proven patterns of interaction in the form of stable societal institutions which serve as constraints and generate a kind of momentum as well (cf. Esser 1993, Weyer 1993a, Schimank 2005).

If we refer to *hybrid* systems, many questions still are unresolved, e.g.

- how interaction works, if actors and agents are involved (and, besides, if we are allowed to apply the term "interaction" to these processes at all),
- how a certainty of expectation can be achieved, which is – referring to Uwe Schimank (1992) – an inevitable prerequisite for strategic action in modern societies, and finally
- how rules, norms and even institutions emerge in hybrid systems, that guarantee a certain amount of integration and stability and make possible the governance of this new type of systems – in a way that avoids risks and allows for a safe conduct of operations.

Referring mainly to the third item, the following paper will show that smart technology allows for creating hybrid systems, which offer the opportunity of a regime change (in aviation and in other large technical systems as well) by deconstructing the old order and establishing a new order that entails a new mode of governance. Additionally, hybrid systems seem to open up *differ-*

ent options to go beyond the traditional distinction of the two well-known governance modes: central control and decentralized self-organization. Hybrid systems create new opportunities, but entail new risks as well. Aviation is one of the societal fields, where experiments with new modes of governance currently take place.

1.1 Preview of chapters

Chapter 2 of the paper sketches the research on smart technology and hybrid systems and tries to identify different arguments in the analysis of the interaction of man and smart machines. One thesis that can frequently be found in literature is the assertion that the introduction of smart technology increases uncertainty and risk, leading to a *deconstruction* of traditional patterns of social order (chapter 2.1). These tendencies mostly are related to a new type of distributed systems, which are able to generate practical solutions by means of self-organization in decentralized networks, thus establishing a new kind of autonomous technology (chapter 2.2). This issue has been integrated into a sociological theory of distributed agency by Werner Rammert and Ingo Schulz-Schaeffer (chapter 2.3). However, they did not deal with the creation of order which is at the centre of this paper. In the work of Gene Rochlin some hints can be found concerning the management of complex systems, leading to a classification of types of order. Thus the question can be raised, whether smart technology facilitates the *construction* of new modes of governance of complex systems, which go beyond the traditional distinction of centralized control and decentralized self-organization (chapter 2.4).

Referring to this state of the art of research on smart technology chapter 3 presents a case study on the Traffic Alert and Collision Avoidance System (TCAS) – one of the first cases of a hybrid system that failed and contributed to a catastrophe in aviation in 2002. The invention and introduction of TCAS can be regarded as the transformation of the traditional, hierarchical system of air traffic control (ATC) and the creation of a new type of order in aviation. The paper presents insights into the operational logic of TCAS (chapter 3.1), especially into the interplay of human actors and non-human agents (chapter 3.2) and then analyses in a Perrow-like style the causes of the mid-air collision near Ueberlingen in 2002 (chapter 3.3).

Chapter 4 first asks, if the debate on "pervasive computing" may serve as a framework even for the analysis of TCAS (4.1), and then tries to answer the question of whether modern aviation can be regarded as a hybrid system of distributed agency (4.2). It then summarizes the argument of the change from the old regime of centralized control to the new regime of decentralized self-organization more systematically (4.3). Chapter 4.4 finally outlines the perspectives of future aviation that go beyond this distinction, leading to a short conclusion (chapter 5).

2 Smart technology and hybrid systems

2.1 Pervasive computing

In aviation, in road traffic as well as in many other sectors of society we can presently observe a new type of technology emerging which differs to some respect from the (automation) technology of past decades. It has been labelled "pervasive" or "ubiquitous computing". The visions of the engineers suggest that in future a large number of smart, embedded agents will monitor and control our actions and help us to manage our everyday life ("smart washing machine") or dangerous situations e.g. in traffic ("smart assistant systems"). These agents may become more and more autonomous, thus displacing the human decision maker.

Referring to Marc Weiser, who first outlined the vision of ubiquitous computing in 1991, Friedemann Mattern (2003) describes the vision of a world, which is inhabited by miniaturized, sensor-equipped devices that have the capability of context-awareness, i.e. they can observe their environment and can react to a change of certain parameters (such as light, temperature, speed, distance etc.). These smart devices are part of almost any object (desk, window, door, coffee machine etc.) and can communicate the collected data with other parts of the system (cf. TA-Swiss 2003b).

According to Mattern and others, a large number of pervasive smart objects will observe the movements and actions of all people involved and check them according to predefined patterns.[1] These smart devices are omnipresent, but they are disappearing at the same time – they become invisible to the user (cf. Weiser 1991). In future no human being will be forced to operate a computer interface any more (like a computer keyboard, a touch pad or any adjusting lever e.g. for the central heating), because all the smart objects around observe their environment and act according to pre-programmed routines, e.g. switching on the light when you enter the room.

However, many proponents of smart technology also have identified considerable *risks*, since smart objects allow for an identification and localisation of mobile objects and people, thus raising questions about data protection as well as about abuse of these systems for surveillance by totalitarian organizations (Mattern 2003: 14). This conflict seems to be irresolvable, because if you strengthen data protection by inhibiting the hidden exchange of data, the performance and the efficiency of the systems will diminish and vice versa.

Mattern points at a large number of unresolved questions, which – according to his opinion – have to be solved urgently, if modern societies want to exploit the potentials of the new technology. One cause of concern is the possible loss of control, if smart objects become disloyal. Another question is the degree of autonomy of smart objects. A further serious problem is the erosion of trust, which emerges for example by dynamic pricing in the internet or by the dynamic adjustment of the (mostly) virtual environment (cf. Skiera 2000, Mattern 2003, TA-Swiss 2003b).[2] Trust is a central feature of modern societies, because – as Uwe Schimank argues (1992) – strategic actors can only execute goal-oriented action if there is at least some sort of certainty of expectation, i.e. a (mutual) expectation that other actors will behave in a predictable way that has emerged as a result of previous actions and interactions. Furthermore said certainty of expectation allows for individual and organizational learning and thus is – in addition with goal-oriented action – one major precondition for societal development. In a world without trust social relations will erode and societal development will slow down or even grind to a halt.

In a world of smart, adaptive things the objects are no longer stable and resistant, but soft and fleeting (cf. Hubig 2003). This may result in a number of severe consequences for

[1] The basic underlying technology is Radio Frequency Identification (RFID), i.e. the equipment of people and objects with transponders that submit all relevant data needed to identify and to track a person; cf. Locquenghien 2006.

[2] Mattern (2003) and others such as Langheinrich (2003) discuss the option of a virtual memory which helps finding a path through the real world by providing information about the objects. If each object has its own website, the "identity" of the objects as well as the – virtual – reality we are living in, may change frequently and may be manipulated easily.

human action, because individual (as well as societal) learning is only possible, if you can fail when acting strategically. According to Hubig, in a smart world that constantly changes people are hindered to act strategically, because strategic action implies to take into consideration the boundary conditions of action (the world outside as well as the presumptive actions of other actors), to calculate the probability of success and failure, and subsequently, to adjust the strategy according to the result of the action.

Hubig and other critics of pervasive computing thus emphasize the deconstruction of the traditional order of social life, which has been triggered by the introduction of smart technology. Intelligent systems, as described above, prevent human actors from acting strategically and from learning that way because they try to avoid situations in which the individual can fail (and learn) – by presenting or rather constructing a "perfect" world that shows up according to the system's rules, the user does neither know nor understand.

2.2 Distributed systems

In order to grasp the capacity of smart systems it is necessary to understand the sources of their performance, which differ significantly from previous systems e.g. in automation technology insofar as agency is constituted by the cooperation of distributed components.

Smart systems typically consist of networks of embedded computers, which are equipped with sensors and communication devices in order to collect data and communicate them to other components of the system (cf. Mattern 2003). The singular components of these systems are not intelligent, at least when regarded from the point of view of traditional artificial intelligence (AI) research. They are rather stupid because of lacking computer power as well as missing capabilities to overview the whole situation. The single device doesn't have global information, but the network of "smart" object may develop a remarkable problem-solving capability.

In the last decades the traditional notion of intelligence which mainly focuses on the cognitive capacities and human-like properties of a machine has been replaced by a new concept of intelligence which focuses on the problem-solving capacities of computer systems or rather multi-agent systems ("practical intelligence"). This paradigm shift has among others been promoted by Rodney Brooks. In his book "Flesh and Machines" (2002) he describes his unsuccessful attempts to program a robot that could manoeuvre safely through a building, avoiding collisions with people and objects. All attempts to take into consideration, according to the model of anticipative planning, every possible situation and to supply the machine with a software-based routine to cope with these situations, failed as Brooks shows in his description. It is the simple changes of light and shadow during the course of the day that raise unsolvable problems to a robot of this type (Brooks 2002: 39pp., 52). Every conceivable constellation had to be put down in the memory of the central processor, and it would take several minutes to calculate one single step of the robot. In fact this device would be incapable of solving very simple tasks.

Therefore 20 years ago the idea came up to do without a central processor, to distribute "intelligence" among the different parts ("agents") of a machine and to combine these parts into a multi-agent system (MAS). The singular agents only have little computer power, but they can act autonomously according to their simple internal rules, and – the most innovative feature – they can monitor their environment and thus contribute to a behaviour of the entire system that can be described as adaptive. A MAS robot can very easily move through a building only complying with simple rules of movement and collision avoidance. It is rather the coupling of a number of simple, decentralized agents and not the superior "intelligence" of a centralized brain that makes these systems so powerful. "Intelligence" thus appears as an emergent feature of the network (and its coordinating activities) and not as a given property of the elements (also cf. Weiser 1991: 72). MAS systems can act in real time and they can adapt to their environment. Brooks created small insect-like machines which moved around with an astonishing agility and thus contributed to the emergence of the new research field of "Artifical life", because the behaviour of the machines resembled living organisms. Above all: The performance of MAS was much better than the performance of classical robots constructed by referring to the traditional, "cognitive" AI paradigm (also cf. Christaller 2001).

Since then the idea has gained ground in different sectors of society (e.g. transportation or aviation) that decentralized systems of distributed agents can perform better and help to avoid risks (cf. chapter 3).

2.3 The question of agency

Promoted by Brooks and others, during the last 20 years a new generation of technology has emerged, which can be categorized – according to Werner Rammert and Ingo Schulz-Schaeffer (2002) – as interactive, intelligent and adaptive. This results in implications for the interaction of man and machine, since the traditional instrumental notion of technology no longer applies, if technological devices gain the capability of autonomous decision making. Thus, from a sociological point of view the question of agency of objects arises.

Rammert and Schulz-Schaeffer have made an attempt to answer this question in a way that goes beyond the symmetrical ontology of Bruno Latour (1996, 1998). They raise the question of how technology studies shall deal with technical objects, which behave and interact in a way that resembles social interaction (Rammert/Schulz-Schaeffer 2002: 16).[3]

There are more and more technical systems where intelligent agents assist or substitute the human decision maker (e.g. in modern airplanes, trains or cars, cf. Timpe 2002). The behaviour of a car which brakes automatically in case of danger looks very similar to the behaviour of a car where the action has been taken by a human controller. In many instances we are unable (from an outside point of view) to distinguish human action from non-human action, because the system's behaviour is almost identical. It can only be said, the socio-technical system, consisting of the driver, the brake assistant and other devices, has performed in a way that usually is described as an action, which is based on a decision. Thus, people attribute a more or less strategic behaviour even to non-human agents and technical objects, if they behave in a way that resembles human action (cf. Brooks 2002: 56).

Rammert's and Schulz-Schaeffer's construct a model of "distributed agency between people and objects" (2002: 21), which distinguishes different levels of "agency" that can be achieved either by human actors or by technical agents (43-50):

- causality: the ability to trigger changes,
- contingency: the capability to act in a different way (i.e. choosing alternatives),
- intentionality: the ability to control and to give meaning to the given behaviour.

At the first level there are almost no differences between men and ma-

[3] Bruno Latour never dealt with smart objects, but with representatives of a technology that can also be understood by using the traditional instrumental notion of technology, such as key tags or speed bumps; cf. Rammert 2003.

chines. A dish washer can do its job at least as good as the well-behaved husband. However, to meet the decision which kind of dishes may be put into the dish washer (second level), requires some sort of advanced technology which can for example distinguish different material. Bid assistants at electronic market places or autopilots in modern planes obviously can be subsumed to this category.

The third level is the most complicated one. Rammert/Schulz-Schaeffer avoid a final statement (e.g. on ontological issues) and call for an observation of the societal practices of attribution of intentionality to either people or objects instead (47). They argue that intentionality is not a natural ingredient of human action, but mostly a product of processes of interpretation and attribution. Human beings are used to suppose that someone who acts in the way he acts, has done so because he intended to do so. But nobody really knows, if this assumption of rational decision making is true. The same could even apply to machines. Today we still are not used to assume that a brake assistant acts intentionally, but – according to Rammert/Schulz-Schaeffer – this is a societal practise we should reflect about and not a fixed ontological fact.

Rammert/Schulz-Schaeffer have sketched a new framework that helps to better understand the roles, actors and agents can play in hybrid systems. However, some questions remain. First they do not deal with the interaction of actors and agents as well as the emergence of social order out of this interaction. Their model just integrates non-humans into a framework of agency, which obviously is guided by the concept of equality in character of human actors and non-human agents. This implies that sociology can construct agent societies according to the rules of human societies, taking a similarity of actors and agents for granted.

Second – as a kind of consequence of the first issue – from their point of view the interaction of a human with other humans cannot systematically be differentiated from the interaction of a human with non-humans.[4] Rammert/Schulz-Schaeffer thus cannot put forward the question, if different types of systems and even new types of social order emerge from these different kinds of interaction. They confine themselves to the micro-level of agency, which is important without doubt. However, since they do not treat the problem of social order, they also do not deal with the question, if these new types of hybrid systems are feasible or even desirable.

Finally Rammert/Schulz-Schaeffer do not care about the consequences or risks of hybrid systems and their diffusion in society. Instead, they call for a new approach, which explores the broad variety of distributed agency open-mindedly. Their model thus can be regarded as a neutral point of view which does not care about possible societal risks of hybrid systems, as put forward by the authors quoted in chapter 2.1.

2.4 A new mode of governance?

A more sceptical, pessimistic view is taken by Gene Rochlin, who summarizes the experiences already made by implementing agent systems in different sectors of society. In his book "Trapped in the Net" (1998) Rochlin discusses the "unanticipated consequences of computerization" (subtitle of the book), which is – to start with the conclusion – a fundamental transformation of society. His argumenta-

[4] The still open question, if one should apply the terms "interaction" or "cooperation" even to machines, can be answered here, referring to Rammert (2003: 297), as follows: if technology can change its behaviour according to the given situation – which is level two of the scheme presented above – then it might appropriate to use this term. This concept differs deeply from Latour, who attributes agency to every kind of (technical or natural) object.

tion is based on a number of case studies on the informating of labour, the management of organizations, computer trading, the automatisation of high reliability systems and, finally, on different instances of the implementation of smart technology in the field of the military. His main argument is that in history we can observe a sequence of modes of management of organizations as follows (7p.):

- Hierarchical, centralized control and rational planning (core technology: mainframe computers, period of time: 1950s and 1960s),
- flexible, decentralized self-organization (core technology: personal computer, period of time: 1970s and 1980s),
- central control of decentralized structures by means of networking (core technology: networking of heterogeneous, distributed systems, e.g. via the internet, period of time: since the 1990s).[5]

Rochlin's book deals with the apparent paradox that in the third mode (mode C) the networking of autonomous elements eventually ends up with a total control and loss of autonomy. Road traffic is a good example to illustrate this recent paradigm shift (cf. Spehr 2006): in a first step the singular cars could improve their performance by adding electronic assistants such as the navigation system, which largely increased the autonomy of the drivers, e.g. in finding an alternative route in case of congestion (mode B). As soon as cars become "knots in the net" (TA-Swiss 2003a: 2) which communicate all relevant data bidirectional, a re-centralization and a redistribution of authority takes place (mode C), which in principal gives way even to visionary concepts of the remote control of road traffic, e.g. in order to avoid negative effects such as congestions (cf. TA-Swiss 2003a, Weyer 2006a). This would imply far-reaching interventions from outside and an almost total loss of control on the side of the drivers.

Referring to this partly foreseeable, partly even realized change of the system's architecture and its control logic, Rochlin uses the term "computer trap" (217) to point at the unintended and unpredicted consequences of the implementation of smart technical devices. His main concerns are the foreseeable risks of this development such as the deconstruction of social institutions (56, 208p.) and the growing vulnerability and dependency of society on a kind of technology which can hardly be controlled, but entails unpredictable risks (11, 14, 106, 186).

One would obviously misinterpret Rochlin, if one relates these negative impacts to the character of the technology and nothing else. Rochlin insists that it is the striving for a permanent improvement of efficiency (and the utilization of computer networks to achieve this objective) which causes a development that eventually ends up with a standardization of processes and a subordination of decentralized systems under a central plan (as e.g. in the case of inventory or data warehouse systems). The technological foundation of this type of systems, which operates in a mode of central, anticipative control, is the electronic networking and integration of numbers of elements in real time (mode C). Rochlin uses the term "micro-management" (149, cf. 63), to indicate a strategy of vertical coordination, which intervenes directly at any level by means of advanced IT devices, thus governing every process in the whole organization. Rochlin also hints at the risks of such a development, which are a loss of autonomy and "slack" (63, 213) – i.e. the ability to react to unexpected situations flexibly – as well as "the potential losses of social means for learning, social capacity for adaptation, and social space for innovation and creativity" (213).

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[5] In the following the paper will refer to these three stages as "mode A", "mode B" and "mode C" (cf. chart 3 on page 144).

Rochlin apparently is a promoter of decentralized self-coordination (mode B). He argues that systems of this type are able to cope with unexpected situations, because the members of the organization are well-trained in crisis management (cf. Rochlin 1991, La-Porte/Consolini 1991, Krücken/Weyer 1999). Every measure that transfers the decision-making authority to a central control body therefore entails the risk of a fatal error, because the design of a centralized system may entail errors, which finally inhibit the participants to act according to the concrete operational needs in a given emergency situation.

To summarize Rochlin's argument: The new type of smart technology facilitates the emergence of a new mode of governance of complex systems, which goes beyond the well-known types of central control and decentralised self-coordination. "Intelligent" systems give rise to the capability to execute some kind of central control of decentralised systems (mode C), since smart devices can collect large amount of data about the world and the people and integrate them – by networking – into a unique control architecture.

2.5 Summary

If we compare the concept of Rammert/Schulz-Schaffer with the approach of Rochlin, the divergences are obvious. Rammert/Schulz-Schaeffer have constructed a model for an unbiased analysis of hybrid systems (with distributed agency) which still lacks empirical evidence and is open-minded concerning the results of future development. Rochlin, on the other hand, does not take much care of theoretical questions of agency, but has analysed a number of cases of the informating of society which give evidence to the assumption that networks of pervasive smart devices may lead to totalitarian systems of central control which eventually end up with a fundamental transformation of society.

Up to now the debate has been unresolved and the two approaches have not yet been conciliated. But we can take this controversy as a starting point for the analysis of the case study on TCAS (cf. chapter 3). This case shall help to discuss the issue of distributed agency on the one hand and the topic of governance of hybrid systems on the other. It will show that the traditional, hierarchical order of aviation (mode A) has been deconstructed by the implementation of innovative technological systems, leading to a reorganization of air traffic control and an introduction of another mode of governance (mode B), which, however, entails some previously unknown risks. Therefore the question will be discussed, if the new regime of decentralized self-organization in aviation, which is facilitated by TCAS, can guarantee the same level of safety as the old hierarchical system of centralized control. The following chapter 4 will take a look at future developments beyond TCAS that may lead to new combinations of governance modes (mode C).

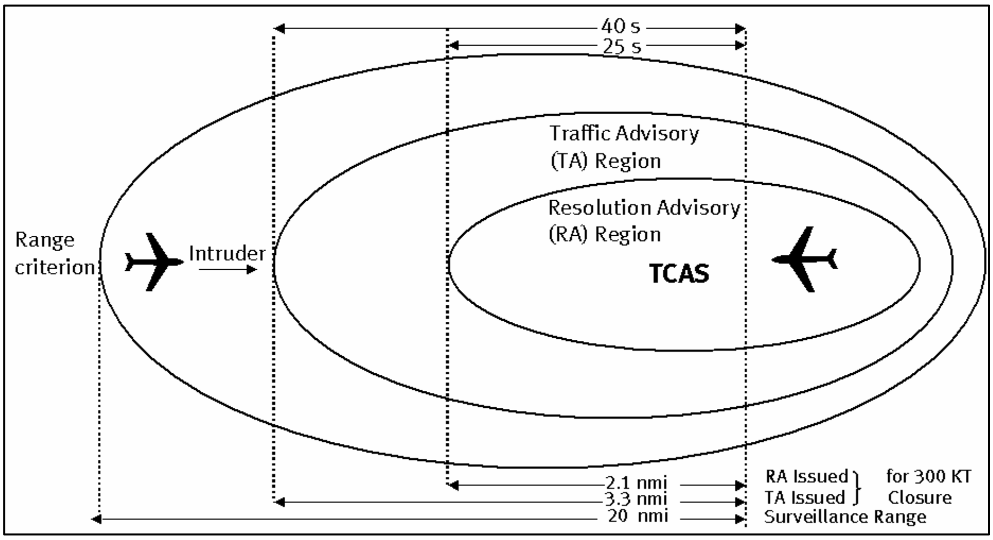
3 Case Study TCAS

In the following section a case study on the Traffic Alert and Collision Avoidance System (TCAS) will be presented, which explores the operational logic of a hybrid system, discusses the challenges and risks and raises some – tentative – questions about different control logics and system architectures. The experiences, which have been gathered with the interaction of human actors and non-human agents in TCAS guided aircraft during the last ten years, are being interpreted in the following as a part of the effort to create a new type of socio-technical order in hybrid systems.

3.1 History and operational logic of TCAS

TCAS is an airborne short-range collision avoidance system which is mandatory equipment of modern passenger aircraft in the U.S. since 1994 and in the European Union since 2000 (Denke 2001, Nordwall 2002). Its purpose is to prevent aircraft from midair collision by warning the pilot when another plane is in a predefined range of about six kilometres (which is about 40 seconds flight time, cf. chart 1). This is especially important at night or when weather conditions are bad.[6]

Chart 1: TCAS – Traffic Alert and Collision Avoidance System
(souce: Mensen 2004: 374)



If a TCAS system detects a conflict situation it warns the pilot ("traffic advisory") and some seconds later issues commands to climb or to descend ("resolution advisory"). If both aircraft which are part of the conflict are equipped with TCAS "they will communicate to avoid mirror-image manoeuvres" (Nordwall 2002).

TCAS thus can be regarded as a distributed system where two (or even three) agents "communicate intentions" (Nordwall 2002) and coordinate their actions autonomously. Even if the pilot finally takes the action, the proposal to act is generated by a set of communicating agents. TCAS is a "foolproof" system, and pilots "have a high regard" (Nordwall 2002) for this device (cf. also VC 1997). Nevertheless TCAS has been one cause among others in the midair collision of a Russian Tupolew Tu154M and a DHL cargo Boeing B757-200 on July 1, 2002 over the Bodensee in southern Germany, killing all 71 passengers aboard. Both aircraft had been equipped with the latest version of TCAS.[7]

Before describing the chain of events that led to the disaster, it is necessary to understand the role TCAS plays in the overall system of aviation safety.

3.2 ATC or TCAS?

The well established system whose task is to avoid accidents in aviation is the ground based air traffic control (ATC). ATC centres are equipped with modern devices – mostly redundant – to detect airplanes far away. They have

[6] For more details see VC 1997, BFU 2004.

[7] The recent midair collision in Brazil on September 29, 2006 might also partly be caused by a malfunctioning TCAS or a gap in the system which arises from the invisibility of a plane that has switched off its transponder; cf. Fiorino 2006.

global information of schedules and current traffic on different flight levels. Moreover they can communicate with the airplanes by radio telephony but also by asking the transponders of the planes to communicate all relevant data. So in an ideal situation the ATC has complete information. The ATC system is a typical example of a *hierarchical, centrally controlled system* which in principle is able – referring to Perrow (1984) – to guarantee a high degree of safety.

However, since the 1960s an alternative safety system has been developed which functions according to a very different logic, which is *decentralized coordination*. TCAS creates a communication link between two (or more) aircraft and so can avoid collisions independently of the ATC ground control. It is obvious that this system can only work reliable, if every aircraft is being equipped with (at least similar) TCAS devices. And it generates questions about the co-ordination of ATC and TCAS which can be answered in different ways – either replacing the ground control by an independent system or finding reliable ways of cooperation of the two systems. One cause of the Ueberlingen accident is the fact that different aviation communities had generated different answers to this question.

The U.S. Standard Operation Procedures (SOPs)

In the U.S. as well as in Europe TCAS is being regarded as an additional short-range "safety net" (VC 1997) that only issues warnings if the ATC systems already has failed (Nordwall 2002). Pilots are being trained to rely on TCAS and to obey its commands strictly in a case of emergency – especially concerning the fact that in these situations there remain only a very few seconds to react properly. U.S. pilots are used to ignore the commands of ground controllers, because they are aware of the fact that in such a critical situation the ATC has imperfect knowledge, since the (decentralised) TCAS systems are not designed to communicate their data to the ATC computer.

U.S. pilots rely on TCAS even if they know that this system has some shortcomings. In the U.S. TCAS had only been mandatory for passenger aircraft with more than 30 seats, whereas the European Union had put the limit to a weight of 15 metric tons.[8] Every pilot flying a TCAS-equipped aircraft therefore must be aware of the fact that there may be some other aircraft, e.g. military or small planes, in the vicinity which are invisible to him (VC 1997).

The Russian Standard Operation Procedures

The Russian SOPs concerning TCAS are very different, since they distrust the system because of its well-known limitations and pitfalls. The Russian logic to cope with situations of conflict between ATC and TCAS was very simple: "In Russia pilots will take ATC's orders *over* the instructions of *any* onboard navigational system." (Venik 2002, emphasis added) Besides the invisibility of some sort of aircraft the reason is, that ATC has "a complete picture of the sky" (ibd.) which is based on redundant systems (TCAS is not redundant). Obviously there is some confusion in the skies and a *conflict between different safety cultures*. This confusion is partly due to the fact, that the two safety systems are not interconnected. There is no feedback that informs the ground controller of the recommendations given by TCAS to the pilots. Such a feedback obviously would help to improve the system's performance and avoid opposing commands. In the current state the conflict must be resolved by the lonely pilot who has to decide – in a very short period of time – to ignore one of the two safety measures the original

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[8] These rules have been changed and internationally harmonized in 2003 (17 metric tons) and again in 2005 (5.7 metric tons, cf. Mensen 2004: 375).

intention of which had been to increase air transportation safety (cf. Venik 2002). And he takes the full responsibility for his actions – a typical pitfall of automation which apparently cannot substitute for human decision making, but creates situations of human decision making which are much more difficult to solve than before.

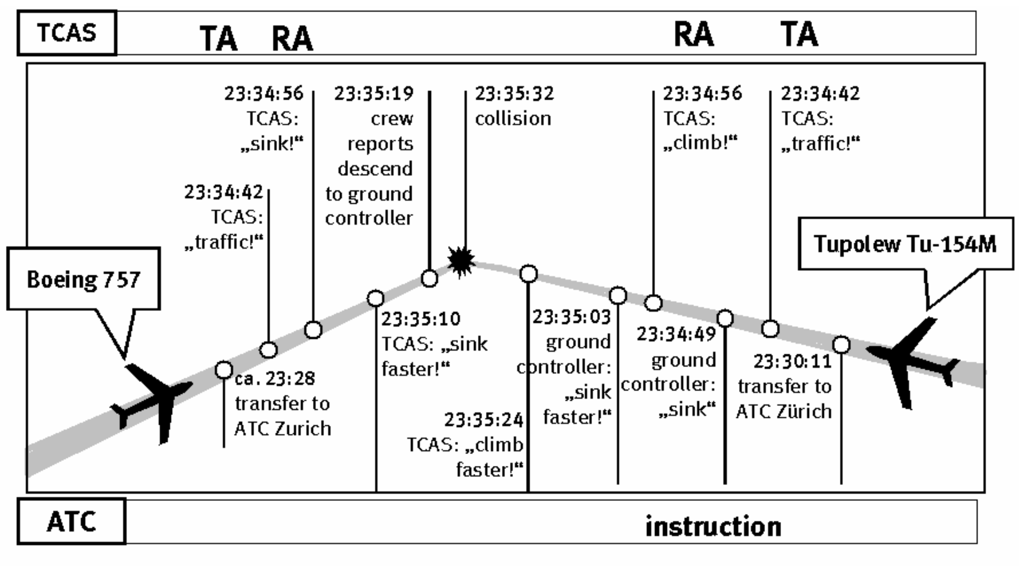
However, the confusion is also partly due to the incompatible operational logics of the two systems: Either you rely on central control and put the responsibility on the controller, who organizes the system's performance by hierarchical governance, or you rely on the problem-solving capacity of decentralized self-organization and distribute responsibility within the system. But you cannot do both at once. We'll come back to this question later.

Now it is easier to understand the Ueberlingen crash, because the crew of the DHL cargo Boeing followed the U.S. SOPs, to obey strictly TCAS, while the crew of the Russian Tupolew was divided on the question which procedure to follow and finally adopted the Russian way which urged them to rely on the ground controller and to neglect the recommendation of the TCAS, which unhappily was exactly the opposite. This conflict, however, could have been resolved, if there had not been an unfortunate concatenation of events which contributed to the dramatics of the situation.

3.3 The Mid-Air Collision at Ueberlingen

The two planes crashed at July 1, 2002 at 23:35:32 at flight level FL 360, which is a height of about 11.000 meters. Both planes had been guided by the ATC at Zurich (Switzerland) where only one controller was on active duty. He had taken over the two planes only a few minutes before, but did only realize the conflict 43 seconds before the collision. When he issued his warnings, the TCAS systems of the two aircraft had already automatically generated their recommendations (TAs and RAs), and the tragedy was that he urged the Russian crew to descend – which was exactly the contrary of the TCAS recommendation (cf. chart 2). Additionally an instructor, who was not familiar with the TCAS system, had taken over the role of the pilot in command (PIC) in the Russian plane, while the other pilot – in normal situations the commander – acted as the pilot flying (PF). After the contrary recommendations had been issued the crew was not only confused about the facts but also had to cope with author-

Chart 2: The Mid-Air Collision at Ueberlingen
(source: Frankfurter Allgemeine Zeitung 20.07.2002: 7)



ity and coordination problems, since the PIC demanded to comply with the commands issued by the ATC, while the PF insisted on relying on TCAS. The rearrangement of the crew (at a night flight!) and the missing comprehension of the TCAS system on part of the instructor were major causes of the subsequent mistake. So the question arises: Was it simply a human error?

Similar to other cases of highly automated systems, modern aircraft are also conducted by people, the main task of which is to monitor the system's operating in the routine mode, were nothing happens for hours and hours. Additionally modern technological systems are designed to prevent the emergency case, which mostly works very well – but with the consequence that unforeseen situations occur only very rarely and can hardly be trained systematically. As in other cases, the investigation of the Ueberlingen crash revealed that the operating procedures for TCAS, issued by the International Civil Aviation Organization (ICAO), were confusing and inconsistent (BFU 2004: 4, 7). At least the Russian crew was not familiar with the system and had only little experience with it.

However, if we take a look at the organization of Skyguide, the operator of the ATC Zurich, and the safety culture of this organization we will find some more factors which contributed to the disaster:

In that night there had been maintenance works at the ATC, which required to partially shut down the radar system. As a consequence the Short Term Conflict Alert (STCA) system – a ground based pendant to TCAS – which warns the controller of an upcoming conflict constellation, was only partly operating, i.e. it could not present the information optically on the screen. However, the controller was not aware of this. Generally, no one at Skyguide knew exactly which effects the maintenance works had on the overall performance of the ATC Zurich. For example the telephone line was out of duty for a few minutes. Evidently there was no awareness that this constellation with a coincide of uncommon events raises the risk and the probability of errors. One possible consequence might have been that the informal practise of a one-man-operation had been abandoned that night.

During the critical period of time (from 23:30 to 23:35) the attention of the unfortunate controller, who later was murdered by a relative of one Russian victim, was distracted by a third aircraft, approaching the nearby airport of Friedrichshafen, he had to guide, too, working at two desks simultaneously at different radio frequencies. A colleague at Karlsruhe airport who also observed the scene and had been alerted by his STCA, could not reach him by phone because the lines were out of duty exactly at that moment. (Remember: The STCA at Zurich airport could not issue an optical warning at that time.) Therefore the controller at Zurich only realized the conflict between the Boeing and the Tupolew a few seconds before the crash. He had to switch abruptly from the routine to the emergency mode (cf. LaPorte/Consolini 1991), but it was too late to find a proper solution because of the parallel working – above described – of two badly coordinated control systems working with opposite operation logics. He suddenly was heavily under pressure and made a number of mistakes: He didn't understand a radio message of the Boeing crew properly (partly because of several simultaneous messages at the two desks), and he didn't register the acoustic STCA warning.

Again: Was it a human error? Or organizational failure (at Skyguide as well as in the cockpit of the Tupolew)? Or was it a system's failure – a failure of a system that must fail because of complexity, of tight coupling, of lax safety cultures with a lacking awareness for risky constellations, and finally of unavoidable inattentiveness in boring night shifts in highly automated facilities and systems?

The following chapter will not deal with these questions in detail, because they can be treated in the framework of the traditional automation debate (cf. Weyer 1997). It will instead pitch on only one of the multitude of causes of the midair collision: the coexistence of two contradictory governance modes as well as the role of smart technology. Thus the question can be put forward, which governance mode is best suited to manage the risks of complex systems.

4 Creating order in hybrid systems

4.1 Smart systems

Modern aviation obviously is a good example for the omnipresence of embedded, sensor-equipped computers, which automatically and increasingly autonomously operate in the background, achieve a remarkable problem-solving capability by networking and generate solutions by the interaction of non-humans. Although it is only a quote from literature, the impression that TCAS systems "communicate *intentions*" (Nordwall 2002, emphasis added) refers to the fact that something is happening in aviation that comes close to the kind of relation we are used to attribute only to humans up to now. Many of the features of "pervasive computing" apply, even if the voluminous and costly TCAS system cannot be compared with a simple RFID chip, and well-trained professionals as e.g. pilots behave differently than non-trained people in everyday life.

However, the TCAS case showed that even in a professional environment smart technology may lead to some confusion and a loss of learning capability, since new uncertainties arise that cannot be solved by learned routines. Often it is difficult for pilots to really understand what happens, and it is equally difficult to learn by experience how TCAS works in an unforeseen situation. Steering a modern airplane means to totally rely on technical devices which construct a virtual picture of the sky that is hardly distinguishable from a computer game as e.g. "Flight Simulator" from Microsoft.[9] Aviation has gained a high level of safety, but with every innovative technology new, uncommon risks arise.

Finally attitudes have changed, since pilots' behaviour more and more can be described as adaptive rather than strategic (cf. Weyer 2006b): even though the pilot sees the intruder on the screen in advance, he is not forced to develop an evasion strategy (if he relies on TCAS), but he can calmly wait for the advisory automatically generated by the interacting TCAS systems. It is almost impossible to guess in advance if the recommendation will be "climb" or "sink", because this depends on a whole string of factors (among others the rank of the IDs of the communicating TCAS computers) the pilot can hardy determine let alone assess. The interaction of TCAS and the pilot thus resembles more a stimulus-response-model than the traditional concept of strategic (inter-)action.

As a result the debate on "pervasive computing" points out to be a valuable context for the analysis of modern aviation.

4.2 The risks of distributed agency

Aviation can also be regarded as a hybrid system of distributed agency. This applies to the meso-level of air traffic control as well as the micro-level of the cockpit. In the latter the (human) pilots and a number of (non-human) assistance systems such as TCAS work together in finding a solution to a given situation: TCAS takes the responsibility for the definition of the situation, the interaction with the other plane as well as the recommen-

[9] Personal communication Burkhard Kruse (Lufthansa) April 7, 2005.

dation of action to the pilot (in a human-like manner of oral speech), whereas the pilot is in charge for carrying out of the action and the supervising and evaluating the whole system (including the meta-decision to rely on TCAS). In many regards smart technology substitutes human actors and "acts" autonomously (e.g. in finding an agreement with the other plane – previously the task of the human controller), but the complete action to evade a critical situation is taken by a hybrid set of human actors and non-human agents, both of whom are responsible for different sequences of the action chain (cf. Rammert/Schulz-Schaeffer 2002).

As far as that goes hybrid systems with distributed agency are a continuation of the well-known path of automation, and they share the risks of many other highly automated systems. At the same time the participation of autonomous technology in decision-making processes contributes to an *intensification* of problems and risks. Operating a plane is routine work with boring monitoring duties that leads to a low level of attention and awareness of risks – especially in systems regarded as self-controlling and inherently safe. In those rare cases of emergency, which mostly take the operators by surprise, an unexpected interaction of system's components produces a situation which is only partly understood and which can only hardly be managed – especially under time pressure, as the Ueberlingen case showed.

However, in an emergency situation the operators suddenly find themselves in a situation where they have to take the responsibility to control the facility (including a number of smart devices). This implies to make very difficult decisions, which emerge because of unfamiliar and previously unknown uncertainties. To some regard we can talk of a dramatization of the well-known automation paradox: the re-entry of the human decision maker, which had been excluded from making first-order-decisions (steering the plane on a climbing or descending path) and now has to make second-order-decisions, i.e. determine if the automation device gives the correct advice or not and if he can rely on its recommendation to climb or to descend.

Hybrid systems of distributed agency tend to intensify the over-reliance on technology, which increases risks solely by the invisibility of the processes and the enormous time pressure. Additionally hybrid systems, which allow for autonomous action of technology and aim at a "perfect" control of the world, run the risk of a loss of competence on the part of the operators, since they try to avoid situations in which the operator can gain experience and learn from experience. Distributed systems of the given type thus have an inherent tendency to turn into completely automated systems – with the human functioning only as a stopgap.

4.3 A new mode of governance

Moreover the case study has shown that the introduction of TCAS has triggered the deconstruction of the established order in aviation, leading to some confusion and irritation not only about the functioning of the device, but also about the rules which hold in the system. It is still an ongoing process of social learning and experimentation which uncovers the limits and pitfalls of the new system architecture. As in other cases of the introduction of a radically new technology, usually an experimentation period of some years is needed, until measures will have been generated to cope with unforeseen situations (cf. Krohn/Weyer 1994, Weyer 1997). However this process must also include the construction of new institutions, i.e. new modes of governance of hybrid systems, which will probably need a longer period of time.

The implementation of TCAS thus can be regarded not only as the introduction of a new device, but as a first step in a *regime change*, which may lead to a fundamental transformation of aviation, since pilots now are able to resolve conflicts in the mode of decentralized self-organization (cf. Deuten 2003). The next step will be a completely self-coordination of the aircraft during the *entire* flight ("free-flight"), including autonomous routing and navigation, which has been developed in the U.S. as a successor of TCAS and is currently tested in daily flight operations in Australia (cf. Hughes/Mecham 2004).

At the moment pilots find themselves in a contradictory situation: their autonomy, i.e. their freedom to act towards the controller has grown, whereas their autonomy to fly the plane has diminished because of the substitution of many actions by smart technology. Despite these uncertainties and only partly determined role conflicts, the introduction of TCAS has started to establish a new order in aviation and a new mode of the governance as well (mode B), which coexists beside the traditional mode of central control (mode A). This may be a cause of hardy resolvable conflicts, as the Ueberlingen case shows, because both modes follow a different operational logic:

Centralized control

In densely coupled traffic systems such as aviation or railway transportation the safety architecture mostly is based on the principle of *global optimisation* (cf. TA-Swiss 2003a). The governance structures are shaped by the top objective of overall system's safety, which is – for instance in civil aviation – realized by giving strict orders to the participants they have to obey. The control architecture intends to guarantee the system's performance and efficiency (with a load factor as high as possible) as well as the safety of operations (with an accident rate as low as possible). Social order thus is superimposed in a top-down-manner by actors which have superior knowledge and are conducted by the goal of maintaining public welfare. Technology serves as an instrument to monitor and to steer the participants of the system.

Decentralized self-organization

On the contrary the concept of decentralized self-organization argues that endogenous processes within a given system lead to good and stable solutions, which mostly cannot be attained by central control, since the external controller doesn't have the knowledge that the participants have. Modern technology such as TCAS enables the user to create solutions for current problems (such as optimizing the course or avoiding collisions) which are doubtlessly superior to the user who operates in a conventional manner. The basic logic here is *local optimisation*, since the singular user mostly doesn't have global information and doesn't take care of the external effects of his actions, but optimises his performance regardless of the consequences for other users as well as for the global system. Social order finally emerges in a bottom-up-manner as the unintended product of the interaction of selfish actors. So this kind of local optimization doesn't need to end with a global maximum (cf. Epstein/Axtell 1996: 13).

However, if safety is at stake, the argument of the unpredictable emergence of order can also be read from the opposite. Emergence also can imply unforeseeable, undesirable behaviour, especially in the case of smart systems which are designed to act and evolve autonomously (cf. Resnick 1995, Richter/Rost 2004). Air traffic controllers for example are reluctant to accept the new system architecture, because they do not believe that in the future system architecture of "free-flight" a number of ten or more self-coordinating pilots will be able to generate solutions with the same level of safety as in the traditional system, where one person is in charge of the control of the entire system (Hughes/Mecham 2004: 50). This may indicate that we have only little knowledge what happens if self-organized systems get out of control.

The "double trap"

In the present transition period between the old and the new regime, where two modes of governance coexist, a "double trap" appears:

- On the one hand self-organizing systems are able to create innovative solutions by own means and to generate emergent effects – a performance which hardly can be produced by centralized systems. However, these effects are – according to the concept of unintended consequences (cf. Vanberg 1975, Esser 1991) – unpredictable, which sometimes might also imply: undesirable and uncontrollable. Self-organizing systems may get out of control – with irreversible consequences –, and societies, which rely on them, do not have measures to recapture them.[10]
- On the other hand a central control can integrate the system's elements and coordinate their behaviour in order to avoid or even eliminate undesirable or unintended effects of self-organization and to achieve a global optimum (e.g. safety and reliability). However, according to Rochlin (1998), this kind of control network may be inflexible and even endanger the sources of self-organization and social learning.

Thus, referring again to Rochlin's idea of a third mode, the question arises if other options exist which combine the advantages of those two modes (and help to avoid their shortcomings). Smart technology allows for different options and different combinations to be explored in future. These options will be discussed in the final paragraph of this chapter.

[10] This may be partly due to the lacking theoretical understanding of the mechanisms of self-organization, cf. Greshoff/Schimank 2003, Richter/Rost 2004.

4.4 Paths to future aviation

The future of aviation – here locked upon as a sector, where hybrid systems advance – can be shaped in different ways, extending or restricting the capabilities of human actors and non-human agents, thus constructing different combinations and constellations of hybrid systems (cf. chart 3).

Complete decentralization

One obvious option might be the complete decentralization of aviation, based on a high level of electronic equipment on board of each plane, thus allowing for a decentralized self-coordination in every phase of the flight – as well as a complete dissolution of ATC. (This is actually the "purest" version of mode B.) When TCAS was invented in the 1970s this detachment of the old system had indeed been the guiding vision of many engineers (Venik 2002). Experiments with "free-flight" now carried out in lowly frequented areas in Australia show that this might be one path into the future of aviation. The single planes must be able to locate themselves precisely (via GPS) and communicate all relevant data to the ground station (via ADS-B[11]), but they do so simultaneously to other aircraft in a radius of 250 km, thus allowing for a far-reaching autonomous coordination without intervention of the controller (cf. Hughes/Mecham 2004, Hughes 2005). The first time in the history of aviation the pilot has a complete picture of the sky. The task of ATC thus shifts from control to management and monitoring, while the pilot receives responsibility for navigation, coordination and separation – similar to the situation in the early days of aviation, but now on a high level of electronic assistance.

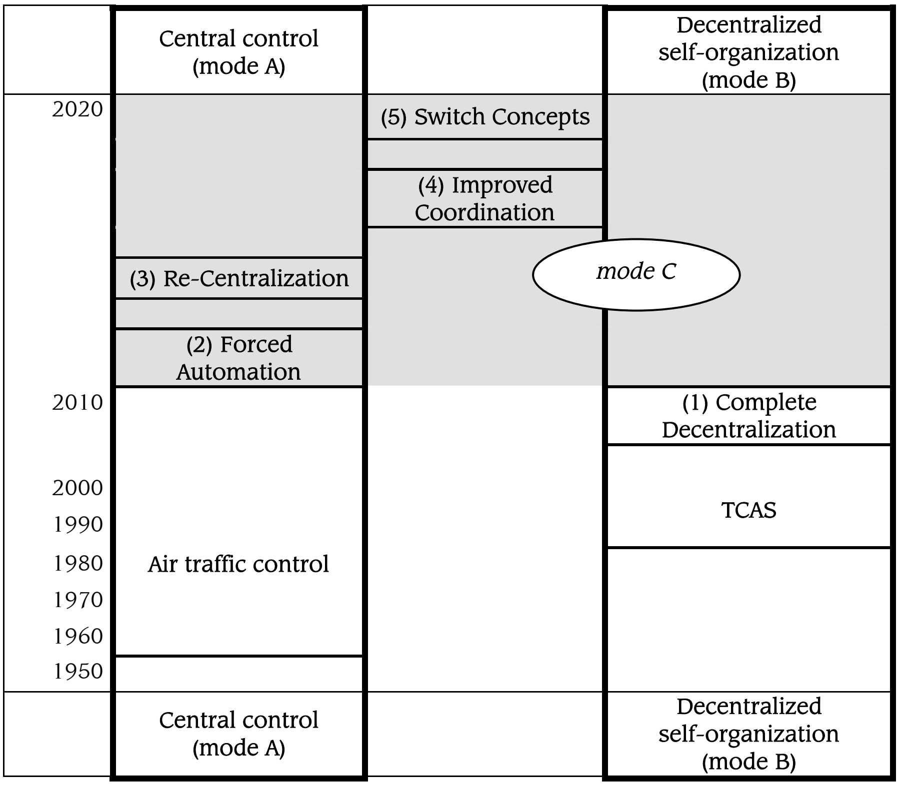
[11] Automated Dependent Surveillance – Broadcast.

Forced automation

However, a high level of equipment with smart devices could also lead to the complete displacement of the human decision maker in the cockpit (which stands for a major step towards mode C). In the early days of TCAS, the intention had been to directly transmit its commands to the autopilot, but these plans were dropped because of technical problems and a still low performance of TCAS (Venik 2002). The present solution is a half-hearted compromise that leaves room to error, as the Ueberlingen case shows. Thus the next step could be to establish a direct link between TCAS and the autopilot in order to automatically navigate and avoid collisions without human intervention. Even if actually nobody in civil aviation puts forward this proposal, the unstoppable advance of unmanned aerial vehicles (UAVs) in military aviation indicates that this second path is also on the agenda today (cf. Friese/Hein 2004).[12] Experts believe that at least in cargo transport we will have unmanned planes in about ten years, and the cockpit crew of passenger planes will be reduced to only one pilot, who will work as an observer of a completely automated system.[13]

However this strategy of automation totally relies on the autonomous action of smart systems as well as their capabilities of decentralized coordination. This is a risk-taking strategy, because the extension of the area of automated decision making only implies that the borderline between humans and machines is being moved. Especially in the case of mode selection someone has to identify, in which

Chart 3: Paths to Future Aviation



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[12] The implementation of unmanned transportation systems e.g. in the field of passenger subways is another indication of this trend (cf. Wille 2004).

[13] Personal communication Karsten H. Severin (Bundesstelle für Flugunfalluntersuchung - German Federal Bureau of Aircraft Accidents Investigation) Oct. 20, 2005.

kind of situation (e.g. landing approach versus cruising) the system is currently operating, and take the decision to select the appropriate control mode. In partly automated systems the pilot is the decision maker, whereas in completely automated systems the decisions have been incorporated into the system's architecture (e.g. software). In this case software engineers have to anticipate critical states in which the system shifts automatically to another mode. However, they are unable to check if this solution is appropriate to the given situation, unless they learn from experience, namely by incidents or accidents.[14] Even in completely automated systems human error is possible and even unavoidable – especially if we take into consideration that the decision maker now is a person with no practical experience in flying planes (cf. Gras 1994, Weyer 1997).

Re-centralization

To avoid these risks described, the strategy of forced automation in many cases is accompanied by a closer networking of the elements and a subsequent recentralization of authority – which marks another path to future aviation. As Rochlin warningly argues, there may be a novel option of the central control of decentralized systems (mode C, cf. chapter 2.4). This can be regarded as a *combination* of the two well-known modes of governance, since it relies on the problem-solving capabilities of self-organization, and simultaneously highly profits from the advantages of central control. Thus it promises to achieve a combination of flexibility and efficacy. Paradoxically autonomous systems, which are effectively interconnected via networks, would allow for a recentralization, i.e. a centralized remote control. Referring to the case of German railways one could easily image all aircraft to be guided by one control centre – while the pilot on board would only monitor the system and manage those emergency cases which cannot be handled by the ground control.

This scenario requires an effective means of self-control of the vehicle (via smart technology) and of self-coordination within the system (e.g. for the purpose of collision avoidance) as well as real-time data communication with the centre, allowing also for effective intervention from outside. In this scenario the human operator would lose a great deal of his decision autonomy, whereas the control centre would gain force and the capacity to control the entire system. At the same time the control architecture described here decreases the capability of on-site crisis management by the operator, whose freedom to act is not only substituted by smart technical devices but also by the new governance mode of central control of a decentralized, networked system.

However, even in this case the problem of the effective distribution of authority remains unresolved, since two operational logics still co-exist in a way that may lead to confusion in a situation of crisis. Moreover, up to now we have only little experience with this new type of mixed governance.

Improved coordination

Therefore another path to a new order in aviation might be an improved coordination of the two systems (e.g. ATC and TCAS), as repeatedly indicated in the case study. Until now both systems are only badly interconnected, because the recommendations which are generated by TCAS are not automatically communicated to the ground. (Pilots and controllers are used to communicate via radio telephony instead, but this technology is rather trouble-prone and often insufficient in a crisis situation.) This missing link is due to the deliberations about the design of TCAS in the 1970s, where aircraft owners

[14] This is the reasons why accidents are – regarded from a methodological point of view – so worthy for application-oriented science; cf. Krohn/Weyer 1994.

were opposed to implement a more advanced, but also more costly version (cf. Deuten 2003: 233). So a cheaper, but also less efficient system came into being. Today it is possible to bridge the gap between TCAS and ATC with an automated data link, which will provide the control centre with complete information about the results of the decentralized coordination in the sky (thus establishing another variant of mode C). However, even if this data link will be installed overall in a few years, the authority conflict will remain, since both modes continue to exist side-by-side. So even if the technical problems will be resolved, the question of coordination of the two governance modes persists, especially the urgent issue, when to obey TCAS and when to listen to the ground controller.

Switch concepts

One obvious option to cope with the problem of mixed governance is to create an organization which is able to operate in different modes and, additionally, is capable to switch between different modes according to the situation (again a specimen of mode C). This concept can be found in the literature on "high-reliability organizations" (HRO, cf. LaPorte/Consolini 1991) as well as on "group interaction in high risk environments" (GIHRE, cf. Dietrich/Childress 2004). The central idea of both concepts is that organizations cannot be directed by only one mode of governance, since different situations (e.g. routine, emergency) require different responses. The message is: successful organizations, which manage complex, highly automated systems with high risks, can guarantee safety, if they develop an organizational safety culture that is based on the ability to switch between different modes – as well as an intense and systematic training of all kind of situations in order to gain and maintain this capability to switch. That way HROs can successfully cope even with unforeseen crisis.

As the TCAS case study showed, this idea may be a promising tool to analyse the governance of hybrid systems, too; future research will be necessary to explore the potential of this approach more deeply. However, it can already be assumed that the appropriate distribution of responsibility and action capability between human actors and non-human agents as well as the development of a new institutional framework of interaction will be the core of an organization's ability to manage complex, hybrid systems. In the current situation different paths to the future of aviation are open.

5 Conclusion

As the case study on TCAS showed, currently a regime change takes place in aviation, which can be interpreted as the deconstruction of the traditional order of central control, triggered by the implementation of smart technology. The invention of a hybrid system gave rise to another mode of governance (decentralized self-organization – mode B), which nowadays co-exists – badly connected – with the traditional mode A, thus raising the question of future options that may combine features of the two modes of governance (mode C). Currently experiments take place in aviation (as well as in other traffic systems such as road traffic or railway transportation), which aim at exploring the practicability of new system's architectures with different mixtures of humans and non-humans, of central control and decentralized self-organization. It is still an open question, which kind of order will succeed, but the outline of the different paths to future aviation (chapter 4.4) supports the assumption that strategies of a complete displacement of the human decision maker will probably prove to be a dead end. Even in future, aviation will remain a hybrid system of distributed agency, where good solutions for the management of crisis have to be established in order to achieve a high level of safety.

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