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Insights gained from a series of systems studies

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Safety in large-scale socio-technological systems

Insights gained from a series of systems studies

Auteur: Gwendolyn Bakx

Simon Stevin Series in the Ethics of Technology

Safety in large-scale socio-technological systems

Safety in large-scale socio-technological systems
Insights gained from a series of military systems studies

Proefschrift

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doctorandus in de arbeid- en organisatiepsychologie
Master of Science in human factors & system safety

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Thanks Rudy, for your contagious enthusiasm!

So as to keep in mind:

"Everything torn from its [socio-technological, addition GB] context, [is] full of the tyranny of that externally fixed stance that accounts for the uncanny fascination of tableaux vivants, as though life had suddenly been given a sleeping pill and was now standing there stiff, full of inner meaning, sharply outlined, and yet, in sum, making no sense at all."

Robert Musil, [1952] 1995

Also:

"Even after the completion, it is in the nature of artworks [and theses, addition GB] to preserve their destination as hypothesis"

from the book Notas, ( ), etc, 2006

Waltercio Caldas, Exposition Horizontes, Museum of Contemporary Art, Lisbon, Portugal, 2008

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Chapter 3

Bakx, G. C. H. and Nyce, J. M. (2013) 'Is Redundancy Enough?: A Preliminary Study of Apache Crew Behaviour', in: *Theoretical Issues of Ergonomics* 14 (6): 531-545.

Chapter 4

Bakx, G. C. H. and Nyce, J. M. (2012) 'Social Construction of Safety in UAS Technology in Concrete Settings: Some Military Cases Studied', in: *International Journal of Safety and Security Engineering* 2 (3): 227-241.

Chapter 5

Bakx, G. C. H. and Nyce, J. M. (forthcoming) 'The Safe Integration of Military UAS in the (Inter)national Airspace: Some Underlying Processes', in: *Cognition, Technology & Work*, DOI: 10.1007/s10111-016-0377-z.

Chapter 6

Bakx, G. C. H. and Nyce, J. M. (2015) 'Risk and Safety in Large-scale Socio-technological (Military) Systems: A Literature Review', in: *Journal of Risk Research,* DOI: 10.1080/13669877.2015.1071867, published online first on 7 Aug 2015.

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1 Introduction

1.1. Dissertation objective

This first chapter discusses the rationales and backgrounds of the main research objective of this dissertation, which is:

> To assess large-scale socio-technological military systems in order to further actual assessments of safety in general, especially when the assessments concern the issue of technological safety in large-scale socio-technological systems.

The following sections describe the relevance of studying the relation between safety and the military, with a focus on technology in particular, and why insights gained from this process would have the potential to further actual assessments of technological safety in large-scale socio-technological systems in general. An oversight of the dissertation has been provided in the final section, combined with a detailed description of the research strategy.

1.2. Safety and the military

Concepts of risk and safety and what they mean in the context of military missions can be highly contested. Indeed, safety and the military can be said to have a complex relationship. The military pre-eminently operates as a force employer, inflicting thereby injury and danger to others when necessary. Its activities, however, take place in environments that are often characterized by high risks, stakes, ambiguity and urgency. Because of this, the military can bring its own and other people at risk unintentionally in its efforts of creating safety and security in a national and international context. Protecting (specific parts of the) civilian population, for instance, can endanger others, including the own and allied personnel.

One could argue, of course, that putting military personnel at risk for the sake of (inter)national safety and security is part of the job, especially in the Netherlands where the creation of safety and security in both national and international contexts is constitutionalized (Dutch Ministry of Defence: 2013).

Still, whether approached from a personal perspective, an organizational one, or a societal one, safety is a value that is often regarded as central – if only in hindsight – to any military activity. People in the own country, for instance, may have concerns about putting their 'boys and girls' in line of fire, especially when missions abroad are considered. Domestic support indeed seems to be linked with perceived national interests, expected and actual casualties, and prospects for success (Larson and Savych: 2005, 213). These links are, however, not straightforward. Dimitriu and De Graaf (2014), for instance, point out that the level of public support follows the narrative dominance[1] in the public debate on national interests rather than the supposed strength of the formal strategic narrative itself.[2] Also, although domestic support will decline, generally, with an increase in the number of casualties on one's own side, the sensitivity to these casualties tends to vary greatly across past wars and military operations (Larson and Savych: 2005, 19). At the same time, declines in domestic support can have devastating effects in Western democracies since their leaders seem to be quite responsive to domestic public opinion (Ringsmose and Borgesen: 2011, 505). Indeed, as the past has shown, a decrease in support from the home country can lead nations to cease their operations (e.g., the Dutch in Netherlands New Guinea; the US in Vietnam). Even when taking into account that some evidence points at a much more nuanced role of domestic support ('policy-makers are [not] the powerless victims of shifting popular attitudes' (Ringsmose and Borgesen: 2011, 508)), this remains a considerable factor for leaders in Western countries. Force protection, for instance, has a prominent place in the planning of many modern Western operations (e.g. Dutch Minister of Foreign Affairs and Minister of Defence: 2001; Dutch Minister of Foreign Affairs, Dutch Minister of Defence and Dutch Minister of Development: 2005).

Putting the own people at risk is, however, not the only reason why safety often is put central to military conduct. Collateral damage (harm to non-combatants) is another one as this, when considered from a military strategic

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1. The narrative dominance follows from the confrontation of the formal strategic narrative with counter-narratives such as they are often presented by the opposition and in the media (Dimitriu and De Graaf: 2014).
2. This connects well with what Berinsky argued in 2007 on this: "I find little evidence that citizens make complex cost/benefit calculations when evaluating military action. Instead, I find that patterns of elite conflict shape opinion concerning war. When political elites disagree as to the wisdom of intervention, the public divides as well. But when elites come to a common interpretation of a political reality, the public gives them great latitude to wage war."

perspective at least, can jeopardize the local population's trust and thereby local support of the military campaign (e.g. Condra and Shapiro: 2012, 167). Similar to what we have seen in the former paragraph on domestic support, however, the link between civilian casualties, injuries and damage on the one hand and local support on the other tends to vary with a number of factors. The nature of the violence, for instance, the intentionality attributed to it, and the precision with which it is applied (Condra and Shapiro: 2012, 167) all seem to matter here, factors that all seem to be connected, somehow, to justifiability (Benmelech, Berrebi and Klor: 2010). All in all, it is obvious that collateral damage, like a lack of domestic support, can endanger high-level mission objectives, especially when caused by 'high-tech' 'precision' equipment that Western armed forces are supposed to deploy.

So far, the considerations mentioned here for putting safety central to military operations bring to the fore the strategic dimension. Casualties, injuries, and damaged properties, however, even when lawfully inflicted, should bring with them, of course, humane concerns also. Decision makers, quite apart from the strategic dimension mentioned already, thus have a moral obligation, in addition to their tasks of ensuring human and national security, to minimize adverse effects of military conduct such as civilian casualties. Non-governmental organizations such as Pax Christi, Human Rights Watch, Amnesty International, and many others, acknowledge this also and advocate for the safety of non-combatant populations. This moral obligation, however, includes the protection of the own personnel, not only from being hurt themselves, but also from unintentionally inflicting risks on others, and to ensure just treatments if things turned accidentally to the worse.[3] Safety and risk, all in all, can clearly be considered as central to contemporary military practice. How to assess safety though, and how safety comes about (or not), in contemporary 'high-tech' military systems especially, is still subject to much debate. Elements of this debate will be discussed next.

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[3] This particular phenomenon has recently been referred to in the literature as "second victimhood." Dekker (2013) has been one of the first scholars to explore this phenomenon. He defines second victims as "practitioners [who have been] involved in an accident with (potential) harm to others for which they feel personally responsible." Dekker's work does, however, not stand on itself as it can, of course, be related to earlier work on post traumatic stress disorders and, more recently, on moral injury (Sherman: 2011). Especially this latter work describes the emotional toll that conduct can have on soldiers, even in just wars.

1.3. Contemporary military systems

Since the twentieth century, armed forces often use advanced technologies so as to achieve their ends, be it aircraft, drones, command and control systems, armoured vehicles, or more abstract technologies such as risk management tools and other sophisticated decision aids. Technological changes in warfare have over time made casualty aversion more possible (Mueller: 2000), so at least it is believed. Improved technology often promises improved intelligence and added precision, facilitating thereby a more accurate tactical planning and execution of missions (RUSI: 2013). Whether the use of new technologies does lead to more safety and for whom, however, has often been contested, (e.g. Shaw: 2005 cf. Beck: 1986/1992). Also, as research on automation has pointed out, even if it seems that technological interventions help to reduce overall risk, they can create new types of risks also that operators are often not prepared for, such as in automation surprise (e.g. Sarter and Woods: 1994). In other words, safety in contemporary military systems is not easily achieved nor assessed. Still, concepts and tools have been developed that aim to help people act as moral agents in the sense that they attempt to help us to do whatever is in our reach to avoid or ameliorate unsafe behaviour or technologies. One example of this is the concept of responsible innovation, which aims to help diminish adverse effects of new technologies by promoting, amongst the actors involved in development processes, some sense of collective stewardship (e.g. Stilgoe: 2013).

Concepts such as responsible innovation, although they might specify what adverse effects can be, have often built in them the assumption that one knows how these effects can be measured. In the safety literature, however, by no means does any consensus exist on how, for instance, the safety of technology and other artefacts in large-scale systems such as the military can be assessed. Classic positions in this literature have a tendency to focus on the performance of the individual and seem to oppose, in this regard, contemporary views of safety, which rest on systems theory (e.g. Dekker: 2001, 2002, 2004). These contemporary approaches to safety, which have also been referred to as New View approaches to safety, attempt to link actions and events at the micro-level to macro-level dynamics and vice versa, and acknowledge linkages between the social and the technological domain. As such and on top of this they acknowledge the complexity and dynamics of technological safety in large-scale systems as technology is embedded in these systems and therefore in its socio-technological context. What the system safety literature generally lacks, however, is practical applications that can support safety assessments in these kinds of systems. Thus, while research uses this literature, much work needs to be done still on investigating how this research can actually assist in assessments of safety, on how it can pragmatically help people to connect the micro to the macro and vice versa. The objective of the research presented in this dissertation is therefore:

> To assess large-scale socio-technological military systems in order to further actual assessments of safety in general, especially when the assessments concern the issue of technological safety in large-scale socio-technological systems.

1.4. Research strategy

To achieve the above objective, a number of issues need to be addressed. What these issues are will be discussed in this section. A graphic representation of these issues can be found in Figure 1.

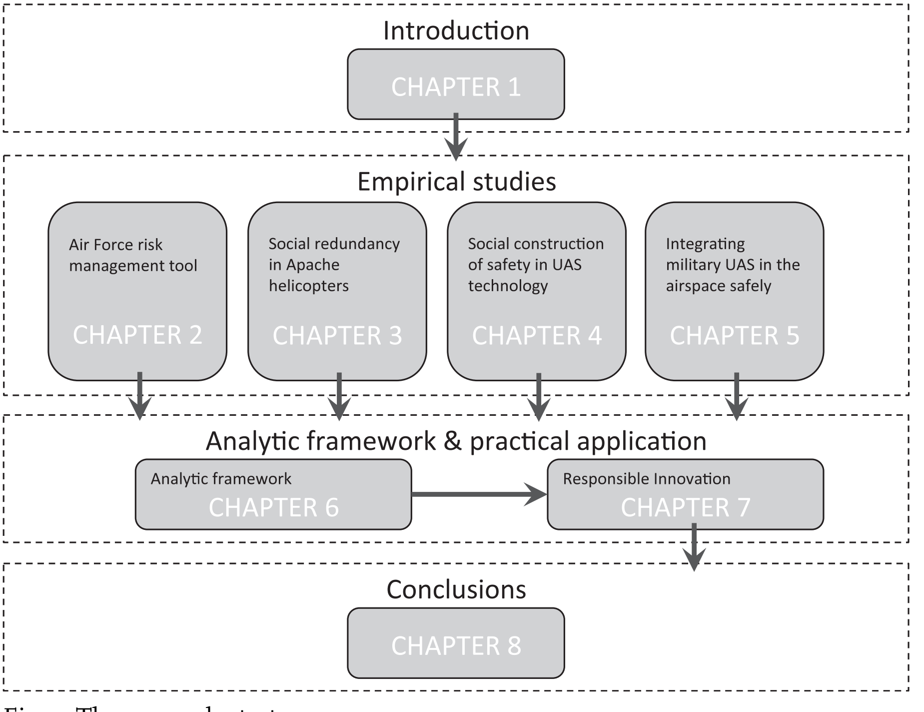

Fig. 1: The research strategy

First of all it is important to understand, as a subject of analysis, military technology as it is embedded in its socio-technological context. Therefore, the first research question that has been taken up here is:

> (1) How does safety arise (or not) in large-scale socio-technological military systems? (chapters 2, 3, 4 and 5)

To formulate an answer to this first research question, a number of empirical studies concerning the safety of technology in the military have been carried out, mainly in the Netherlands. One study was conducted on a Dutch Air Force risk management tool (chapter 2). Subsequently, a study was performed about how redundancy, a safety measure that has often been applied successfully in the technological domain, works when applied in the social domain. This phenomenon was studied here in the context of operating Dutch Apache attack helicopters. More specifically, this study looked at how the concept of redundancy works between the two pilots that need to work closely together to operate these kinds of helicopters (chapter 3). A third technology, unmanned aircraft systems (UAS), was studied in two stages. Some general safety issues with UAS were analysed on a rather abstract level first (chapter 4). After this, a more concrete issue in UAS technology has been looked at, the integration of military UAS in the (inter)national airspace (chapter 5), which, for reasons of data availability, has been carried out mainly in Germany.

Gaining a thorough knowledge on how the safety of technology and its artefacts comes about in military systems, which these studies led to, was necessary so as to proceed to the next step in this research: to build an analytic framework that can help one assess the analytic strength of accounts of safety in large-scale socio-technological systems. This is not to say that the empirical studies mentioned above have been performed from a blank sheet. After all, any researcher will bring with him to any research problem his own knowledge, experience(s), preferences, worldview, etc. Furthermore, this researcher specifically has had training and experience directly relevant to this dissertation's topic – lengthy military experience as a military helicopter pilot and an academic background in psychology, system safety, and in the ethics of technology. This multi-perspective background, with a focus on the system safety perspective though, has thus been the main perspective through which the military systems have been studied here. This perspective, however, has not served in this dissertation as some kind of deductive framework. Rather, it has been used here in a form that probably comes closest to what can be called abduction, a form of reasoning in which theories are thought of as heuristics tools (Coffey and Atkinson: 1996, 175). This has been precisely how models and theories from the system safety literature have been applied in this dissertation. It allowed for the system safety literature to be used constructively and critically in this research, as framework to look through, without, however, getting trapped or overly committed to it when addressing issues related to safety in complex socio-technological military systems. Nevertheless, this system safety literature has served as a basis for the analytic framework, which has been used in the remainder of this dissertation and which has been established by means of this second research question:

> (2) How can we theorize about technological safety in large-scale socio-technological military systems so that the resultant analytic framework has sufficient analytic power to assess whether accounts of risk and safety in large-scale socio-technological military systems can deal with the complexities and dynamics of these kinds of systems? (chapter 6)

It turned out that a combination of literatures – more specifically a combination of the contemporary or New View safety literature, Giddens' structuration theory from the social sciences, and elements from the multidisciplinary STS literature (science, technology and society studies) – seemed to be most promising in dealing with the complexities and dynamics of large-scale socio-technological military systems. It also turned out that actual accounts that comply best with this framework, can be found, at this time, mainly in the STS and system safety literature.

With the empirical data collected and the analytic framework laid out it was now possible to investigate whether this conceptualization of technological safety in military systems can actually further assessments of technological safety in large-scale socio-technological systems in general. So as to explore this, concepts should be studied that implicitly (or explicitly) perform actual assessments of technological safety. The concept of responsible innovation is an example of this and has been used here as it attempts to diminish adverse effects of new technologies (Stilgoe: 2013) by addressing and including moral values (such as safety) at the outset of the development of innovations (Van den Hoven: 2014, 9). The research question that guided this particular step in the research is:

> (3) How can insights gained from studies of technological safety in large-scale socio-technological military systems further the development of concepts such as responsible innovation in the actual assessment of technological safety in large-scale socio-technological systems? (chapter 7)

The concept of responsible innovation has been used in this research for explorative purposes, as a more definite judgment whether the conceptualization of technological safety that resulted from the military systems studies would indeed further actual assessments of safety in general would require a large number of concepts and domains to be studied. This, however, fell outside the scope of the research objective that was aimed for in this dissertation. Having discussed, so far, the contents of chapter 2 till 7 of this dissertation, chapter 8 will discuss, as a concluding chapter, how the studies described in these chapters have contributed to the main research objective, which, again, is to investigate how technological safety can be conceptualized in military systems specifically, so that it can help concepts such as responsible innovation to further their actual assessment of technological safety in complex socio-technological systems in general.

1.5. Concluding remarks

This dissertation reports on a series of military systems studies and on how these studies in the military domain can further actual assessments of technological safety in large-scale socio-technological systems in general. Each chapter in this dissertation (with the exception of chapter 1 and 8) equals a paper that can be read on its own. All the papers together provide a detailed report of this dissertation's research. The papers of chapter 2 till 6 have been published as articles in journals or will appear soon. They have been taken up here as such. The second chapter starts off with the first of four military systems studies, the one that handles about the Dutch Air Force risk management tool.

2 Risk assessments at the Royal Netherlands Air Force: an explorative study

The paper that is presented in this chapter reports on the first of four empirical military systems studies. This particular study concerns the study of a Dutch Royal Air Force risk management instrument, which is commonly used in the Air Force for the assessment of operational risks. Pointed out in this paper are the limitations of modeling risks, which is a typical tool for classic approaches of risk management. The instrument appears to influence – by its design – the outcome of the risk analyses such that perceptual differences about risks between respondents did not surface very quickly.[4]

ABSTRACT – In this paper, differences in the assessment of mission risks and mission benefits between operators and members of the management level in the transport helicopter branch of the Royal Netherlands Air Force (RNLAF) are studied. Results were obtained from a risk analysis that was conducted in accordance with RNLAF procedures. The analysis suggests that the two organizational levels have a coherent perception on risks despite their hierarchical position. Perceived measures of control – controllability – seem to induce the inclusion or the exclusion of what is appeared to be a risk. The analysis also suggests that risk management tools may *obscure* these perceptual differences. Risk management tools may therefore not be sufficient to attain safe operations. In discussions and future studies on risk management and on hierarchical differences in risk perception, this is something to take well notice of. Also, managers and others involved in risk management need to recognize the implications of using risk management instruments that are based on simplified models of risk. This research adds to the risk management theory because it connects multi-dimensional risk theory with actual organizational risk management practice.

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4 This paper originally appeared as an article published by Taylor & Francis in the *Journal of Risk Research* 16 (5) 2013, available online: http://wwww.tandfonline.com/DOI/full/10.1080/13669877.2012.726249.

2.1. Introduction

Risk society, risks and risk management have become important issues in the past decennia, especially in western societies, instigated mainly by Beck (1986/1992) and Giddens (1990). A risk society is defined by Giddens (1993, 3) as 'a society increasingly occupied with the future (and also with safety), which generates the notion of risk.' Within such a risk society, risk can be defined as 'a systematic way of dealing with hazards and insecurities induced and introduced by modernization itself' (Beck: 1986/1992, 21). Risk management, then, refers to the process of reducing these risks to a level deemed tolerable by society, and controlling, monitoring and communicating these risks in public (Morgan: 1990). Organizations, societies and international corporations are studying, canalising and determining all kinds of risks they themselves and their members could encounter. Military organizations, such as military aviation departments, form no exception here. Some aspects of the process of risk reduction have been explored in the Royal Netherlands Air Force (RNLAF) and described in this paper.

2.2. Theoretical framework

It is common knowledge that the actions and perceptions of individuals at one (hierarchical) level of an organization can influence the actions and perceptions of individuals at another level of the organization (Griffin and Mathieu: 1997). This does not imply necessarily, however, that these perceptions are shared perceptions. Safety perceptions, for example, may differ between employees depending on their position and/or hierarchical level within the organization (Arboleda, Morrow, Crum and Shelley: 2003). Also, not only Prussia, Brown and Willis (2003), in their study of mental models of safety in the steel plant industry, but also Mearns and Flin (1995), in their study of perceptions and attitudes of safety in the offshore oil and gas industry, found that perceptions of managers differed from the perceptions of their workers where safety issues within the organization were concerned. This is plausible since research in the past has suggested that people select issues of concern (risks) as a result of cultural conventions and social constructions (Renn: 1998), and of institutional, procedural and societal processes (Slovic: 2001). Crucial issues in this process, and thus factors of significance in risk assessments, seem to be features such as (perceived) controllability, voluntariness, fear, fairness, etc. (Slovic: 1999). It is clear that these features could well differ between workers at distinct hierarchical levels. For instance, although it is the operators on the work floor who physically bear the operational risks, they normally have only limited control on what the management level deems acceptable. All this is consistent with the concept of 'local rationality'.

The concept of local rationality was first introduced by Woods, Johannesen, Cook and Sarter (1994), and forms an adaptation of Simon's (1969) concept of 'bounded rationality'. Where classic decision-making theories allocate shortcomings in rationality mainly to limitations of cognitive capacities, Woods et al. (1994) emphasize with their concept of local rationality that any problem solving process – or risk assessment if you will – is context dependent, even when cognitive capacity would be infinite. According to Dekker (2002, 9),

> people [do] what makes sense given the situational indications, operational pressures, and organizational norms. [They] do things that are reasonable – or rational – based on their limited knowledge, goals, and understanding of the situation, and their limited resources at the time.

In other words, what people do or not do – or how they assess safety – can be fully (although local) rational and still differ dependent, for example, on the position that people have been allocated. This also holds in the military.

Military aviation missions nowadays take place in modern theatres of war. Units regularly are deployed on expeditionary operations far away from home base. International support for these missions is ensured by forming multinational alliances, often referred to as 'combined' forces. Above all, in order to enlarge the effectiveness of operations, army, air force and navy units often work close together in so-called 'joint' units. These combined and joined operations abroad make that today's military theatres can be said to be highly complex. The complexity of such situations follows among others from the inherent incompleteness of information that is available to decision-makers at all levels. These decision-makers, at the same time, are ethically obliged to establish not only a safe environment for the community around them, but also for their own and friendly forces (Richardson, Verweij, and Winslow: 2004). After all, the inevitable risks inherent to accomplishing international security do not relieve military (aviation) upper level managers from their responsibility to create work safety up to the maximally attainable level. In environments such as described here, they can be expected not always to succeed in this, at least not in the eyes of the beholders of perceived residual risks, the operators in the field. The acceptance of these residual risks, at the same time, depends largely on the degree to which the risk bearers trust their decision-makers (Freudenburg: 1993). Operators can be highly motivated to take risks and suffer the consequences. However, this motivation can change very quickly if risks cannot be justified or are not congruent with their own attitudes and values (Linnerooth-Bayer and Fitzgerald: 1996). For interpersonal trust to be achieved it is further important that risks fall within the operators' 'interpretative frames'[5] as Ekman (2009) called them in his presentation on interpersonal trust at an operational headquarter of a military mission in Tchad.

Considering the apparent value of top level risk assessments to be acceptable to military operators in the field, it would be interesting to explore the landscape of risk and risk assessment of the so-called 'sharp-end' military aviation front line operators on the one hand, and their decision-makers at the upper management levels on the other. Another argument to explore this area has been argued for by Uhr and Ekman (2008) in a study of trust and its consequences in emergency response operations: there seems to be a link between distrust and 'not-having-the-same-opinion.' By exploring the differences between these two hierarchical levels regarding assessments of risks we think we can gain a more complete understanding on risk, risk perception and risk management in organizational settings – more specific: in military organizational settings.

Research question and expectations

In military aviation units, it is common practice for decision-makers at all levels to manage operational risks through the use of a risk management instrument called operational risk management (ORM). Although differences can be observed, the general principles of ORM remain the same, even internationally. In contrast to risk research that suggests that risk has many different dimensions (as we have described briefly above as well), in ORM procedures risk normally is determined along two dimensions only: frequency of appearance (risk frequency) and severity of the event (risk severity). The tool, thus based upon 'the traditional [simplified] view of risk as some objective function of probability

[5] Interpretative framing: the mental mechanisms in social interaction that help participants define how others' actions and words should be understood, make sense of a situation they find themselves in, to find and interpret specifics that, to them, seem central to understanding the situation, and to communicate this interpretation to others (Bateson: 1954/1972 as cited in Ekman: 2009).

(uncertainty) and adverse consequences' (Slovic: 2001) is, however, part of the real world risk management practice and hence valuable to study. The main question to be answered in the study therefore was formulated as whether and to what extent operators and upper level managers perceive frequency and severity of operational risks differently using the same formal risk management instrument. Because one step in the ORM procedure is to make a decision where risks are to be weighed against – among others – mission benefits, assessments and perceptions of mission benefits have been investigated as well.

In his standard work on risk (Risk Governance), Renn (2008, 55) argued that 'since those who create [or decide on] risks expose others to dangers, congruency between the risk takers [upper level management] and he risk bearers [the operators in the field] is not possible.' Renn refers here to the differentiation that Luhmann made in 1990 between danger (what people are exposed to) and risk (what people choose to dare). Indeed, past research suggests that upper level employees normally see their organizations as safer than workers at the front line (e.g. Gaba, Singer, Sinaiko, Bowen and Ciavarelli: 2003). The assumption in this study is therefore that personnel on the work floor (operator level) will assess higher risk levels both on frequency and on severity than personnel from upper level management (headquarter level). Regarding the assessment of benefits, it is clear that the nature of day-to-day activities differs across hierarchical levels within organizations. While activities at the headquarter levels will be more coordinating and political in nature, activities at the operator level will primarily be focused on establishing the final product. Therefore, in this study, it is assumed that personnel on the work floor will consider tangible benefits more important than benefits that are of more political nature.

2.3. Method

Research was conducted in the Dutch Air Force (RNLAF). Employees from the work floor and employees from the headquarter level were asked to perform a realistic risk analysis of a fictional military aviation mission abroad. A between groups analysis design was used to compare their output (Siegel and Castellan: 1988). The RNLAF, at the time of this study, had five different main branches: fighter and training aircraft, helicopters, air transport, ground-to-air weapons and C4ISR (Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance). This study was conducted in the (transport) helicopter branch as far as the operator level is concerned. At this level, employees conduct tasks that are more or less branch-specific. At the headquarter level, the other hierarchical level in this study, respondents were chosen from all branches. After all, task specification at this level is somewhat more diffuse than on the operator level.

The case

A fictional mission scenario was written for this study. Expert knowledge, such as experienced scenario writers from the intelligence section and operational experts, was used to help design this fictional mission. The mission scenario described a multinational peace enforcement operation on the border of two fictional countries with six RNLAF transport helicopters after a shift in the Dutch political landscape.

Two different types of RNLAF helicopters were included in the mission scenario, indicating a severe strain on the available equipment. Tasks to conduct by the RNLAF helicopters included the deliverance of logistic support to ground troops, food relief, evacuation, insertion and extraction of special forces and general support. Ground troops to be supported included Dutch Special Forces, as well as infantry troops from countries other than NATO. Standard procedures thus could not be relied on. Above all, these troops were unfamiliar with helicopter operations in general. Although this is a situation that is familiar to RNLAF helicopter crews, especially in the past, it does complicate things.

Circumstances were described in such a way that a lot of stress was put on the helicopter crews. Attack helicopters for offensive support were not available. The climate was described as tropical, implicating known and unknown tropical diseases to calculate with. The terrain was depicted mainly mountainous, combined with desert, putting constraints on load capacity and power available on the one hand and severe difficulties with landings in sandy and dusty environments on the other. Some of the parties were described as offensive. Sabotage, subversive activities and terrorist attack were all defined as realistic events. Ground-to-air threats were described as present in the area, although consisting of heavier equipment in low volumes only. Air-to-air threats could be regarded as absent according to the mission scenario. In order to support local air traffic control services, a Dutch controller was added to the detachment.

All in all, the mission scenario was set up in such a way that many risks were included. However, one of the main targets of the scenario writers was to keep the mission scenario as realistic as possible. Risks as described above are not abnormal for today's complexity of missions abroad.

Procedure

Respondents were asked to perform a risk analysis on the fictional case described above. To be able to compare the results, respondents were all led through a risk management procedure based on the RNLAF standard procedure for ORM. Since 2004, this procedure has functioned as the RNLAF standard for managing operational risks in the RNLAF. The procedure has been widely known throughout the RNLAF, both at the operator level as well as at the headquarter level. One of the fundamental ideas behind this procedure, according to the RNLAF ORM handbook (RNLAF: 2004), is that a better insight into how the organization manages risks may take away feelings of unfairness among its risk bearers.

The RNLAF ORM procedure prescribes six steps that have to be applied chronologically. The first step is to identify risk scenarios on the basis of the available information on the mission. The second step is to assess the risk value for each of these identified scenarios. The final four steps that are prescribed by the RNLAF ORM procedure are to identify, to weigh, to implement and to review relevant counter measurements, so as to avoid or to contain the identified risks. For reasons of standardizing the research set-up, the first step of the RNLAF ORM procedure – the identification of risk scenarios and mission benefits – was performed by the researchers. Since the researchers' focus was on the risk analysis part of ORM, the final four steps of the procedure – identifying, weighing, implementing and evaluating possible counter measurements – were left out of consideration.

In our study, the respondents were to apply an analysis on 25 risk scenarios as defined by the researchers. Following the RNLAF ORM procedure, respondents were asked to assess risk severity of scenarios on a scale ranging from one to four (negligible to catastrophic) and risk frequency of scenarios on a scale that ranged from one to eight (unlikely to very frequent). Risks however form only one side of the coin; the other side contains benefits. In this context, 10 benefits were also identified by the researchers. Respondents were asked to rank these on a scale from one to 10. The benefit they assessed least valuable was ranked one, while the benefit they assessed as most valuable was ranked 10. Double rankings were not permitted.

For the purpose of generating maximal participation in the research, commanders of the RNLAF were informed about the backgrounds of the study and the expected workload for respondents participating. Together with the questionnaire, respondents received an accompanying letter in which the background of the research was explained. In total, 186 questionnaires were distributed from which 75 were filled out correctly and returned (40%). From the headquarter level, 20 questionnaires were returned (44%), from the operator level 55 (38%). This level of response has to be weighed against the substantial efforts that the RNLAF had to bring out in missions abroad at the time of this study. Also, it should be taken in mind that reading the scenario and filling in the questionnaire took most of the participants about one to one and a half hour, some even more.

Data analysis

Since the results of the ranking task in the questionnaire concerned ordinal data only, non-parametric tests were used in the analysis. Another reason for the use of non-parametric tests was that the sample group from the operator level was more than 1.5 times larger than the sample group from the headquarter level. When this is the case, the parametric t-test can only be conducted under severe restrictions (De Heus, Van der Leeden and Gazendam: 2003). Especially with small samples, the power-efficiency of these non-parametric tests is often equal to and sometimes even greater than that of parametric tests, especially with small samples (Siegel and Castellan: 1988).[6]

The RNLAF ORM procedure that was used during the research, prescribes to assess risk levels as a combination of two separate constructs: risk severity and risk frequency. To check whether these two concepts were indeed evaluated as separate constructs by the respondents, bivariate correlations between risk severity and risk frequency were analysed. Since the literature does not provide further guidance here, an arbitrary level of two-thirds was chosen by the researchers. With this it is meant that when results on correlation between risk severity and risk frequency are not significant ($p \leq 0.05$) with two-thirds or more of the respondents, the concepts of risk severity and risk frequency have been evaluated by the respondents as separate constructs. Besides this check on correlation between constructs, checks for outliers were conducted. Also, the research groups were checked whether they agreed within groups on their scores. For this check Kendall's coefficient of concordance (Kendall's W) ($p \leq 0.05$) was used.

6 In this case, parallel testing with t-tests showed similar results.

For group comparison between the headquarters and the operators on risk severity, risk frequency, and mission benefits, the two-tailed Wilcoxon–Mann–Whitney test was used ($p \leq 0.05$). With the principal component analysis (PCA) (Varimax rotation) further analysis was conducted on risk severity and risk frequency. Prior to this PCA, the suitability for factor analysis was assessed by the Kaiser–Meyer– Olkin (KMO) index (≥ 0.6) and Bartlett's test of sphericity ($p \leq 0.05$). Cattell's scree test was used in order to determine the number of factors. Further analysis on the assessment of mission benefits was done by transforming the rankings of the mission benefits into scales using Torgerson's Law of Categorical Judgement. The results of this were visualized in two graphs, one for each hierarchical level. The rankings are presented on a scale from least to most valuable.

2.4. Results

The RNLAF ORM procedure that was used during the research, prescribes that risk levels should be assessed as a combination of the two separate constructs risk severity and risk frequency. Results on bivariate correlations at the individual (case) level indicate that risk severity and risk frequency indeed have been evaluated as independent constructs by the respondents in 56 of the 75 cases (74.7%) ($p \leq 0.05$). 74.7% is well above the chosen cut-off level of two-thirds.[7]

Checks for outliers and Kendall's coefficient of concordance (Kendall's W) reveal no peculiarities. Results on Kendall's W are all significantly high, indicating thereby that inter-group homogeneity in both groups that had been created for this study – the headquarter level and the operator level – is present for scores on risk severity, scores on risk frequency, as well as for scores on mission benefits. In other words, the respondents in the two separate groups each applied roughly the same standard to their responses as the other members of their group, as indicated by a sufficient degree of association among their scores.

Risk severity and frequency

The scores on risk severity and risk frequency are shown in Table 1, which indicates that the scores for risk severity barely differ across the two hierarchical

7 As has been pointed out earlier in this paper, the cut-off level of two-thirds was chosen arbitrarily since no standard was found in the literature.

levels. The scores for risk frequency on the other hand are consistently slightly higher at the operator level than at the headquarter level (some of these differences are significant).

		Risk Severity					Risk Frequency				
		Staff		Airbase		Mann-W Asymp Sig.	Staff		Airbase		Mann-W Asymp Sig.
Item	Risk Scenario	Mean	SD	Mean	SD	(2-tailed)	Mean	SD	Mean	SD	(2-tailed)
R1	board	1.70	0.98	1.56	0.90	0.589	4.90	2.07	5.25	1.97	0.464
R2	Incidents due to assignment of crew members that are not fully operational capable	2.45	1.15	2.25	0.80	0.436	6.05	1.15	5.62	1.43	0.410
R3	Assignment for unfamiliar missions, i.e. not trained for or not equipped for	2.80	0.77	2.65	0.82	0.538	6.00	1.38	5.35	1.62	0.181
R4	Incidents due to inexperience with new equipment or unfamiliar configurations	1.90	0.79	1.95	0.80	0.805	5.90	0.97	5.27	1.59	0.195
R5	inserting or extracting troops	3.15	0.75	3.25	0.82	0.502	5.20	1.24	4.95	1.82	0.995
R6	Air-to-ground incidents due to newness, thereafter due to complacency	1.95	0.94	2.04	0.90	0.630	4.45	1.76	4.76	1.37	0.708
R7	Incidents due to unfamiliarity of foreign troops with Dutch helicopter procedures	2.00	1.08	1.80	0.85	0.581	5.70	1.17	5.45	1.61	0.695
R8	Deteriorating weather below flying regulations in mountaineous terrain	2.30	1.22	2.31	0.92	0.817	5.30	1.42	5.89	1.23	0.078
R9	Trigger hesistancy due to former experiences with legal justice of others	1.80	0.70	1.96	0.75	0.409	4.50	1.57	5.07	1.34	0.117
R10	Landing in criminal areas	1.75	0.72	2.00	0.77	0.217	5.35	1.69	5.56	1.60	0.646
R11	Landing in unregistered mine fields	3.55	0.83	3.33	0.86	0.190	4.50	1.43	4.44	1.60	0.845
R12	Emergency/precautionary landing in hostile environment while quick fix is not possible	2.65	0.81	2.93	0.84	0.172	4.60	1.05	4.64	1.24	0.747
R13	Incidents with crew or passenger weapons	2.00	0.65	2.09	0.78	0.768	4.10	1.55	4.80	1.41	0.025*
R14	Ground-to-air threats ranging from small weapons to man portable systems	3.15	0.88	3.00	0.82	0.501	6.15	1.23	6.07	1.39	0.812
R15	Incidents with landings in brown-out conditions (dust landings)	2.75	0.91	2.76	0.94	0.899	5.75	1.16	5.73	1.48	0.809
R16	Near-misses at the airbase due to lack of air traffic control	2.20	1.20	2.15	1.08	0.880	4.25	1.74	4.84	1.50	0.275
R17	Dropping out of personnell due to malaria or leisbolitis	1.50	0.69	1.78	0.71	0.103	5.85	1.57	5.87	1.17	0.706
R18	Incidents due to operating in mountaineous terrain	2.70	1.13	2.58	0.83	0.417	4.65	1.35	5.09	1.09	0.237
R19	Less availability of helicopters in theatre due to	1.70	0.66	2.02	0.85	0.163	6.35	1.09	6.35	1.38	0.801
R20	Less availability of helicopters back home due to focus on mission abroad	1.70	0.57	1.78	0.92	0.845	6.45	1.05	7.00	0.98	0.032*
R21	Resistence of personnell against deployment abroad while in a reorganization	1.40	0.60	1.83	0.91	0.058	5.55	1.79	6.07	1.79	0.134
R22	Terrorist attacks on the airfield	2.75	0.97	2.67	0.77	0.669	4.90	1.45	6.35	1.42	0.000*
R23	Incidents due to multiship operations with self-defense systems and procedures	2.60	1.14	1.89	0.98	0.014*	3.80	1.51	4.82	1.47	0.013*
R24	Incidents due to deviations from SOP's, unclear flying procedures	2.20	0.83	2.00	0.82	0.340	4.95	1.82	5.33	1.17	0.532
R25	Acceptance of chain of events due to actual or perceived operational pressure	2.55	1.00	2.53	0.86	0.975	5.45	1.36	5.78	1.34	0.522

* Significant by α=0.05 (2-tailed)

Table 1: Medians, standard deviations, and results for Mann-Whitney test *risk severity* and *risk frequency*

Mission benefits

Table 2 shows the results on mission benefits for the two hierarchical levels. As Table 2 clearly shows, none of the differences between the hierarchical levels is significant. This means that there are hardly any noticeable differences between the two organizational levels when it comes to their assessment of the mission benefits.

		Benefits				
		Staff		Airbase		Mann-W Asymp Sig. (2-tailed)
Item	Risk Scenario	Mean	SD	Mean	SD	
B1	European combined operations	5.00	2.09	5.00	2.29	0.374
B2	Proof of value of Dutch transport helicopters	5.00	2.41	5.00	2.39	0.401
B3	Extra allowance for being deployed abroad	4.00	1.64	4.00	2.26	0.159
B4	Experience gain individual / squadron	6.50	2.31	7.00	2.03	0.725
B5	None	1.00	2.53	1.00	2.08	0.911
B6	Joint (with different military services together) operating	6.00	1.90	5.00	2.19	0.506
B7	Presence of Dutch helicopters in the international theatre	5.00	2.63	4.00	2.05	0.138
B8	Opportunities for fast procurement of equipment and weapons	5.00	2.01	6.00	2.34	0.933
B9	Providing humanitarian assistance for local population	9.00	2.77	9.00	1.58	0.575
B10	Contributing to the establishment of international peace and security	9.00	2.11	9.00	2.23	0.476

* Significant by α=0.05 (2-tailed)

Table 2: Medians, standard deviations, and results for Mann-Whitney test *benefits*

2.4.1. Going below the surface: zooming in

The most important conclusion so far is that neither the analysis for risk severity and risk frequency, nor the analyses for mission benefits, suggests evidence for perceptual differences between the hierarchical levels with regard to mission risks and benefits. However, some perceptual differences could be present below the surface. This line of reasoning follows from research that was conducted in the steel plant industry by Prussia, Brown, and Willis (2003). In this research, it was concluded that, although managers and employees above the surface 'share[d] an embedded mental model about the factors that influence safe behaviour decisions[,] managers and employees [below the surface] disagree[d] to some extent on their perceptions of most of the safety constructs.' In order to check our supposition, the data were examined more closely.

Examining risk severity and risk frequency more closely was done by means of a PCA. In Table 3, the scheme of the PCA is represented. The KMO index and Bartlett's test of sphericity indicate that only the PCA of risk frequency at the operator level is statistically reliable (X^2 = 551.00,200, DF = 300, p = 0.000). Despite this, all results are shown in Table 4, so as to be able to provide an indication of the characteristics of the underlying processes that help workers and managers to evaluate risk severity and risk frequency.

	Headquarters	Airbase
Risk severity	PCA 1	PCA 2
Risk frequency	PCA 3	PCA 4

Table 3: Scheme of PCA risk severity and risk frequency at headquarter and operator level

Risk severity

When examining risk severity more closely, Table 4 clearly shows that both at the operator level and the headquarter level, the assessment of risk severity is grounded in similar components, suggesting no underlying perceptual differences between the two hierarchical levels at a first glance. At both hierarchical levels, "Direct physical threats" is considered the most prominent component followed by "Indirect threats". However, the explained variance of the two components varies substantially between the two hierarchical levels. At headquarter level, the first component of risk severity ("Direct physical threats") accounts for 29% of the variance, while it accounts for only 18% of the variance at operator level. The explained variance for the second component of risk severity (Indirect threats) is above all 13% at headquarter level, as opposed to 9% at the operator level. Perceptual differences on risk severity can thus still not be ruled out. Therefore, results on risk severity are analysed at the item-level (see Tables 5 and 6).

PCA 1 (Risk severity, Headquarters)		PCA 2 (Risk severity, Airbase)	
1st component	*Direct physical danger (29% of variance explained)*	1st component	*Direct physical danger (18% of variance explained)*
2nd component	*Indirect threats (13% of varance explained)*	2nd component	*Indirect threats (16% of variance explained)*
PCA 3 (Risk frequency, Headquarters)		**PCA 4 (Risk frequency, Airbase)**	
1st component	*Unfamiliarity/uncertainty outside organizational control (26% of variance explained)*	1st component	*(Perceived) exposure (28% of variance explained)*
2nd component	*Complexity of organizational challenges (17% of variance explained)*	2nd component	*Hidden or startling threats (20% of variance explained)*

Table 4: Results on factor analysis *risk severity* and *risk frequency* at headquarter and operator level

PCA 1 (Risk severity, Headquarters)

Item	Dimension 1	Dimension 2	Risk scenario
R24	0.840		Incidents due to deviations from SOP's, unclear flying procedures
R23	0.825		Incidents due to multiship operations with self-defense systems and procedures
R15	0.801		Incidents with landings in brown-out conditions (dust landings)
R11	0.735		Landing in unregistered mine fields
R22	0.712	0.412	Terrorist attacks on the airfield
R14	0.705		Ground-to-air threats ranging from small weapons to man portable systems
R5	0.663		Landing in a landing zone with enemy activity while inserting or extracting troops
R8	0.638		Deteriorating weather below flying regulations in mountaineous terrain
R7	0.594		Incidents due to unfamiliarity of foreign troops with Dutch helicopter procedures
R16	0.582		Near-misses at the airbase due to lack of air traffic control
R6	0.582		Air-to-ground incidents due to newness, thereafter due to
R18	0.556		Incidents due to operating in mountaineous terrain
R3	0.537		Assignment for unfamiliar missions, i.e. not trained for or not equipped for
R12	0.537		Emergency/precautionary landing in hostile environment while quick fix is not possible
R4	0.517	-0.390	Incidents due to inexperience with new equipment or unfamiliar configurations
R13	0.417		Incidents with crew or passenger weapons
R2	0.380		Incidents due to assignment of crew members that are not fully operational capable
R9	0.352		Trigger hesistancy due to former experiences with legal justice of others
R21		0.709	Resistence of personnell against deployment abroad while in a reorganization
R20		0.625	Less availability of helicopters back home due to focus on mission abroad
R19		0.594	Less availability of helicopters in theatre due to complications in logistic support
R25		0.574	Acceptance of chain of events due to actual or perceived operational pressure
R17		0.571	Dropping out of personnell due to malaria or leisbolitis
R1		-0.480	Hypoxia due to flights above 6000ft without oxygen on board
R10		0.427	Landing in criminal areas

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization
Rotation converged in 3 iterations

Table 5: PCA *risk severity* at headquarter level

When comparing the high-loading items on the component "Direct physical threats" between the hierarchical levels, differences can be discerned. At headquarter level, the high-loading items seem to refer to threats that are *outside the direct control of members at the headquarter level*. Examples of such threats are risk

PCA 2 (Risk severity, Airbase)

Item	Dimension 1	Dimension 2	Risk scenario
R11	0.762		Landing in unregistered mine fields
R12	0.642		Emergency/precautionary landing in hostile environment while quick fix is not possible
R14	0.631		Ground-to-air threats ranging from small weapons to man portable systems
R5	0.624		Landing in a landing zone with enemy activity while inserting or extracting troops
R15	0.609	0.412	Incidents with landings in brown-out conditions (dust landings)
R6	0.606		Air-to-ground incidents due to newness, thereafter due to complacency
R18	0.599		Incidents due to operating in mountaineous terrain
R22	0.497		Terrorist attacks on the airfield
R10	0.462		Landing in criminal areas
R13	0.460		Incidents with crew or passenger weapons
R16	0.439		Near-misses at the airbase due to lack of air traffic control
R3	0.413		Assignment for unfamiliar missions, i.e. not trained for or not equipped for
R25	0.363		Acceptance of chain of events due to actual or perceived operational pressure
R7	0.537		Incidents due to unfamiliarity of foreign troops with Dutch helicopter procedures
R20		0.775	Less availability of helicopters back home due to focus on mission abroad
R19		0.749	Less availability of helicopters in theatre due to complications in logistic support
R21		0.701	Resistence of personnell against deployment abroad while in a reorganization
R24	0.386	0.598	Incidents due to deviations from SOP's, unclear flying procedures
R23		0.528	Incidents due to multiship operations with self-defense systems and procedures
R8		0.528	Deteriorating weather below flying regulations in mountaineous terrain
R17		0.514	Dropping out of personnell due to malaria or leisbolitis
R9		0.513	Trigger hesistancy due to former experiences with legal justice of others
R4		0.359	Incidents due to inexperience with new equipment or unfamiliar configurations
R1			Hypoxia due to flights above 6000ft without oxygen on board
R2			Incidents due to assignment of crew members that are not fully operational capable

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization
Rotation converged in 3 iterations

Table 6: PCA *risk severity* at operator level

scenarios that follow from procedures that are set aside by workers in the field or are badly understood (R24, Table 5), as well as risk scenarios that follow from the utilization of equipment that is rarely used during peace time (R23, Table 5). In contrast, at operator level, the component "Direct physical threats" mainly seems to refer to threats that are considered to be outside the aircrew's controllability. High-loading risk scenarios here include scenarios on mine fields, enemy threat and terrain (R11, R12, R14, R5, R15, Table 6).

With regard to the second component of risk severity, "Indirect threats", a similar difference reveals. At headquarter level the component "Indirect threats" seems to refer to higher order organizational threats that are overall difficult to control. High-loading risk scenarios here include those that refer to the motivation of personnel, a reduced operational capacity in the theatre due to logistic challenges (R21, R20, R19, Table 5). At operator level on the other hand, the component "Indirect threats" not only includes these threats, but also those threats that directly and indirectly can hamper the workers' mission accomplishment in the field. The exemplary high-loading risk scenarios here refer to unfamiliarity with procedures (R24, Table 6), along with those containing threats related to equipment and weather (R23, R8, Table 6).

Risk frequency

Results in Table 4 indicate that with the analysis of the assessments of risk frequency, a step-down towards the item-level needs not to be made for differences between the hierarchical levels to reveal. Table 4 shows no commonalities in components for the respondents' evaluations of risk frequency. These findings correspond with the result that scores for risk frequency differed more across the two hierarchical levels than those for risk severity.

At headquarter level, "Unfamiliarity or uncertainty outside organizational control" seems to be the first component on which the assessment of risk frequency is grounded. Risk scenarios that are high-loading here are those that include threats such as unclear procedures, unfamiliar equipment and circumstantial uncertainties (R24, R23, R13, R6, R8). This component refers to 26% of the explained variance. The second component at headquarter level is considered to be "Complexity of organizational challenges", accounting for 17% of the explained variance (high-loading risk scenarios: R20, R21, R19). At operator level, the first component is "(Perceived) exposure" of the crews towards risks in general (R19, R22, R15). The second component at this level has been titled "Hidden or startling threats", a factor that addresses the (in)visibility or the (im)possibility to observe threats in the theatre (R13, R14, R8, R2). These two dimensions account for 28 and 20% of the explained variance, respectively.

Mission Benefits

Examining mission benefits more closely was done by means of the application of Torgerson's Law of Categorical Judgement. Figure 2 contains the resulting graphs.

From the graphs in this Figure 2 it can be concluded that, although not significant as results in Table 2 have pointed out, members of the headquarter level perceive "Presence of Dutch helicopters in international theatre" (Item B7) as much more valuable than members of the operator level. Another conclusion that follows from the results as presented in Figure 2 concerns the two most valuable mission benefits. Where "Contributing to international peace and security" (Item B10) is perceived as most valuable at the operator level, followed by "Helping local population" (Item B9), these same two items are perceived as most valuable at headquarter level, yet in the opposite order.

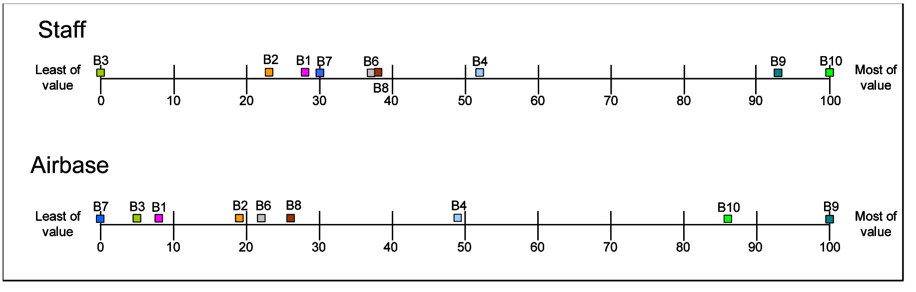

Fig. 2: Mission *benefits* scaled with Torgerson (B5 "No benefits" deleted from results)

2.5. Discussion

In this discussion, some advantages and disadvantages of how the study was executed will be discussed. Also we will give some theoretical reflections. However, we first start with highlighting some of the most interesting outcomes.

The outcomes

In this paper, two hierarchical levels were studied for differences in perceptions on risk frequency, risk severity and mission benefits as obtained from a risk analysis conducted in accordance with RNLAF procedures. It was expected that significant differences between different hierarchical levels in the RNLAF would be found in the assessments of all three categories. In contrast to our assumptions, however, almost no significant differences were found. The ones that were found though, (on risk frequency) appeared to be in line with former research, suggesting that upper level management estimates less risk than work floor employees (e.g. Gaba et al.: 2003). A somewhat closer examination of the data did suggest perceptual differences.

Especially with regard to risk severity and risk frequency, we found indications for perceptual differences in a recurrent pattern of 'local rationality' (Woods et al.: 1994). This was most apparent in the analysis of risk frequency. Nevertheless, also in the assessment of risk severity the two organizational levels seemed to rationalize risks from their own hierarchical perspectives. 'Controllability' seemed to be the keyword here; what was included or excluded in the perception of risks seemed to depend on the own controllability of the risks mentioned. The PCAs differed between the hierarchical levels in such a way that many of the high-loading items referred to those threats that can be considered outside the direct control of members of the respective hierarchical levels making the assessment. These results confirm a notion that was brought up by Dekker (2005, 78): 'Human actions and assessments can be described meaningfully only in reference to the localized setting in which they [were produced].' This study also mirrors another conclusion of Dekker (2006, 185): the local rationality principle does not only apply to the operational level, but to managers as well. More research is however needed in order to find out if local rationality in risk management can be recognized with more analytical depth. After all, only after several levels of analysis we distinguished these underlying (sources for) hierarchical differences in risk assessments.

Some methodological reflections

The study described in this paper has been conducted within the RNLAF. This could imply that results cannot unconditionally be generalized to other organizations. Research constraints furthermore allowed the evaluation of one mission only, implicating that results should be regarded as exploratory in nature. However, results provide us with new insights and, above all, offer a few interesting themes for discussion and further research.

When conducting research in the own organization, there is always the imminent risk of bias. On the other hand, conducting the research from 'within' and taking an emic perspective has some benefits as well. One of these benefits in this case was that, because of our own experience within the organization, we were able to construct a realistic and attractive scenario. Having a realistic scenario heightened response substantially as many respondents stated afterwards. This can be seen as a significant achievement since participating in this study was rather time-consuming for the respondents. We have further chosen to compose the research in such a way that organizational procedures were followed closely. One reason for this was to study risk assessment in its most natural form, i.e. as it is conducted in realistic military aviation settings. Another reason was that this enabled us to provide useful feedback to the organization studied here on their risk management tool, which increased organizational support for the study even more.

Some theoretical reflections

It would be too naïve to say that the apparent commonality of assessments of risks and benefits followed inherently from using the same instrument since other accounts can have similar or even better explanatory power. For example, this commonality could as well have been the result of having expert participants only. After all, much of the risk perception literature, such as Renn's seminal paper on risk perception in 1987 and Beck's Risk Society in 1986, focus on the sheer difference in risk perception between lay and expert people. While experts are considered to be rational and to rely on real, objectively analysed and calculated risks, lay people, according to this literature, have a subjective, even emotional view on risk that they think is of equal importance although of sheer different nature.

Expert models of risk, as we have stated in the theoretical framework, are however not incontestable as well. The RNLAF, we pointed out, uses a highly simplified bi-dimensional model of risk while the literature has long debated for multi-dimensionality in risk models (e.g. Kunreuther and Slovic: 1996; Renn: 1998; Slovic: 1999, 2001). Maybe more differences could have been distinguished when we would not have persisted in using the RNLAF ORM procedure, with its ample two dimensions of risk frequency and risk severity (weighed against a third dimension: the mission benefits). Maybe other and more differences could have been distinguished when we would have used a more enriched, multi-dimensional model of risk. On the other hand, we would then still be wondering perhaps about how these differences would work through in actual organizational risk management processes with their more simplified risk models.

What this study brings to the risk literature is maybe exactly that: it connects risk theory with organizational risk management practice. One way to interpret the results is that in this particular organization the culture is such that, contrary to our hypothesis, its members across hierarchy have an unexpected coherence in their values when it comes to the perception of risk. Such an interpretation however counters former research that predicts hierarchical differences in risk perception (Arboleda et al.: 2003; Gaba et al.: 2003; Mearns and Flin: 1995; Prussia, Brown, and Willis: 2003). Another interpretation, supported by a more thorough examination of the data, is that risk management tools can well obscure hierarchical perceptual differences concerning the very nature of risk within organizations. Perceptual differences may not get mirrored in the outcomes of formal risk management tools. The establishment and use of safety management tools may therefore not be enough to achieve safe operations. One even can get to doubt, as Nyce, Bakx, and Dekker (2010) expressed as well, whether 'these tools are used in an attempt to improve decision-making, or if these merely are utilized to justify (political) decisions already made.'

3 Is redundancy enough?: a preliminary study of Apache crew behaviour

A second study related to military systems is presented in this third chapter. The study concerns the concept of social redundancy between the two pilots of an Apache attack helicopter, which is an aspect of their cooperation and coordination activities. Redundancy is a typical classic safety measure that is often applied with success in the technological domain. Redundancy in the social domain, however, as this was studied from a contemporary (or 'New View') safety perspective within its larger context here, appears to be of a much more complex nature. Especially the backgrounds of the wire strike that has been described in this paper has been used for several times throughout this dissertation as a typical example of how safety – or in this case, the lack thereof – emerges from how micro-level activities and macro-social events and developments can interact.[8]

ABSTRACT – Redundancy often is considered a safety multiplier. In complex socio-technological systems however, according to proponents of complex systems theory, the impact of social redundancy (the social counterpart of technological redundancy) can be suboptimal. Ethnographically inspired research was therefore conducted on whether and how members of a European Apache attack helicopter unit applied the concept of social redundancy in their helicopters when conducting operations. Research results suggest that social redundancy is a far more nuanced phenomenon than its technological counterpart. Technological innovations and enhanced system integration of machine and operators have tightly coupled human tasks, system and environment over time. The impact of this on inter- and intra-crew behaviour has been neglected so far in traditional approaches to social redundancy. At a micro-level, above all, social redundancy appears to be affected by a broad range of contextual factors at a macro-level that have to be balanced and rebalanced again and again.

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8 This paper originally appeared as an article published by Taylor and Francis in *Theoretical Issues of Ergonomics Science* 14 (6) 2013, available online: http://www.tandfonline.com/DOI/full/10.1080/13669877.2015.1071867.

3.1. Introduction

Ground troops often call in for so-called 'air power' to help them out on the battlefield. Apache helicopter units often respond to these calls, or are specifically requested, to bring 'eyes' on target – or to get 'steel' delivered. In the first case helicopter crews provide an additional set of eyes on the battle theatre from above, where in the second case they deliver fire-support ('steel') as well. Today's battle fields can be ambiguous and enemy troops such as Afghan Taliban fighters may not be recognisable as such. In some cases this leads to the locking into a course of action, which sometimes only hindsight can determine was appropriate or not.

> Wikileaks today released a video depicting the slaying of more than 12 people – including two Reuters news staff – by two Apache helicopters using 30mm cannon fire. The attack took place on the morning of 12 July 2007 in the Iraqi suburb of New Baghdad. Two children were also wounded. Among the dead were two Reuters news employees, Saeed Chmagh and Namir Noor-Eldeen. Chmagh was a 40-year-old Reuters driver and assistant; Noor-Eldeen was a 22-year-old war photographer. An investigation by the US military concluded that the soldiers acted in accordance with the law of armed conflict and its own rules of engagement. (Thompson: 2010)

In this article, we report on an analysis of social performance that has been conducted with a group of Apache crews. More specifically, the analysis has focused on a particular aspect of social performance, the concept of 'social redundancy'; the availability of other people to take over task performance, either partly or fully. The concept of social redundancy has not (yet) received the attention it deserves, we believe.

3.1.1. Research on social performance

Research on social performance, especially in the field of aviation, has a long history. Well-known in this field, and rapidly expanding at this time to other industries, is the applied research domain of crew resource management (CRM). A related, however somewhat broader defined field of research is the domain of non-technical skills (NTS). Both domains focus on so-called NTS, i.e. those 'cognitive, social, and personal resource skills', accordingly these domains, 'that complement workers' technical skills' (Flin, Martin, Goeters, Hörmann, Amalberti, Valot, Nijhuis: 2003, 96). In short, NTS are regarded those skills berti, Valot, Nijhuis: 2003, 96). In short, NTS are regarded those skills held necessary for effective teamwork.

Social redundancy normally is not mentioned in the CRM or NTS literature. Crew backup behaviour and macro-cognitive processes, such as communication and coordinating activities, however are mentioned. Therefore, overlap with these concepts can be expected. However, whereas CRM and NTS scholars often address competences in a more or less prescriptive sense ('what is it that one should do'), this research aims to specifically address the many challenges and difficulties of situated performance, i.e. performance that 'grows directly out of the particularities of a given situation' (Nardi: 1996). As a result of this, analysis of social redundancy has been conducted in this study both at a micro-level and a macro-level. After all, these two levels inevitably are connected and thus influence each other.

3.1.2. Teamwork in Apache helicopters

Apache attack helicopters are operated by a crew of two pilots (a dual-crew concept) in a tandem configuration, a backseater (BS) and a frontseater (FS).[9] A tandem configuration means that one pilot sits behind the other, as opposed to next to each other, such as in airliners. Operating in a dual-crew concept creates the opportunity for providing each other with a fresh perspective on the situation at hand when things tend to turn for the worse. Apache crews therefore are exemplary candidates for the study of issues on social performance.

Apache crews are socially entangled with each other – both inside and outside the helicopter. Typically, Apache crew-pairings consist of members from the same military aviation unit. They might even be members of the same flight group within that unit. Also, chances are high that Apache pilots within an aviation unit have been through similar initial training. In the helicopter, obviously, they are held physically tightly together by the shape and size of the helicopter fuselage. All this enables them to establish a substantial amount of overlap in cognitive functioning – and thus to function as a team. After all, as Jenkins, Stanton, Salmon, Walker and Young (2008) summarise a 2006 study of Stanton et al. on distributed situation awareness: 'to fully exploit the benefits

9 For the remainder of this article the acronyms FS and BS are used. Dependent on the context, FS for instance can refer to the actual front seat, but could also refer to the front seat operator, the so-called FS.

of distributed [cognitive] activities within complex systems, there is a need for compatibility in situation awareness'.

Such similarities in backgrounds and working conditions could however make it difficult to actually provide a fresh perspective on things. From a systems point of view therefore – that takes the position that more of an operator's performance is shaped by its contextual surroundings (Dekker: 2006, 91) – one could ask how these pilots could be able to create something analogous to a 'stereo binocular vision' on things? (which is the kind of cognitive benefit that – many believe – results from social redundancy). It is concerns like these that led to the study described in this article.

3.2. Theoretical framework

In the past decennia, high reliability theorists (HRTs) 'have studied a variety of high risk organisations and have reached quite optimistic conclusions about the prospects for safely managing hazardous technologies in modern society' (Sagan 1993, 14). They believe that functional duplication or overlap – 'redundancy' – can contribute greatly to a larger system's reliability (e.g. Rochlin, La Porte and Roberts: 1987; La Porte and Consolini: 1991, 23). In the case of functional duplication, this means that 'two different units perform the same function', whereas in the case of functional overlap it is understood as 'two units have some functional areas in common' (Rochlin et al.: 1987, 84). If one system fails, the other – redundant – system takes over, partly or fully, and – theoretically – the more automatically the better.

The concept of redundancy originates in the technical realm, as a design feature to be embedded in mechanical systems. Over time, however, redundancy has been introduced in the social realm as well. Based on the definition for 'operational redundancy' proposed by Rochlin et al. (1987, 84)[10] a definition for social redundancy could be 'the presence of people with the ability to take over (cognitive) task execution from others when deemed necessary, either partly or fully.' Substituting one actor for another may however not help much for safety when the one who is stepping in operates under similar presumptions and beliefs about the situation at hand as the one who is replaced. Also, contrary to

10 'Operational redundancy', according to Rochlin et al. (1987, 84), is 'the ability to provide for the execution of a task if the primary unit fails or falters.'

mechanical performance, 'correct' human functioning cannot be captured in algorithms. Only hindsight can tell (sometimes) whether an intervention on human performance by another human was for the best. A distinction thus has to be made between the 'dry' concept of social redundancy and *effective* social redundancy, where effective social redundancy can be defined as 'to utilise the area of (cognitive) duplication or overlap amongst social actors in such a manner that social accomplishment is established in a safe and effective manner.' HRT scholars, unfortunately, do not provide much guidance on how to establish this. Proponents of resilience engineering, on the other hand, have begun to address this issue. They suggest that 'bringing in a fresh perspective' might be an effective – although not ultimate – strategy to achieve social accomplishment (e.g. De Keyser and Woods: 1990; Patterson, Cook, Woods and Render: 2004; Patterson, Roth, Woods, Chow and Gomes: 2004). Fresh perspectives after all, so they argue, can 'generate more hypotheses, cover more contingencies, openly debate rationales for decision making, and reveal hidden assumptions' in collaborative systems (Dekker and Lundström: 2007, 8).

One issue is that bringing in a fresh perspective specifically, and social redundancy in general, may not have the kind of impact resilience engineering theorists believe it should have. Social systems, after all, are complex systems since they contain 'unfamiliar or unintended feedback loops' (Perrow: 1984/1999, 82). It is this complexity that sheds another light on the issue at hand here. Sagan (1993) elaborated on this in *The limits of safety*. He argued that the application of redundancy in complex worlds has downsides. Redundancy in complex systems, according to Sagan (1993, 39), can 'lead to unanticipated common-mode failures',[11] because 'redundant systems [in complex systems] often [are] less independent [from one another or from other system components] than their designers believe [they are]'. In the case of social systems for instance, individuals 'must be able to predict the responses of others to some extent for coordinated action to be possible' (Gersick and Hackman: 1990, 68). Since redundancy can build in more capacity, a second downside of redundancy in complex systems that Sagan mentions is that this capacity is intended to benefit production goals, rather than be a resource for emergency situations (Sagan: 1993, 40). In social contexts this may especially be the case. After all,

11 'Common-mode failures' refer to a simultaneous, concurrent or related failure of several critical components due to the 'sometimes deliberate, but usually inadvertent condition where critical components share a common feature' (Sagan: 1993, 33).

maintaining fully redundant personnel with no other tasks can be costly. A third consequence of building in redundancy in complex systems, according to Sagan (1993, 39), is that redundancy can increase the opaqueness of already complex systems: 'individual component [...] failures will often be less visible, since they have been compensated for [– or hidden –] by overlap or backup devices'.

Taking all this into account, insights in complex social systems may not emerge due to subsystem dependency. Even if they do emerge, they may not be utilised, because within opaque systems it can be difficult to communicate these insights to other members of the community in an effective manner. In complex systems therefore, the impact of the application of social redundancy can be suboptimal – an issue that scholars of both HRT and resilience engineering have for the most part ignored.

3.3. Research setup

Ethnographically inspired qualitative research was used to collect multiple sources of information in order to triangulate data. For two months research was conducted as a participant observer within the unit studied for 1 day per week. Research was conducted thereby from the inside outwards so that tasks that seem to be straightforward could be 'taken apart' analytically but with their contextual richness taken into account as much as possible. The study was divided into six phases; a preliminary research phase, two field data gathering phases (separated from each other by an intermediate analysis phase), a final analysis, and the writing of the report. Field data were gathered through interviews as well as through observation.

Object of study

Research for the purpose of this study has been conducted with a European Air Force Apache unit. By selection, candidate Apache pilots with this specific Air Force go through similar levels of education before joining. Once in the Air Force, they all receive the same training program, although staggered over time. The unit studied here normally operates with their FSs acting as the aircraft commanders, i.e., they are responsible for flight and mission accomplishment. FSs further manage the aircraft's sensor and weapon systems installed in the front cockpit. Co-pilot BSs fly the aircraft from the rear seat.

In the Air Force studied here, Apache units normally are organised in subunits called flight groups. A flight group of nine pilots participated in the program. Participants included one BS, as well as a BS who became FS during the research. Participants also included four FSs, of which one was qualified as a maintenance test pilot, one as a section leader (SL) and flight instructor, and one as a flight leader and weapon instructor. This study presented here is a preliminary case study – in this case of one flight group within an Apache aviation unit. Members of the unit who participated in the research were mainly males, and aged generally between 21 and 40.[12]

Much of the research was conducted as a guest of the flight group studied. Teaming up with this specific flight group potentially narrowed the possibility of generalising results. On the other hand, it maximised access to data since it enabled the use of their facilities, the ability to witness their daily activities on a regular basis and to conduct the research 'from the inside'. The generalisability issue was also compensated for by the participation of key staff members in the second data collection phase as described below in the interview section. Also, a former Apache flight commander (still currently flying the Apache helicopter), and a current simulator instructor, served as expert informants. These expert informants have been utilised throughout the research cycle to obtain more detailed information about the roles of the respective Apache pilots (the FS and the BS), to refine the semi-structured interview instrument, to cross-check interview contents and to help validate results and interpretations.

Preliminary research phase

Preliminary research included data gathering about unit organisation, mission types and mission execution. Technological aspects were reviewed as well, such as helicopter layout and in-flight data representation in the cockpit. Also, individual and crew tasking were studied; general and navigation procedures, and aspects of crew coordination. Organisational, technical, tactical and other relevant documents were looked at and simulator instruction participated in, including a simulator flight in the Longbow Crew Trainer (LCT). Also, start up and shutdown procedures were witnessed from within the helicopter.

To keep the research tasks manageable, micro-level task analysis was confined to the navigation task of Apache crews; to how it is that Apache crews bring their helicopters from point A to point B. Since the unit of study is

12 In this article, the term respondent refers to the interviewees. The term informant has been reserved in this article for those who have acted as expert witnesses to help validate research results.

equipped with very sophisticated navigating systems on board, the term navigation refers here not so much to classic air navigation principles, but to a more general awareness of the helicopter's current position and of how to proceed from here to there, using all or any possible means. With regard to position awareness, no distinction has been made during the study between the awareness of the geographical position, and the awareness of the position in relation to other elements, such as terrain features or enemy or friendly forces. Also, travel over longer distances was looked at, as well as repositioning the aircraft within the tactical areas of interest.

To focus on navigation was a strategic choice since from this task others could be reflected upon as well. Weapons for instance cannot be delivered on time or on target without navigating the helicopter to the area of interest in a timely and accurate manner. Also, an effective use of sighting equipment for observation or surveillance purposes cannot be performed effectively without knowledge of both the geographical and the relative position of the helicopter. As a result, the data collected covered many – if not all – aspects of Apache operations. Therefore, research results – although limited by sample size and task – does have something to say about cross-collaboration of Apache crews in general.

Interviews

Two sets of interviews were conducted. The first set of interviews covered six out of nine members of the flight group that participated in the research. These interviews mainly were used to gain understanding about how members of Apache crews normally conduct their navigation tasks in collaboration with each other during mission execution. The focus here was on where and how cognitive overlap – necessary markers of social redundancy – is established during micro-level inter-crew collaborative task accomplishment. Also, the ability to bring fresh perspectives to each other during this process was reflected upon.

In the first set of interviews, participants were asked to recall situations in which task intervention or verbal corrections on task accomplishment occurred, as well as situations in which proactive cross-collaborative handling was successfully performed. Cross-collaborative proactive handling refers to those actions – as performed by the other crewmember – that are desirable but not explicitly asked for (yet). The specific situations as mentioned here were chosen because these represent situations where cognitive overlap does occur. After all, neither intervention, nor corrections nor any kind of proactive cross-collaborative handling can occur without (cognitive) task overlap (Gersick and Hackman: 1990). A preliminary search for contextual factors that affect the cross-collaboration of crewmembers was conducted during the first interviews as well.

A second set of in-depth interviews was conducted with five key staff members regarding these contextual factors. Participants here included 2 flight commanders of other flight groups than the one that participated in the first interviews, the unit's Chief of Operations, the unit's Current Operations Officer and the Airbase Chief of Operations. The focus during these interviews was on how context can affect social redundancy among crewmembers. Participants were asked to elaborate upon how they considered contextual factors to promote unity of acting and thinking within their unit (in order to establish necessary task duplicity and overlap among Apache crewmembers). On the other hand, participants were also asked about how contextual factors could induce diversity in acting and thinking, e.g., to enable the emergence of fresh perspectives. Participants were encouraged first to bring up relevant factors themselves to reflect upon. Only after this a list was given to them to comment that contained contextual factors derived from the first data set. In this manner, analysis of the first data set could be validated.

All the interviews took about 1 hour each, were semi-structured and were conducted and transcribed in the native language of the Air Force members of study. Relevant passages were translated into English. During both sets of interviews data saturation was regarded to occur after four to five interview sessions.

Observation

Observed task accomplishment helped triangulate the data obtained from participants during interviews. For 2 months, 1 day a week, research has been conducted at the (squadron) unit. This included participant observation of daily squadron life. During this period, an order assignment was observed, during which mission objectives and constraints are communicated between commanders and operators. The respective training mission concerned a two-ship low-level reconnaissance mission. Following the order assignment, mission preparation, pre-mission briefings and post-mission debriefing were observed. Also, the on-board videotapes of actual mission execution were reviewed. These training missions, participants said, gave a reasonable picture of real-time mission execution. The process from order assignment to debriefing took about 9 hours, of which 2 hours were actual flight time. Further observations included videotapes of three regular training sorties, as well as some 25 videotapes of live weapon deliveries. Also, videotapes of a complete in-theatre combat mission were reviewed. In the simulator, an LCT in this case, a gunnery session was witnessed, including the pre-mission briefing and post-mission debriefing. Total observation hours of videotapes, simulated missions and mission preparations, was some 20 hours.

Data analysis

Data analysis was accomplished in several stages. First, at the end of the initial data collection phase, data was edited using 'global analysis techniques', providing a rough editing of texts before their actual interpretation (Flick: 2009). After this, the data was reviewed to gain knowledge about if and how social redundancy was exercised among Apache pilots on a daily basis. The same set of data was then coded and recoded using 'open coding' (Flick: 2009). The purpose of this was to identify common themes – contextual factors – that could affect the occurrence and the character of social redundancy during mission accomplishment.

After the second data collection phase, a final – interpretative – analysis was performed on the entire data set. The aim here was to gain knowledge of how contextual factors balance unity and diversity in acting and thinking of Apache pilots – and thereby how these factors might affect the pilots' understanding and use of social redundancy. Results included here appeared at least twice in the data set in different data sources (e.g. were brought up and confirmed by different participants). Exceptions to this have been made only when single events were thought to be illustrative of certain important points. In these cases, this has been noted clearly in the text.

Some of the data sources reviewed – such as the Tactical Standard Operating Procedures document and some of the mission videotapes – were classified. Data from these sources served as background information, but have also been used to assess if findings from non-classified data should be adjusted in the light of the information contained in this material. Intermediate drafts and the final report have been sent to the armed forces J2 intelligence section for security reviews with regular intervals. This has not led to any alterations.

3.4. Research results – social redundancy in Apache operations

'It is very difficult to recognize making a mistake when you think you are doing things correct. [...] One certainly needs help from others to recognize this.' This remark was repeated in a number of different ways during the interviews. It indicates that participants thought social redundancy was beneficial. While crewmembers of Apache helicopters said to experience relatively high degrees of task separation, they also seem to exercise and rely on social redundancy extensively. Social redundancy however was not regarded omni- and ever-present within the unit studied here. One of the participants for instance recalled an exercise in which a formation of multiple helicopters inadvertently entered a no-fly zone. This is what he had to say about this incident: *'[Rationally,] everybody in the planning process could have intervened. Somebody had drawn a line on the map for rough time calculations. However, this line was never intended to be the actual route to be flown.'*

Apparently, although participants agree in the abstract that social redundancy is a good thing, social redundancy does not seem to be able to achieve the desired results in all cases. Contextual features may be a factor here. However, before going into these, results on where and how cognitive overlap gets established among Apache crewmembers will be presented. Earlier in this article, cognitive overlap has been mentioned as a necessary ingredient for successful application of social redundancy to occur. Also, two sets of situations were described by participants as indicative for the establishment of cognitive overlap among Apache crewmembers. The first set concerned situations in which task interventions or verbal corrections occurred. The second set of situations concerned those situations in which cross-collaborative handling takes place. Results are presented on both these indicators. After this, some general research results on coordination are presented to provide some understanding of how it is that high-tech socio-technological collaborative systems such as Apache helicopters are operated by its crewmembers.

Task interventions and verbal corrections

Interventions in and corrections of one another's tasks frequently resulted from monitoring the other crewmember's actions via the aircraft's systems, indicating thereby cognitive overlap among crewmembers. FSs for instance cross-checked their Tactical Situation Display (TSD)[13] regularly in order to see if the helicopter was still heading where it should be and even used the aircraft's displays to pass on corrections to their BSs. Also, BSs sometimes glanced at what the FS's sensor was looking at, although this seemed not to be done primarily for monitoring purposes. Other sources for intervention resulted from task separation. For example, FSs directed their BSs to bring the helicopter towards a certain position, only to be told shortly thereafter that he or she could not comply with the request. The reason for this was that FSs often base their directions on what they are looking at with their sensors at a distance, while BSs tend to focus more on visual cues outside in the immediate environment.

Interventions and corrections seemed to be communicated 'through the aircraft' quite often. What this means is that inter-crewmember communication was conducted by means of the display of graphical symbols on the aircraft's systems, such as cockpit screens or the helmet display unit (HDU), rather than through verbal transactions. *'The use of symbols on our TSDs makes it very easy for us to communicate corrections'*, one participant said. For example, one crew was seen to reposition their aircraft successfully after receiving a re-task over the radio, without the exchange of any verbal information between each other in the aircraft. The FS – responsible for taking the re-task – processed the information silently into the aircraft navigation equipment, visible to the BS on his TSD, which the BS then acted upon. Apparently, the BS had listened in on the FS's tactical radio communication since he never asked the FS for additional guidance. He just waited instead for the necessary guidance information to appear on his cockpit displays.

Field observations further illustrated that cognitive overlap – necessary for social redundancy to be effective – seems to be established among Apache crewmembers on a more or less continuous basis, but generally in a kind of background (reserve) mode. At the very least, crewmembers seemed to be sensitive to signals that could indicate a decline in cognitive or physical functioning of the other crewmember. For example, a BS once challenged his FS about his orientation in a hostile area during an actual mission abroad. Just a few minutes before that they had had a short conversation about cumulative fatigue due to the tempo of operations in the days before:

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13 A Tactical Situation Display (TSD) is available in both cockpits. This TSD presents a bird's eye view of the current geographical location of the helicopter relative to relevant mission essential features, along with information put into the aircraft's navigation equipment.

> *FS: "Huh" [combined with some vague sensor movements]*
> *BS [instantly]: "You are looking at the south side?" [indicating that he is looking at some information source that tells him exactly that]*[14]
> *FS: "Yeah, I just dropped out for a moment. Uhh, yeah, south indeed." BS [after a few seconds]: "What's up?"*
> *FS: "Oh, I just had to re-orientate myself"*
> *BS: "Ah, ok, roger."*
> *FS [ironic]: "Djee, I start orientating myself pretty well at night now".*

Proactive cross-collaborative handling

Examples of proactive cross-collaborative handling were derived, among others, from cases in which BSs set up tactical flight profiles in accordance with the tactical information available to them. By listening in on the tactical radios, BSs sometimes acted on the basis of the information contained in these messages, so that FSs did not have to spend time and attention on guiding their BSs. In other cases, BSs helped out their FSs in scanning for targets outside without being asking to do so. More experienced BSs sometimes even answered radio calls that were directed to their FSs when FSs temporarily were not able to do so. Afterwards, they relayed relevant information to the FS.

From the observations of mission (video) tapes and LCT activities it became clear that – especially when communication and coordination demands raised – inter-crew communication shifted often towards a telegram staccato style of communication. When task load increases, it appears, social redundancy gets challenged. This was not only observed on mission tapes, but was also mentioned by the majority of the participants. As one participant explained: *'Inexperienced [BSs] will not notice [a FS's mistake] since they are so busy doing their things that no [cognitive] bites are remaining to bring to the FS.'* Also, demands for coordination increase substantially when there is a need to coordinate with multiple people such as forward air controllers on the ground. Observations showed that crewmembers remained silent when the other crewmember clearly was occupied, waiting for windows of opportunity to exchange information. In

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14 A BS has several ways to determine position and direction which the FS is looking at. During daylight he might see the helmet of the FS move. More likely however, aircraft systems will be used such as selecting sensor video underlay on one of his cockpit screens in the backseat or by looking at the symbology presented on his HDU indicating direction and azimuth of where and what the other crewmember and/or the sensor are looking at.

these cases however, tasks often seemed to be executed in ways that more or less matched the expectations of the other crewmember, indicating an overlap in cognitive functioning. BSs for example brought the Apache helicopter into a position and at altitudes the FSs wished for in order to spot the enemy. Instead of waiting for directions, BSs acted autonomously. In these cases, BSs told their FSs what they did afterwards when time and situation permitted, enabling their FSs to intervene if necessary. An example of this kind of communication between BS and FS is the following: *'BS: 200 feet [altitude], FS: Yep, maintain.'*

Proactive cross-collaborative handling, it seems, often serves to reduce an FS's workload, increasing thereby the total crew's operational output. The literature, as has been pointed out before, argues that such application of redundant or backup resources in favour of production can make some assets unavailable when they are needed in emergency situations (Sagan: 1993, 40). This research however did not bring evidence to support this argument. On the other hand, it also did not provide any evidence to the contrary.

Coordination in a collaborative system

The area of cognitive overlap is not only downsized or expanded as necessary. In fact, *a social redundancy vector* – an abstract representation of the current amount and direction of social redundancy – could be diagrammed. This social redundancy vector alternates between FS and BS as circumstances change. The vector may even point in both directions simultaneously, and can vary in degree and extent as well. New BSs for instance, argued study participants, need close monitoring of their activities, resulting in social redundancy to occur from FSs to BSs especially. With more experienced BSs however, or when conducting mission types that require intensive coordination and in-flight planning on the part of the FS, social redundancy – as in checking the workflow of the other crewmember or just helping him/her out – will probably occur less from FS to BS than the other way around. Monitoring the BS's end state performance will probably suffice for the FS in these cases. As soon as obstacles to a BS's task accomplishment are perceived; however, the social redundancy vector can instantly reverse again. The dynamics of in-flight Apache operations, in other words, seem to reflect how social redundancy gets exercised.

3.5. Research results – contextual factors affecting social redundancy

Many contextual factors can affect how social redundancy is exercised in Apache helicopter operations. Indeed, a long list of contextual factors were identified by the participants and observed during this research. At the micro-level contextual factors that had been derived from the research concerned aircraft system and layout, task separation, experience and proficiency, tactical mindset, personal aspects, task load, and mission type. At the macro-level, the relative independency of the sub-units was regarded a contextual factor that affected social redundancy. Other factors included the planning structure, the unit's choice on what to standardise on and what not, the unit's training structure, and the social climate as reflected in frequency and quality of briefings, debriefings and other moments of 'reflection space'. By this we mean moments and opportunities to reconsider one's own and others' performance that can lead to collective learning. Interestingly, while some features, like focus and attention differences among crewmembers (e.g. because of aspects of task separation or experience levels), were regarded important because they could lead to a fresh perspective on things, other features like task dependency, mission type and the structure of the planning process, seemed to determine how such alternative perspectives could be utilised in the interaction with others. Mission type for instance – or certain related aspects of it such as the operating height and time of day – dictate much of how task load is distributed among crewmembers over time during a mission.

One of the participants said, when he was given this list at the end of an interview: *'All these items affect one another.'* This statement, simple as it may be, reflects the sheer complexity of the socio-technological system which Apache crewmembers are part of. Task load for instance is derived largely from other factors such as mission type, environmental conditions, and skills. Skills 'themselves' are affected by – among other factors – the unit's training structure, one's personal and others' abilities, as well as recent task history and task experience. A BS's performance for instance, appeared not only to reflect natural ability and experience. It also depends on the FS's prior and current performance, and even on how this particular FS had been socialised within the unit. Contextual changes can be so small that collective blindness can occur and thereby their cumulative impact – or 'drift' (Dekker: 2005, 2006, 194) – can be missed. One of the participants gave an example when the unit had failed to recognise an important shift in the abilities of its pilots: *'We now have come to the point where we frequently alter between [high and low] profiles, which brought some new aspects [a* *new concept of operations] that we were not explicitly aware of.... [Seven years ago] the low flying era ended, which means that the majority of the [current] community comes from the [high flying era instead]'*, and thus was not explicitly trained in changing from high to low flying profiles.[15]

Interestingly, some of the contextual elements, this research identified, could not be related to social redundancy in any straightforward, predictable fashion. For example, the exchange of experience in debriefings seemed to enhance a unity of behaviour and thinking among Apache crewmembers. On the other hand however, it also could equally encourage a diversity of behaviour and thinking that could broaden one's toolbox, enabling one thereby to generate more – and more creative – hypotheses. Another example of this is that both task separation and task dependency seemed to attribute to social redundancy, making it difficult thereby to arrive at an optimal value to balance these two. While this has been noted in the literature before, its implications have not been systematically explored. 'Redundant safety systems, if truly independent, can enhance system reliability in theory' Sagan argues (1993, 39). Task separation can help crewmembers to act relatively independent from each other, and thus to develop their own vision on things. In order to utilise these alternative perspectives in an effective manner however, as Katzenbach and Smith (2006, 60) have pointed out, social actors need to be 'interdependent' and to 'trust' each other up to a certain point in order to get work accomplished as a team. Task dependency, as opposed to task separation, establishes just that. Task dependency however, can also increase the area of cognitive overlap. This may raise any number of questions about how independent (separate) actors and actions really are.

3.6. Discussion

Research results suggest that, while Apache crewmembers experience relatively high degrees of task separation, they often exercise social redundancy. Social redundancy is defined in this article as 'the presence of people with the ability to take over (cognitive) task execution from others when deemed necessary, either partly or fully.' Like features mentioned in the CRM-literature, such as crew

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[15] With current labour contracts the unit's pilot community gets more or less refreshed in less than every 10 years.

backup behaviour, communication and coordinating skills, applying social redundancy effectively could be considered as one of the operators' non-technical teamwork skills. The feature of redundancy originates in the technological realm; a design feature with the purpose of enlarging mechanical system reliability. Social redundancy, however, is not necessarily the same thing, and can even be distinct from its technological counterpart. Often however, system designers, operators and also scientists do not sufficiently distinguish technical redundancy from social redundancy. Redundancy in the social realm, as results here indicate is a far more nuanced phenomenon. If this is the case, redundancy could not unproblematically be treated as a (partial) duplication of means and asset that can be prescribed for crew management tasks.

At a micro-level

Apache helicopters and their crews have evolved into high fidelity socio-technological weapon systems over the years. Crew and machine have become integrated more and more. Examples of this have been described here, especially in the discussion of communication and coordination. Crew communication and coordination nowadays seem to be conducted 'through the aircraft' in many instances, using graphical symbols, various displays and sensor information. Human tasks, system and environment can get tightly coupled this way. Interestingly, this is not something that traditional approaches to social redundancy have much reflected upon.

Inter-crew interaction today – as well as intra-crew interaction – apparently is quite different than in the past. When discussing navigation issues some operators even said: *'We do not navigate at all anymore with this aircraft.'* This seems contra-factual – a helicopter by itself is not going anywhere unless an operator somewhere in the process has given it a certain input. What this does suggest, however, is that operators may not see or feel themselves as doing certain tasks anymore (or at least not in the same way as they used to do), although in fact they are still the ones that operate the system. They seem in interviews and discussions even to rule themselves out of tasks once seen as defining or pivotal to human flight. If that is correct, this says much about how technological innovation has redefined aviation work, tasks and job. Traditional approaches to social redundancy however, have made little effort so far to trace how redundancy is achieved and works out in concrete examples. The result is that this has led to a rather distorted and naïve acceptance of what redundancy means in high-tech socio-technological systems in which humans and machines have to collaborate. In reality, what may be needed is more theory building on social redundancy and other non-technical teamwork skills in these collaborative systems. Theorising on situation awareness for instance has led to some appreciation of the value that analysing collaborative socio-technological systems in actual settings can have (Salmon et al.: 2010). This could in time lead to more and different kinds of benefits for operators than we can imagine. In the case of social redundancy, one can ask for instance whether, if technological redundancy first is 'built in' the system, if this will necessarily support (or lead to) social redundancy?

The tendency is, also with scientists in NTS, to assume that the 'better' the system design is, the more it supports redundancy of both kinds (technological and social). Social redundancy, according to such worldviews, will necessarily emerge and be effective due to innovations in technological design. However, as has been described here as an example, with technological innovations in aircraft system and layout, verbal communication among Apache crewmembers has decreased substantially over time. Participants reported this during the interviews. Examples of this have been given in the first results section. A decrease in verbal communication could lead to FSs erroneously to assume that their BSs have noticed certain system inputs on their cockpit displays, simply because it is right there 'in front of them' in the BS. FSs may even be strengthened in this belief since they will probably regard the information highly visible on their own (redundant) cockpit screens in the FS, disregarding the fact that they were the ones who initiated the system input in the first place. What this illustrates is that assuming that 'improvements' in design and technology will necessarily deliver increased social redundancy, may well be a case of analytically putting the cart before the horse.

At a macro-level

The main question in this research was whether Apache pilots, who often share substantial similarities in background, are able to arrive at different perspectives in 'hands on' situations. An Apache crew can be regarded as a social system (forming a socio-technological system together with their machine). Social systems, according to Perrow (1984/1999, 83), are complex systems since its components 'interact in more than linear, sequential ways, and therefore may interact in unexpected ways'. This research confirms this and also suggests that social redundancy itself is a complex phenomenon. The application of social redundancy in Apache operations can be influenced by a broad range of contextual factors. On the one hand, this is good news. It can mean that contextual similarities can work out in a slightly different manner for each individual. This could provide opportunities for a stereo binocular vision to emerge, or for fresh perspectives to emerge between crewmembers. Indeed, research results suggest this can be the case. Many instances were observed during this research in which one pilot intervened the other because of a difference in perspective on the situation at hand.

With this number of contextual factors at work, however, it can on the other hand be difficult to trace how all these factors link together in any fixed – or predictable – manner. In complex systems, patterns may be discerned, but these will be probability patterns at best (Laszlo: 1996, 84). Indeed, many of the contextual factors identified in this research – if not all – appeared to be interdependent and can interact with each other in unexpected and unforeseeable ways. Examples have been given here which demonstrate how a multitude of contextual factors directly and indirectly affect task load and a BS's performance. Social redundancy, so it seems, is not a fixed attribute that can be switched on and off according to any kind of predefined logic. This raises the question of whether technological redundancy can ever be isomorphic with social redundancy.

3.7. Conclusion

Social redundancy apparently – and this is not often acknowledged – is bounded by the limitations of complexity in and of social systems. This means that social redundancy can appear in negative or positive ways, often in ways that we least expect or are prepared for. An example of this was the flying into a no-fly zone because none of the many members in the planning process discovered that a rough drawing line had come to represent the official route to fly during this mission. Another example here was the unobserved shift in performance of a unit's piloting abilities that occurred when a group of pilots no longer knew what to do when changing from high flying profiles to low ones. What these examples illustrate is that large parts of learning in these operational (socio-technological) contexts are what Lützhöft and Nyce (2006, 14) have called 'situated activit[ies]' or 'learning in context'. This is generally seen as a good thing. However, these learning contexts can have important and rich, but sometimes unpredictable and unfortunate outcomes.

A *social redundancy vector* has been proposed in this article as an abstract representation that could graph the current amount and direction of social redundancy. The characteristics of this vector seem to depend heavily on context. Further, this vector can shift direction frequently between Apache FSs and BSs; it may even point in both directions simultaneously, and can vary in degree as well. Apparently – and in contrast with its technical counterpart – *social* redundancy and the features that support it can be difficult to identify or predict. Nor is it, like most social phenomena, universal or constant, except at some very high level of generalisability.

For social redundancy to be effective once in the air, one obviously has to start working on it well before taking off. Manoeuvring, especially at the higher order systems levels, seems to require across time a continuous balancing and rebalancing of contextual factors – and thus a balancing of multiple (and sometimes conflicting) goals and benefits. Perhaps, acknowledging this would lead to more realistic representations of how to manoeuvre best in high-risk environments.

4 Social construction of safety in UAS technology in concrete settings: some military cases studied

This chapter contains the first of two papers on military Unmanned Aerial Systems (UASs). This first UAS paper introduces in this dissertation the science, technology and society (STS) literature and presents, from this perspective, a desk study on the social dynamics related to the construction of safety in military UASs, i.e., how issues of safety in military UASs can emerge from their socio-technological contexts. It is concluded here that the STS perspective, in particular the constructivist studies of technology, can be very helpful in making analytical sense of the assumptions and tacit understandings regarding safety in platforms like UASs that often remain unnoticed, until it is too late.[16]

ABSTRACT – Unmanned aerial systems (UASs) in general and UAS safety in particular have so far received little attention in the science, technology and society (STS) literature. This paper therefore reports on several (military) cases of this relatively new technology, focusing specifically on issues of safety. Quite often, safety of technology is considered the result of a rational process – one of a series of rational, often calculative, linear steps. The paper's results suggest that establishing safety in military UASs is very much a social process. Approaching (military) UAS safety from this perspective could perhaps be complementary to more analytical and rational perspectives on safety of this type of technology. Further research is therefore suggested on the implications that social processes can have for safety in UASs. So far, it seems, such a position on safety in technology has been little explored in both the STS and safety literature explicitly.

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[16] This paper, used here with courtesy of WIT Press, originally appeared as an article in the *International Journal of Safety and Security Engineering* 2 (3) 2012, available online: http://www.witpress.com/elibrary/sse-volumes/2/3/640.

4.1. Introduction

April 6 2011 two US servicemen were killed in the first (at least publicly acknowledged) drone friendly fire incident. An account of this tragic accident appeared in the Houston Chronicle October 15 2011:

> Marine Staff Sergeant Jeremy Smith, 26, of Arlington, and Navy corpsman Benjamin Rast, 23, of Niles, Michigan, were killed by a Hellfire missile fired from a U.S. Predator drone in southern Afghanistan [Helmand Province] on April 6. Both men served in 1st Battalion, 23rd Marine Regiment, a Houston-based reserve unit, also known as The Lone Star Battalion. The Predator crew targeted Smith and Rast after mistaking their heat signatures on the drone's sensors for those of enemy forces, according to the 381-page redacted report obtained by the Houston Chronicle on Friday [but not officially released]. ... Smith's father, Jerry Smith, said the images he saw from the drone's sensors were not clear. "It was one-inch long blobs," he said. "That's all you can see on their scope." (Wise: 2011)

This tragedy raises questions about UAS (unmanned aerial systems) safety, and also about how this is negotiated in concrete settings from development to the battlefield. For instance, if it is indeed the case that target representations were nothing more than one-inch blobs on a screen, as Jeremy Smith's father apparently was shown, then how could the Predator have been regarded a safe system to work with? How could such a target representation have been regarded as 'workable' and reasonable by stakeholders throughout military UAS development, evaluation and system use? Questions such as these are important to ask. After all, current trends, at least in modern societies, have been to increase the development and fielding of unmanned combat systems. Given the Western military's increasing reliance on UAS, issues like these require further study. The purpose of this paper is therefore to raise some scientific questions regarding this topic.

So far, UASs in general and the safety of UASs in particular have received little attention in the science, technology and society (STS) literature. This may be because this particular technology is relatively new. Another reason for this – and regarding military UASs in particular – could be that they have only recently been repurposed from a sole reconnaissance and surveillance platform for intelligence purposes into a weapon system as well. This is not to say that STS has not reported on military technological innovations. For example, Rappert, Balmer and Stone (2008) provided an overview in 2008 on the development and dynamics of science, technology and the military within STS. STS research on military technology has also looked at the relationships between politics, society and cultural issues. Examples here are the use of science and technology for military purposes (McNeill: 1982; Van Creveld: 1991) and the impact that (American) military research has had on the organization and institutions of science (Forman: 1987). In STS, the development and use of military technology has generally been treated as the product of institutional and socio-political factors (Sapolsky: 1977). The emerging literature on the social construction of technology has brought in topics such as the 'social shaping' of military technology (MacKenzie and Wajcman: 1999) and the analysis of missile-guidance systems (MacKenzie: 1990). The topic of the social construction of safety in technology however, although touched on implicitly sometimes, does not really seem to be addressed in the STS literature. This paper will be, it is hoped, a contribution to the STS literature. Not just because it reports on a new technology, but because it demonstrates how useful an STS perspective can be when it comes to making analytical sense of what is built in platforms like UASs as assumptions and tacit understandings, especially regarding safety.

4.2. Methodology

What does safety mean when this is related to socio-technological concepts like UASs? With the help of the friendly fire incident described above and some other cases, the next section will consider this question. Socio-technological concepts will be understood in this paper as the whole of technology and its application, embedded in a structure of interdependent performing social actors and institutions, both operators and others. Throughout the paper therefore, any mention of military UAS, military UAS technology, or UAS and UAS technology in general, refers to (and implies) a particular socio-technological system taken as a whole, thus including both the technical and the sociological part unless when mentioned otherwise. After the first section, the second section will present a more in-depth analysis of military UASs as a social construction of relevant actors within boundaries of concrete settings. In this section, we will use terminology introduced by Wiebe Bijker (1997), a classic in the constructivist studies of technology.

Cases are of course context-dependent and are thus of limited use for generalizations. Case studies however can expand and generalize theory (Yin: 2012), in this case the theory of safety in military UASs. It is not possible to treat all safety aspects of military UASs, no matter what method of analysis is used. Even more, it is not clear whether an exhaustive elaboration of all aspects of safety of military UASs would be possible anyways. We believe though that working towards 'thick descriptions' of case material (Geertz: 1973) can help us outline some of the critical issues related to safety and military UASs. Our aim therefore, was to study case material. Since we lacked access to data from the inside' we mainly used open source material (mainly news sources), insights from the domain of safety, and insights from studies in naturalistic or concrete settings, to identify and define the UAS case material studied here. From there, we have used the STS-literature, with an emphasis on Bijker's theory on the social construction of technology, as a tool through which we have evaluated the selected cases. By applying this part of the STS-literature to specifically issues of safety of a particular technology (in this paper the socio-technological system of military UAS) we have tried to extrapolate this theory towards something that we would define as the social construction of safety.

4.3. Safety of military UAS: domains and aspects

Often safety is taken to be the same thing as numbers of injury, death or mechanical failures (e.g. Slovic: 1999). When approaching safety from this angle, safety – or the lack thereof – is in its most tangible form as the presence or absence of personal harm or technological breakdown. In socio-technological systems however, such as the UASs, it is the high-tech equipment and the social actors that, in conjunction with each other, yield these numerical features of safety. More to the point, these numbers are then seen as the inherent by-product of design and of establishing the system's final output. In short, from this point of view safety could be defined as those elements, or rather those interactions of elements, that amplify or dampen the mechanisms that ultimately lead to this personal harm or technological breakdown.

Military UAS safety domains

UAS engineers tend to focus on the possibility (and prevention) of technological breakdown. They focus on safety as the airworthiness of the aerial vehicle, i.e. the safety of the air vehicle itself and, indirectly, the safety of the people on the ground that could be hit if it crashes. Catalysed by the upcoming of non-military application of UASs, airworthiness efforts have been expanded recently to include the issue of how to integrate UASs into the (inter)national and commercial airspace system (Ramalingam, Kalawsky and Noonan: 2011). Safety from an engineering perspective thus broadened to include a concern for other aerial components. Currently, this results in a whole host of efforts directed on developing new technologies, enhanced reliability, procedures and standards in an attempt to handle this issue of military and civilian UAS safety.

Another safety domain of military UAS can be derived from the friendly fire case described above. In this case, safety – or again, the lack thereof – has expanded to include the well-being of friendly troopers. Obviously, some UASs have turned from 'simple' reconnaissance and surveillance platforms into stand-off precision weapon systems, with intelligence collection as an additional task. Intelligence services (especially from the US and Israel) have exploited this capability extensively for the purpose of targeted assassinations of alleged terrorists (Mayer: 2009). In the military, however, a similar shift has taken place. In theory, UASs can perform any military task traditionally conducted by fighter aircraft and attack helicopters, ranging from precision killings and bombings, to the delivery of close air support for own and coalition ground troops. This shift for military UASs from reconnaissance and surveillance platforms to weapon systems has emphasized a concept of safety that includes third and other parties more than before. As the technology and its use changed and evolved, issues such as collateral damage and civilian victims – especially women and children – as well as the risk of victims among members of friendly forces, have become realistic safety concerns.

One safety domain related to military UAS is not an obvious one. Although UASs normally are referred to as unmanned systems, some prefer to call these systems 'remotely operated' since, 'although [they] do not carry humans on board ... to control [them], skilled and coordinated work of [distant] operators ... is required' (Salas: 2006). The health of these operators, a recent study on US Air Force drone pilots suggests according to the New York Times (Bumiller: 2011), is an issue of safety that needs to be explored. Obviously, degraded functioning of UAS operators could have consequences that are undesirable. The primary stressor here, according to the report, seems to be working long-hours and shift changes, necessary in order to keep the platforms in the air 24 hours a day. The report also suggests that some of the drone operators, due to the nature of their work, are developing post-traumatic stress disorders (PTSD). Since the extended functionality of the UAS as a distant weapon delivery platform is a relatively new development, it can place its operators in positions that are out of the ordinary; into the unknown. Issues that these operators confront with can thus be unfamiliar to even experts. Longitudinal data has yet to be collected on these kinds of distant war operations, especially from a 'front row seat'. Experience has been gained with warriors returning to their families after a day at war. For example, bomber crews for instance have operated from outside the operations theatre, sometimes from overseas, since at least WW II. A difference however is that these bomber crews, contrary to some of the UAS operators, do not see the effects of their work through magnifying glasses. It would seem then that occupational safety, in this case the physical and mental health of UAS operators, is another domain of safety that should be looked at, besides the safety of aerial vehicles, that of third parties, and that of friendly forces.

Aspects of safety of military UAS: the friendly fire case

At the surface the friendly fire incident described above seems to be a simple case of target confusion. When we look a little deeper however, a whole range of elements associated with military UASs and their deployment comes into view that, possibly in conjunction with each other, could have led to the mechanisms that enabled this target confusion. As has been suggested by the Houston Chronicle (quoted at the beginning of this paper), one contributing factor may have been some of the technological features that the drone operators had to deal with such as the quality of target representation: fuzzy blobs on a screen. Another factor could have been the numbers of actors such as a drone operator, analysts and a mission coordinator that apparently had to work together over long distances to get their weapons delivered half a world away. In absence of the official US Air Force report this analysis is based on what was written in the Portland Press Herald on November 9 2011:

> The Air Force captain [at Creech Air Force Base in southern Nevada] angled his joystick and the drone veered toward the fighting taking place half a world away. ... At the Air National Guard base in Indiana, [an] Air Force analyst watched the battle unfold on the drone's video feed. He sent ... fragmentary reports to March Reserve Air Force Base in California, his communications link to the drone crew. ... The analyst had doubts. "Disregard," he wrote, followed by "Not friendlies," followed by "unable to discern who pers[ons] are." ... Receiving his message [at March Reserve Air Force Base], the mission intelligence coordinator and a trainee were dubious. ... The trainee ... didn't relay the information to the drone crew. ...

> The Predator pilot was unaware of the analyst's doubts. (Cloud and Zucchino: 2011)

What might have been another contributing factor is the chat-like communication apparently used during the incident. Again, according to the Portland Press Herald article:

> The analyst typed "3 friendlies in FOV," meaning three non-insurgents in the camera's field of view. A second later, he wrote "Pers[ons] are shooting W[est]," meaning they were firing west, away from the Marines on the road. … Almost immediately, the analyst had doubts. "Disregard," he wrote, followed by "Not friendlies," followed by "unable to discern who pers[ons] are." But he was certain of one thing: The shots were aimed away from the Marines. … [At March Reserve Air Force Base], the mission intelligence coordinator and a trainee were dubious. … As debate about the direction of the gunfire continued over the chat system, the analyst did not have access to radio traffic indicating a strike was imminent. (Cloud and Zucchino: 2011)

It would be unfair on the basis of this one case to attempt to draw any conclusions about the effectiveness (and role) that chat-like communication – with its short messages and weak contextuality – could have during high-consequence processes like this UAS weapon delivery. As far as we know the data is not simply there yet. In 2005 Nevile and Walker pointed out that not much systematic research had been conducted on patterns of speech between individuals in professional settings, and little seems to have been changed since. It would also be unfair to make statements now about the apparent inferior quality of UAS imaging, or on the seemingly weaknesses in UAS command, control and communication infrastructures. What can be said though, is that features like these apparently could pose safety issues for military UASs because under certain circumstances they could ultimately lead to technological failure(s) or personal injury.

Aspects of safety of future military UAS: breaches in cyber space

The development of future military UAS has already begun. One current challenge in UAS technology and deployment that needs, without a doubt, further attention in the future, is security. On December 18 2009, the LA Times published this:

> Iraqi insurgents intercept live video feeds from Predator drones. Using a $26 program available on the Internet, militants were able to view raw footage, a breach discovered last year. ... According to the Wall Street Journal, which first reported the intercepts Thursday, insurgents used a program called SkyGrabber, made by a Russian company for downloading music, photos and video from the Internet. (Zucchino and Barnes: 2009)

According to The Wall Street Journal, a person familiar with official reports on the incident said a day earlier that there was evidence that this was not a one-time event. Since the 1990s, when unarmed Predators were deployed in the Balkans, the Pentagon had known of this breach, one that opponents could exploit to intercept UAS video data streams. Also it is believed that certain states such as Iran train fighters how to do this. This interception flaw is however not the only cyber space breach in military UAS deployment. In 2011, the Predator and Reaper ground control stations have apparently been infected with a virus that, despite efforts to control it, affected ground control operations (Air Force Space Command Public Affairs: 2011). Also in 2011, another US drone, a RQ-170, was claimed to be hacked and landed in Iran (BBC News Middle East: 2011). These are cases that have appeared so far in the open literature. Whether there have been more such attacks against UASs is not really the issue here. What needs to be stressed instead is that cyber-events of this kind will increase in the future. What form or forms they will take is a difficult question to even predict. Singer, a Brookings Institution scholar and author of Wired for War, phrased the dilemma this way: 'Robotic warfare is open-source warfare' (Zucchino and Barnes: 2009). Given the very nature of software, vulnerable to all kinds of disturbances and take-overs from the outside, especially when one's opponents include many Western trained computer sciences and engineers, who would argue against this?

Despite the obvious risks illustrated here, one could ask whether these cyber breaches should be considered as safety issues, as security issues, or as both. It can be argued that only a thin line exists between security and safety, especially in the military. One for example could say that whenever a security breach occurs in the military, someone's life can be at stake. Soldiers or units can become victims of targeted attacks with improvised explosive devices (IEDs) if tactical information such as UAS reconnaissance data has been compromised.

In similar ways, the well-being (and morale) of units can be at stake when (they believe) the objectives of their mission are known to enemy forces. These should be considered realistic threats, especially since cyber space activities have some typical characteristics, such as an independence of location, time and spatial distance. Furthermore, because more and more digital networks are connected to each other, events can get 'coupled tightly' (sometimes without this being noted), thus having the potential to propagate quickly and increase in unpredictable unfortunate ways, sometimes exponentially (Perrow: 1984/1999). The result is that what is often thought of as simply security breaches should be considered safety issues.

Safety: a fluid concept?

UAS engineers have derived much of their knowledge on safety from their manned counterparts. This has meant that much attention has been given to UAS airworthiness. Focus thereby is on establishing standards, normally followed by regulatory efforts, quality control and quality assurance. The result of this concern with classic safety control measures has been that safety is often equated with the reliability of individual components that then together constitute the socio-technological system of the UAS. Attention then thus far has been with the quality of vehicle and ground control station parts, and with establishing and upholding procedures for maintenance and for piloting vehicles safely. Framed this way, establishing safety of UASs seems to be a relatively simple, straightforward process, or at least one of predefined consecutive steps within a process that can be modelled and controlled.

The issues of safety that the cases presented here, however, are of quite a different order. They seem to belong to a more complex 'anatomy' of safety, one that would be difficult to capture by rules, standards and segmentation alone. Perhaps, safety in actual settings could best be regarded a fluid concept, a concept that is difficult to regulate or control, because these actions depend ultimately on a subjective and momentary interpretation of what is to be regarded as both relevant and as facts. To represent targets as fuzzy one-inch blobs for instance was apparently regarded as safe by many before the friendly fire incident took place, or at least as sufficiently safe. This probably is no longer the case after the fact. Also, a network of operators, analysts and controllers is considered safe when its members manage to monitor and correct each other's actions. Such a network can however become a safety risk, when team members hold different, even conflicting, understandings of 'the same thing'. In similar ways, open-source technology can provide an advantage against an opponent because it can speed up innovation and change processes. Safety in concrete military UAS settings may not be possible by rule, mandate and establishing procedure(s) alone. At the same time however, this can make these systems more vulnerable for hackers.

Safety in concrete military UAS settings may not be possible by rule, mandate and establishing procedure(s) alone. It surpasses ideal types of modelled safety management on a regular basis, so it seems. Imagery designed for conducting surveillance tasks may prove to be of insufficient quality when used for precision weapon delivery. Safety here, this suggests, resides in the interplay between design, implementation and use. What this means is that, acknowledged or not, safety is an integral part of any design (technological, organizational or procedural) and of how this design is put into practice. The matter of the fact is that this is a social process, informed and constrained as such. The design and fielding of UAS technology, including its aspects of safety, in other words, is a social construction. The next section will look into this.

4.4. Safety of military UAS: social construction in actual settings?

If it is indeed the case that safety resides in the interplay between design, application and use, then understanding how this works could be way to improve safety. In his book on the development of bicycles, Bakelite and bulbs, a classic in the constructivist studies of technology, Bijker (1997) argued that technology gets constructed in the interplay between multiple 'relevant social groups'; groups that, through their actions and understandings, in direct and indirect ways ultimately define the appearance and use of technology. What this means is that the development of technology, including its aspects of safety, would at least partially be a social process. The ideal type of safety management however, has known denominators and parallels thus largely a rationalistic decision making. Rationalistic decisions, after all, imply the availability and cognitive processing of all relevant knowledge and a subsequent objective weighing of all the possible alternatives by the decision maker(s) (Simon, 1978). It is not clear whether in actual (or naturalistic) settings such objectivity is possible when dealing for example with safety of military UASs. Keeping Bijker in mind, let's look at this issue using the cases discussed before.

The friendly fire case

The friendly fire case offers much to consider when it comes to dealing with safety in actual settings. One issue of course is that of targeting imagery. From the Portland Press Herald of November 9 2011:

> A firefight had broken out. Taliban insurgents had ambushed about two dozen Marines patrolling a bitterly contested road. The Air Force captain [at Creech Air Force Base in southern Nevada] … powered up two Hellfire missiles under [the drone's] wings and ordered a crewmember responsible for operating the … cameras to search for enemy fighters. It didn't take long. Three figures, fuzzy blobs on the pilot's small black-and-white screen, lay in a poppy field near the road. "Hey now, wait. Standby on these," the pilot cautioned. "They could be animals in the field." (Cloud and Zucchino: 2011)

The UAS operators obviously had to deal with inferior imaging technology. One-inch blobs that could be animals in the field are not exactly the kind of representation or symbology one would expect to find in high-tech equipment such as a Predator. In today's world of high-definition television, there must have however been good reasons to accept this kind of representation as sufficiently safe for weapon delivery. After all, it must be assumed that the Predator system would not have been developed in ways that potentially would be unsafe for one's own troops. How is it then that such a targeting imagery came to be regarded as 'workable' by stakeholders during military UAS development, evaluation and use? Was this because the Predator imaging technology sufficed for the earlier reconnaissance tasks? This friendly fire incident, however, is not the only incident that involves target imagery. It closely resembles another deadly mistake involving close air support with a Predator. In early 2009 at least 15 Afghan civilians were killed after a Predator crew mistook them for Taliban preparing to attack a US Special Forces unit. In this latter case, analysts, located at Air Force Special Operations Command in Florida, also had doubts about the target's identity. Their warnings that children were present were disregarded by the drone operator and an Army captain who authorized the airstrike. If these limitations of this technology have been exposed before, did this issue then lack traction? And if so, why would this have been? When exploring how safety gets established in actual settings, these are the kinds of questions that need to be answered.

Another issue to be looked at more closely in the friendly fire case concerns the command and communication format and infrastructure in which the incident took place. Procedural check-ups apparently were part of the target acquisition and weapons delivery process. An intelligence data analyst in Indiana checked the drone's video streams and communicated his assessments through a coordinator team in California to the drone pilots at the UAS ground control station in Nevada. While on the one hand procedural checking seems a wise and obvious thing to do when delivering weapons half a world away, it also makes one wonder why such procedural checks are necessary at all in apparent safe systems. Are systems of this type themselves that weak that they need multiple double checks? And if so, why is then a chat-like form of communication used for coordination in high-consequence missions like the one described here? Is this for technical reasons? Is it because the Predator originally had been developed and equipped for reconnaissance flights? Have communication channel(s) and the infrastructure used today for UAS target acquisitions and weapon deliveries at all been the result of some conscious deliberation of alternatives? Or did it rather emerge from UAS technology (and missions) in place at the time?

It would be unwise, based on two cases, to argue that the information structure used during the friendly fire incident is a failure. Still, it could be valuable to take a closer look into the processes and factors from which both designers' and users' commitments to such communication structures emerged. Such a study could provide a more complete understanding of how conceptions of safety, at least in regard to military UASs, come about.

The interception case

A similar analysis can be performed on the interception case. Should, for instance, the interception of drone video streams by Iraqi insurgents in 2009 be attributed to 'laziness and arrogance', as was stated in the LA Times on December 18 2009:

> P.W. Singer, author of "Wired for War" and a scholar at the Brookings Institution, ... said insurgents' interceptions of video feeds are, in part, a result of "laziness and arrogance" by the Pentagon, which didn't encrypt the unmanned systems because officials assumed militants wouldn't be able to figure out how to intercept them. Singer said the Pentagon knew about the problem in the mid-1990s, when unarmed Predators were used in the Balkans conflict. Hackers in Eastern Europe were able to intercept Predator video feeds, he said – but complained that they were unable to

> intercept encrypted feeds of the Disney Channel. (Zucchino and Barnes: 2009)

Could it be that simple, that laziness and arrogance were at the heart of this? Or is there more that needs to be added to this discussion? Could there have been other rationales behind this? As has been argued with the friendly fire case, UAS technology and its safety can ultimately be regarded as social constructs. Could it be, for instance, that indications from the intelligence sources were such that opposing forces, organized or acting as individuals, were not seen as being able to exploit flaws in system design so that own or coalition forces would be in real danger, as was suggested in the Wall Street Journal (Gorman, Dreazen and Cole: 2009)? Could it be that the voices of intelligence specialists got more traction in today's environment in which development and implement costs for military technology both have risen and are under increased scrutiny? Perhaps, chances of opponents exploiting Predator technologies were not regarded enough to outweigh the costs needed to secure the data streams, especially since some would believe that they, even when able to intercept this type of data, would remain exempted from the further operational decision process anyhow. Or perhaps these voices would have lacked traction anyways because the enemy may be able to gain the same information through other design flaws? There may be more macro-level issues involved here too. In the United States, and probably also elsewhere in the Western world, Predator attacks are seen as a triumph of Western science and technology. This is because by many they are considered as accurate and relatively humane (because of its pinpoint kill-zones), and because the effects of these attacks seem so easy to measure (Schmitt and Dao: 2001). Has this led us to underestimate the potential that opponents have, to exploit and turn to their advantage our own technologies (Nyce and Dekker: 2012)? Questions such as these have been informed by what is going on at this time in the military UAS industry as derived from open source material. Answering these questions, however, is beyond the scope of this paper. What these questions do bring to mind though is that the notions of those who are directly involved in system design and system application can be affected by how they see others in this process. The interaction between opponents regarding the perceptions each holds of the other's technology and military competence for instance also figures in here. What this means is that not only technological processes and its safety 'markers' can be regarded as social constructs.

Stakeholders and other actors in the process, as far as they inform design and implementation, even indirectly, can be considered such as well.

This interception case brings up another issue. Evidence suggests that there has been a trend in the past decennia for military organizations to shift from in-house development and innovation to buying ready-made or ready-to-be-adapted available products. These are often referred to as commercial off-the-shelf (COTS) technology. The Dutch Minister of Defence for instance ordered this in his policy letter of April 8 2011, as a result of severe budget cuts (Dutch Minister of Defence: 2011). After the 2008 worldwide financial crisis, he said, any equipment to be bought for future use in the Dutch Armed Forces, has to be purchased either commercially or military off-the-shelf (COTS or MOTS). Exceptions will be made only rarely, he concluded. This has been the case too for simulator technology within the Royal Armed Forces of the UK (Hughes: 2011). Industries like the gaming industry invest so much money that it would be impossible with current defence budgets to start innovation projects that could compete with these industries. There has also been, for the same reason, an increase in the military use of open-source software and technology, perhaps without even realizing some of the security and safety issues embedded in how these technologies are developed. Also, there is the increased demand for interconnectedness and interoperability in national and international military theatres. Another worldwide trend is that life-cycles of technological products have shortened over time. The effect that these developments, especially when working in parallel, could have on the development of military UAS technology and its broader operational concepts, is that safety issues are not given the hearing they deserve. Perhaps the interception of video data streams and last year's virus-infection of the Predator and Reaper UAS ground control station software could in part be the result of these developments?

A Bijkerian inspired reconnaissance

What these cases illustrate is that establishing safety – or the lack thereof – of military UASs in concrete settings is not a straightforward linear process. The friendly fire case for instance seems to confirm Bijker's (1997) argument that technology is constructed through the interplay of notions and activities of social groups. Many stakeholders seem to be involved in the processes of military UAS design and application. Engineers, military commanders, analysts, end-users, but also for instance the public have their own perspectives, inputs and needs. It seems as if their goals and demands all have to be balanced against each other at the same time. How else could we for instance have proceeded from using the Predator system as a surveillance tool to using the very same system as a remote weapon delivery platform providing close air support?

This shift in UAS application could be understood through Bijker's concept of 'interpretative flexibility', the variety of meanings that could be attributed to a certain artefact. After all, without the ability to visualize (or conceptualize) a reconnaissance platform as a tool for weapon delivery, it would have been impossible that this shift could have been made at all. The attribution of meaning to artefacts seems limitless at first. But as Bijker (1997) pointed out, 'attributions of meaning are social processes and [are], as such, … bound by constraints. Previous meaning attributions', he argues, 'limit the flexibility of later ones.' The issue of imaging technology and the communication structure used in the friendly fire case can be seen in this way. Both these issues suggest that the Predator technology and its application were built on notions of what was already there; the tools and procedures were designed and optimized for reconnaissance. That establishing safety of military UASs is a social process and therefore inherently informed and bound by these constraints, seems to be confirmed here. What the friendly fire case also seems to suggest is that – in turn – the Predator, its current technology and its operational concepts, are defined by this reality. Social actors and socio-technological concepts are inextricably linked; the one informs the other.

Stakeholders, at the same time, can differ from each other with respect to their proximity to the design and utilization of military UAS. Some affect these processes directly, others in more indirect ways. While Bijker pays little attention to these latter ones (e.g. consumers), with UAS technology these 'extended' stakeholders such as opponents inform, through their actions and non-actions, the perception of designers and other stakeholders that are more directly involved. One's opponents' actions and influences therefore do need to be taken into account when analyzing how concepts of military UAS and deployment and related issues of safety come about. Even more, the perception held of one's adversaries should be incorporated in any analysis of UAS technology. After all, the social construction of opponents by those directly involved (like the social construction of customers by engineers and industries in Bijker's cases) can affect their perception of what will 'work' and what certainly not. If one's understanding of the opponents' understanding of UAS technology, their role in warfare, and their competence regarding countermeasures, is not very accurate, this can have any number of unanticipated results.

It is necessary to return to the influence that current technology and its operational concepts can have on how stakeholders understand this and future technology and their related operational concepts. Bijker introduced the concept 'technological frame'. This concept can be associated with for instance mental models, organized knowledge structures (Mathieu, Heffner, Goodwin, Salas and Cannon-Bowers: 2000), or with what Thomas Kuhn (1962/1996) referred to as a scientific paradigm. A technological frame comprises all those elements of the technical artefact, from material and technical to social and cognitive, 'that influence the interactions within relevant social groups and lead to the attribution of meanings to technical artefacts.' Examples of such elements are accepted theories, tacit knowledge, design methods and design criteria. In Bijker's analysis in 1997, these technological frames were seen as relatively distinctive and stable ones, thereby providing fertile grounds for standardization efforts. Modern digital technology however, it could be argued, has quite possibly altered the landscape in which current and future military UASs are to be developed and brought into practice. Today's digital technologies, by enabling swing-role capabilities, customized options and easier updates, can lead to more hybrid technological frames with diffused boundaries and relatively lower product life-cycles. The adaptability and flexibility that follows from this, once it has become the new norm, could give rise to even more hybridity as can be seen when comparing today's smartphones to the first generation mobile phones. Although such processes can lead to great opportunities for the range of applications to be covered, at the same time it implies less opportunities for standardization efforts to succeed.

One problem with Bijker's theoretical frame for the social construction of technology is that it is constituted by more or less static and distinctive concepts such as the concept of 'technological frames'. Also, it presumes relatively stable, fairly easy to identify, social groups that tend to have almost binary roles (higher or lower 'inclusions') in these frames. Less attention is given by Bijker to the dynamics of process; on how for instance, social groups become relevant ones, and why the traction of their messages has the value that it has. For example, digital technology has enabled the creation of readily available technology and shorter lifespans for products, thus increasing profits. It has also redefined and reallocated where expertise is located and defined. In some sectors, digital technology has even changed the power dynamics between the defence forces and other stakeholders in the development of military systems. An example of this is the case of simulator technology mentioned earlier. Stakeholders and current technology apparently are more than inextricably linked; the one seems to bring forth the other.

4.5. Discussion

The paper raises some questions on how aspects of safety regarding military UAS technology come about in concrete (or actual or naturalistic) settings. As has been argued, ideal types of safety management, resting on assumptions of objectivity and rationality, are not sufficient, at least for some of the safety issues in the cases presented here. In this paper, several cases on military UAS technology have been taken from the real world and their aspects of safety identified. Establishing safety in these concrete settings appeared to be a social process with many stakeholders, all with their own perspectives, knowledge, capacities, inputs and demands. Safety in military technological concepts such as UASs, it can be argued, is a social construction, informed and constrained as this can be by social mechanisms and processes. Establishing safety in UAS technology, in short, can be regarded a social process as opposed to, or rather in addition to, a mere technical rationally calculative one. If this indeed is the case, then understanding how this works could help establish more comprehensive analytical foresight and hindsight opinions on (aspects of) safety related to socio-technological concepts such as military UASs.

The social sciences have long acknowledged the shortcomings of rationality in actual settings (Simon: 1995). The establishment of scientific domains such as intuitive (or naturalistic) decision-making has been the result of this (Klein: 1999). The social sciences however do not stand alone here. The bounded rationality of social actors, especially when facing risks, has been pointed out by Kahneman and Tversky in a research program that ranged from 1937 till 1996. The results of this program have been recognized even in such domains as economics in which the notion of rational actors has long been fundamental for theory development (Kahneman: 2003). Organizational decision-making research has also focused on what decision makers actually do, as defined by their organizational and real-world context (Shapira: 1997). Scholars from philosophy further called attention to the 'normative aspects of safety and risk' because of which estimates of these concepts will by definition be value-loaded (Möller:

2012). Currently, the field of quantum physics is mentioned sometimes as a method to tackle this issue of non-rationality in social contexts. Although we would embrace any kind of theoretical examination from the natural sciences that could help to bridge the existing gap between the natural and social sciences, we believe that in the cases discussed here, to understand the social dynamics and the issue of non-overall rationality, the best available frame of analysis is that which has emerged from the STS literature.

What the analyses presented here suggest is that social actors and socio-technological concepts are inextricably linked and that together they constitute the reality in which technological innovation, development and fielding of military UAS technology occurs. In brief, it seems as if both help to construct the other. Social actors obviously construct technology and its broader operational concepts. At the same time, technology seems to enable one network of social actors above others. This would have to be a process of social construction again. After all, technology by itself can not initiate anything. The question here is: How does a current technology, through the understandings and actions of social actors, help to add others to the network of social groups, and how would the relevancy, or traction, of these social actors be established? This would be an item to pick up for further research on safety of military UAS technology since each player in the network has the ability in one way or another to add their own perspective to the construction of safety. More in general, one could ask whether regarding establishing safety in military UAS technology as a social or sociological process could add to the quality of our foresight and hindsight opinions of safety of this type of technology.

The STS literature, as we have pointed out at the beginning of this paper, does not say much about military UASs at all, and even less about UAS safety issues. The safety literature on UASs, above all, seems to be dominated by a technocratic and engineering approach, covering issues such as airworthiness, regulations, requirements and licensing (Cork, Clothier, Gonzales and Walker: 2007; Dalamagkidis, Valavanis and Piegl: 2008; EASA: 2009; Hobbs: 2010; Eurocontrol: 2010; USAF Scientific Advisory Board: 2011), machine autonomy (e.g. EASA: 2009; USAF Scientific Advisory Board: 2011), and sense-(or detect-)and-avoid technology (Hobbs: 2010; Eurocontrol: 2007; NATO JCGUAV: 2012). Social aspects of UAS safety do get addressed in human factors literature. However, it is mainly empiricist positivist micro-level cognitive issues such as situational awareness and its related aspects of human-machine interfacing (EASA: 2009; Hobbs: 2010; Williams: 2006) that get attention in this literature.

Social aspects of risk have of course been addressed in the past (Douglas and Wildavsky: 1982; Johnson and Covello: 1987). Risk and safety have even been considered a social construction sometimes (Slovic: 1999; Möller: 2012; Turner and Tennant: 2009; Turner and Gray: 2009). The establishment of safety of technology in general however, and of military UAS safety in particular, is in STS and safety literature normally not considered a social process explicitly, leaving the ramifications and implications of this unknown. Answering questions like the ones above would therefore add to the STS and safety literature.

4.6. Conclusions

The literature on UAS safety, civilian and military, has so far been dominated by engineering (technological) and regulatory perspectives. This paper attempts a correction of this by noting that, to make analytical sense of issues of safety with this kind of technology, we need to proceed beyond these conventional means of dealing with safety. Some cases on military UAS have been evaluated and demonstrate that this 'turn' makes some sense, at least with the kind of data that we had access to. What the evaluation of these cases suggests is that safety in military UAS technology is not only a case of technology, of setting standards, and of enforcing rules, but that underpinning and alongside this, safety of military UAS technology is also informed and constrained by a whole set of social dynamics. Safety in military UAS, is therefore not only 'built in', i.e. engineered, managed, and enforced, but also includes for instance assumptions and tacit understandings of various stakeholders involved in the design, implementation and use of UASs. Safety of military UASs, in short, is above all a socially constructed phenomenon. This paper has demonstrated there is sufficient rationale to perform further studies on UASs from this perspective. If one takes this angle, this can provide us with valuable insights on UAS safety issues – ones which current engineering and regulatory approaches have left so far unexplored. This would also help us understand the military and the UAS industrial practices in which UAS safety is embedded. Further, pursuing studies like these can add to the empirical and analytical diversity that is one of STS's strengths.

5 The safe integration of military UAS in the (inter)national airspace: some underlying processes

The second paper on military UAS in this dissertation is presented in this chapter. The paper presents a study on the social dynamics related to the 15 year old and ongoing process of integrating these unmanned systems in the manned European airspace. This seemingly technological issue has been studied here from a particular social science perspective, in this case the diversity and ethnicity literature, which helped in explaining why the UAS debate has taken so long, and why it has encountered the difficulties that it has. Present structures, procedures and technology, which emerge from the social dynamics and power issues involved, seem to constrain and inform, at the same time, the interaction of stakeholders, which in the end has resulted in this lengthy debate on the issue.[17]

ABSTRACT – This paper brings a social science perspective (from the ethnicity and diversity literature) to bear on a process that is regarded by many as essentially a technical one: the safe insertion of military unmanned aircraft systems (UAS) in the (inter)national European airspace. The aim of this qualitative study was to gain a more adequate scientific socio-technological understanding of the topic, so as to strengthen issue dialogue and discussion. Indeed, studying the "integration" of these UASs (as this process is often referred to) through the lens of acculturation literature, revealed some socio-technological processes that have been little noticed but which seem to underlie and inform this debate. For example, some voices seem to be favoured over others, a well-known phenomenon in the ethnicity and diversity literature. Safety, it could even be argued, is in this debate the pivot point around which social and other dynamics revolve. Belief and power may thus be more important factors here – "masked" of course – than technical aspects of safety. The results of this study are important not

[17] This paper is forthcoming in *Cognition, Technology & Work* (published by Springer), DOI 10.1007/s10111-016-0377-z.

only for the military since the incorporation of military UAS occurs, partially at least, in civilian airspace. Civil actors thus formed a substantial subset of those interviewed here.

5.1. Introduction

The Unmanned Aircraft Systems (UAS) market is expanding rapidly and more and more missions with UASs are being planned and implemented in both national and international airspaces. The military, so far, has operated in designated permanent training areas, or applied segregation creatively (as in using flexible blocks of time and/or space) so as to ensure the necessary training and operational facilities. This, however, reduces the airspace available for other users. There is thus a need to work on some other way to integrate military UASs in the national and international airspace (Tytgat: 2014). The safe introduction of UASs (military or otherwise) in the (inter)national airspace may, however, not be so easy to realize (e.g. Ramalingam, Kalawsky and Noonan: 2011). The aim of this paper, therefore, is to find out why this would be and so contribute to the science, technology and society (STS) literature, which, as an inter-disciplinary enterprise, often studies the social, political and governance dimensions of complex, technological processes such as the introduction of UAS into the airspace (e.g. Grunwald: 2011).

Historically, attempts to safely 'integrate' UASs (as this process often is referred to) have taken approaches that assume that technological innovation (such as sense/detect-and-avoid technology for UAS) and, to a lesser extent, standardization and regulation efforts will be sufficient to the task (e.g. ICAO: 2012; Eurocontrol: 2012; EASA: 2012; Loh, Bian and Roe: 2009; Cork, Clothier, Gonzales and Walker: 2007). Despite these efforts, however, the debate on how to safely integrate UASs (military and otherwise) has by now acquired some time depth. An alternative – socio-technological – approach is proposed here, so as to consider how social aspects, i.e., social dynamics, may help define and determine this seemingly technologically determined process and the discussions around it. Such a perspective may be a valuable addition to the analysis of the UAS integration debate since it could perhaps help to reveal obstacles in this process that other approaches tend to neglect. A socio-technological approach could therefore strengthen on-going discussions regarding the integration of UAS technology as it would provide a more adequate scientific understanding of some of the issues that underlie what has often been taken to be a (relatively) simple case of managing trade-offs in the interest of safety (Bakx and Nyce: 2013a).

This paper reports, in this light, on an empirical study of the harmonized integration of military UASs in the (inter)national airspace, which has been carried out from a socio-technological perspective. More specifically, the issue of UAS integration is approached here from a diversity (or cross-cultural) perspective. The reasons for this specific approach, and for how the diversity literature has been brought to bear to the issue of UAS integration, has been explained in detail in the next two sections, together with some other related features of this research, such as that the stakeholders that have been approached for this study include representatives from the UAS industry, regulators, and operators, from both the civilian and the military domain. The military, after all, although not bound normally by civilian regulations, needs to synchronize with some civilian parties, so as to be able to structurally integrate its UASs in the bigger (inter)national airspace. To give the discussion a focus, the study has looked at the Northern European airspace situation only.

5.2. Methodology

Researching a topic like the integration of UAS is not so easy to carry out because no 'end products' exist yet to investigate. The research has therefore remained confined to the investigation of the UAS integration process itself. This has led us to study relevant documents on the issue, and to carry out 18 interviews with members of a number of relevant organizations and institutions involved in the process. The data gathering focused mainly, but not only, on issues concerning larger military UASs since these normally operate at the same altitudes as manned (military and civil) aviation.

When this study started in 2012 in the Netherlands, discussions there on the integration of military UASs had not proceeded very far yet. The German armed forces, to the contrary, were in the midst of their efforts, at the time, to integrate their Eurohawk UAS into European airspace. However, data on this specific case were unfortunately not available. Although much of the data has been gathered from people involved in the Eurohawk case, this study focused thus on the integration of military UASs in the North European airspace in general.

Documents

Documentation about the integration of military UAS specifically, especially when it considers another country than one's own, can be difficult to locate. The original safety case document on the Eurohawk, for instance, was not made available for this study. Other documents have therefore been studied, which included documents from relevant regulating and policy institutes in the aviation sector such as NATO, the United Nations International Civil Aviation Authority (ICAO), the European Committee (EC), the European Aviation Safety Agency (EASA), and Eurocontrol (the European Air Trafffic Management Organization).[18] The UAS/RPAS Yearbooks (UVS International: 2011-2014) were also reviewed, just as were German news articles on the Eurohawk, news articles on UASs in general, and a number of requirements and certifying documents provided by one of the major German UAS manufacturers, Cassidian.

Interviews

Of the 18 people interviewed for this study, 14 provided in depth evaluations of the German situation. 4 came from the Netherlands and were interviewed for comparative purposes. We used the second set of interviews to check, to some extent, the results that had been obtained on the German situation so that an assessment could be made as to whether or not both the interview instrument and study results could be generalized to other countries. The interview protocol used was semi-structured, which means that interviewees had some freedom to interpret and answer questions as they wished. These interviews focused on issues related to military UASs. However, where relevant, attitudes, thoughts and strategies regarding UASs in general were also collected. The interview protocol was sent to interviewees beforehand to allow them to prepare the interview as they desired. The main question asked in the protocol was:

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18 Documents included NATO's STANAG 4671 (Ed. 1) – Unmanned Aerial Vehicles Systems Airworthiness Requirements (USAR) (2009), NATO's document on Sense and Avoid Requirements for Unmanned Aerial Vehicle Systems Operating in Non-Segregated Airspace (2007), ICAO's Annex 2 to the Convention on International Civil Aviation (2005), ICAO's draft RPAS Manual (2012), ICAO's Circular 328 on UAS ((2011), the EU Roadmap (2013), and Eurocontrol's (2007/2012) Specifications for the use of Military Unmanned Aerial Vehicles (2007) / Remotely Piloted Aircraft (2012) as Operational Air Traffic Outside Segregated Airspace.

> For safety reasons, should we at all consider the integration of military UAS in the European (inter)national airspace structure and if so, how can or should we do that safely?

From this question, a number of issues emerged such as the background of the interviewee, their position in the UAS community and operations, and how they perceived the role of the UAS national and international regulators. At the end of the interview each interviewee was asked whether there was anything else that should have been carried in the interview.

In an attempt to provide a 'complete' picture a broad range of relevant stakeholders was interviewed, including military UAS operators, UAS industry representatives, manned aviators and staff, air traffic managers, and aviation policy makers.[19] In the Netherlands only members from the manned aviation sector were interviewed.[20] All the interviewees were chosen because they can be considered as 'true' representatives of their institutions. Civilians like civil airspace regulators also formed a substantial subset of those interviewed here. Civilian decision makers and representatives, after all, are very much part of the debate on the insertion of military UASs as this issue involves, partially at least, civilian airspace.

All the interviews took 1,5 up to 2 hours and all were conducted either in English or in Dutch. With the exception of three interviews[21] they all took place on a one-to-one basis, two by telephone.[22] The interviews were taped and transcribed, and coded thereafter by using measures for acculturation strategies that a

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19 One member of ICAO; two members of EASA; two members of Eurocontrol; one staff member from the civilian German air traffic control organization (Deutsche FlugSicherung, DFS); one staff member from the military German air traffic organization (Amt für Flugsicherung der Bundeswehr, AFsBw); two members of the German Air Force, including one active UAS pilot; three employees of Cassidian, including one active UAS pilot who is released by Cassidian to fly the Heron UAS in Afghanistan for the German armed forces (Cassidian is one of the larger companies that belong to the German military UAS industry); one member of the German Aircraft Owners and Pilots Association (AOPA) representing German General Aviation in this debate; one member of the airline pilots' branch organization (Cockpit).

20 One member of AOPA NL, three members of the Dutch Airline Pilots' Association (VNV).

21 One with two members of the EASA, one with two members from Cassidian, and one with three informants from VNV.

22 One interviewee, for instance, was at the time in Afghanistan.

diversity study to be discussed in more detail below.[23] The data set was then recoded using 'open coding' techniques (Flick: 2009), so as to identify common themes – the social dynamics – that appeared to affect the UAS integration debate. These were included here only when they appeared at least multiple times in the data (e.g. were brought up by different participants or could be found in the documents). As for the ethnicity framework used in this study, the next section will explain some aspects of this framework that the current debate on UAS integration seems to reflect, especially in the policy documents that we collected.

5.3. Document analysis – the ethnicity framework

Obviously, a central issue in the deployment of UASs (military or otherwise) is how to safely integrate them into the current airspace with its current (manned) 'inhabitants.' From the beginning, nationally and internationally, and for both the civil and the military domain, two premises seem to be central to this debate, as the UAS policy documents suggest (Bakx and Nyce: 2013a):

(1) UAS must meet the equivalent levels of safety (ELOS) as manned aircraft, and
(2) UAS must be able to integrate seamlessly in the current air traffic management (ATM) structure

Over time, a third and a fourth premise has become part of the UAS debate (Eurocontrol: 2014):

(3) UAS should be transparent to other airspace users and air traffic control
(4) UAS should not penalise other airspace use

As this debate has gone on, the requirements for UASs obviously have been raised. Even more, the stakes for the newcomers seem to have been raised

[23] These included: the attitude towards multiculturalism; the attitude towards newcomers; identification with one's own background, experience(s) and origin; agreement with policies and policy makers in relation to this specific issue; threats and perceived threats related to newcomers such as fears for the own position; intergroup anxiety.

repeatedly. Just recently, for instance, UASs have also been required to meet an equivalent or better level of safety than manned aviation (Eurocontrol: 2014). This, however, is not what we focused on here. What all the premises and requirements imply, implicitly, is that the introduction of UASs in the (inter)national airspace is supposed to rest on the ability of a minority of things in the air (UAS), to act like – or outperform – the majority, i.e., current airspace users. Framing the issue this way does resemble what the ethnicity and cross-cultural literature terms 'acculturation strategies': those strategies that people often use in the '...process of cultural and psychological change that takes place as a result of contact between two or more cultural groups and their individual members' (Berry: 2005).

Although the idea of acculturation is often applied to a different social domain than the introduction of a new technology such as UASs in the current airspace, there may be more similarities here than one might initially think. The issue of UAS integration, after all, does involve the introduction of newcomers – of non-dominants (UAS) – in a community of already existing, dominant, practitioners and technologies (conventional aircraft). Further, not much imagination is needed to see that, like with ethnicity, these UAS negotiations are a social process that can either change or reinforce previous attitudes and behaviours because of the contact with and perception of 'the other group' (Berry: 2001). Indeed, the term integration is critical to (and often used in) discussions on the introduction of UASs into the European airspace and many restrictions have been placed upon the UAS community by the current airspace 'habitants'. This is a process very similar to how many cross-cultural issues work out in today's society. In short, all, this seems to legitimatize a diversity approach to UAS integration, which has led us to perform a qualitative analysis of the UAS debate from a diversity/ethnicity perspective. More specifically, it led us to look at how the social science literature generally has dealt with the issue of diversity in society, and how this could be used to analyse the issue that we are interested in here, i.e., the introduction of UAS into the European airspace. In the next paragraph, the specific framework that we used for the analysis is described, which included Berry's acculturation strategies, the fusion model of acculturation, and a number of supposed underlying social mechanisms.

The ethnicity framework – methods section continued

People can exercise particular acculturation strategies for many different reasons. In an attempt to establish a theoretical framework, the diversity literature was therefore scanned not only for measures for acculturation strategies, but also for its underlying themes and assumptions.

Measures for acculturation strategies were found in Berry's model (Figure 3), which includes eight strategies and is regarded as the most influential model of acculturation, both inside and outside academia (Arends-Tóth and Van de Vijver: 2002). Although anthropologists Redfield, Linton and Hersokovits coined the term acculturation in 1936, it was Berry who helped spread the term throughout the scholarly literature (e.g. 1992, 1999, 2005). We thus included Berry's strategies in our framework, together with a more recent model: the fusion model. This fusion model describes elements of the acculturation process that Berry's model does not include, i.e., groups that together create a whole new structure (e.g. Hermans and Kempen: 1998; for other references for this fusion model, see Coleman: 1995; Padilla: 1995; LaFromboise, Coleman and Gerton: 1993).

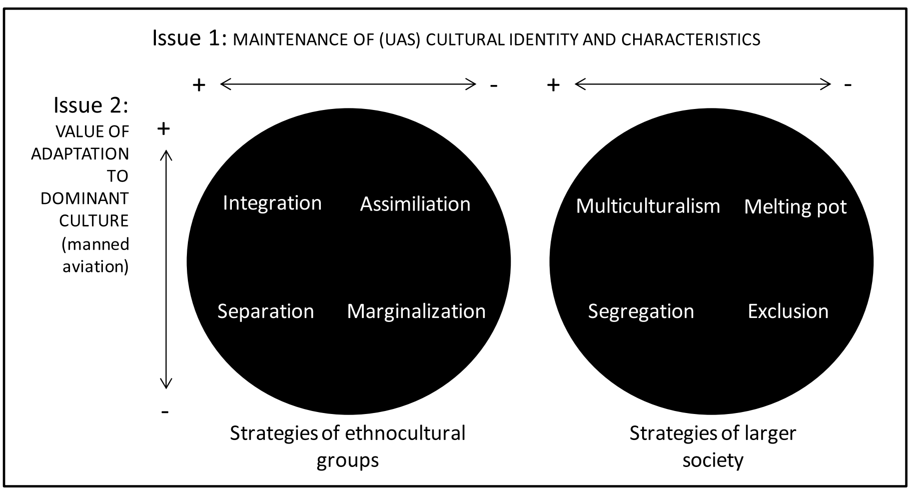

Fig. 3: Berry's acculturation model (Berry: 2005)

Applied to UAS integration, the fusion model allows for the possibility that interaction between the dominants' (conventional aircraft) and the non-dominants' (UAS) behaviour(s) could lead to something completely new. Such dynamics are important to notice because the members of the new system, after such a transformation, will have to reconsider even what it regards as its most fundamental values and norms (among which those related to safety). Existing norms and values will be altered in this process rather than modified, as the establishment of new norms and values requires more than just adding up existing ones (Moore: 1903). Also, it has to be thought through how these new norms and values should (and could) be understood and addressed in this new system by all those involved.

A large quantitative diversity study was used to illustrate the linkage between the underlying social processes in the UAS integration and acculturation strategies. This particular study assessed diversity attitudes in the Dutch armed forces (Rietveld, Op den Buijs and Richardson: 2012) and included a large review of the literature. Furthermore, it assessed, using questionnaires, this group's attitudes regarding diversity, rating them using a number of quantitative scales. It turned out that almost any item mentioned in this study could easily be 'translated' into a UAS integration issue. Examples of this can be found in Table 7.

1	Original text:	*"I sometimes worry that my financial position will regress the coming years"*
	Translated:	*"I sometimes worry whether I will still have a job in the aviation sector in a couple of years"*
2	Original text:	*"The Dutch defence organization does enough to counter the discrimination of ethnic cultural minorities"*
	Translated:	*"Regulators put sufficient efforts in countering the discrimination / disadvantage of UAS"*

Table 7: Examples of items translated from a diversity study to the UAS integration issue

The first example comes from a questionnaire that measures perceived threats by majorities regarding minorities, the second example is one that measures attitudes towards acculturation policies. In order to ensure the congruence between the original survey and the extrapolated version of the items (to the UAS domain), both have been checked against the other by one of the authors of the original study. Some of the translated items helped to measure the sample's "preferred acculturation strategy(ies)" (Andriessen and Phalet: 2002) in the context of the insertion of UAS. Other scales have been used to assess related processes and attitudes and included: the attitude towards multiculturalism

(Berry: 1997; Berry and Kalin: 1995); the attitude towards newcomers (Andriessen and Phalet: 2002; Berry: 1997; Berry and Kalin: 1995); identification with one's own background, experience(s) and origin (Rietveld, Op den Buijs and Richardson: 2012); agreement with policies and policy makers in relation to this specific issue (Glastra: 1999); threats and perceived threats as a result of the newcomers (Eisinga, Need, Coenders, De Graaf, Lubbers and Scheepers: 2012; Stephan, Diaz-Loving and Duran: 2000; Stephan, Boniecki, Ybarra, Bettencourt, Ervin, Jackson, McNatt and Renfro: 2002); intergroup anxiety (Stephan et al.: 2000).

The transformed items were used to structure the interview protocol and were later used for coding purposes. The measures identified this way formed the lens through which the data has been analysed in this study, which resulted in the analysis that is discussed next. Of particular interest here is how words like integration underpinned and influenced these communities' efforts to incorporate UASs in the airspace safely.

5.4. Analysing the integration debate

At the onset of this study, the issue of how to safely integrate UAS technology in the (inter)national airspace seemed to be just that; a technological issue of how to structure the airspace such that both current users and UASs (military and otherwise) can use it together safely. In effect, the problem was reduced to and regarded as a relatively simple and solvable case of compromise and standardization if, at least, the aviation community would reach an agreement regarding a few numbers and safety procedures. Only when the topic is explored more in-depth, as this study's results show, some of the actual complexities and difficulties are revealed.

One example concerns the lack of progress in the establishment of airspace regulations. The UAS industry, it seems, is waiting for regulations to inform them what they are allowed to bring into the airspace. This seems quite straightforward. The regulators, however, want at the same time for the UAS industry to demonstrate what UASs are capable of so as to build appropriate regulations. The innovation of (mainly civilian) UASs, as a result, seems to have come to a standstil in some respects. The resulting lack of a solid business case did not help here either, as quite a number of interviewees reported. A second example considers the 'detect and avoid' equipment[24], for instance, is often mentioned in this debate as a key factor for establishing safety in an airspace in which both manned aircraft and UASs are present. This argument, however, seems to be informed mainly by 'exactly' matching the UASs' technical specifications with existing technology, i.e., with 'see and avoid' in manned aviation.[25] Today's (manned) structures, procedures and technology thus seem to both inform and constrain the debate on the issue. One possible result of this is that what UAS technology will look like in the future rests, for a large part at least, on having UAS characteristics match what we already have in manned aircraft, regardless whether this is the most effective (or safe) thing to do.

Here the technological and social processes and domains regarding UAS are so intertwined that it is sometimes difficult to tell them apart. This supports the socio-technological approach taken in this study. What this also suggests is that social and technological acculturation processes have much in common, and this argument seems even stronger when we note how well many of the informants' statements reflect the diversity theme:

> 1. 'We're here first. And I think we are using the airspace safely. And, if somebody else wants to come... I think you've got to accept the standards that are there where you want to go. Like in everyday life ... We don't want to be stuffed into reservoirs, like the red Indians in America.'
>
> 2. 'It is like ... imagine a group of people, people knowing each other, and you are new ... At the beginning, you better shut up, oke, and say, don't worry, I will be here, you will never know I'm here. And that's the best way, actually, as a newcomer, to be accepted.'

It would not be hard to assume that these statements were collected during interviews about socio-cultural processes related to ethnicity and diversity. The literature on (social) acculturation strategies thus seems to provide a foundation

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24 Detect and avoid equipment includes technologies such as sensors or radars that should be able to detect other aircraft as to avoid collision.

25 In manned aviation the pilot is ultimately required to 'see and avoid' obstacles like other aircraft, especially when operating in airspace where traffic is operating without the help of air traffic control.

– in an analytic sense at least – for how interpretations and ideas on current and future technology (here manned and unmanned aircraft, and the airspace structure) can emerge and are discussed. Indeed, the data analysis showed how the rhetoric related to social acculturation and exclusion sometimes inform these discussions in ways that can make it difficult to deal with technology change and innovation in any rational way. In fact, a large number of these myths as we have called them here – were found to underlie the UAS discussions and negotiations. In the following paragraphs we give some examples of this (see Table 8 for an overview), starting with a discussion of the integration-myth. Quotations from this study's interviews have been added (in italics) where relevant.

The integration-myth

In the data analysis, we found the interviewee statements to fit remarkably well with the "translated" measures derived from Andriessen and Phalet's (2002) bi-dimensional scale for measuring preferred acculturation strategies. 13 out of 14 interviewees seemed to prefer a strategy that much resembles the assimilation/melting pot strategy *('Part of it is, of course, fitting into the current system.'; 'You have to act like a manned aircraft.')*. 3 out of these 13,[26] however, appeared to prefer segregation when military UASs were concerned.

It may not be much of a surprise that those with a commitment to manned aviation prefer a segregation or melting pot strategy, strategies in which they can remain dominant. It is surprising, however, to notice that members from the UAS community (5 out of 5) also generally support these strategies by embracing the non-dominants' variant, i.e., assimilation *('The easiest way, the fastest way, to integrate UASs in the airspace is to use the current system.')*. Some of them, however, nuanced this preference. One, for example, saw assimilation as a best initial strategy, necessary for UASs to be accepted *('It would be unrealistic to make a whole change to the system ... equivalence is just the entry card.')*. Two others saw the UAS community as essentially being forced into this strategy *('Unfortunately we are the new kid on the block.')*. What is remarkable here is that, although the safe introduction of UASs is widely referred by those involved (and by the interviewees as well) as the UAS *integration* issue, none of the informant data showed anything that would directly fit in the integration category. It seems instead that the notion of integrating UASs is more an ideological commitment,

26 With a background in policymaking and air traffic management.

an underlying belief, regardless of the actual social process these actors themselves are involved in.

However, taking a position of assimilation, no matter how implicitly, can shift the debate in ways that are difficult to trace, let alone for others to address or critique. It may even be that the existence of this unacknowledged incongruence between assimilationist and integration positions is the reason that, despite much time and effort, this UAS debate has still not been resolved. Further, consider the consequences that an assimilation/melting pot would have on how this debate might get resolved. In the paragraph on responsibility-myth below, it has been described, for instance, how the burden of UAS integration is placed on one party more than the other. First, however, we will discuss another dynamic at work in this debate, the substitution-myth.

The substitution-myth

The substitution-myth identified here is one expression of the fusion acculturation model described in this paper's methodology section. Implicit in this position is the idea that the introduction of any number of UASs into the airspace will change the airspace system, its fundamental values and norms, and also the operations within it. It is generally believed in the UAS debate that, as long as UASs act as any other (piloted) aircraft, i.e., as long as a melting pot strategy is pursued, it will be safe for UASs to share the airspace. Since UASs can never be made to act (exactly) like manned aircraft, however, this assumption seems to rests on what elsewhere has been termed the substitution-myth; the apparent – but false – belief (applied originally to engineers by Sarter, Woods and Billings [1997]) that human activities can be substituted by automation 'without otherwise affecting the operation of the system' (Christoffersen and Woods: 2002, 3).

In the UAS integration debate, the substitution-myth thus holds that UASs can be added to the airspace without the airspace evolving into something new. In reality, however, such "substitutions" actually add another factor to the system, which will redefine the system, and thus its most fundamental values and norms also (among which what safety is). Tasks, roles, duties, and responsibilities within the system will change accordingly. So what seems to be a simple substitution of one thing [UAS] for another [a manned aircraft] can, to a greater or lesser extent, impact the system as a whole, resulting at times in a completely different system. The fusion model may thus be a better framework to discuss the incorporation of UASs into the (inter)national airspace. After all, the interactions between manned and unmanned aircraft will qualitatively differ from those between manned aircraft alone, and this could totally redefine what airspace (as a system) is and means. The hold that the assimilation model has on this debate and those involved, however, has led to more than some of the stakeholders to attempt to deny this: *'The process is, of course, not to create something new.'* Much the same sentiments were expressed by EASA staff: *'For us, the rules of the air, the airspace classification ... and the air traffic control, will remain basically as they are today ... and, unmanned aircraft need to comply.'* Other dynamics, such as acceptance, may be at work here too such as the following strings from another interviewee suggest: *'Don't change the existing system ... Because of acceptance.'; 'I think to start totally fresh [as in rebuilding the airspace], Bwoh..!!!!'* Acceptance and fear too, obviously, have a role in this debates, just as power does, which can be illustrated by how another informant described what a new aviation system might possibly look like: *'[Me:] Why not have the ATC controller have some control input into the aircraft? [Y:] Woohoo, this is, this is really far away from now, but euhm... why not? [laughing] ... but ... with the structure we have right now, with the people in charge, difficult.'*

In the same sentence sometimes, informants would even both acknowledge and deny that the substitution-myth plays a central part in the UAS debate: *'[Me:] Can we keep the [manned] aviation system intact [after the introduction of UASs]? [X:] Yes!; Me: As a closed system? ... Hmhm! [as in yes] ... We have to wait until the system collapses, very simple.'* Here an informant denies, initially at least, that the substitution-myth has any role in the UAS debate by claiming that the aviation system can remain intact after UASs have been introduced. At the same time, he also acknowledges that, that airspace system, due to a lack of capacity, cannot handle UASs and so will fundamentally change to the point of collapse. This is exactly what Sarter et al. (1997) warned engineers would happen (and this did occur when the Traffic Collision Avoidance System, TCAS, was introduced [Bakx and Nyce: 2013a]). In short, not recognizing the role that the substitution-myth, like the integration-myth, plays in the UAS debate will distort any discussion of safety in this debate.

The it's-all-an-air-traffic-management-problem-myth

Another social mechanism the ethnicity literature discusses is the identification of the self with one's own background, experience(s) and origin (and from there, judging others). This mechanism seemed to occur in the UAS debate as well, as one informant explained: *'Yes, we [Air Traffic Management, ATM] think in manned structures and if you fit the unmanned aircraft in the existing ATM system, or the ATM world, of course you fit into the manned aircraft.'* The perspective that ATM actors tend to hold is historically connected to manned aviation and this congruence with the current airspace 'inhabitants' may be why others in this discussion regard UAS integration as an ATM issue also: *'Why should we [manned aviators] make the work for the guy sitting on the ground [Air Traffic Controller, ATC] much more difficult?'* In short, the UAS debate not only relies on an integration- and a substitution-myth, but also, on an it's-all-an-air-traffic-management-problem-myth. What these myths do is they frame the discussion so that it favours some voices over others. It selects out and strengthens these voices (by rendering them seemingly more rational and logical) and it establishes and reinforces, in this way, the dominant position of assimilation in the discussion. This, in turn, legitimatizes a central element in this debate, the principle of similarity, i.e., the best, 'safest', way to proceed is that UASs duplicate manned aircraft in some absolute sense: *'From the ATC perspective, there is not much difference between manned and unmanned'* Although reasoning from one's own background can seem logical, and even almost inevitable, this can turn the UAS debate into directions in which safety may not be discussed in any rational way.

The myth of the perfect person

This (mistaken) analogy of UASs with manned aircraft finds, perhaps, its ultimate expression in the requirement that UASs need to be held to manned aircraft requirements for last resort collision avoidance: 'see and avoid'. This requirement is stated for manned aviators in qualitative terms only and boils down, basically, to that the pilot must be able to 'look outside the window very carefully' (ICAO: 2005). It is difficult, of course, for UASs to demonstrate anything like this or anything that is functionally equivalent. As well, any use of this this analogy tilts the debate – again – unfairly in favour of manned aircraft. This is reinforced even, as the human ability in this regard is generally – but falsely – assumed outstanding. As one interviewee points out: *'See and avoid does not work because of the eye ball. It works because of this big sky, because they have professional ATC, and because the chance that two aircraft hit each other are remote.'* Still, the standards that UASs are expected to meet are encapsulated in this 'myth of the perfect person': *'For detect and avoid, [UASs] must have a system which should work 100%.'*

Although many interviewees acknowledged this incongruence somehow, this did not change the position they took in respect to UASs. Many of the interviewees made this clear in one way or another: '*They have to prove that they are as safe or, even better, that they are safer.*' What this means is that even if technical and/or functional equivalence(s) can be achieved between UASs and manned aircraft in quantitative terms, this would not necessarily be accepted as a airspace "solution." For instance, not a single, vehicle based, detect and avoid sensor technology, has been approved for flights in non-segregated areas, even when this technology performed better in many ways than the human eye. Some reasons for this, such as worries about unforeseen consequences, emerged during the interviews: *'They have to prove because they are somewhat unknown.'* Public acceptance of (and fears for) a new technology were also cited for why people were sceptical of detect and avoid technologies: "The community accepts humans making errors, but they do probably not accept machines making errors."

Other than objective characteristics thus seem to inform the UAS debate, and both individually and collectively people in the debate seem to tend to raise the requirements (and stakes) for UASs to be inserted into the airspace "safely." The result is that UASs, as "the new neighbours on the block", seem to be saddled with additional, perhaps even unnecessary, technical and policy requirements when compared with manned aviation. UASs are now held by some, for instance, not to decline safety throughout the entire aviation system when they enter the airspace: *'[Me:] What do you mean with integration? [Z:] You just fly into the same airspace without degrading the level of safety of that general activity...'* While this position could have some merit, there seems to be no objective reason for the technical and regulatory burden to be placed on the newcomers alone. This brings us directly to the next mechanism or myth that has been identified: the responsibility-myth.

The responsibility-myth

Some stakeholders argue that the position of unequal burden-sharing taken above, a position that is mentioned frequently in the acculturation literature, is necessary for: *'If it comes to an airborne collision between a manned and an unmanned aircraft, only the manned part shares this ultimate risk [of dying] ... in so far we argued that the risk for airborne collision must go to the unmanned part.'* Even international airspace regulating institutions seem to hold this position, although less explicitly, as the representative of one of them makes clear: *'We will* *not impose any retrofit requirements … on the manned part of aviation because of unmanned aircraft. Equally we will not impose requirements on air traffic management to introduce modifications.'* This position has even become, as mentioned earlier, Eurospace policy: 'UAS should not penalise other airspace users' (Eurocontrol: 2014).

When inequality in burden-sharing becomes institutionalized, one has to wonder why such a seemingly arbitrary and unfair position makes sense to those who take part in the process. Perhaps this has to do with the fact that the UAS socio-technological process ignored (or/and discredited) the fusion model as a legitimate framework to address the issue of UAS integration (see the paragraph on the substitution-myth). In this model, the airspace will inevitably evolve into something new after UASs are added. What this model stresses further, however, is that both current and new users have to share responsibility for that what they shape socially and technologically together: a new airspace structure. The current airspace users tend to portray the UAS community instead as newcomers who, like newcomers everywhere, just have to "fit in", i.e., have to learn to play by (and not challenge) the existing rules: *'The unmanned aircraft, they are the new guys around the block, and they have to adapt to the rules, unless it is proven that new rules are safer and, and accommodate all users.'* Instead of accepting a shared responsibility for creating a new environment together, the result is that the requirements for entrance (in terms of policy and safety requirements) get raised and that the burden (the price of admission as it were) is put almost entirely on the newcomers alone, as if safety can be achieved through the actions of only one actor in a system.

Summary

Despite the time and effort invested in the UASs policy discussion it is clear that many questions and issues central to this debate have not yet been resolved. What should UASs be compared with? What requirements should they adhere to? Should all the parties accept a responsibility for the creation of a joint manned/UAS airspace, or is this an issue only for the UAS community? The answers to these questions depend, among other things, on whose voice frames the discussion. Obviously, this has much to do with power, and with how this is exercised in and across institutional and policy settings today and in the future. The models of (socio-technological) acculturation that stakeholders use (and become committed to) has, of course, much to do with power too.

Integration-myth	
Description	The notion of integration in the UAS debate seems to be an ideological commitment, a belief, as none of the actors involved in this debate really seems to support this position
Anticipated effect	This shifts the debate in ways that are difficult to trace, let alone for others to address or critique
Substitution-myth	
Description	The apparent – but false – belief that it is possible to substitute one thing [UAS] for another [a manned aircraft] without having to reconsider the system's most fundamental values and norms (among which the value of safety), i.e., without the airspace evolving into something new
Anticipated effect	The denial of the airspace transforming into something new distorts any discussion on safety and tilts the debate into the direction of manned aircraft
It's-all-an-air-traffic-management-problem-myth	
Description	The insertion of UAS in the airspace is often seen as just another air traffic management issue, as how to fit UAS into the current, manned, aviation system
Anticipated effect	To frame the discussion in this way favours some voices in the UAS debate over others, strengthens the dominant position of assimilation in the discussion, and tilts the debate into the direction of manned aircraft
The myth of the perfect person	
Description	UASs are frequently held to match up to or outperform qualitatively stated and flexibly interpretable human performance norms such as see and avoid capabilities so that they are held to norms that humans in reality can in fact not live up to themselves
Anticipated effect	Because the norms for human operators cannot be applied directly to UAS, holding UASs to these norms tilts the debate unfairly in the direction of manned aircraft
Responsibility-myth	
Description	Because in an airborne collision only the manned aviator runs the ultimate risk of dying, UASs are considered to diminish any anticipated decline in overall airspace safety that can be related to the entrance of UASs, as if safety can be achieved through the actions of one single actor
Anticipated effect	This myth tilts the debate, once again, in the direction of manned aircraft as it puts the burden for airspace safety in the new system in which manned aircraft interact with UASs almost entirely on the shoulders of the newcomers, the UAS community

Table 8: Overview of myths identified and their anticipated effects in the UAS debate

In this paper we have described a number of mechanisms – in the form of myths – that seem to inform the debate on the introduction of UASs in the (inter)national airspace. As we have shown, these myths help inform the kinds of 'integration' argument that participants tend to make and find persuasive. The assimilation (or melting pot) strategy seems to dominate this discussion. It is accepted, even by the newcomers, the UAS community, if only as an initial entry strategy. What legitimizes this strategy apparently, are the myths that we have outlined here. They help, for instance, to mask the uneven attribution of responsibility (one tilted against the UAS community), which pervades, these policy discussions. They also help to camouflage the kind of power dynamics that not only give the manned aircraft community the upper hand, but also make their position (on what constitutes airspace safety) seem logical and reasonable, even to their opponents, at least at first.

5.5. Reflection

A social science approach, borrowed in part from the ethnicity literature, has been brought to bear in this study on the 'technological' issue of introducing military UASs safely in the (inter)national (European) airspace. The result is that several myths were identified that seem to influence implicitly and explicitly the UAS debate so that some voices seem more stronger, more reasonable than others – often on the basis of little or no evidence. What we have also found is that social dynamics, path dependency and belief and power may be more important factors in this debate – although 'masked' – than, perhaps, safety itself. It could even be argued that safety in this debate is not much more than a pivot around which social and power dynamics revolve; a reference point to return to each time that the debate gets stuck, or goes into a direction that some stakeholders, often the most powerful, are unhappy with.

That individuals and communities resist technological innovations sometimes that challenge their own values and interests is not particularly surprising. Literature from political science, sociology and management science all support this conclusion (e.g. Rogers: 1962; Bass: 1969). What the ethnicity literature as it is used here seems to add though – as opposed to those other approaches – is that it not only seems able to incorporate dominant group member attitudes (here the manned aviation community), but that it accounts also for minority (non-dominant) attitudes, in this case the UAS community. Diversity, ethnicity and other such demographic characteristics have been connected to technology before. Demographic differences in the access to information technology (e.g. Mossberger and Tolbert: 2003) have, for instance, been discussed in the literature, as have some of the social barriers that influenced the development of antimalarial drugs (e.g. Trouiller, Olliaro, Torreele, Orbinski, Laing and Ford: 2002). Also, scholars such as Latour (1987) and Vaughan (1996) have studied scientists and engineering cultures like tribal societies so as to gain access to these groups' deeply rooted values and norms in order to better comprehend their actions and behaviours. Using the ethnicity literature such as in this paper, i.e. using acculturation strategies and its underlying mechanisms to analyse how relevant groups behave when new technology challenges or becomes part of an existing world, has to our knowledge, however, not been attempted elsewhere.

The myths that we identified here emerged from analysing the interview data with an eye on the acculturative mechanisms that appear to inform the UAS discussions. The first two myths, the integration- and substitution-myth, directly relate to an incongruence in acculturative strategies in these discussions. Looking at these myths could thus help to determine how stakeholders believe how policy should be written and resources allocated. The other myths derived from the analysis of the social processes that seem to lie underneath these acculturation strategies. How the safe introduction of UAS is framed, for example, can be connected to the professional role one holds (such as air traffic management), and thus to one's own background and experience. The myth of the perfect person, in turn, seems to emerge from a fear for the unknown and its unanticipated consequences. The responsibility-myth, also, can be connected to fears and anxieties related to the newcomers – the UAS community – as these may come from having possibly to integrate with them on their terms. The result of these myths is that new airspace safety standards are largely determined, today, by members of the manned aviation community. The burden, however, of meeting these standards falls almost entirely on the UAS industry. Such attitudes, as ethnicity literature makes quite clear, can be observed in every social community "threatened" by newcomers. Anxiety and fear, all in all, are central elements in this debate and this will be discussed in somewhat more detail below. Thereafter, the issue of trust and the military will be addressed, followed by a short discussion on policy making and regulations.

Fear and anxiety

Fears expressed by the interviewees (more often by manned aviation participants in this debate) concerned a fear of the unknown and its related consequences. Within the general aviation community in particular, this seemed to stem, at least in part, from their perception of UASs as intruders who threaten their world, the existing (and presumably very safe) aviation system. General aviation participants, however, were not the only ones to express concerns. In fact, fear and anxiety seems to play a central role in this debate. It, we found, gives legitimacy to the melting pot strategy, as well as that it assures that these informants reject the – better-suited – fusion model for socio-technological integration. It may even be that fear and anxiety underlie all the myths described here. After all, this study's interview data, such as the differences between how manned and UAS aircraft are perceived, the perception of UASs as intruders, the biased UAS flight competence by measuring not just against a human pilot, but against a fictive pilot who can handle any potential challenge thrown at him or her, these all seem to reflect fear and anxiety about the unknown.

The quick scan data mentioned earlier seems to substantiate this finding. There we described that 4 people from the Dutch manned aviation sector were interviewed to see to what extent the results of this study that had so far been collected in Germany could perhaps be extrapolated to other countries. In these interviews, the fear of the unknown seemed to be present in equal measures, which could mean that fear and anxiety related to the unknown is something that impacts on all parties involved in this debate. Further, since the topic of fear seemed to underlie, in this study, all the obstacles in the UAS debate described here, other countries may expect to confront similar issues in their attempts to incorporate UASs in their international airspace(s). However, the quick scan data set was too small and included only one other country (the Netherlands) and only one participant set (manned aviators only) so that one should be careful not to draw any definitive conclusions from this part of the research presented here, especially not for countries outside the Northern European region.

Trusting the military?

Originally, this study focused on issues related to the integration of military UASs. It soon became clear though, that if military UASs are not to be simply assigned a separate airspace (segregation/separation), they become part of the same policy and technical safety debates as other UASs. However, one issue emerged only in discussions of military UAS: the issue of trust. A recent German parliamentary investigation that focused on transparency, the risks and spending associated with their Eurohawk UAS illustrates this concern (e.g. Deutscher Bundestag: 2013). In fact, those interviewed for this study mentioned this investigation several times. Air traffic management services staff interviewed here seemed in particular sceptical about whether they should trust the military. This is because, so far, the German military did not often, when it came to UAS, disclose what they believed to be the necessary operations information. Members of the general aviation sector were also concerned that if military

UASs flights increased in number, they could claim larger and larger pieces of civilian airspace, with general aviation becoming the underdog (and eventual losers).

This issue, and ones related to it, like secrecy, we think, is what the military needs to be aware of (and take into account) since it could potentially threaten any attempt to integrate military UAS into European airspace.

Policy making and regulation

As has been pointed out earlier, the assimilation/melting pot strategy seems to be the dominant acculturation strategy involved in this UAS debate. What most of the interviewees reported (and this is worth noting here) is a lack of progress in policy making regarding UAS integration, even though the study's informants were aware of how difficult the regulators' job may be, and how problematic the issues are that they are confronted with. Such (dis)satisfaction with policies and policy makers can be linked though, if one reads the ethnicity literature, to particular acculturation strategies as the inability to derive policy and regulation – perceived or not – can be interpreted as a passive attitude from the side of the authorities, and therefore as an incentive to preserve the status quo and its attendant inequality (Meerman: 2007). This lack of progress in UAS policy making can therefore perhaps account, partially, for the weight that is given to the assimilation/melting pot strategy in this UAS debate, especially when this is coupled to the fear and anxiety that seemed to underlay this debate.

5.6. Conclusion

Historically, the aviation sector has been seen by itself – and by others – as a safety conscious domain. It can be argued then that the UAS integration debate has a firm base in safety science as well. Indeed, many of its arguments – if not all – do seem to boil down to arguments after safety. The first premise in this debate, that UASs must meet an equivalent level of safety to manned aircraft, is perhaps the most obvious one. What this research suggests, however, is that how safety is treated in this debate could, potentially at least, lead to less safe airspace operations. This is because the discussions in this debate seem to be informed, intentionally or not, by a large number of myths – safety myths, no less.

When we say this we do not mean that stakeholders do not regard safety as central to this discussion. In fact, the one thing that all these stakeholders agree upon is that the aviation system should be safe. Still, what we found is that in the debates the topic of safety represents something like an ideological commitment more than anything else. In other words, the topic of safety in this debate is a trope, a pivot, around which much of the discussion revolves. Safety as a kind of rhetorical Sweden or Switzerland – a seemingly safe haven – one that is important because it commits participants to no actual choice or action, and thus an issue to which participants can (safely) return to again and again in the discussion. The topic of safety in these kinds of discussions, and this has been noted too by Dekker and Nyce (2014), is often both an instrument and a venue for social dynamics and power issues (whether this is acknowledged or not). Only when stakeholders go on to discuss how to preserve an ostensibly safe aviation system which includes UASs, then those involved find out – not surprisingly – that they tend to differ, often substantially, on how to achieve this: *'Everyone agrees that we need one equivalent level of safety. But then, as soon as we go one level of detail deeper, we discover that we not necessarily agree.'; 'The target level of safety … you will find out that until today, although we have been discussing that on the UAS side for years, there is no agreement yet.'*

The UAS discussions are obviously intended to establish safety in the system. However, the literature on socio-technological systems reminds us that sometimes even seemingly straightforward processes, like the establishment of safety and safety regulations, can contain within themselves mechanisms that may complicate even the most seemingly rational of human processes. Social factors like the construction and enactment of power and myth that we found here can trump rationality and science. Acceptance and fear (of the unknown), as mentioned in the ethnicity literature, can disrupt almost any attempt at an equalitarian or democratic discussion, as can, as we have argued here, any exercise of power, no matter how subtle. All these factors emerged from and, at the same, informed, the interaction of stakeholders, technology and social processes. If the aviation community stakeholders wish to create for all of us safer and more inclusive skies, they may therefore discover that the policy process this involves will be far less technologically driven than they may have anticipated. Both the values and understandings that participants bring to the table may be contested, (re)negotiated and even redefined as the process continues. Also, the decisions and end products that emerge from this process will reflect, negatively or positively, the social mechanisms described here, and by other mechanism which future research might identify. Taking a social science perspective such as the diversity approach used here can, as Giddens (1984) would argue, make these kinds of mechanisms discursively more accessible, which would enable policy and technology scholars, those who mediate for us both equality and hierarchy, to better understand how policy derives not just from some instrumental rationality, but also from some very human social processes. It would furthermore allow us to identify (and critique) the kinds of issues that policy makers often bring to the table but are not aware of.

6 Risk and safety in large-scale socio-technological (military) systems: a literature review

The paper that is presented in this chapter combines the results of the four empirical military systems studies presented in the chapters 2 till 5 with a review of the literature on risk and safety in large-scale socio-technological systems. A theoretical framework is proposed here as a consequence of this, which connects the 'New View' perspective on safety with elements of the STS literature and Giddens' structuration theory. This particular combination of literatures, it is argued, is able to handle the complexities and dynamics of large-scale socio-technological systems and can help, as such, in improving our understanding of how risk and safety in large-scale socio-technological systems can emerge from the interaction(s) between the social and the artefactual, and how both are enabled and constrained by the other.[27]

ABSTRACT – Contemporary military practice relies more and more on technology and its artefacts and seem to have become, thereby, large-scale socio-technological systems; systems in which the social and the technological are closely tied together. An important issue in these kinds of systems, especially military ones, is how to safely use this technology. This paper reviews the literature for research on risk and safety in large-scale socio-technological systems for their ability to account for the complex dynamics from which safety in these kinds of systems tends to emerge – or not. After this, it evaluates some current accounts of risk and safety in the military specifically, so as to assess the 'status' – or analytical strength – of accounts of risk and safety in this domain. More rigour is needed in evaluations of risk and safety of technology in the military so as to provide analyses with sufficient analytic strength. This rigour, it turns out, can often be found in the interdisciplinary STS (science, technology and society) literature that, until today however, does not often seem to address

[27] This paper originally appeared as an article published by Taylor and Francis in the *Journal of Risk Research* on 7 August 2015, available online: http://www.tandfonline.com/DOI/full/10.1080/13669877.2015.1071867.

risk and safety of large-scale socio-technological systems directly, and which seems to pay even less attention to risk and safety in the military.

6.1. Introduction

Imagining a world without artefacts would hardly be possible, so used have we gotten to these elements of modern society. Many people, organisations and institutions, even modern society itself, would be lost when electricity fails, water stops running and, increasingly, when internet goes down. The Armed Forces as well no longer can be described as just soldiers on horseback. The Navy and the Air Force have a long history of being technology driven. The Army, too, has become over time a technology-dependent entity with the introduction of – among other things – vehicles, artillery and recently even robotics in the operating theatre (e.g. Singer: 2009). They have developed, in other words, into large-scale socio-technological systems; large-scale systems in which the social and the technological domain intimately interact with each other and through which the one inevitably shapes the other (Ropohl: 1999). An important issue in these systems, perhaps even an ethical one given the stakes, is how to use technology in them safely and at the same time increase not diminish military effectiveness. Risk and safety should thus be considered to be core to contemporary military practices (Bakx and Nyce: 2012a) and methods to handle this should have the rigour to deal with the complexities involved.

Performing the many military tasks safely, only one of which is the waging of war, is much less straightforward in this context, however, than it seems. Technology, for instance – military or otherwise – is often seen as separated from its social environment. Because of this, issues regarding the safety of technology are sometimes treated as detached from its social domain. Such an approach neglects, however, that technology – like any other artefact – is inherently embedded within their cultural, professional, institutional and other social structure(s) and context(s) from which it emerges. The relationship between technological and social structures thus is a multifaceted one, something that can be illustrated by the issue of autonomy in military robots. Current debates about this issue simply seem to reflect some normative standards of this time by rejecting the notion of killer robots, i.e. armed robots with full autonomy to decide whether they should shoot to kill (e.g. DSB Task Force: 2012; HRW: 2014; ICRC: 2014). There is, however, more at work here than this. Social context, for example, informs these debates and thereby it helps to shape and constrain what this technology can look like and can do. In turn, however, what is technologically possible (producing full autonomy in weapon systems, for instance) informs these social structures likewise. Prevailing technological possibilities, for instance, help to shape the debates on what form these robots eventually will take. Technology and other artefacts, military and otherwise, are thus part of and are therefore operated and (in)formed by their larger social structure(s) while simultaneously the artefacts themselves help shape these structures. This socio-technological duality has in fact been found over and over again in a series of empirical studies that have recently been performed in a military context of one small European nation (Bakx and Nyce: 2013b; Bakx and Nyce: forthcoming; Bakx and Richardson: 2013).

Accounts of risk and safety in military systems obviously need to be able to deal with this duality so as to be able to handle the complexities of the contemporary socio-technological theatre. Although this paper will mainly address the complexities regarding the use of technology and other artefacts in the military, the claim that accounts of risk and safety in the military should be able to deal with the complexities involved would hold for other issues as well. The military can be said, for instance, to have a paradoxical relationship with safety in the first place, in the sense that they deploy violence sometimes – which is often equated with the 'unsafe' – to create safety. Because of this, the protection of one group in the theatre, be it specific civilian populations, NGO staff, coalition partners or one's own troops, can bring with it an increase of risk for others. This raises, of course, the moral issue of dealing with issues of risk and safety in the military appropriately. At the same time, however, complexity and a paradoxical relationship with safety, although distinct features of military systems, are not exclusive properties of these systems. Also, the literature on risk and safety in large-scale socio-technological military systems is but a small section of the total safety literature. The aim of this paper is therefore two-fold. At first, the aim of the paper is not to focus on the military as such, but to review accounts of risk and safety in large-scale socio-technological systems from the general risk and safety literature for their analytic 'strength'. What we mean by this is that these will be reviewed for their ability to account for the complexity of dynamics in these systems in general. The results of this will then be used to reflect on some current accounts of risk and safety in large-scale socio-technological *military* systems so as to assess whether they have the analytical strength to handle the complexity and dynamics of these systems.

The analytic framework that we used for the assessment of the models of risk and safety for their explanatory power rests on three pillars as it connects contemporary views on safety – often referred to as the 'New View' of safety – to literature on socio-technological analysis, and to Giddens' (e.g. 1984) theory of structuration. Before we turn to a detailed description of this framework, however, this paper starts out with a history of the concept of socio-technological systems and a short discussion of two ways to approach safety that seem to characterise today's safety literature.

6.2. The field of socio-technological systems

If technological and other artefacts are embedded in the social order, then both the artefactual and the social should be part of any analysis of technology-dependent systems. This was perhaps first directly acknowledged in the literature by the use of the concept 'socio-technical systems', i.e. systems in which the social and the technological domain are intimately entangled and can be distinguished from each other only in an analytic sense. This is what Trist, a founding member of the Tavistock Institute, where much of the pioneering work on the concept occurred, wrote about the history of the concept in 1981 (emphasis in original):

> The socio-technical concept arose in conjunction with the first of several field projects undertaken by the Tavistock Institute in the British coal mining industry. The time (1949) was that of postwar reconstruction of industry ... The ... [first] project ... approached the organisation exclusively as a social system. The second project was led ... to include the technical as well as the social system in the factors to be considered and to postulate that the relationships between them should constitute *a new field of inquiry*. ... The idea of separate approaches to the social and the technical systems of an organisation could no longer suffice. (Trist: 1981)

What Trist suggests here is that researchers of socio-technical systems thought that a reductionist view – one that leaves out context – would not be helpful when researching work and work situations. Not only the social and the technical should be considered, according to these researchers, but the dynamic and reciprocal interrelationships between those two domains need to be studied too. They even argued that this required a new field of study. Over time, many scholars have added to this literature (e.g. MacKenzie: 1990; DeLanda: 1991;

Bijker: 1997; Ropohl: 1999). Some of these socio-technical studies led to attempts, at times, to equate analytically the characteristics of humans with those of non-human agents (e.g. Latour: 1987; Star and Griesemer: 1989; Haraway: 1991; Star: 2010). While provocative, a consensus about how to study and make sense of such an analogy has, however, never been reached. The stance that we take here is that there can be no symmetry of functions between actors and artefacts, in particular because artefacts, in contrast with human actors, do not seem to have anything like intention. We do recognise though, that the merging of humans and non-humans can be analytically a valuable thought experiment, and that more overlap can occur between them than one might expect.

While Trist and his colleagues use the term socio-technical systems, we prefer – for the analysis of these systems – to use the term 'socio-technological'. After all, as Ropohl (1997) has pointed out, building thereby on Beckmann's (1777) and Marx's (1867/1988) work: 'we denote knowledge as "technical", when it applies to engineering practice [to technique], and as "technological", when it applies to [the broader] engineering science'. In short, we use the latter term here because it both includes and (in)forms the former, referring thereby not only to technical aspects such as the engineering practice and physical artefacts, but also to associated paradigms, rules, tools and procedures.

Around the same time that the Tavistock members took up the issue of socio-technical systems, the safety industry emerged as it was realised more and more that the use of artefacts not only can bring benefits, but misfortune at times as well. The next paragraph discusses how different views of safety that characterise this industry and research community can be related to the socio-technological perspective.

6.3. Two distinct views on safety

At the beginning of the twentieth century, the safety industry, like most of society, regarded industrial accidents as more or less an act of God (e.g. Amirah, Asma, Muda and Amin: 2013). Over time, this view was replaced by one that considered occupational accidents as the result of individual actions (especially failures). This is, of course, a limited view on safety and on how disaster and accidents come about. Although this particular approach directed some attention – on the surface at least – to environmental and other human factors such as long working hours and the pace of industrial production, this view has been called the 'individual hypothesis' (Swuste, Van Gulijk, and Zwaard: 2009). This was because proponents seemed in fact to focus on the individual. Today, still, variants of this particular view on safety remain popular in the field of safety. In these approaches, often pursued by engineers, regulators, but also by academics, technology is regulated through a focus on 'the machine', or on a system that consists of several machines.[28] At the same time, the social (as in human performance at any system level) is in this approach preferably separated (practically and analytically) from the artefactual, as if the social and the technological and other artefacts do not interact and share no common ground. Such a reductionist view on safety in systems contrasts, of course, with the more holistic socio-technological approach of the British researchers described above.

In the social sciences and philosophy, in the meantime, it was acknowledged that notable differences can often be seen between how processes are organised (or thought to be organised) and how these processes work out in actual settings, i.e. in normal work (e.g. Klein: 1999; Cook, Render and Woods: 2000; Dekker: 2005; Asveld and Roeser: 2009). Contemporary views on safety have developed out of concerns like these in which safety became more and more to be regarded as an inherent characteristic of how systems perform and that can only reveal itself through the analysis of the system as a whole (e.g. Rochlin: 1999; Leveson 2002; Dekker 2011a). Also, because it borrows from the complexity and systems literature, this position acknowledges how both the social and the technological domain are interrelated, not only with each other, but also with the larger system, and with other contextual factors. It also acknowledges, therefore, that these interrelations can have an effect on how (parts of) socio-technological systems are built, and the work in them is carried out. This particular approach of safety has been referred to as the 'New View' on safety, as opposed to the 'Old View' (e.g. Dekker 2001, 2006).

The 'New View' of safety, with its emphasis on whole systems and on the connection between the social and the artefactual, obviously has much in common with the position that Trist took towards socio-technological systems. If proponents of the socio-technological approach have a point – which most contemporary safety scientists believe they do (e.g. Rochlin: 1999; Leveson: 2002; Dekker: 2011a) – then classic positions that tend to view social and techno-

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28 The latter is often referred to as 'a system of systems', in which the latter 'system' refers to apparatus and technology, rather than to its broader entity.

logical (or artefactual) aspects separately and in isolation from each other can actually reduce the chances for understanding and improving safety, especially in large-scale systems. The accounts of risk and safety assessed in this review have therefore been analysed in terms of an analytic 'New View' framework that connects the social and the technological. The specifics of this framework are laid out next.

6.4. Analytic framework

As has been mentioned earlier, the socio-technological concept that the 'New View' of safety seems to be committed to provides an analytic framework that above all considers organisations as social systems while, at the same time, it acknowledges the mediating role that technological and other artefacts can have there as well. It would be helpful, however, not only to examine how practice or practices can emerge from socio-technological structures, but also the other way around, i.e. how activities within systems can produce and reproduce its social and technological structures. After all, it is 'the dynamic interplay between [systems or system] "levels" [that] leads to a whole set of different pathways of system transformation, ranging from incremental innovations to radical transitions' (Fuenfschilling and Truffer: 2014). Analysing this interplay seems therefore necessary so as to address issues of risk and safety appropriately, especially in large-scale systems.

For why this kind of approach is necessary, all one has to do is look at some of the issues involved in the introduction of unmanned aircraft systems (UAS) in the (inter)national airspace. A key assumption in this debate is that safety can be assumed in an integrated aviation system as long as the unmanned population acts according to what is currently known, i.e. as if they were manned. Over time, this particular belief led to official structures and formal rules and regulations that fall within this assumption (Bakx and Nyce: forthcoming). The assumption itself, however, has never been empirically tested, or critically evaluated in any way. What this example shows is how a particular situation can build up (and be defined) over time, i.e. how the interplay between actions and structures in systems over time – consciously or not – can result in transformations that could be detrimental to safety.

Even today, the best social and socio-technological analyses tend to focus either on structure or process. They usually seem to have difficulty accommodating (and understanding) both of them within a single analytic frame. Perhaps the only literature that can capture such interplay and at the same time the linkages between the social and the technological is Giddens' (1984) 'theory of structuration'. According to Giddens (1979, 255), 'the notion of human agency cannot be adequately explicated without that of structure, and vice versa'. In short, any analysis of change and transformation, of agency and systems, of the social and the artefactual, of risk and safety in large-scale socio-technological systems, needs 'a theory of action' ànd 'a theory of structure' which seems to fit well, of course, with the socio-technological approach mentioned before. Without them both (process and structure), it would not be possible to account for how macro-social structures, events and developments emerge and create safety (or not) on, for example, the organisational or individual level – or to consider how this works 'in reverse', i.e. from micro to macro. Using Giddens can thus be useful for the evaluation of accounts of risk and safety in complex systems especially.

Still, Giddens' theory so far does not seem to add much to the analytic framework other than what already followed from the concept of socio-technology. Perhaps more important, therefore, it is to stress the significance of yet another element of Giddens' theory: the 'duality of structure'. Giddens uses this term to describe the dual role that structure can have in systems: that of reflecting and reproducing at the same time. What this means is that actions in a system reflect at a particular moment the system in place but reproduce it at the same time (as in that these actions can reinforce the system or change it). This duality of structure is perhaps Giddens' most significant contribution to social theory. It should have a similar role in the safety science literature, we think, since it shows that structure and process, as well as the 'gap' between them, are not merely analytical constructs. In fact we might rather be dealing here with elements of social life that can be either reconcilable or not. Any analysis of risk and safety in large-scale systems should therefore address this duality of structure.

Using Giddens' conceptualisations of structure and process repurposes the concept of system through which it gives the concept of socio-technological systems, and thereby the analysis of risk and safety in these systems, more analytical and explanatory power. It also broadens the scope, as opposed to the 'early' socio-technical scholars whose category of technological artefacts mainly related to the 'machinery', of what can be defined and understood as technological artefacts. This is necessary for the analysis of risk and safety in large-scale socio-technological systems since these systems – as the series of studies in the military domain that we referred to in the introduction pointed out as well – contain not only hard technological artefacts such as machines, but also soft artefacts such as risk management tools (Bakx and Richardson: 2013), both of which can reduce safety – or not – in these systems.[29]

Now that the analytic structure used in this paper has been outlined in relation to the 'New View' on safety and Giddens' theory of structuration, this will help us assess accounts of risk and safety in large-scale socio-technological systems. For example, the kinds of issues we will consider include to what extent these accounts take into account what is defined here as socio-technological. This depends, of course, on the amount and type of *interplay* assumed between the social and the technological part of the systems they evaluate. After all, as Ropohl (1999, 59, emphasis added) put it: 'The concept of the socio-techn[olog]ical system was established to stress the *reciprocal interrelationship* between humans and machines', that one shapes and transforms the other. One-way accounts – that is accounts that consider either how humans relate to technology or vice versa – have therefore not been regarded here as adequate socio-technological accounts of safety. As a second indicator of analytic strength, accounts of risk and safety in large-scale socio-technological systems should consider agency and structure, and should acknowledge, if not attempt to account for, the duality of structure as well. A third characteristic on which the accounts of risk and safety are evaluated here is, in line with the 'New View' on safety, whether they cover a variety of system levels and whether they can acknowledge and trace the linkages among them. In the next section, we have categorised several risk and safety accounts and assessed them for which could have sufficient analytic power to address the complexities of large-scale *military* systems.

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29 The technological part of sociotechnical systems consist, according to Trist (1981, 10), of both hard and soft technological artefacts that together help 'to carry out sets of tasks related to specified overall purposes'. From his writing, it could be concluded that he considered hard artefacts as those artefacts that are present in a physical sense, while soft artefacts, can be regarded as 'the generic tasks, techniques, and knowledge utilised', a category that Orlikowski (1992) termed later 'social technologies'. However, he did not provide precise definitions and did say even less on artefacts such as rules, procedures and analytical tools. These artefacts, however, can help carry out and inform work as well.

6.5. Accounts of risk and safety in large-scale (socio-)technological systems

Both the risk and safety literature has been reviewed in this section for models that deal with both the social and the technological. Risk and safety, however, are not antonyms (Möller: 2012). Being safe, for instance, is not the equivalent of being 'risk free' (Miller: 1988, 54). Despite this, the concepts are closely related to each other, which is why both literatures are discussed here. Some would argue though that not all the literature reviewed here has been developed for analysing large-scale socio-technological systems in the first place. Our aim here, however, is not to discard any one of these approaches, but to review a substantial part of the literature – illustrative rather than exhaustive because of the size of the literature – so as to find out which literature(s) can tackle, or can at least be helpful to tackle issues of risk and safety in these systems.

Following Trist (1981, 11), who used three interrelated hierarchically informed system levels to order socio-technical accounts ('primary work systems', 'whole organisation systems' and 'macrosocial systems'), the literature has been roughly organised here into 'micro-level accounts', 'organisational accounts' and 'conceptual accounts'. Macro-social accounts have been taken up here in the latter category, that of conceptual accounts. A fourth category, 'whole system accounts', has been added, furthermore, so as to include accounts that extend beyond the organisational level but, at the same time, cannot be labelled as entirely conceptual.

Micro-level accounts

With its primary focus on psychological and physiological performance, the classic human factors and ergonomics literature provide us with many typical examples of micro-level safety accounts.[30] Although some of this research addresses both social and technological aspects, these cannot be said to be

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30 Among these, we include research on rational and naturalistic decision-making (e.g. Simon: 1955, 1972; Fischhoff: 1975; Kahneman and Tversky: 1979; Sen: 1995; Klein: 1999), human error and so-called rogue behaviour (e.g. Heinrich: 1931/1941; Reason: 1990; Kern: 2006), individual and team situational awareness (e.g. Smith and Hancock: 1994; Endsley: 2000; Endsley, Bolte and Jones: 2003; Salmon, Stanton, Walker, Jenkins and Rafferty: 2010), ergonomic issues such as eye tracking behaviour, posture and human–machine interfacing (e.g. Karhu, Kansi and Kuorinka: 1977; Wickens and Hollands: 2000; Sarter, Mumaw and Wickens: 2007), and crew communication and crew coordination (e.g. Helmreich and Foushee: 1993; Salas, Wilson, Burker and Wightman: 2006; Flin, O'Conner and Crichton: 2008).

adequate socio-technological accounts of risk and safety. Generally, this is because they either lack aspects characteristic of a bi-directional interplay with technology,[31] or they focus mainly on interplay at the level of the individual operator(s), thereby neglecting other levels and thus broader contextual, i.e. sociological processes. Also, while this research does pay some attention to issues of agency (defined as 'action') and concrete structures/situations, both are often weakly defined and the role that a duality of structure plays in shaping these interactions is for the most part neglected. Ergonomics, for instance, acknowledges that people's behaviour can be shaped (towards safe or unsafe behaviour) by concrete contexts and social structures. At the same time, however, it often neglects that these same actors generally create and recreate these contexts and structures that (help) produce this behaviour.

Some concepts of safety at this level of analysis though, often connected to the 'New View' on safety, do seem to appreciate – more than classic human factors accounts of risk and safety at least – the dynamic, interactive nature of both the environment and their research subjects and objects. Examples of this include Weick's work on enactment and sensemaking processes (1979, 1993), Neisser's perceptual cycle (1976), Hollnagel's and Woods' concept of joint cognitive systems (2005), and the concept of distributed situational awareness in collaborative socio-technological operational teams (e.g. Stanton, Stewart, Harris, Houghton, Baber, McMaster, Salmon, Hoyle, Walker and Young: 2006; Stanton, Salmon, Walker and Jenkins: 2010). Still, while these more holistic accounts can be useful in analyses of socio-technological systems, they seldom cover (or acknowledge) the system levels, concepts and linkages that other models (discussed below) do pick up. To find out what these other concepts and linkages are, let us first look at some organisational level studies.

Organisational accounts

While micro-level approaches to risk and safety often consider psychological and physiological performance, organisational level studies are usually grounded in the sociological or organisational literature.

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31 Often they describe the influence that technology can have on human performance or the influence that the human sensemaking process can have on the world including its technology, but not the interplay they have with each other.

One of the most important models here is Reason's (1990) Swiss Cheese Model, in which he focuses on what he terms latent (as in 'hidden') failures higher up the organisational level(s) and on in-depth organisational defences against accidents. Other scholars have devised models that also focus on the organisational aspects in accidents (e.g. Perrow's Normal Accident Theory (1984/1999); Rasmussen's analysis of the Herald of Free Enterprise (1997); Woods and Hollnagel's Resilience Engineering (2006)), but few have been as influential as Reason. Reason's model – and its derivatives – is still used in many of today's accident investigation processes and reports. The model has, however, been critiqued as too linear and to default too quickly to the individual, often at the management levels, to explain failure and to accommodate, for instance, 'normal accidents'; accidents in complex systems in which nobody has done something 'wrong' (Reason, Hollnagel and Paries: 2006). Even Reason himself concludes that 'models of "human error" and organisational failures [need to be] complemented by something that could be called socio-technical or systemic models' (Reason et al.: 2006, 18).

In general, very few organisational approaches seem to focus in any systematic way on the artefactual domain(s) of the organisation. Emphasising administrative and objective performance issues, technology and other artefacts such as risk management tools are seldom in this literature seen to mediate or influence system design and system performance. These organisational accounts seem to neglect therefore – like the classic micro-level accounts of risk and safety – the duality of structure; they do not say much about how issues of safety can be produced and reproduced by actors, history or context. Also, like the micro-level accounts of safety, organisational research tends to have a fixed and limited scope of analysis since the analysis normally stops at some arbitrary organisational 'outskirts' or outlier. Only few organisational studies on risk and safety take on issues such as the effects that are extrinsic to the organisation (like policies, policy-making and societal variables) can have on safety *within* organisations. When macro-social issues like these are not built into the equation, the role that both social context and the organisation play in relation to safety and safety agenda(s) is harder to pin down. Also, this limits the extent to which these studies can be regarded as a system analysis, an issue that will be discussed below. First, however, we will look at some more conceptual approaches of risk and safety.

Conceptual frameworks of risk

While most of the accounts mentioned above are published in and borrow from the safety science literature, conceptual frameworks on risk tend to emerge from the risk literature, which originates mainly from sociology, anthropology and philosophy/ethics. One exception is the psychometric approach to risk perception (e.g. Fischhoff, Slovic, Lichtenstein, Read and Combs: 1978; Slovic: 1987). Drawn from psychology, this approach defined numerous factors believed to influence an individual's risk perception (e.g. Kahneman, Slovic and Tversky: 1982). Because of the emphasis on individual cognitive processes, however, this approach has been critiqued for lacking contextual specificity and therefore analytical substance. These same issues we have seen before in micro-level accounts of risk and safety.

In a response to this, some scholars attempted to 'repair' the approach so that it extends beyond the level of the individual (e.g. Kahan: 2012). Kasperson, Slovic and Renn, for instance, have worked on 'the social amplification of risk', which suggests that 'hazards interact with psychological, social, institutional, and cultural processes in ways that may amplify or attenuate public responses to the risk' (Kasperson et al.: 1988, 177). Such developments represent a shift within the risk and safety community towards more adequate and socio-technological accounts of risk and safety. In the end, however, this approach still relies on what was once one of the pillars of the psychometric approach: rational choice theory. This particular theory assumes – even though it attempts to allow for subjectivity in risk perception nowadays – that it should be possible to achieve a 'correct' (as in objective) perception of risk, as long as the 'right' factors are taken into account. Any psychometric approach, therefore, – 'repaired' or not – still boils down to some kind of weighing of social and individual factors with the aim of achieving a kind of reliability which most social scientists today think is impossible to achieve in the analysis of any social phenomena.

Other accounts of risk, such as that of Douglas and Wildavsky (1982) on risk and culture, and Beck's (1986/1992) work on 'risk society', emerged from the sociological and the anthropological literature and reflect a social constructionist view of risk. This particular school studies primarily how our understanding of risk is embedded in (and reflects) its social or societal context. Beck, for instance, looks at how contemporary organisational risks seem to emerge from modernity and modern technology, and at their perceived unequal distribution within certain aspects of contemporary society. Beck connects thereby the social and the technological, something that Douglas and Wildavsky do as well. None of these authors, however, have had much to say about how to connect macro-social aspects of society to micro-level accounts of organisations.

A similar criticism concerns the many ethical discussions of risk and safety. Having surveyed the mainstream ethical literature on risk, Hayenhjelm and Wolff (2011, 21) acknowledged, for instance, that standard approaches to ethics do not 'deal satisfactorily with the uncertainties of life and action'. One area in ethics that seems to counter this tendency – but is still evolving – is the field of applied ethics. This literature, especially that on the ethics of technology, attempts to address real-world situations such as the mediating role of technology in society (e.g. Ihde: 2002; Verbeek: 2006). As such, this literature seems closely related to the social construction of technology literature, a field that studies how technology and technological artefacts become embedded in (and reflect) their social contexts. Both study not only the interplay between the social and the technological, but connect, at the same time, the system levels involved. Both literatures, however, tend to touch on safety in the passing only. Risk ethics, on the other hand (e.g. Roeser, Hillerbrand, Sandin and Peterson: 2012), part of the field of applied ethics, does discuss safety issues at length, but this literature tends to lack a theory of action and structure. Also, and this we have seen with many of the other accounts described here – it seems to have difficulty with how to link macro-social aspects to the micro-levels of analysis.

In sum, much of the conceptual literature and models reviewed here tends not to reflect in any systematic way on mutual interactions that inform the social and the technological in the systems they study. While the conceptual frameworks here may sometimes address issues of structure or process, they pay little or no attention to the production, reinvention and reproduction of structure, and/or do not acknowledge any theory of action or social action itself. As a result, they often lack explanatory power, especially when it comes to how aspects at the macro-social level link to safety efforts at the organisational and micro levels (or vice versa). Indeed, with the partial exception of the social constructionists and the field of applied ethics, the frameworks presented here all fail to cover the varieties of system levels and their interrelatedness. The result is that many of them seem unable to adequately assess risk and safety in large-scale socio-technological systems. Accounts that do attempt to cover a range of system levels are taken up next.

System accounts of risk and safety

Rather 'complete' evaluations of risk and safety in socio-technological systems – as in accounts that acknowledge different system levels and their interrelatedness – can be found in the social science, STS and system safety literature. STS is a field of literature that focuses on the connections between science, technology and society, which can be positioned at 'the intersection of work by sociologists, historians, philosophers, anthropologists, and others [that study] the processes and outcomes of science … and technology' (Sismondo: 2010). The STS literature, thus interdisciplinary in nature, includes the work of the ethicists of technology described earlier here.

A typical systems account of risk and safety is Perrow's (1984/1999) work on 'normal accidents'. According to Perrow, unexpected high-impact accidents are almost unavoidable ('normal') in certain high-risk industries (e.g. the nuclear industry) because of the complexity of the system and the tight coupling of events that exists in those industries. Perrow, however, regards risks, much like Beck, as something that can be linked incontestably to technology alone. System approaches to risk and safety that address other system dynamics as well include Leveson's (e.g. 2004) STAMP accident analysis tool that rests on control theory, and Rasmussen and Svedung's (2000) 'acci map tool' for accident analysis.[32] Both tools and the analyses that emerge from them, however, seem to equate much of their graphical representations with more or less static systems states and do not seem capable, therefore, of displaying anything like process or action, let alone articulate 'a theory of action'.

A more dynamic account in the system safety literature is Dekker's work on drift into failure (2011a), in which he focuses on how interactions and interdependencies within systems can drive systems eventually to collapse. Dekker does not give his readers a specific conceptual model of risk or safety. Rather he uses systems and complexity theory, together with a social constructionist perspective,

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[32] A graphical representation – a cause–effect chart – displays the various causes and contributing factors that emerge from an accident analysis. These representations are meant to portray, cover and explain – according to Rasmussen and Svedung – the system as a whole, including all micro to macro levels. However, these maps tend to reduce social events and their interactions to something very close to common sense (folk) reduction of both society and causality. A discussion of the role that representations like these have in the safety literature could be a dissertation length study of its own.

to present what he believes a more adequate understanding of what system safety can be. Dekker's argument is strengthened because he uses something very much like the concept of a duality of structure discussed earlier. An example of this is in Dekker's discussion of the (2001) Enron fraud scandal which 'grew out of a steady accumulation of habits and values and actions that began years before … smart people had become part of a complex system of their own creation' (189–200). What Dekker grasps here is that people's actions at Enron were informed by what was regarded as normal – accepted – at the time [i.e. they reflected the structures in place], but that it had been these same actions which had worked and reworked that structure before into what it became at the time of Enron's collapse [i.e. normal and accepted].

Dekker's work is often grounded in convincing empirical case histories. Another example of such empirical work is Vaughan's research (1996) on the 1986 Challenger disaster. Although Vaughan focuses on the NASA organisation, her account is much more than an organisational analysis. In line with Giddens and Dekker, she connects here micro and macro levels. She describes, for instance, the institutionalised normalisation of deviance within the NASA organisation,[33] which eventually led engineers to underestimate the effects that O-ring irregularities could have and how this process of normalisation itself was a by-product of macro-level budget decreases over time that reflected the changing political climate in the US. Vaughan's work belongs in fact not only to the system safety literature, but also to the STS literature that has produced other empirically grounded whole system accounts of socio-technology. Mol (2002, 5), for instance, describes how various objects in medical practice such as the body, the disease, the technology and physicians and technicians relate to each other and can result in a multiplicity of meanings while, at the same time, all the objects involved somehow can 'hang together', in often temporary – ad hoc – arrangements and alliances. Like the early socio-technological researchers and New View safety proponents, STS scholars believe that meaning and use of technological artefacts cannot be equated in any straightforward way with the physical characteristics of technology itself (e.g. MacKenzie: 1990; Bijker: 1997). So far, however, with the exception of Vaughan and some others perhaps, this STS

[33] In this case, the normalisation of deviation refers to a local progressive revision of what were seen as legitimate rules and procedures regarding what was safe within the NASA organisation.

literature does not seem to address issues of risk and safety explicitly. Risk and safety, therefore, tend to be residual categories in this literature.

Summary

In this section, we have categorised risk and safety accounts and evaluated them according to the framework set out at the beginning of this paper. In particular, we assessed their analytic 'strength' and their potential usefulness for the analysis of risk and safety processes in large-scale socio-technological systems. From this review, it follows that systemic accounts of risk and safety are valuable because they are able to potentially connect all the social domains in which technology plays a part. For instance, they attempt to connect macro-level events to micro-level empirical dynamics and vice versa. Also, they are able to pick up and analyse the kinds of interactions that occur between different domains, like the social and the technological. Not all system accounts, however, acknowledge – let alone attempt to take into account – the role the duality of structure can have in social life. Only one literature – in which, however, risk and safety is not a major interest – seems to be able to fulfil most of the analytic requirements we set out earlier regarding system, structure and agency: the STS literature. With this in mind, the next section will focus on accounts of risk and safety in large-scale socio-technological *military* systems.

6.6. Accounts of risk and safety in large-scale (socio-)technological military systems

As has been set out at the beginning of this paper, one of the aims was to evaluate current studies of risk and safety in large-scale socio-technological *military* systems specifically for their analytical strength. This section, therefore, evaluates some of this research based on the results in this paper so far. First some theoretical accounts will be discussed, followed by some empirical ones. From what we have seen so far, it is expected that empirical accounts of risk and safety that borrow from the STS and systems theory will address the dynamics that are inherent in these large-scale systems best.

Theoretical encounters

With this paper's results in mind up to here, it seems natural to turn to the STS literature first. One well-known socio-technological analysis from this literature that addresses the military domain and, above all, issues of safety in this domain – although not directly – is MacKenzie's (1990) work on the concept of accuracy in US nuclear missile guidance technology. In this study, MacKenzie addresses both the social and the technological, as well as issues like agency and structure, and the duality of structure. He argued, for instance, that national military strategies of force are not necessarily altered by decisions from above – as many believe – but rather emerge from a co-evolution of bottom-up and top-down activities. As an example of this, MacKenzie shows how the US Air Force, during the Cold War at one time, managed to impose upon the US a particular nuclear strategy. Informed by what missile guidance accuracy was thought to be possible at the time, and in an attempt 'to forge a convincing strategic rationale for the manned bomber' (202), the US Air Force worked hard to impose a nuclear strategy premised on limited war that required a high-accuracy counterforce capability, rather than on an ultimate deterrence capability that would have favoured the US Navy's ballistic missiles fleet.

Another STS analysis of a large-scale military system which discussed safety, albeit implicitly, is Law's (2002) socio-technological analysis of the design, development and the cancellation of a UK military aircraft, the TSR 2. Explicitly or not, safety is, of course, part of almost every decision regarding new aircraft design since the introduction of any new complex military technology brings with it an increase of uncertainty, complexity, knowledge shortfalls and spontaneous adaptations. This can also be seen in Demchak's analysis of the A1 Abrams tank (1991), in which she evaluates the organisational consequences of contending with the complications created by this new complex weapon system. In contrast with Law, Demchak does deal explicitly with issues of risk and safety. However, she seems to emphasise only one side of the equation, i.e. the influence that complex technology and its artefacts have on the organisational structures, ignoring – apparently – how these same structures contextualise(d) and inform(ed) this technology and the artefacts themselves.

A more philosophical account of military technology is DeLanda's *War in the Age of Intelligent Machines* (1991). Here he traces out the history of several military applications of artificial intelligence as part of his larger theoretical project on how he thinks that cognitive structures have become transferred from man to machine. At every such step, he argues, 'we will find a similar mixture of new roads to explore and new dangers to avoid' (231). DeLanda, at times, however, seems to draw almost reductionist distinctions between machine and society: 'just one more example [open source technology] of the fact that the forces of technology are not easy for institutions to capture and enslave' (230). Also, he does not seem to spend much time looking at the role that social process or the dynamics of structures play in this transfer between man and machine. The result is that it becomes almost impossible for DeLanda to explore symmetries and accompanying entanglements that occur between the social and the technological in modern society.

In contrast to these other authors mentioned so far, with the exception perhaps of Demchak, Coker (2009) brings the issue of risk (and, to a lesser extent, safety) to the fore in his analysis of modern, large-scale socio-technological military institutions. In this analysis, Coker argues that risk should be regarded as a structural feature of modern society. He seems to limit his analysis, however, – like Beck – to the macro-social as he mainly ascribes features of contemporary military conduct to more abstract notions, such as complexity, uncertainty, resilience and anxiety. In his more recent work, Coker (2013) attempts to correct this by connecting changes in thinking about and fighting wars to a re-evaluation of technology and to a shift in our relationship with this technology, both functionally and performatively. He still does so, however, using a relatively rudimentary set of assumptions about social order and modern society.

In sum, the accounts of risk and safety from the STS literature reviewed here seem to be of sufficient analytical strength as they treat the socio-technological military systems often according to the principles that have been defined in the theoretical section. The topics of risk and safety, however, – as we have seen in the former section as well – tend to be treated indirectly or implicitly in this literature. Studies that do address risk and safety in the military, on the other hand, often seem to be analytically weak. They do not, for instance, explore macro–micro connections, the duality of structure and/or have a tendency to reduce causality to one, single direction, i.e. from technology to organisational and other social structures. These theoretical accounts can thus not be described as careful socio-technological accounts for how risk and safety can emerge in large-scale military systems. The STS perspective, therefore, seems the most promising way to 'attack' issues of risk and safety in any socio-technological system, including the military. Whether empirical accounts on risk and safety of military technology also have such an analytic rigour will be taken up next.

Empirical encounters

While most military accident reports remain inaccessible to researchers, external reports often are not classified. One such report is the Haddon Cave report (2009) on the 2006 loss of a Royal Air Force reconnaissance aircraft in Afghanistan that resulted in 14 fatalities. In military circles, this report is seen as one of the most detailed, exhaustive accident accounts that any military has ever issued. Although the report goes into detail on things like engineering practice, work and risk management procedures, and risk perceptions, it mainly seems to 'demonstrate' how wrong certain people were – rather than to attempt to explain how all these elements together worked to inform the events which led to this accident. The organisational analysis chapters, for example, do not seem to connect back to any of the issues addressed in the technological chapters. It could be argued though that the report was never meant to be a scientific account of safety in a particular socio-technological system. Indeed, it does not seem to rest on any theory of socio-technological systems at all, nor does it seem to make any theoretical contribution to discussions of how safety is constructed in military systems.

One empirical account of risk and safety of military technology that does seem to be able to live up to the analytic framework defined in the theoretical section here (and strongly resembles STS technological research) is Snook's (2000) analysis of an accidental shoot down over Iraq of two US helicopters by two F-15 US jets. Snook's analysis looks like a whole-systems account because it takes into account several organisational levels (and the value they have in the US military). Also, Snook describes how technology and its associated artefacts possibly influenced actors' micro-level behaviour. He shows, among other things, how the Identification-Friend-or-Foe technology provided ambiguous signals to the F-15 pilots. In this way, Snook's analysis seems to take into account both agency and structure. Furthermore, Snook's concept of 'practical drift' has some parallels to Giddens' duality of structure – an indicator of analytic strength, as we argued in the theoretical section – because it describes how practice (as accepted by formal structures) – over time – gradually and imperceptibly deviates locally from the original set of formal procedures...until the system fails. A weak point, however, is that Snook's concept of practical drift seems teleological; drift for Snook occurs in and runs through a series of fixed phases. This, in Giddens' terms, is too causal, too linear and too deterministic to occur in or account for any kind of social process. Also, while Snook does cover several system levels, he does not spend much time looking at interactions between these levels and at the role that these interactions might have played in producing and reproducing the overarching structure(s) that led to this particular accident. Still, Snook's account comes very close to what can be called a socio-technological analysis of safety in a complex military system.

Summary

An STS perspective, it should be clear now, not only offers an interdisciplinary orientation but could also lead to more precise and analytically complete accounts of risk and safety in large-scale socio-technological military systems, especially when these accounts both 'trap' and make sense of the relevant empirical data. The STS literature, however, does not often seem to address risk and safety of large-scale socio-technological systems directly, and seems to address risk and safety in military systems even less frequently. At the same time, empirical accounts that can be found on military risk and safety can seem to be quite convincing. These accounts, so far however, generally seem to lack the analytical strength that is needed for any adequate understanding of the complexity and dynamics in these systems. There seems to be a need, therefore, to combine more frequently empirical accounts of risk and safety in military systems with an STS perspective.

6.7. Conclusion

A number of different literatures have been assessed here for their analytic 'strength' when it comes to risk and safety in large-scale socio-technological systems. This has been followed by an evaluation of several accounts of risk and safety in large-scale socio-technological *military* systems specifically, so as to be able to assess the rigour of these kinds of accounts.

What this review suggests is that accounts of risk and safety generally lack the analytical substance needed to make adequate sense of these systems. What this review further suggests is that analytically strong studies on risk and safety in largescale socio-technological military systems could emerge from the STS literature. Such accounts not only offer a multifaceted perspective, but could – above all – cover the interplay of the social and the technological domain in these systems as well as address and cross hierarchical system levels. They would, therefore, have the analytic strength to connect macro-social issues to micro-level events and vice versa. Also, they would have the potential to draw on analytic structures that resemble Giddens' duality of structure; how existing structures both inform agents' actions and, at the same time, how the actions of these same agents can produce past, present and future structures and processes. In sum, such accounts would potentially fulfil the requirements set out at the beginning of this paper. They could thus help us better understand how risk and safety in these systems can emerge from the interaction(s) between the social and the artefactual, and how both the social and the artefactual are enabled and constrained by each other. However, not many accounts of risk and safety on large-scale military systems – as far as we know – exist at this time in the STS literature. There is a need, therefore, to combine empirical, convincing accounts of risk and safety in military systems with an STS perspective. The need for such rigour will only increase as complexity and socio-technological dynamics in military conduct are anticipated to advance in the future (as with cyberwar), not diminish.

What such accounts would look like (and how they might differ from accounts from others, such as historians, sociologists and anthropologists) is still very much an unexplored territory. What is clear at this point is that to understand how safety and risk in military systems emerges from the interrelatedness between the social and the artefactual, one has to look at large-scale socio-technological military systems empirically using the proper analytic models. Such research would have to take into account but extend beyond the 'New View' of human factors and safety, as well as to incorporate best practice analysis of complex socio-technological systems. While the issues of (and the analysis of) structure and process can be very refractory, Giddens' work does allow us to write about the role both play in large-scale socio-technological systems in precise, analytically strong ways.

7 Responsible innovation in large-scale socio-technological systems: concepts from safety and system dynamics

After the military systems studies and the literature review, which together resulted in the analytic framework presented in chapter 6, the paper in this chapter will go back to the original research question, which comes down to: Can we, and how can we then, with this knowledge, further actual assessments of safety in large-scale socio-technological systems? So as to explore this, the insights gained so far have been applied in this paper to a field that is closely related to technological safety: the field of responsible innovation. This field aims to diminish adverse effects of new technologies. It turns out that the knowledge gained so far on how to handle the complexities and dynamics of large-scale socio-technological systems in real-life settings, can indeed be helpful as it seems to help take into account (and account for) the empirical dimension. Not only does such a focus on socio-technological system dynamics seem to further actual assessments of technological safety, it also seems to make related allocations of responsibility distributions more just.

ABSTRACT – The field of responsible innovation aims to protect society from adverse effects of new technologies. It attempts to achieve this, above all, by intervening in innovative processes in an as early stage as possible by promoting some kind of collective stewardship for what comes out of these processes. To understand how this works in actual contexts specifically, not only the normative-ethical dimension, but also the empirical dimension should be addressed. This paper attempts to substantiate this empirical dimension with the help of a series of studies on military technology. Based on these socio-technology military systems studies this paper proposes that responsible innovation should focus on an innovation's socio-technological system dynamics. Only by including an innovation's (future) socio-technological path dependency and by acknowledging that agency can in some sense be distributed between the social and the artefactual domain, one can become proactive rather than reactive, and one is able to distribute responsibility in more just ways over the many actors involved.

7.1. Introduction

This paper discusses how the concept of 'responsible innovation' could benefit in 'the real world' from a series of studies on safety in large-scale socio-technological military systems, i.e., how it can benefit in concrete settings from a system dynamics approach by discussing some cases of military technology. The concept of responsible innovation has recently been developed by applied ethics so as to stimulate environments that have the potential to bring about innovations that are well thought-out regarding the values that these innovations have built in. It aims to protect society, in other words, from the development of technologies that might be detrimental, either in the short or the long run.

7.2. Responsible innovation – the state of the art

Although innovations usually aim to improve human well-being or effectiveness, they can have unintended side effects. Vallor (2011) and Wynsberghe (2012), for instance, emphasized, together with many others, possible ethical consequences when implementing robots in our care systems such as the potential reduction in the amount of human contact (Sharkey and Sharkey: 2012). Other examples concern the side effects of autonomous weapons (Johnson: 2015), the privacy implications of smart electricity meters and electronic patient record systems (Van den Hoven 2013), and the effects of using nano-technology in cosmetics such as sunscreens (Jacobs, Van de Poel and Osseweijer: 2010). Responsible innovation aims to minimize these adverse effects of new technologies. As a second but related aim responsible innovation above all attempts to help distribute responsibility during processes of innovation more fairly throughout the actors involved in the 'web' of scientists, entrepreneurs, users, governments and others (Stilgoe: 2013). The overall goal of responsible innovation is thus to achieve an ethical 'upstream movement' (Grunwald: 2014) in the field of innovation. What this means is that it attempts to intervene in innovation processes in an as early stage as possible by laying upon all the actors involved – from beginning to end – some kind of collective stewardship (Stilgoe: 2013) for the effects that new technologies can have once they are applied. Responsible innovation differs, however, from the precautionary principle, which was a popular concept for dealing with innovations in the environmental sciences at the end of the 20th century. This precautionary principle required proof of safety before new technologies could be introduced (Kriebel, Tickner, Epstein, Lemons, Levins, Loechler, Quinn, Rudel, Schettler and Soto: 2001, 872). This, however, could stifle innovations, something that responsible innovation attempts to prevent. Instead, responsible innovation attempts to integrate values, norms and obligations in an as early stage as possible into new technologies by promoting, for instance, a design of technologies that does not diminish privacy, and meets, at the same time, the requirements that values such as security, sustainability, etc., bring with them.

Concerns regarding new technologies do not necessarily remain confined to the material domain. Hillerbrand (2010), for instance, addresses the consequences of using 'state of the art' modeling techniques. She highlights, among other things, the implications of putting too much trust in these numerical modeling techniques for global warming assessments. Numerical modeling techniques, she argues, can influence decisions on global warming by giving an appearance of accurateness and objectivity while in fact they embody all the uncertainties of their input parameters. Policy decisions, based on these models, can have far-reaching and real consequences for people. The height of dykes, for instance, will determine, as specified by these models, whose house will be saved and whose not. Hence, not only 'hard' artefacts (like physical technology) can produce unintended consequences. 'Soft' artefacts, such as risk management tools and assessment procedures, can produce them as well. Indeed, although often a limited understanding of innovation is applied according to Blok and Lemmens (2015), responsible innovation also concerns non-physical artefacts.[34] It thus attempts to prevent unintended, yet hard to predict consequences of hard and soft artefacts from the design phase onwards.

Responsible innovation is not the only concept, of course, that attempts to diminish adverse effects of new technologies. The concept has its roots, for instance, in the field of technology assessment (Grunwald: 2014, 16). The inclusion of non-physical artefacts by the field of responsible innovation may be distinctive between the two fields. Another distinction is that responsible innovation, especially with its second aim *to distribute responsibility more fairly throughout the actors involved*, attempts to establish a shift specifically from

34 'Innovations in this sense typically concern technical artifacts or technical systems – but ... they are not limited to the material domain – that allow us to do things we could not do before, or allow us to think about things we had not thought about before, or allow us to do familiar things in new ways, for example, do them better, faster, cheaper, and so on' (Van den Hoven: 2013).

'shaping technology' to 'shaping innovation' (Grunwald: 2014, 21). What this means is that responsible innovation attempts to shift the focus from diminishing adverse effects through interventions on the level of technologies towards possibly even earlier interventions through laying upon the actors involved the moral obligation of responsibility. Responsible innovation adds, in short, explicit ethical reflections to the early warning function of technology assessments. This addition of ethical reflections to technology assessments seems to be paramount to processes of innovation in the twenty-first century as it helps to avoid the Collingridge dilemma[35], or the 'too late'[36] of ethical guidance for innovations (Van den Hoven: 2014, 6). Also, it clearly functions as a tool for the concept of responsible innovation to achieve its aims. Responsible innovation attempts to achieve these, above all, in concrete settings as '[its] projects shall 'make a difference' not only in terms of research but also as interventions into the 'real world'' (Grunwald: 2014). A relevant issue to study in the field of responsible innovation would thus be how to optimize several (competing) values in a technology in concrete settings in which multiple agents (and stakes) are involved. This paper does not aim to solve this particular issue though. What it does aim will be discussed next.

7.3. Research aim: adding a systems-dynamics approach

The moral dimension apparently is not the only relevant dimension in the assessment of new technologies and in the ascription of responsibility for the (possible) effects of these new technologies. This is even more so because the actual development of new technologies takes place, typically, in socio-technological environments, i.e., in contexts in which the social and the technological domain intimately interact. Technological innovations, for instance, generally involve many different actors – ranging from high-level regulators to

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35 'When we can still make changes to the technology, one lacks the information about effects which only the introduction and use of the technology in society could provide, but at the moment that the technology has been introduced in society and information about its effects and morally salient characteristics starts to become available, it is often very hard to still make changes' (Van den Hoven: 2014, 6).

36 'Results [of applied ethics research] were sometimes delivered at such a late stage in the development of the issues that it could no longer usefully be employed to make a difference' (Van den Hoven: 2014, 6).

micro-level scientists and end users – that can be highly interrelated. From the dynamic interplay between these actors and their system levels, multiple pathways for innovative processes can emerge. In these kinds of environments the creation of new technologies and the actual attribution of responsibility can be considered as active and societally embedded processes. These processes, obviously, can include all kinds of complex social and socio-technological dynamics and nuances (i.e., 'messy' details) that should be empirically investigated. Indeed, the value sensitive design literature, a subset of the literature on responsible innovation that was once initiated by Friedman (1996) seems to confirm the value of this empirical dimension: 'The desired normative and ethical purchase of the research needs to draw upon an analysis of the problems that is empirically informed by a number of other disciplines' (Van den Hoven: 2014, 7). Others have confirmed this as well. So as to include both concrete contexts and ethical reflections in assessments Grunwald, for instance, suggested that:

> 'Responsible Innovation ... requires inter- and trans-disciplinary approaches. In particular, a cooperation of applied ethics addressing the moral dimension, philosophy of science taking care of the epistemic dimension and social science (STS) researching the social and political dimension as well as governance issues is needed.' (Grunwald: 2011, 12)

While such cooperation might provide some clues in the abstract, it may not provide much concrete guidance on how to integrate normative and empirical viewpoints in responsible innovation. Bringing in an STS approach (from the Science, Technology and Society literature) does suggest, for instance, that the social and the technological domain should be studied together, but this in itself is not very informative on how this can be done, especially if it is supposed to support moral inquiry. This paper aims, therefore, to provide some guidance for how researchers could address the empirical – real-life – dimension, so as to further the concept of responsible innovation. It will focus thereby on large-scale socio-technological contexts in particular, since innovations tend to emerge from these kinds of contexts. More specifically, this paper will argue, through a series of recent studies on the safety of technologies in large-scale socio-technological military systems (Bakx and Richardson: 2013; Bakx and Nyce: 2012b, 2013b, 2015, forthcoming), that the concept of responsible innovation could benefit from a focus on socio-technological system dynamics.

A focus on socio-technological system dynamics as proposed here could further actual applications of responsible innovation, as such a focus can help to make sense of empirical data in large-scale socio-technological systems. Because of this, it would have the potential to better inform ethical reflections on (future) innovations. This, in turn, could help to identify and assess the effects that new technologies can have in real-life large-scale socio-technological contexts. Also, it could lead to more just distributions of responsibility in these settings. Especially the issues 'path dependency' and 'distributed agency', the issues that have been derived here from such a systems dynamical focus on responsible innovation, can improve, it will be argued, the early warning function that responsible innovation aims for. Both path dependency and distributed agency would, above all, impel to include a notion of collective socio-technological action into the attribution of responsibility to people involved in innovations. Such a notion would enable one to consider the complexities of the socio-technological contexts that these people have to deal with in actual settings.

The technologies that have been studied in the military for aspects of safety included existing technologies such as conventional helicopters, other existing artefacts such as an operational risk management tool, and future technological concepts, in this case the full integration of unmanned aircraft systems (UAS) in the (inter)national airspace (Bakx and Richardson: 2013; Bakx and Nyce: 2012b, 2013b, 2015, forthcoming). These military-systems studies are helpful here as both analyses of existing and future technologies can add, of course, to our understanding of innovation processes. Also, safety is a key value in responsible innovation, as well as a typical example of a 'thick concept' (Möller: 2012), exemplifying thereby the intertwined elements of social-moral evaluative and technical aspects inherent in responsible innovation. Furthermore, although the studies are all on military topics, they explicate as well the concepts and principles of socio-technological systems in general, which is why it seems legitimate to extend insights gained in these studies to other domains. It seems credible, therefore, that the military-systems studies can make a contribution to the responsible innovation literature. The next section, therefore, discusses these studies and what came out of them. Also, case material from these studies has been used, throughout this paper, for illustrative purposes.

7.4. Safety analyses in large-scale socio-technological systems

Actual debates on responsibility in technology and innovation often remain restricted to its moral dimension (Grunwald: 2014), paying less attention, thereby, to socio-technological empirical complexities that people need to deal with in actual settings. A literature that could thus be beneficial for the concept of responsibility, because it explicitly addresses the empirical dimension and the complexities of actual situations, is the contemporary literature on system safety. This literature, often referred to as the 'New View' approach of safety, emphasizes how work (including innovations) is produced in actual (or 'messy') situations, rather than in ideal type settings whose ends and results can be predicted. New View approaches to safety, in short, make sure to include in their analyses of safety the contextual and empirical details and dynamics of normal, daily work from which (a lack of) safety tends to emerge (e.g. Dekker: 2005; Iedema: 2009; Dekker, Cilliers and Hofmeyr: 2011; Woods, Dekker, Cook, Johannesen, Sarter: 2010). In their research, these approaches draw on systems theory and complexity theory, as well as on social science literature. All three literatures help their researchers to include and explore the interplay of and within hierarchical system levels, as well to cross system domains. In this way, New View approaches to safety attempt to include a system's dynamics in any safety analysis. Also, they aim to capture whether and how macro-social empirical structures create safety on the organisational or individual level, and vice versa.

The studies on safety in large-scale socio-technological military systems mentioned earlier (on Apache helicopter crews, a risk management tool, and UAS), reflect such a New View approach with its sensitivity for socio-technological dynamics in concrete settings. In order to also address the aspect of socio-technological systems, these military-systems studies further include notions on structures and agency by the sociologist Giddens, and elements of the STS literature. What these military-systems studies have brought to the fore, furthermore, as a result of this combination of literatures, are some valuable insights for how to empirically study large-scale socio-technological systems. A position is needed, according to these studies, which addresses the interrelations between the technologies studied and the actual social processes in which these technologies are embedded; how both can inform and constrain each other in real-life settings. Also, one should not only address but also cross hierarchical system levels, so as to be able to connect macro-level events to micro-level actions and vice versa. Such a position would, at least, address the complexities and 'messiness' of real world socio-technological interactions. This is important as one consistent result of the military-systems studies is that safety issues – or at least how people think about these safety issues – appear to emerge cumulatively but in no predefined ways from their socio-technological contexts. One example of this was how a friendly fire incident with an unmanned aircraft system (UAS), in this case a drone, could be traced back to low quality imagery (sensor technology), which in turn could be connected to macro level dynamics such as a series of decisions regarding design, cost and implementation of war equipment (Bakx and Nyce: 2012b). The Predator UAS, after all, entered the US military service as a reconnaissance tool, but was repurposed quickly thereafter for targeting purposes without, apparently, building in the necessary accompanying accuracy in targeting imagery. Another study showed that the effects of having two pilots in a crew in an attack helicopter can only be understood when contextual issues at both the micro-level (including, in this case, the cockpit screens via which the pilots can share information with each other) and at the macro-level (such as the unit's training structure and social climate) are taken into account (Bakx and Nyce: 2013b). In yet another study it was revealed that risk assessment outcomes, at least partially, depend on how and for what purpose the risk management tool used for the assessments was initially designed (Bakx and Richardson: 2013). A fourth example concerns the social dynamics and power issues involved in the debate about whether or not to allow military UASs as additional users of the (inter)national airspace structure. These dynamics were both informed and constrained by structures, procedures and technologies currently known and accepted in manned aviation, so it appeared, rather than by specific details of UAS and UAS technology (Bakx and Nyce: forthcoming). Knowledge on manned aviation alone, however, could of course never fully determine how a future airspace with UASs as additional users would look like.

In the cases mentioned here, the social and the technological realms are so entangled that any possible distinction between them is only an analytical one. The importance of this entanglement for system analysis was first discussed by the Tavistock Institute (Trist: 1981), and later adopted by New View approaches of safety (e.g. Dekker: 2004; Leveson: 2004; Rasmussen: 1997). Giddens (1984), at the same time, enabled researchers to approach socio-technological issues with his 'structuration theory' in which he emphasises that any adequate system analysis should address both structure and agency in systems since, because of their entanglement, they both shape and constrain each other.[37] One particular element in Giddens' theory, what he calls 'duality of structure,' is of particular importance to socio-technological studies (Bakx and Nyce: 2015). With this notion it is possible to describe how complex socio-technological dynamics can emerge in and from existing socio-technological systems in the first place: current structures not only shape events and activities between and of agents within a system, but can at the same time reinforce themselves (as in that they reproduce the system as it is), or enable new ones to emerge. The historical dimension thus seems important, which is where the STS and system safety literature could make an important contribution, as Giddens has paid little attention to this in his work. The military-systems studies on safety, in sum, conclude that the literature on socio-technology analysis, Giddens' structuration theory, and the New View of safety are all relevant for the analysis of safety in large-scale socio-technological systems. In fact, what these studies hold is that any evaluation of safety in large-scale socio-technological systems should include an analysis of the socio-technological dynamics according to the principles put forward by these literatures if we are to understand how safety is established in these systems (Bakx and Nyce: 2015).

What can be gained from the military-systems studies reviewed here are two important, closely related issues for the assessment of safety in any large-scale socio-technological system (and in fact for the assessment of any 'thick' concept in these kinds of systems). The first is that safety in these systems – or lack thereof – has a complex path dependency; safety apparently emerges from its socio-technological context in a way that is not always easily predictable. The second is that (a lack of) safety emerges from a strong interplay between the social and the technological domain in these systems. The relevance this has for the concept of responsible innovation will be discussed further on. First, how-

[37] Structures refer here to the rules and resources that a system starts off from at a particular moment, such as how both hard and soft artefacts, but also patterns in social relations – or conventions – can shape and constrain activities and transformations in systems (e.g. those forces that help create risk management tools as they are, or those that define the norms according to which future airspaces will be regulated). Agency, on the other hand, refers to those that can mobilize these transformations.

ever, some additional reasons to focus on system dynamics, when it comes to innovation, will be addressed.

7.5. Dynamics in processes of innovation

So far, this paper has focused mainly on the relevance of socio-technological system dynamics for the study of safety, or any other value of interest, in large-scale socio-technological systems. The process of innovation itself provides, however, additional reasons why a focus on system dynamics would be beneficial for the concept of responsible innovation.

A first reason would be that a focus on system dynamics could help to map effects that a particular technology could have in the world, and the agents involved, especially in cases in which innovations have not yet been (fully) realized. As Jacobs et al. (2010) have pointed out it is not possible to assess any direct effect as long as the technology or other artefacts are simply not there to be studied. At the same time, waiting for the effects to substantiate in reality would not be an option since some of the effects (unknowable often, on forehand, which ones) may be irreversible (Collingridge: 1980). Also, this would be against the very essence of the concept of responsible innovation, which aims at the anticipation and amelioration of adverse effects of an innovation in an as early stage as possible. A focus on system dynamics could help here. As has been argued in the previous sections, system dynamics could help us to better understand the micro-macro connections in actual situations. Such a focus could thus help to assess how actions, decisions and other events at the societal, micro-, or any other hierarchical system level, can interact with each other across these levels. Also, it would help us to understand how and through whom these interactions are to be expressed, as particular effects in the world. A focus on prevailing system dynamics could thus help to identify and anticipate at least some of these effects and the agents involved in future scenarios, even when the actual technology or artefact is not yet available.

An example of this is the early identification of power, anxiety and fear during a study on the anticipated integration of military UAS in the (inter)national airspace (Bakx and Nyce: forthcoming). Macro-social aspects in this study appeared to work out as effects in the world, both at the individual and the macro level. The many possible pathways that UAS technology can take, for instance, combined with the anticipated capabilities these unmanned systems may gain in the future, appeared to lead to fears and anxiety about personal safety and jobs. Current conventions in airspace structure and regulations, on the other hand, resulted in, among other things, the manned aviation sector to establish and maintain regulations that favoured that sector from the beginning of these discussions. These mechanisms, revealed in this case by a focus on socio-technological system dynamics while the innovative process was still ongoing, would have been difficult to identify otherwise. In particular anxiety and their effects would probably have disappeared (making it almost impossible to measure them), once UAS technology would have been implemented. After all, it is often the absence or anticipation of a future technology that brings uncertainty, through which feelings of fear and anxiety can be triggered (cf. Roeser: 2014). What this example illustrates, therefore, is that especially emotions and feelings can be easily overlooked because of their temporary nature. Also, they are often taken to be irrelevant or irrational factors (cf. Sunstein: 2005). Following Roeser (2006, 2012) however, emotions and feelings can be important signals for moral values being at stake in potentially risky innovations. Both understanding and responding to system dynamics could, therefore, provide valuable input for the concept of responsible innovation, and thereby, perhaps, clues for more responsible, more moral, innovation.

A focus on system dynamics could also help to study day-to-day developments in (the use of) commonplace technology and artefacts. One example of this can be found in the study of Apache helicopters crews in a European unit. In this study it was found that a particular disability in flying skills in the unit had remained unnoticed for a long period of time (Bakx and Nyce: 2013b). It turned out that for a decade, a large number of the unit's pilots had barely been trained in changing flying profiles from high to low and vice versa, due to step by step changes in training and flying practices. The result was that these pilots often lacked the skills and proficiency to identify trouble that could emerge during these changes. Also, once such trouble had been identified, pilots were not always able, because of this, to take over the controls from the other pilot effectively. The older group of pilots, however, who now formed the unit's management, had not realized these consequences because this group had been changing profiles all the time during their initial training and in the years thereafter. Sensitivity for system dynamics could, perhaps, have helped to detect this earlier. A decrease in capabilities to change flight profiles, after all, emerged here as the cumulative effects of system dynamics, in this case some small changes over time in the training programs and the missions flown, combined with some natural dynamics of an evolving unit. A continuous assessment of such on-going developments and the interactions between them could therefore have helped to identify beforehand rather than in hindsight some of the underlying socio-technological mechanisms that led to these pilots' problems.

Since a focus on system dynamics can help to evaluate and identify positive and negative elements of on-going processes, such a focus can, perhaps, help to include also 'disruptive' innovations and spin off projects within the scope of responsible innovation. This is important because, as the discovery of penicillin and x-rays have shown, it is difficult to foresee what will be regarded as an innovative technology or artefact (and what will not). One might therefore have been working on an innovation in the past without, however, having been explicitly aware of this at the time. Because of this important windows of opportunities to intervene may have been missed. In a similar way but for different reasons this could happen as well in the case of spin offs projects. These projects, after all – anticipated or not – could result from increasingly rapid innovations these days in technology. Also, such innovations could come about during the use of a certain technology rather than from some kind of preordained plan that starts from scratch with a design phase. Unmanned aircraft reconnaissance systems, for instance, have at one point been turned into targeting systems, something that they were never originally designed for. Such innovation paths often proceed unnoticed (partially at least), or are expected to proceed (initially at least) in another direction. Modeling, in these cases, at least as engineers conventionally carry this out, therefore, could not pick up issues like these. Also, predicting the mechanisms that innovations might emerge from would be difficult since no one can tell, in advance, which mechanisms will – in hindsight – be the significant ones. Still, attention for such mechanisms might provide a chance to identify at least some of them, giving a clue thereby, at least, about some of the possible consequences to anticipate. As well, without an intellectual strategy that can capture such mechanisms at all, it could be too late to assess or ameliorate the effects of some technological developments anyhow. A focus on system dynamics would therefore be beneficial, not only for the study and assessment of known projects of innovation, but also for the early identification and study of elaborations and spin off projects. How this could be done, will be discussed in the next section.

7.6. Path dependency and distributed agency

The concept of responsible innovation can benefit from the insights gained in the series of military-systems studies on safety discussed here. Recollecting from this discussion, what these studies on large-scale socio-technological military systems point out is that, in line with Giddens' structuration theory (1984), any evaluation or assessment of (the effects of) innovative technology and other artefacts should address and account for at least two things:

- Effects in the world such as safety emerge from and effect their socio-technological contexts and
- In socio-technological systems social and technological aspects can be distinguished from each other only in an analytical sense.

What these considerations suggest is that any study of an innovation's possible effects in the world and the attribution of responsibility over the actors involved, both in hindsight and when looking forward, should include the innovation's socio-technological path dependency. In other words, any such analysis should include an analysis of the historical/future system dynamical context from which the technology (could) emerge(d). What these considerations suggest furthermore is that these analyses should include also, in these complex socio-technological contexts, the concept of distributed 'agency.' After all, if new technologies indeed tend to emerge from socio-technological contexts in which the social and the technological domain can be distinguished from each other in an analytical sense only, then technology can be so apparent in a system that it can be seen in a sense as having some kind of agency. As a result of this, as we will argue in the remainder of this paper, one should take into account, both in the assessment of possible effects, and in the distribution of responsibility over the actors involved, the ethical significance of the artefactual domain. In sum, any inquiry of an innovation's effects of the world and the ascription of responsibility among actors should thus be considered both context and artefact dependent. The concepts of path dependency and distributed 'agency', which are obviously related to each other, can help with this and will be discussed in the paragraphs below, along with a discussion of their relevance.

Path dependency

Innovation processes can involve many different actors in the process that – consciously or not – take any number of decisions about this process and what comes out of it. In such a process, like in any social process, the actors and artefacts involved can – up to a certain degree – both shape and constrain each other. Also, many decisions will – in hindsight at least – be interconnected: 'whereas traditional ethics reckoned only with local and noncumulative behaviour, our modern engineering has [it is believed] unprecedented and *cumulative* influences on multitudes of people' (Bowen: 2009, 7, emphasis added). Because of these interdependencies all these decisions, some seemingly insignificant when considered in isolation from each other, can be weakened or amplified throughout the system as it emerges in unpredictable ways: 'That is the sort of *path-dependency* that can help produce drift into failure' (Dekker: 2011b, emphasis added).

Safety and other effects in the world thus tend to emerge from their socio-technological contexts in which social and technological aspects are intimately intertwined. Socio-technological systems, to put it otherwise, have a socio-technological path dependency: 'their past, and the past of the events around them, is co-responsible for their present behaviour' (Dekker et al.: 2011b). Any assessment, therefore, of an innovation's effects in the world should take history into account. This, however, can be difficult when the objects of analysis, the effects in the world, are not physically there yet, as is usually the case with almost any kind of innovation. What looking at these issues can add to the concept of responsible innovation though, as has been illustrated in the military-systems studies on safety, is that it enables one to focus not so much on the eventual effects, but rather on the prevailing socio-technological system dynamics and mechanisms that tend to produce and reproduce these effects in actual situations. In the case of future UAS integration, for instance, it is unknown at this time how safe this will be. At the same time though, the study showed that it is possible to reveal at least some of the dynamics in this specific socio-technological context that contribute – or not – to safety in the future (Bakx and Nyce: forthcoming). Based on this analysis, one could pro-actively monitor these dynamics on a daily basis so as to identify possible innovative twists and spin offs – and their possible effects – from an early stage onwards. It is the assessment of this kind of historical path dependency, i.e., the assessment of the contextual socio-technological system dynamics, which STS scholars have largely focused on.

Path dependency, however, with its focus on history – or future pathways in the case of looking forward – emphasizes something else as well: innovations usually involve, over time, a large number of different and interdependent agents. These agents can range not only from scientists through designers to end users, or from lay people through experts to governments or NGOs, but perhaps even from social to technological agents. This wide array of agents that can be involves in the development of new technologies leads us to the next issue: the distributed agency of socio-technological systems.

Distributed 'agency'

Socio-technological systems, the systems from which innovations tend to emerge, are complex because their behaviour results from the interaction between components rather than from the fundamental or intrinsic characteristics of the components themselves (Cilliers: 2005). It follows then that in these systems agency can be considered as distributed. After all, a central feature of complex systems is that 'the knowledge of each component is limited and local' (Dekker et al.: 2011b); it is not possible to assemble all relevant knowledge of a system with only one single person – or machine. System components thus rely on each other (interdependency) since their individual capacity to fully grasp the system they are part of is inherently 'bounded' (Simon: 1955). The concept of responsible innovation acknowledges this – in the social domain at least – and aims to distribute responsibility accordingly among the actors involved.[38]

Technology, however, is often considered these days to obtain 'ethical significance' also, because of its centrality in and impact on modern society (Jonas: 1984, 9). The low-hanging overpasses on Long Island's are a well-known example of this. According to Winner (1980), these overpasses had been designed such that they would discourage public buses to drive into the 'middle' and 'upper' class areas in the New York County. The overpasses, in short, seem to be value-laden, i.e., they seem to have some kind of 'morality' built in – in this case a despicable morality with racist implications, be it intentional or not. Technology and other artefacts, in other words, cannot be regarded as something that

[38] 'RI ... distribute[s] this responsibility throughout the innovation enterprise, locating it even at the level of scientific research practices' (Fisher and Rip: 2013, 165)

would 'favour no particular set of cultural values' (Ess: 2008); as inherently neutral.

Because technology and other artefacts are not neutral, some scholars have argued that they can possess some form of agency (cf. Verbeek [2010]; but see Peterson and Spahn [2011] for a critical discussion). This is in line with insights from other scholars who argued also that agency and values are often embedded in and distributed across actors, artefacts, rules, and routines (e.g. Hutchins: 1995; Callon and Law: 1997; Garud and Karnoe: 2005). With this it is not meant, of course, that technology or any other artefact should be regarded as moral agents, since they lack 'moral autonomy' (Leveringhaus and De Greef: 2014; Peterson and Spahn: 2011). However, technology and other artefacts can obviously impact a human's agency and they do entail values. The risk management tool that had been studied in the series of military-systems studies discussed here appeared to favour, for example, organizational agreement and solidarity over accurateness in risk assessments as the tool appeared to obscure, by design, differences in risk perception (Bakx and Richardson: 2013). Not much imagination is needed to see that such a built-in preference in military risk management tools can be highly consequential for the units and individual soldiers that are subject to the decisions that may follow from these tools.

Ascribing ethical significance in this way to the artefactual domain has implications for inquiries and research into responsible innovation, especially when considered from a system dynamics perspective as such a perspective would not just point this significance out, but would actively engage in trying to understand how such 'agency' would propagate throughout a system. Ethical significance, for instance, does affect which effects can materialize in the world, how responsibility is thought about, and therefore also how one eventually distributes responsibility over the 'web' of human agents involved such as designers, constructors, advisors and end users. Understanding the non-neutrality of risk management tools could therefore help to assess the effects that such tools can have. Also, one could say that those that design these risk management tools bear some kind of responsibility, at the least, for the significance that these tools can have, and thus for the decisions and consequences that follow from them, even if it was not their intention to build these in in the first place.

The distribution of 'agency' over the social and the technological domain should thus be included in any assessment of innovative technology, its effects in the world, and the attribution of responsibility to the actors involved. Also, responsible innovation should acknowledge, more than is currently the case, that innovations take place in a context of collective socio-technological action in which actor, activity and effect are closely interrelated. System dynamics approaches can contribute for important insights as they can make people that deal with responsible innovation more aware of such complexities and interconnections.

7.7. Conclusion

The concept of responsible innovation attempts to protect present and future communities from unintended, but above all unwanted, consequences that new innovations can bring about. It further aims to distribute responsibility for these consequences fairly over the myriad of actors that can be involved in those innovations. Such an approach is, of course, justified, considering the severe impacts that some of these innovations can have. So as to achieve these two aims, however, stressing the moral or normative-ethical dimension would not suffice. A multidisciplinary approach is necessary, in which the empirical dimension is addressed also, so as to inform moral inquiry.

Based on a series of socio-technological studies on safety in the military some guidance has been provided here for how to address the empirical dimension. The value of a focus on socio-technological system dynamics for the concept of responsible innovation has been pointed out here. Innovations and the possible negative (and positive) effects that these innovations can have in the world emerge, after all, from these dynamics. Addressing the empirical dimension from such a focus would therefore help to make sense of the empirical data. It would thus help to make sense of the contextual details and dynamics of how new technologies come about in actual settings.

A focus on system dynamics could be beneficial in the intervention in innovative processes for other reasons as well, so has been argued. Perhaps the most important one is that waiting for effects in the world to materialize would be too reactive a solution. Other scholars have emphasized this problem of reactivity as well. This paper, however, has argued that a focus on an innovation's socio-technological dynamics can provide for important insights on how to become more proactive in this sense. Such a focus, it has been argued here, can enable us in gaining foresight in innovative processes – up to a certain extent at least – because it can provide information on those mechanisms from which future scenarios tend to emerge. Also, such a focus would enable us to monitor for possible unplanned innovative developments and spin offs, and, at the same time, to assess – not predict – their possible effects in the near and farther future where conventional modeling would not work.

Gaining an adequate understanding on an innovation's socio-technological dynamics is, however, not so easy to achieve. Two considerations have therefore been proposed here, based on the military-systems studies, to substantiate the empirical dimension of responsible innovation. In line with the New View approach on safety, the STS literature, and Giddens' structuration theory, the first consideration includes a forward-looking attention for an innovation's path dependency. The second includes the acknowledgement of the distribution of 'agency' in socio-technological systems over not only the social but also the technological domain. Taking these two considerations into account could help to identify and assess possible adverse effects of innovative technology in an as early stage of innovation as possible. This is because attention to these issues would raise sensitivity regarding socio-technological system dynamics, and thus regarding the emergence of the unpredictable. It would also raise attention for the role that history plays in innovation processes. All this could aid actors in being or becoming moral and responsible agents in the innovative process, perhaps even in cases in which the innovation was not deliberately planned for. At the same time, by taking the entanglement of the social and technological domain into consideration, the context of collective socio-technological action can be acknowledged. This specifically would enable the ones involved to identify 'agency' with technology in their historical and forward looking analyses, which in turn would enable them to distribute responsibility for innovation effects in the world in more just ways throughout the system. How this should be done, however, has not received much attention yet in the responsible innovation literature. System dynamics can make an important contribution here and requires, therefore, further exploration.

8 Conclusions

8.1. Summary of findings

Having finished the research presented in this dissertation, it is time to go back to the initial research objective and to see whether and how this objective has been met. So, this objective was:

> To assess large-scale socio-technological military systems in order to further actual assessments of safety in general, especially when the assessments concern the issue of technological safety in large-scale socio-technological systems.

The main issue of this dissertation is whether it has provided an adequate understanding of complex socio-technological systems, one that can actually be helpful for assessments of technological safety in these kinds of systems. A first step in this direction was to carry out a series of studies, from a contemporary perspective on safety, on technological safety in – mainly – the Dutch military (Bakx and Richardson: 2013; Bakx and Nyce: 2012b, 2013b, 2015, forthcoming). Several safety-related technological issues were covered in these studies, such as the use of a Dutch Air Force risk management tool, the concept of social redundancy in attack helicopters, and the insertion of unmanned aircraft systems in the airspace. From the inclusion of the risk management tool in these studies, it should be noted that the scope of technology in this dissertation included, following Trist (1981, 10), both 'hard' technological artefacts such as helicopters, and 'soft' technological artefacts such as risk management *procedures*.[39] In line with this inclusion, the term "socio-technological systems" has been used

[39] The technological part of sociotechnical systems consist, according to Trist (1981, 10), of both hard and soft technological artefacts that together help 'to carry out sets of tasks related to specified overall purposes'. From his writing, it could be concluded that he considered hard artefacts as those artefacts that are present in a physical sense, while soft artefacts, can be regarded as 'the generic tasks, techniques, and knowledge utilised', a category that Orlikowski (1992) termed later 'social technologies', to include rules, procedures and analytical tools as these artefacts can help carry out and inform work as well.

throughout this dissertation instead of the more commonly used "socio-technical systems" (see chapter 6 for a more extensive explanation of this).[40]

The contemporary perspective on safety, from which the military systems were studied, is often referred to as the 'New View' on safety (e.g. Wiegmann and Dunn: 2010; Dijkstra: 2007; Dekker: 2005). This contemporary perspective was chosen because classic ('Old View') approaches of safety do not tend to perform very well, generally, in dealing with the 'messiness' of real-life situations in complex systems. New View perspectives, on the other hand, generally draw on system safety, complexity theory and social science literature, so as to address the complexities of concrete settings specifically. In contrast to classic approaches, however, New View approaches, as they largely do not tend to pin themselves down to a subset of theories or modeling techniques, generally lack to provide practical applications or guidelines for assessments of safety. This dissertation attempted, therefore, not only to provide an adequate understanding of safety in large-scale socio-technological systems, but also some practical guidance for actual assessments of technological safety from a contemporary safety perspective in these systems. What these practical guidelines can look like, and whether these indeed seem to further assessments of technological safety, has been described below. First, however, the analytic framework will be addressed that has been developed in this dissertation so as to be able to generate these guidelines in the first place.

8.1.1. Developing an analytic framework

The analytic framework that was formulated has a basis in New View theory and the potential, I argue, to handle the complexities of technological safety in large-scale systems in real-world settings. In order to develop this framework, an initial understanding was needed of how to study technological safety in large-scale systems best. The series of studies in the military were used in this light to gain this knowledge. What became clear from these studies is that actual analy-

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40 While Trist and his colleagues use the term socio-technical systems, I preferred in this dissertation to use the term 'socio-technological'. After all, as Ropohl (1997) has pointed out, building thereby on Beckmann's (1777) and Marx's (1867/1988) work: 'we denote knowledge as "technical", when it applies to engineering practice [to technique], and as "technological", when it applies to [the broader] engineering science'. In short, I have used the latter term because it both includes and (in)forms the former.

ses of technological safety of large-scale systems require an empirical analysis of intertwined socio-technological system dynamics. This position was formulated based on the general finding from these military systems studies, that each of the technologies (or technological artefacts) investigated seemed to be embedded, somehow, within its larger (social) structures. Also, both these (social) structures and the technologies embedded within them, seemed to influence one another, sometimes in unpredictable ways. Examples of these findings can be found in chapters 2-5. In chapter three, for instance, it has been described how, over a period of ten years, a series of small changes in mission objectives, training hours and unit composition, among other things, had cumulatively – but unnoticed – led to a decline in certain flying skills with some members of a Dutch helicopter unit. In chapter four, another example relates to a friendly fire accident with a drone that resulted, supposedly, from an unclear "blurred" image as the imagery technology lagged behind, at the time, in the war-driven process that was going on as surveillance drones became targeting drones.

From the military systems studies it thus followed that the social and the technological domain in large-scale systems can be intricately linked. Because of this, a first step in coming to an analytic framework was to connect the New View perspective to the socio-technological concept. This concept comes from the Science, Technology and Society (STS) literature and refers to social systems primarily, but acknowledges, at the same time, the mediating role of technology and other artefacts in systems also. It sees the social and the technological domain, above all, as intimately entangled. This way, the socio-technological concept can help to grasp how safety related activities could follow in actual situations from socio-technological structures and dynamics. For an even better comprehension of concrete issues, however, it would be helpful to examine this process in reverse also; how the activities can produce and reproduce these social and technological structures. After all, it is the *interplay* between systems and system levels that, over time, can change and transform these systems, and which can lead to more (or less) safety in these systems. To handle issues like this, Giddens' structuration theory (e.g. 1984) was added to the framework as this is a respected theory in the social literature that focuses on the interplay between these activities [process] and structure in systems specifically, i.e., on the kinds of interplay that can be related to the socio-technological structures and dynamics of systems mentioned earlier.

The analytic framework developed in this dissertation thus connects the New View perspective in safety to the socio-technological concept from the STS literature and to Giddens' structuration theory. With this theoretical perspective, which combines these three literatures, it became now possible to try to account for not only how macro social structures, events and developments (such as delayed regulations for the insertion of unmanned aircraft in the current airspace) can influence safety efforts of individuals in concrete settings (for better or for worse), but also the other way around, how micro-level elements can influence structures and dynamics 'above' them. The question from here was, how could this help further actual assessments of safety in large-scale socio-technological systems? The concept of responsible innovation was chosen to explore this question, and also to provide some practical guidelines for the assessments of technological safety in these kinds of systems.

8.1.2. Exploring the effectiveness in a context of Responsible Innovation

Responsible innovation requires regular actual assessments of values in large-scale socio-technological systems – among which the value of safety – as it aims to actually anticipate and ameliorate adverse effects of new technologies. Because of this, it formed a well-suited context for validating, in a sense, the results of this dissertation so far. Before going into this concept of responsible innovation, however, it is best to go back, once more, to the military systems studies that had been used initially to explore the features of large-scale socio-technological systems. As mentioned earlier, an important finding from these studies was that technology seems to be embedded within its social structures and that both seemed to be intimately entangled. It thus followed from these studies that any inquiry of technological safety in large-scale systems should focus on the empirical socio-technological system dynamics from which safety (or the lack thereof) can actually emerge. More specifically it was concluded from these studies that any such assessment of the empirical dimension should address and account for at least two closely related issues (chapter 7):

- Effects in the world such as safety emerge from and effect their socio-technological contexts and
- In socio-technological systems social and technological aspects can be distinguished from each other only in an analytical sense.

Once this was acknowledged these two general principles were applied to the concept of responsible innovation. The results of this suggest that the insights gained from the military systems studies can indeed further actual assessments in the context of responsible innovation. This context of responsible innovation, on the other hand, delivered the concepts of path dependency and distributed agency as proposed practical guidance material for these kinds of assessments. Both findings will be drawn upon a bit more extensively below.

Furthering or not?

From the responsible innovation paper in chapter seven it became clear that a focus on socio-technological system dynamics as proposed in this dissertation can help to identify adverse effects of new technologies sooner. As such it would have the potential to create more safety. This can be illustrated with an example from the military systems studies. The Dutch helicopter unit, for instance, which has been mentioned above also, had a number of pilots that, over time and without being aware of it, lost a particular part of their flying skills (chapter 3). If in this case one would have been more sensitive for the cumulative effects that small and large changes in mission types, unit composition, and training objectives can have over a long period of time, and also for how these effects, in turn, can trigger other changes that can interact throughout the system, then perhaps this decline in flying skills would not have happened at all, or could have been identified in an earlier stage. In a similar way, friendly fire incidents with drones (chapter 4) could perhaps have been prevented with a focus on system dynamics as such a focus could have helped to identify, in an earlier stage, that imagery technology lagged behind at the time, when unmanned surveillance aircraft, in the dynamics of war, were transformed into targeting drones.

The concept of responsible innovation that was studied here includes, however, not only the assessment of adverse effects of new technologies, but also the attribution of responsibility for these effects. It attempts to do this, above all, through the development of some kind of collective (but in fact distributed) moral stewardship among the many actors involved in this process. It turned out that both the assessment of the effects and the allocation of responsibility can benefit from the focus on the socio-technological system dynamics proposed here, as this focus seems to have the potential especially to help responsible innovation in addressing the empirical dimension of its assessments and allocations. This is necessary because responsible innovation aims to intervene in concrete settings specifically. Making sense of empirical data is then needed, for being able to understand and intervene in complex (and 'messy') real-world events, structures and processes. Without this empirical dimension, responsible innovation could focus just on the moral dimension alone, which would make it difficult to "make a difference" into the actual worlds of users and technology.

Making a difference in the actual world may be even more difficult in those cases in which the technology is not yet (fully) developed. A focus on socio-technological system dynamics, i.e., on those dynamics from which these new technologies may emerge, would then be especially helpful. That is, those dynamics would then be an important empirical source as the technology itself (and its effects) is then simply not physically there yet to be studied.

Path dependency and distributed agency

Promoting a focus on system dynamics for good reasons is one thing. How to fill this in practically, so as to be able to actually make sense of empirical data in pursuit of a certain goal (such as diminishing the adverse effects of new technologies), is another. Studying the context of responsible innovation helped in this case in translating the theoretical position that was developed in this dissertation into some practical applications. The result of this was that it could be argued that both the assessment of effects of a new technology, and the allocation of responsibility for these effects, would benefit from the inclusion of both an account of its path dependency and a notion of distributed agency.

By addressing a path dependency it is meant here to include, at the least, an analysis of the historical socio-technological dynamical context(s) from which the technology emerged (or can emerge in the future). This, however, would cover only one side of the interplay in systems. Ideally, therefore, the concept of path dependency would also address how, in this process of emerging technology, the context(s) was/were affected by this technology (or can be affected by it in the future). Distributed agency, on the other hand, made it possible take into account, in this process of judging effects and assigning responsibility, the ethical significance that technology and other artefacts in large-scale socio-technological systems can have on the actors involved. Both path dependency and distributed agency seemed to help to study, this way, an innovation's effects in the concrete world, and also to generate a more just attribution for these effects.

Path dependency and distributed agency apparently provide for important additional dimensions of the theoretical position taken here. Both notions, especially when combined with each other, seem to have the potential to provide some practical guidance for how to assess the empirical dimension, at least in a context of responsible innovation, and perhaps also in other contexts.

8.2. Discussion

In this dissertation the contemporary perspective on safety, i.e., the New View approach of safety, has obviously been favoured for the analysis of technological safety in complex systems over the classic position. The classic idea that technology can exist and can be developed disconnected from its environment and other entities has long passed. Technology, we know today, is embedded within and co-evolves with its social structures. Technological innovations come (and go) faster than ever, and more and more people are involved in their development, if only because in current democratic and complex societies, more people want (and need) to be consulted for a specific innovation. Also, it is possible, today, to integrate more knowledge and knowledge domains into these innovations. The contemporary literature acknowledges this, and acknowledges thus the complexities and dynamics of these large-scale systems, in real-life settings especially. Still, a sensitivity for socio-technological system dynamics, which is proposed in this dissertation, does not provide us with methods and models that would help us to predict these dynamics and complexities with absolute accuracy. It can be suggested though that even with unlimited resources, this goal of modeling processes and events in complex actual settings with accuracy, which is a conventional classic strategy for safety, is most likely not possible to achieve. Even if it would be possible to come up with accurate models these models would probably come too late to avoid at least some issues where safety is at stake because of the high speed of change.

From a New View perspective it has been proposed in this dissertation to bring to the fore the significance of socio-technological system dynamics. Pointing out this significance only, however, would not say much on how to address these dynamics in such a way that it would actually help one to make sense of real-life complexities. As a result of this, the theoretical framework was developed (chapter 6), which connects the New View of safety to the socio-technological concept from the STS literature, and to Giddens' structuration theory. This combination of literatures seems to provide, theoretically at least, the analytical power to handle empirically complex phenomena. So as to fill the gap between theory and practice, the work for the dissertation could, however, not stop there. The concepts of path dependency and distributed agency have therefore been derived from this framework, so as to provide some practical guidance for making sense of the empirical dimension. The research presented here has thus attempted to contribute to a safer world in a different way than conventional safety approaches would do. It presents a theoretical framework and some practical applications so as to further actual assessments of technological safety in large-scale systems. Both the framework and the applications would provide one not so much with more accuracy in safety predications but could help, at least, in the identification and assessment of socio-technological dynamics, so as to make sense of the empirical complexities of real-life settings.

System dynamics, path dependency and distributed agency are, of course, not concepts that are new to the safety literature. What this dissertation attempts to point out though is that it is the *combination* of concepts such as path dependency and distributed agency specifically, as I will argue here, that can further actual assessments of technological safety in complex systems. A sensitivity for socio-technological system dynamics, for instance, has been advocated here so as to be able to understand and evaluate the safety of technology in large-scale socio-technological systems. The concept of path dependency can be helpful in this because, as this has been illustrated in the context of responsible innovation, it can help one to map changes in and between the social and the technological domains that can occur over time. This in itself, however, provides not much more than a chronology. The comprehension of today's complexity in systems, however, so much is clear now, asks for more than just a chronology. The concept of distributed agency was therefore added in this case, so as to help gain a better understanding on the mechanisms from which this chronology could have resulted in the first place. Also, distributed agency made it possible to emphasize the ethical significance that technology and other artefacts can have, because of which it has the potential also, to help allocate responsibility in more just ways. It is thus the combination of concepts, as derived from the theoretical perspective that has been developed in this dissertation, which seems to enable us to understand the complexities and dynamics of today's large-scale socio-technological systems.

Although this dissertation has its roots mainly in social and systems theory, issues of morality and ethics have been discussed also. Most apparent, perhaps, this was in chapter seven where the allocation of responsibility and the ethical significance of technology in systems in this regard were addressed in the context of responsible innovation. In the other chapters, however, these issues can be found also, although implicitly often. Ethics and morality, after all, can be regarded as intrinsically linked with the value of safety, which is the main theme here.

In chapter two, one could say, the moral significance of risk management tools has been addressed. It was showed here, that risk management tools can, by design, obscure differences in risk perception because of which these differences may not get mirrored in a formal risk assessments. In chapter four, issues of morality can be identified also. There, the friendly fire case that has been mentioned earlier was analysed, in which the imagery technology for drone operators appeared to lag behind on what was needed for making a clear distinction between friend and foe. It was analysed, however, that this could in turn be ascribed to the war-driven process at that time, of transforming reconnaissance into targeting drones, something that was never anticipated for. Even more, safety issues such as these seemed to reside in the interplay between design, implementation and use, which would considerably complicate, of course, any reflection on the issue of responsibility. In chapter five, furthermore, some relevant actors were studied in the process of how to safely insert unmanned aircraft (UAS) in the (currently manned) airspace. It was found in this study that considerations that often get presented as simple trade-offs for the sake of safety in this process were in fact influenced by a number of socio-technological dynamics. Among these dynamics were, understandably perhaps, the protection of one's own (or the group's) norms and values. Some of these dynamics, however, among which that of power, appear to have tilted the debate on this issue unfairly, as it has been made quite difficult for the UAS community to enter the airspace.

The aim of this dissertation was not to make any substantive normative statements in these kinds of issues, but rather to highlight and understand the complexity of real-life settings, which may include underlying normative issues. The theoretical framework and practical applications that have been proposed here were developed to adequately address the empirical dimension. Addressing the empirical dimension is, however, a precondition for addressing the moral dimension. The New View approach of safety that has been formulated here (as expanded with the socio-technological concept from the STS literature and with Giddens' structuration theory) can thus be said to provide a well-grounded foundation to address the moral perspective.

8.3. Proposals for future research

The focus of this study has been two-fold. First, the safety of a number of technologies has been studied in large-scale socio-technological *military* systems. The knowledge gained in these studies – with an emphasis on the need to study the socio-technological system dynamics from which safety tends to emerge (or not) in complex systems – was then used to further actual assessments of these kinds of systems in general. An analytic framework has been proposed in this process. With this framework, current accounts of risk and safety can be assessed for their analytic strength, i.e., for whether and how these accounts can address and account for the complexity and dynamics in these systems. Path dependency and distributed agency have, furthermore, been presented here for providing direction in actual assessments of technological safety in large-scale systems, i.e., as practical guidance in the study of the empirical socio-technological dynamics in large-scale systems. Indeed, both path dependency and distributed agency, especially when combined with each other, seem to have the potential, in the context of responsible innovation at least, to better assess (adverse) effects of new technologies, and to attribute responsibility over the actors involved more just.

Based on the results summarized here it could be said that this dissertation has achieved its ambition of furthering actual assessments of safety in large-scale socio-technological systems. It can, however, be suggested but not assured that the elements that have been put to the fore in this dissertation will also actually improve technological safety, as empirically testing this has remained outside the scope of this dissertation, together with a number of other issues. Some suggestions for future research have therefore been identified here, which can perhaps form the beginning of a research agenda for (assessments of) technological safety in concrete large-scale socio-technological systems, military or otherwise:

- The aim of this research was to further actual assessments of safety in socio-large-scale socio-technological systems. Whether this has been achieved has been explored here on a conceptual level, not an empirical one. The scope of this exploration was, above all, limited to the context of responsible innovation only. Both conceptual and empirical studies could find out whether a focus on socio-technological system dynamics can indeed actually improve these assessments, and whether the results presented here can be extended beyond the context of responsible innovation. Studied could be, for instance, whether path dependency and distributed agency can indeed serve as helpful guiding concepts for how to make sense of the actual socio-technological dynamics, i.e., for how to make sense of empirical data.

- Not many studies have yet applied an STS perspective to safety specifically (chapter 6), and to military safety even less. Still, studying safety from this perspective seems promising. Studies of technological safety from the perspective of the analytic framework developed here (and which combines the New View perspective on safety with the socio-technological concept from the STS literature and Giddens' structuration theory) would enlarge this body of research.

- The analytic framework developed in this study has been used here for assessing the analytic strength of risk and safety accounts. To find out whether this can become general practice and whether the framework can be used for the analysis of other values also, it needs to be validated and altered accordingly if necessary.

- Investigating the quality of *assessments* is one thing. In the end, however, one would, of course, like to know whether the research presented here has the potential also to actually make a difference into the world. Studying whether and how these assessments can play a role in the real world can therefore perhaps be as important. It could be studied, in this sense, whether the research presented here can actually improve safety. In the context of responsible innovation, furthermore, it would be valuable to study whether this research could help in being or becoming a moral agent as in that this research would have the potential to lead to more just allocations of responsibility and better informed decisions regarding new technologies.

All in all, what is proposed here for a research agenda is a combination of empirical and conceptual studies that can validate and extend the research presented here. As such it should enable people to account for and address the empirical dimension in studies of values such as safety in today's complex socio-technological systems. Its primary aim, however, should be to turn the contemporary safety literature into practicable applications that have their effects, i.e. that can make a change, in the real world.

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Summary

Safety is often regarded as central to contemporary military activities, if only in hindsight. However, concepts of risk and safety and what they mean in the context of military missions are very contested. Much of this is congruent with what we see in other complex 'high-tech' systems (like other sectors, the military has become very much technology-dependent). The subject of much debate is there also still how to assess safety in these kinds of systems and how to assess how safety comes about in them (or not). The main goal of this dissertation was therefore to study, in this regard, a number of high-tech military systems to provide those responsible in some way for these systems with a more adequate understanding of the complex socio-technological dynamics in these systems. From there, the aim was to derive some applications or guidelines that could actually be helpful in the assessment (and design) of technological safety in these kinds of systems (military or otherwise). The objective of this study was therefore:

> To assess large-scale socio-technological military systems in order to further actual assessments of safety in general, especially when the assessments concern the issue of technological safety in large-scale socio-technological systems.

Four empirical studies on safety related to, mainly Dutch, military technical systems and other artefacts were carried out to help achieve this objective. In each of these studies it was found that the social and the technological domain were linked to an extent that is not often acknowledged in system design, development and use. Technology and other artefacts are, in other words, inherently embedded, apparently, within its larger (social) structures. They interact, above all, with these structures. Making sense of these kinds of interactions could help us understand, therefore, at least some of the important mechanisms of safety in large-scale socio-technological systems, although it cannot predict them with accuracy.

Once these studies were executed, a review of the literature on risk and safety in large-scale socio-technological systems was performed. Based on both the results of the empirical studies and this literature review, a theoretical framework was developed that can help us deal with the complexities and dynamics of

large-scale socio-technological systems. This framework developed, at first, out of the contemporary safety literature, i.e., out of the 'New View' on safety. It adds to this New View perspective two other literatures though. At first, the socio-technological concept was added, a concept that is featured in the STS literature (Science, Technology and Society studies), which is a literature that intersects a number of scholarly fields and literatures. This socio-technological concept emphasises, more explicitly than the New View on safety, the interrelatedness of the social and the technological domain in complex systems. The second literature that was added is Giddens' structuration theory. This theory, which comes from sociology, emphasises the interplay between agency and structures in systems and is specifically useful in examining socio-technological system dynamics in somewhat more detail. Also is it capable of examining interplay between systems, and between system levels.

Once this theoretical perspective was developed, it was investigated in this dissertation whether this framework could indeed yield helpful applications and guidelines for the assessment of technological safety in real-life settings. It did this in the context of Responsible Innovation, which aims to diminish adverse effects (such as a lack of safety) in the design, development and implementation of new technologies. What this dissertation found is that assessments of technological (or artefactual) safety in large-scale complex systems require an empirical analysis of the socio-technological system dynamics involved, something that would fit the framework developed here.

Making sense of empirical complexities in real-life settings is, however, not easy. To do this, guidance was found in the concepts of path dependency and distributed agency. These two concepts can add, in line with Giddens, an often neglected element, history, to the analysis of technological safety. Also, they bring to the discussion the ethical significance or valence(s) that technology and other artefacts can have for those involved. By using these two concepts, especially when combined with each other, it is possible, therefore, to extend safety assessments so that they can take into account (and account for) the empirical dimensions of complex systems, of how they develop, and to do this in such a way that certain issues of morality, especially those related to technological safety, can be addressed more adequately also. In the context of Responsible Innovation, for instance, it was found that path dependency and distributed agency together could help assess the effects of a new technology, and to allocate responsibility for these effects in more just ways over the actors involved.

Samenvatting

Veiligheid wordt over het algemeen van belang geacht bij hedendaagse militaire activiteiten, al is het achteraf. Wat veiligheid en risico in een context van militaire operaties betekent is echter vaak onderwerp van discussie. Dit zien we ook bij andere complexe 'high-tech' systemen (net als vele andere sectoren is de militaire sector meer en meer afhankelijk geraakt van hoogwaardige technologieën). Onderwerp van discussie is ook daar nog steeds hoe veiligheid te beoordelen in dit soort systemen. Ook bestaat er nog altijd onduidelijk over hoe veiligheid in dit soort systemen tot stand komt (of juist niet). Deze dissertatie bestudeert in het kader hiervan een aantal technologisch georienteerde militaire systemen om zo de verantwoordelijken voor dit soort systemen te voorzien van een meer adequaat begrip van de complexe socio-technologische dynamieken in die systemen. Getracht is vervolgens om hieruit directieven te extraheren die het beoordelen en ontwerpen van veiligheid in dit soort systemen (militair of anderszins) zouden kunnen vergemakkelijken. Het doel van dit onderzoek was dan ook:

> Het bestuderen van grootschalige socio-technologische militaire systemen ter bevordering van de beoordeling van veiligheid in grootschalige socio-technologische systemen in het algemeen en in de praktijk, vooral voor wat betreft de beoordeling van veiligheid rondom technologieën in die systemen.

Vier empirische studies zijn in het kader van deze doelstelling uitgevoerd naar de veiligheid van, hoofdzakelijk Nederlandse, militaire technologieën en andere artefacten. Deze empirische studies lieten stuk voor stuk zien dat in grootschalige socio-technologische systemen het sociale en het technologische domein meer met elkaar verweven zijn dan over het algemeen wordt aangenomen bij het ontwerp, de ontwikkeling en het opereren van die systemen. Technologieën en andere artefacten lijken in dit soort systemen onherroepelijk te zijn ingebed in hun bredere (sociale) structuren. Ze interacteren, bovenal, met die structuren. Aangenomen is daarom dat het bestuderen van dit soort interacties zou kunnen leiden tot het doorgronden van tenminste enkele van de mechanismen die ten grondslag liggen aan veiligheid in dit soort systemen, al

zal dit niet leiden tot gedetailleerde voorspellingen ten aanzien van die veiligheid.

Behalve de vier empirische studies naar militaire technologieën is ook de literatuur bestudeerd over risico en veiligheid in grootschalige socio-technologische systemen. Gebaseerd hierop, en op de resultaten van de empirische studies, is vervolgens een theorisch raamwerk geformuleerd voor het bestuderen en beoordelen van de complexiteit en dynamieken in grootschalige socio-technologische systemen. Dit theoretische raamwerk kent een initiële basis in de hedendaagse veiligheidsliteratuur, of meer specifiek, in de 'New View on safety'. Twee onderdelen zijn echter aan dit raamwerk toegevoegd. Ten eerste is dat het socio-technologische concept uit de STS literatuur (Science, Technology and Societies studies), een wetenschappelijk domein dat op het snijvlak acteert van meerdere wetenschappen. Dit socio-technologische concept adresseert meer dan de 'New View on safety' de onderlinge samenhang tusssen het sociale en het technologische domein in complexe systemen. Als tweede is Giddens's 'structuration theory' toegevoegd. Deze theorie is afkomstig uit de sociologie en benadrukt vooral de wisselwerking tussen het handelend vermogen (agency) in systemen en de structuren van die systemen. De theorie is daarmee specifiek bruikbaar voor de analyse van socio-technologische dynamieken in systemen, maar ook van dynamieken tussen systemen en tussen systeemniveaus.

Nadat dit raamwerk eenmaal geformuleerd was is verkend of dit raamwerk daadwerkelijk het beoordelen van veiligheid rondom technologieën in concrete situaties verder kan brengen. Hiertoe is een verkennend onderzoek uitgevoerd in het kader van 'Responsible Innovation', een op de praktijk georiënteerde onderzoeksrichting die als doel heeft het terugbrengen van ongewenste effecten in het ontwerp, de ontwikkeling en implementatie van nieuwe technologieën (zoals een gebrekkige veiligheid). Uit deze verkenning volgde in eerste instantie dat voor het beoordelen van veiligheid rondom technologieen (of andere artefacten) in grootschalige complexe systemen het noodzakelijk is om vooral de empirie te addresseren; om een grondige empirische analyse uit te voeren van de desbetreffende socio-technologische dynamieken, iets dat goed met het hier ontwikkelde raamwerk gedaan kan worden.

Het doorgronden van de empirische complexiteit van concrete situaties is echter niet makkelijk. De begrippen 'path dependency' en 'distributed agency' kunnen helpen in deze, onder andere doordat ze, volledig in lijn met Giddens, een vaak vergeten element aan empirische analyses kunnen toevoegen, namelijk historie. In het verlengde daarvan helpen ze bovendien bij het ter tafel brengen van de ethische significantie of lading die technologieën en artefacten kunnen hebben (gehad) voor betrokkenen. Vooral de combinatie van de twee begrippen kan er voor zorgen dat veiligheidsanalyses zo worden ingericht dat ze de empirische dimensie van complexe systemen meenemen en doorgronden. Zo helpen ze bij het analyseren van hoe de empirische dimensie in complexe systemen zich ontwikkelt en doen ze dat zo dat morele kwesties rondom de veiligheid van technologieën en andere artefacten meer adequaat geadresseerd kunnen worden. In de studie naar Responsible Innovation lijken 'path dependency' en 'distributed agency' tezamen bijvoorbeeld te helpen bij zowel het inschatten van effecten van nieuwe technologieën als bij het op een meer rechtvaardige wijze toewijzen van de verantwoordelijkheid voor deze effecten over de betrokken actoren.

About the author

Gwendolyn Bakx has a degree in psychology, which she obtained at the Open University in the Netherlands (drs. 2007). She also has a degree in human factors and system safety, which she obtained at Lund University in Sweden (MSc, 2010). Gwendolyn holds furthermore the rank of major in the Royal Netherlands Air Force. In the military she studied Military Management Studies at the Royal Netherlands Defence Academy (1994) and thereafter she accomplished the military flight school (1996). She has flown helicopters for 13 years from then on, among which the Chinook helicopter. She has been on missions in Bosnia, Kosovo, Iraq, and Afghanistan, both as a pilot and in supervisory roles. Between 2006 and 2011 she worked at the Air Force Headquarters as a flight safety officer. During this timeframe she has executed several accident and incident investigations. Since 2011, Gwendolyn works as an assistant professor at the Royal Netherlands Defence Academy, first in the realm of Human Factors and System Safety, now also in the domain of Leadership and Ethics.

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Simon Stevin (1548-1620)

'Wonder en is gheen Wonder'

This series in the philosophy and ethics of technology is named after the Dutch / Flemish natural philosopher, scientist and engineer Simon Stevin. He was an extraordinary versatile person. He published, among other things, on arithmetic, accounting, geometry, mechanics, hydrostatics, astronomy, theory of measurement, civil engineering, the theory of music, and civil citizenship. He wrote the very first treatise on logic in Dutch, which he considered to be a superior language for scientific purposes. The relation between theory and practice is a main topic in his work. In addition to his theoretical publications, he held a large number of patents, and was actively involved as an engineer in the building of windmills, harbours, and fortifications for the Dutch prince Maurits. He is famous for having constructed large sailing carriages.

Little is known about his personal life. He was probably born in 1548 in Bruges (Flanders) and went to Leiden in 1581, where he took up his studies at the university two years later. His work was published between 1581 and 1617. He was an early defender of the Copernican worldview, which did not make him popular in religious circles. He died in 1620, but the exact date and the place of his burial are unknown. Philosophically he was a pragmatic rationalist for whom every phenomenon, however mysterious, ultimately had a scientific explanation. Hence his dictum 'Wonder is no Wonder', which he used on the cover of several of his own books.

There is still much debate in the safety literature about how to deal with the complexities and dynamics of large-scale socio-technological systems especially. How, for instance, comes safety about in 'high-tech' complex systems? Also, how should assessments of technological (or artefactual) safety be performed in these kinds of systems? This thesis attempts to provide some practical applications and guidelines for these kinds of assessments, in real-life settings specifically. To this, four empirical studies of several high-tech military systems are discussed, and then how these studies were used for gaining a more adequate understanding of the dynamics of technological (or artefactual) safety in large-scale socio-technological systems in general. The thesis discusses furthermore a study after the concept of responsible innovation, which is a field that closely relates to technological safety. This particular study points out that what was found for the assessment of technological safety could also be helpful for related allocations of responsibility in the systems studied here.

An important factor appears to be in this all, that in practice the social and the technological (or artefactual) domain are linked in these kinds of systems to an extent that is not often acknowledged. Assessments of technological or artefactual safety in large-scale socio-technological systems, as well as allocations of responsibility in these kinds of systems, require, therefore, an empirical analysis of the socio-technological dynamics involved. These assessments and moral judgments should attempt, in short, to make sense of the empirical complexities in real-life settings. Important in this is that they should take into account – but also account for – the interactions between the technologies (or artefacts) studied and the social structure(s) that these technologies (or artefacts) are embedded within.

'Wonder en is
gheen wonder'

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