Is resilience engineering realist or constructivist ?

Jean-Christophe Le Coze, Kenneth Pettersen

Is resilience engineering realist or constructivist?

Jean Christophe Le Coze[1] and Kenneth Pettersen[2]
[1]*Research and consulting scientist. Accidental Risk Division. National Institute of Industrial Environment and Risks (INERIS),* jean-christophe.lecoze@ineris.fr

[2]*Coordinator, Centre for Risk Management and Societal Safety, University of Stavanger, Norway, e-mail:* kenneth.a.pettersen@uis.no

Abstract: This exploratory paper questions whether resilience engineering is a realist or constructivist approach of safety. After a presentation of two positions: critical realism and radical constructivism, the authors explain how the frameworks provided by these two positions were used in different researches, answering different questions that arose during the work. For one, critical realism offered an answer to the problem of the relationship between agency and structure. For the other, radical constructivism afforded a good definition of what models can be thought as. Both developments show the relevance of taking into account of philosophical antecedents for applied research and how this is valuable for resilience engineering and the directions that could be pursued for future development.

1. INTRODUCTION

In the process of writing papers for a book gathering young researchers from the field of accident and safety research (Svedung et al., 2008), we found ourselves asking similar type of questions regarding human and social science. With experience from independent research projects conducted in, among other, civil aviation and chemical industry, we have arrived at some similar questions regarding the status of models applied in safety science. In this paper, we suggest to introduce some of these questions and to see how they can provide an interesting point of view on resilience engineering. The focus will be on the distinction between realist positions and constructivist epistemologies. Before discussing the relevance of these questions for resilience engineering, we will, in a first part, introduce the context in which they emerged.

Resilience Engineering (Hollnagel 2006; 2008) has relatively rapidly emerged as an approach to be reckoned with in relation to how we understand and manage safety and vulnerability in socio-technical systems. What makes the approach innovative is, as described by Hollnagel in the introduction to the latter of the two resilience books, not advances in applied methodology within the field but more the basic system model it explicates related to the production of failures and successes in socio-technical systems. But can we however separate models from methodologies as it is asserted? Does a model not shape methodology? Does a methodology not

shape models? This is the type of concrete question that the philosophical discussions (asking whether resilience engineering is realist or constructivist) have led us to.

2. BACKGROUND

For one author, his experience is mainly in the chemical and petrochemical industry, and his empirical cases range from studies for research or consulting either following accidents or for diagnosis of safety. His empirical works and subsequent theoretical developments led him to deeper philosophical issues when questioning the use of models in general and their relationship with reality (Le Coze, 2005, 2008a, 2008b, Le Coze and Dupré, 2006). One of these questions, in relation to assessing the level of reliability or resilience of organisations, was "*how does the past teach us lessons for the future*"? Can models constructed from past experience be useful for predicting the future? Also, other philosophical issues were raised when questioning the necessary interdisciplinary nature of safety research and the difficulty of embracing the whole given the variety of disciplines that need to be articulated. How do we get a global picture? Can we do so? Can we do it by reducing phenomena to simple model, formula or principle (issue of reductionism in science)? Ultimately, all these questions led to a core one regarding the value of the models for safety. In trying to find elements of answers to these different problems, theoretical development on philosophy of complexity (Morin, 1977, 2007) and constructivist theory of knowledge (Le Moigne, 1995, 2003, Glasersfeld, 1995, 2001) provided viable frameworks in which these issues fitted all together.

For the other author, empirical research on safety and aircraft maintenance has led to several questions regarding theory of social systems and the relevance of currently applied models for managing system performance (Pettersen 2008; Pettersen et al 2007). Among these questions is how to understand human action as part of socio-technical system performance (McDonald & Morrison 2006a, McDonald & Morrison 2006b). Approaching a possible answer has involved digging into philosophical positions concerning the role of, and relationship between, human agency and social structure. What are the alternative theoretical models of this relationship? How can theory be applied to model how actions of aviation personnel are enabled and constrained by the social system they are part of, also taking account of the role of human intentionality in producing human actions? Within the available philosophical discussions on to these topic, critical realism developed by Bhaskar (1979) and further advanced by among other Archer (1995), is proving to be a relevant framework for developing his research into a more consistent articulation between philosophical assumptions, methodology and applied theory.

The aim of the first part of the paper is to elaborate on one of the questions associated with these philosophical positions as it has not yet been treated much in the field of safety science. This situation is probably linked with the philosophical nature of the investigations required by the questions that we have. The aim of an applied field of research such as safety science is not to produce philosophical thoughts but to provide useful models and methods so that safety is concretely, in the reality of industrial practices, enhanced. We however believe that any applied scientific field also needs to ask itself where it stands in terms of commitments rather than only concrete results. Avoiding methodological and ontological questions is in fact a statement in itself and does not "save" an applied field of

research from its ontological and methodological commitments. Without giving definitive conclusions to the questions raised, we introduce the two related but distinctly different philosophical developments that have proved to be useful for addressing our questions concerning safety science perspectives: critical realism and constructivist epistemologies. One of their main differences will be stated and explored as support for a following discussion on resilience engineering, asking whether resilience engineering is realist or constructivist. But first of all, here are two presentations of critical realism and radical constructivism.

2.1 The relevance of the philosophy of science perspective for resilience engineering

As indicated in the previous section, both our empirical and practical researches led us back to theoretical questions. The type of questions philosophers, historians and sociologists of science deal with (i.e. Soler, 2001, Andler et al, 2002, Barberousse et al, 2000). Questions about induction & deduction, about causality and teleology, about laws and determinism, about empiricism and rationalism, about truth and growth of knowledge, about realism, etc are some examples. All of these are very much linked together but can also be studied separately. Moreover, they are today discussed in many scientific areas, from natural to social sciences. We are here interested in how these types of questions underpin and are introduced in the resilience engineering approach.

Simultaneously, given the size of the paper many shortcuts are taken that might leave some of the outlines a bit blurry for those who are not familiar with the philosophical positions we introduce. For us, these are complex and evolving philosophical topics, and we will never give credit to their depth and subtleties in few pages. Nonetheless, we however hope to make it clear to the reader, firstly, that taking a philosophy of science perspective is of fundamental relevance for the resilience engineering project and, secondly, that discussing resilience engineering as realist or constructivist provide some interesting references for understanding and developing the resilience engineering project. We are ourselves not philosophers but believe in the importance of addressing philosophical questions in the context of safety science and resilience engineering as any scientific approach is influenced by its philosophical preconceptions.

2.2 Critical realism

On realism. In *A realist theory of science* (1975) and *The Possibility of Naturalism* (1979) (PON) Roy Bhaskar distinguishes between *intransitive* (ontological) and *transitive* (epistemological) objects and argues that it is essential that these dimensions are clearly distinguished. The intransitive is that what is and so exists independent of identification. It is based on the ontological claim that "*If men ceased to exist sound would continue to travel and heavy bodies fall to the earth in exactly the same way, though ex hypothesi there would be no-one to know it. Let us call this, in an unavoidable technical neologism, the intransitive objects of knowledge (...) they are the real things and structures, mechanisms and processes, events and possibilities of the world; and for the most part they are quite independent of us*" (Bhaskar, 1975). There are thus real entities and relationships that make up the natural and social world. In contrast, the transitive dimension is a social product, such as our knowledge and perception (concepts, models etc.) of reality (e.g. social science). As Bhaskar said in an interview (Norris, 1999) " *A realist theory of*

science re-thematised ontology, argued for its necessity and irreductibility in any account of science, and gave it a radically different shape or context. In particular, it is argued against the epistemic fallacy, that is the idea that one can reduce or analyse knowledge in terms of being. It was argued that being was an absolutely irreductible and necessary category." As its name suggests, critical realism involves a critical dimension that acknowledges the fallibility of our knowledge. Thus, there is no unquestionable foundation for science; knowledge is a social and historical product and, as a consequence, all facts are theory-laden (Robson 2002). Bhaskar (archer et al. 1998 p.xii) argues that Western philosophical traditions have mistakenly reduced the question of what is to the question of what we can know and conceptualises this blunder as the "epistemic fallacy". Critical realism presupposes that theories, both natural and social, are alternative accounts of the same world, and that there is a rational criterion for theory choice based on the possibility that one theory can explain better or more significant mechanisms than another.

On social sciences. Critical realism is a movement that in relation to the social sciences delivers a realist social ontology and addresses the epistemological implications of this ontology for social science. According to critical realism, social systems have unique characteristics that must be dealt with conceptually in an *analytical dualism* between agency and structure because; 1) social reality depends upon human activity and 2) social reality is transformable, but 3) as human agents, we are not immutable because we are constrained and enabled by the society in which we live and work (Archer 1995). The ontological premise for analytical dualism is the notion of society's emergent properties, which, in terms of structure and agency, is their interplay over time and space: *[The ontological premise of emergence] being so, then social realism implies a methodology based upon analytical dualism where explanation of why things social are so and not otherwise depends upon an account of how the properties and powers of the 'people' causally intertwine with those of the 'parts' (Archer 1995 p.15).*

2.3 Radical constructivism

Constructivist is a rather fashionable term used in many different domains (see Hacking, 1999). Radical constructivism is the term given by Glasersfeld (1981) to Piaget's constructivist approach of knowledge (1967, 1970). Glasersfeld interprets Piaget's contribution to epistemology by radicalising the idea that there is no possibility of describing a world as it is by separating between epistemology and ontology. Ontology is not in the scope of this theory of knowledge. Ontology belongs to the realm of metaphysics, and is outside the constructivist epistemology, which describes a rational way of knowing. As Glasersefeld (1982) puts it "*The difficulty in explicating the radical constructivist epistemology springs above all from the fact that, from the very beginning of our Western philosophical traditions epistemology has been tied to ontology. "Truth" and "objectivity" have an unalterable meaning, once the impossible condition has been set that cognition should lead to verifiable knowledge of a pre-established ontic reality.*" Therefore "*radical constructivism is intended as a model of rational knowing, not as a metaphysics that attempts to describe a real world*" (Glasersefeld, 1995).

Based on an analogy with biology and evolutionary theory, "truth" in constructivism (following here also ideas promoted by an instrumentalist approach of science among which pragmatism) is replaced by "viability" or "fit" instead of a "match"

with the environment. Only the observer can judge of the experiential relevance of his models given his/her purposes, and therefore not an objective criterion but rather subjective ones (such as for example simplicity, generality, accuracy etc). This point view is difficult to admit for realists convinced of a world existing independently of them. To this, Glasersfeld (1995, p 52) clearly replies "*Recently it has been suggested that radical constructivism is contradictory because it attacks realism and at the same time assumes a realist position by admitting that an ontological reality must constrain human action. (...) In the usual language of philosophers, "realists" are those who believe that they can obtain knowledge of a world as it is in itself. This I deny, and admitting "ontic" constraints does not contradict it, because while they may determine what is impossible, they do not determine the ways of acting and thinking that can be constructed within them*".

The constructivist approach of knowledge considers that models and theories are viable (combining usefulness, purpose and coherence) but not "true" in the common sense. Famous event in history in favour of this instrumentalist position is Osiander preface of Copernicus treaty on heliocentrism. In order not to upset the religious dogma held by institutions about the earth being at the centre of the universe (geocentrism), Osiander indicated that the mathematical model of Copernicus did not need to be true. It was a way of "*saving the phenomena*" rather than providing an accurate representation of the world as it is. Within this perspective, it is impossible to step out our human way of experiencing and perceiving the world in order to compare it with an "objective" or a "true" picture of the world as it is. It is, in a sense, "agnostic" toward this specific metaphysical problem of ontology (Riegler, 2001). This statement is met with much resistance and misunderstanding from many. "*The constructivist conclusion is unpopular. The most frequent objection takes the form of the accusation that constructivism denies reality. But this it does not. It only denies that we can rationally know a reality beyond our experience. (...) From my point of view, the trouble is that most critics seem to be unwilling to accept the explicit, programmatic statement that constructivism is a theory of knowing, not of being. That a model of the construction of knowledge could be designed without making ontological claims about what is known, is apparently difficult to accept*". (Glasersfeld, 2001, p10).

2.4 Main difference between critical realism and radical constructivism

With these short presentations of the two positions as a background, we direct attention to similarities and differences. Both critical realism and radical constructivism indicate that it is important to distinguish epistemology from ontology. However, their positions concerning this matter differ. Critical realism is a realist theory of science asserting that there is a world existing independently of us necessitating ontological developments to support this. Radical constructivism is a model of rational way of knowing. But it does not commit to ontological position because these concerns metaphysics rather than epistemology such as described in its model of knowing based on experience. An important difference is also found in the lack of clear extension of radical constructivism in terms of social sciences, whereas critical realism has extensively developed this side of its model. Recent contributions regarding the application of radical constructivism to sociology are however now available in Glasersfeld (2008).

3. APPLICATION TO EMPIRICAL RESEARCHES

3.1 Critical realism in aviation safety

In my research on aircraft maintenance and aviation safety I have found that the activity of aircraft maintenance comprises an unofficial social system, documenting unofficial actions and informal social structures within the workplace as characteristic tendencies of work (Pettersen 2006; Pettersen & Aase 2008; Pettersen 2008). In this research I suggest that there is another side to what goes on in the process of ensuring aircraft safety than what is described in formal descriptions of work, which needs to be accounted for in applied theories of safety and accidents in technological systems (Pettersen et al. 2008). Following this, I argue that studying normal functioning is essential because it encompasses the same conditions that precondition all forms of outcomes and events. However, as argued in Pettersen (2008), data gathered from a specific background and made relatable to other areas can only develop from being context-validated knowledge if it is related to a more general model of socio-technical functioning. This emphasises why the possibilities of system meta-theory are so important and fundamental to socio-technical analysis in the field of safety. i.e. it argues for the fundamental need to address ontology and being clear on fundamental models, independently of possibility or goodness of a specific set of ontological assumptions.

In order to contribute to the above, critical realist philosophy and social theory developed within the critical realist approach (Bhaskar 1979; Archer 1995) has been applied for analysing the relationship between individual actions and social structures in aircraft maintenance emphasising how these properties contribute to the production of safety (Pettersen et al. 2008; Pettersen 2008). This research has strengthened an argument for a social conception of technological systems and provides a basis for categorising different social science approaches to such systems. Through this research critical realism is argued to hold a largely unused potential for meeting many of the current objectives and requirements of socio-technical safety research and management.

3.2 Radical constructivism in applied safety researches for the chemical industry

Radical constructivism as I understood it, has proved to be very helpful the researches I have been involved in. I have tried to explain such a position in the field of accidents investigations (Le Coze, 2008a) but it is also appropriate for research in normal functioning (Le Coze & Dupré, 2006, 2008) . Because within a radical constructivist perspective a model is assessed according to its viability based on experience, appreciating its relevance is impossible without making clear what its purpose is. How much "true" is the model is therefore a matter of how viable it is. This is important in an applied research on organisational safety. As outsider of the system that I studied, I will not in the end implement the actions required in order to transform it. Insiders will potentially do. A radical constructivist approach of this problem would therefore insists on the importance of taking into account the background and experiences of insiders and the adequacy of the model according to these backgrounds and experiences. If the purpose is to improve safety thanks to organisational measures implemented by individuals, then the model produced needs to be viable within the context of its use. It is what Starbuck (2006, 165) says

"Social scientists who believe they have something valuable to say to contribute have to be willing to persuade others of this value; and to do that, they have to adapt their manuscripts to the perceptual framework of potential readers". Therefore, with a radical constructivist point of view, describing from an outsider point of view the way safety is organisationally produced will not be sufficient (i.e. HRO descriptions), although viable within a particular community of people (i.e. researchers in social sciences). This is a point that LaPorte (2006, 151) made very clear *"Researchers in this field assert that identification of the characteristics of highly reliable organisations is not the same thing as knowing as to make them so"*. It means that making organisations safer does not consist in simply applying results from more descriptive models. This position rather implies specific research designs, designs allowing actionable models to be produced through interactive work between researchers with practitioners and tested in real situations (i.e. action research type of approach).

4. THE RELEVANCE OF THESE APPROACHES FOR RESILIENCE ENGINEERING

4.1 Resilience engineering and critical realism

It is clear, both from the basic concepts and precepts of resilience engineering (Hollnagel et al. 2006) and the work that has evolved following these foundations (Hollnagel et al. 2008), that resilience engineering differs from traditional approaches to safety that focus on failures as isolated cases. It explains instead safety and accidents as dynamic outcomes of normal functioning of socio-technical systems. By so doing, resilience engineering shifts focus from actual events to underlying facts and mechanisms of systems that are driving the functioning of socio-technical systems. However, refocusing the attention on system functioning is not only about making the statement, but developing a consistent approach of how this is in fact possible. This is where critical realism does hold some substantial potential as a philosophical reference.

Currently, critical realism is not applied widely in the field of safety and socio-technical theorising. However, two well known accident theories in the field, Turner's (1978) theory of Man-Made Disasters and Diane Vaughan's Normalisation of Deviance (1996), can be argued as commensurable with critical realist theorising (Pettersen 2008). However, I would also ad, the socio-technical models argued for in Hollnagel et al. (2006; 2008) may share this commensurability. At a fundamental level the critical realist epistemology comprising an analytical dualism between structure and agency seems to be central to the socio-technical theorising developed in resilience engineering as it delivers an explanation of the basic relationships between individuals and their social environment that addresses the relationship between stability and change in systems (McDonald 2006). There is thus a fundamental potential in critical realism in relation to what it contributes to the possibility and potential for modelling technological systems that have relevance for the Resilience Engineering project.

In summary, fundamental gains can be made by looking deeper into how critical realism may inform the resilience engineering approach to system modelling, how the critical realist conception of social causality may inform resilience and the applied theory of emergence (Hollnagel et al. 2006) as well as how resilience

engineering defines it self in terms of a methodological project.

4.2 Resilience engineering and radical constructivism

Given what has been said about radical constructivism in the previous sections, it will be found that the following sentence (Hollnagel and Woods, 2006) is very close to it. "*A model that is cumbersome and costly to use will from the very start be at disadvantage, even if from an academic point of view it provides a better explanation. This should, however, not lead to the conclusions that we must give up on models and try to describe reality as it is, since this is a philosophically naïve notion.*" And a note is added to comment on the use of "better": "*Better is, of course a dangerous term to use since it implies that some objective criterion or standard available. Although there is no truth to be used as a point of reference, it is possible to show that one explanation – under given conditions – may be better than another, e.g., in providing more effective countermeasure*" Hollnagel & Woods (2006 p. 353). By questioning the notion of reality as it is, and by introducing an example of purpose ("*providing more effective countermeasure*") against which the relevance of the model can be assessed instead of an objective external criteria, this sentence favours a radical constructivist approach of resilience engineering. It can be noted that such a relationship between resilience engineering and radical constructivism would not be surprising as "engineering" in the expression is clearly associated with the search for practical relevance. In management sciences, "actionable knowledge" (as a definition of models aiming at practical purposes), has gained strong support from philosophies of knowledge (such as pragmatism[1] or constructivism, Avenier, 2007).

5. CONCLUSION: IS RESILIENCE ENGINEERING REALIST OR CONSTRUCTIVIST?

This paper result from the confrontation of two philosophical perspectives, based on different experiences of researches in the field of safety. One author found critical realism to provide a good framework for his research. The second authors found radical constructivist theory of knowledge as a useful approach for the questions that came up throughout his projects. The two perspectives are however quite different and imply different positions with regard to ontology and epistemology. Choosing one over the other can be linked to personal conviction and beliefs. There are in fact no definite answers as both positions are still hotly debated in philosophy. However, subscribing to one or the other led to different conclusion when applied first to our researches, then translated to resilience engineering issues. Critical realist suggested to consider the importance of social system ontology (in particular the dualism of structure and agency) and this has implications for methodologies. Radical constructivist stressed the importance to put the viability of models (usefulness, purpose and value) into tests within their specific context of use, and consequently to create the proper research conditions to do so (such as action research). What we find interesting is that philosophical questions often seem as inconsequential to practical problems. On the contrary, they reveal here to have concrete implications.

---

[1] See for example the conference theme of the academy of management, 2004, using as an introductive sentence James pragmatic principle "Truth in our ideas means their power to work."

This exploratory paper would need to be developed further in order to better ground these implications, we for example think that the consequences of the two positions might not exclude each other. But it is a first step.

REFERENCES

Andler, D., Fagault-Largeault, A., 2002. Philosophie des sciences. Volume 1 & 2. Seuil.

Archer, M. (1995). Realist social theory : the morphogenetic approach, *Cambridge University Press*

Avenier, M-J., (2007). *Repères pour la transformation d'expérience en science avec conscience*, dans Avenier, M-J., Schmitt, C. La construction de savoirs pour l'action. L'harmattan.

Barberousse, A, Kistler, Ludwig, (2001). La philosophie des sciences du Xxè siècle. Flammarion.

Bhaskar, R. (1976), *A Realist Theory of Science,* Harvester Press.

Bhaskar, R. (1979). The Possibility of Naturalism – A Philosophical critique of the contemporary human sciences, *Harvester Press.*

Glasersfeld, E.Von. (1981). Introduction to radical constructivism. Originally published in P. Watzlawick (Ed.), Die Erfundene Wirklichkeit. Munich: Piper, 1981. Author's translation in P. Watzlawick (Ed.), The Invented Reality. New York: Norton, 1984.

Glasersfeld, E.Von. (1982). An interpretation of Piaget's constructivism. In Revue international de philosophie, 36 (4), 612-635.

Glasersfeld, E. Von., Cobb, P. (1983). Knowledge as environmental fit. Man-Envrionment systems, 13 (5) 216 – 224.

Glasersfeld, E.Von. (1995). Radical constructivism. A way of knowing and learning. *Routledge. Taylor and Francis Group.*

Glasersfeld, E.Von. (2001). The radical constructivist view of science. *Foundations of science 6 (1-3):31-43.*

Glasersfeld, E.Von. (2008). Who conceives of society? In Constructivist foundations. 3 (2) 59-64.

Hacking, I. 1999. The Social Construction of What? Harvard University Press.

Hollnagel, E., Woods, D. D. and Leveson, N. (2006). *Resilience Engineering – Concepts and Precepts,* Ashgate Publishing.

Hollnagel E., Woods D. D., (2006) Epilogue: resilience engineering precepts, in Hollnagel E., Woods D., D., Leveson N. Resilience Engineering: concepts and precepts. Ashgate Publishing.

Hollnagel, E., Nemeth, C.P. & Dekker, S. (2008), *Resilience Engineering Perspectives – Remaining Sensitive to the Possibility of Failure,* Ashgate Publishing

La Porte T. M. (2006). Organiszational strategies for complex system resilience, reliability and adaptation. In Auerswald, P., Branscomb., L, M., La Porte, T, M., Michel-Kerjan., E.O in Seeds of Disaster, Roots of Response. How Private Action Can Reduce Public Vulnerability. Cambridge University Press.

Le Coze, JC. (2005). Are organisations too complex to be introduced in technical risk assessment and current safety auditing? *Safety science (43) 613-638.*

Le Coze, JC., (2008a). Organisations and disasters: from lessons learnt to theorizing. Safety science (46) 132-149.

Le Coze, JC., (2008b). Complexity and learning from experience. In Anthology on learning from experience. *in Anthology on Learning from Accidents, Svedung, I., Enander, A. & Axelsson R. (Eds.), Swedish Rescue Services Agency, fortcomming*

Le Moigne, JL. (1995). Les épistémologies constructivistes. Que sais-je? *Presses Universitaires de France. [Constructivist epistemologies].*

McDonald, N. (2006). Organizational resilience and industrial risk, in *Resilience Engineering – Concepts and precepts, Hollnagel, Woods & Leveson (Eds.), Ashgate*

McDonald, N. & Morrison R. (2006a). The human role in operational systems – perspectives on change. *Proceedings of the European Safety and Reliability Conference (ESREL) 2006, Safety and Reliability for Managing Risk – Guedes Soares & Zio (eds), Taylor & Francis Group, London.*

McDonald, N. & Morrison R. (2006b). Modelling the human role in operational systems – theory and practice. *In Proceedings of the 3rd International Conference Working on Safety 2006, The Netherlands*

Morin E. (1977). La méthode – tome I, La nature de la nature. *Ed du seuil (coll point). Paris.*

Morin, E. (2007). Restricted complexity, general complexity. *Worldviews, science and us. Philosophy and complexity. In Gershenson, C., Aerts, D., Edmonds, B. (eds) World scientific publishing.*

Norris, C. (1999). Roy Bhaskar interviewed. The Philosopher's magazine. Isuue 8. Available on the web at http://www.philosophers.co.uk/current/bhaskar.htm

Pettersen, K. (2008). Interactions between social reality and the physical – A causal nexus for operational safety and vulnerability, *in Anthology on Learning from Accidents, Svedung, I., Enander, A. & Axelsson R. (Eds.), Swedish Rescue Services Agency, forthcoming*

Pettersen, K., McDonald, N. & Engen, O. A. (2007). The possibility of a socio-technical science – a critical realist approach to aircraft maintenance, *working paper, available by contact: kenneth.a.pettersen@uis.no*

Pettersen, K. (2008). *The social production of safety,* PhD thesis in Risk Management and Societal Safety, University of Stavanger

Riegler, A. (2001). *Towards a Radical Constructivist understanding of science. Foundations of science 6 (1-3):1-30.*

Starbuck, W. H. (2006). The production of knowledge. The challenges of social sciences research.Oxford University Press.

Soler, L. 2001. Introduction à l'épistémologie. Ellipses.

Svedung, I., Enander, A. & Axelsson R. (2008). Anthology on Learning from Accidents, *Swedish Rescue Services Agency, forthcoming*

Turner, B. A. (1978), *Man-Made Disasters,* Wykeman, London

Vaughan, D. (1996), *The Challenger Launch Decision.* The University of Chicago Press, Chicago.