Safety and security in the light of complexity. Uncertainty & qualification of systems analysis

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ABSTRACT

There exists a field of epistemology or philosophy[1] of complexity using contemporary scientific developments for questioning our relationship with reality, knowledge and science developments. This field is extremely stimulating and points at ways of thinking about safety science and risk management in general. This paper will elaborate on and present how the epistemology of complexity - focusing in particular in the challenge of articulating disciplines - offers concepts for tackling accident investigation and auditing of complex socio-technical systems for at least two purposes worth discussing in light of complexity: safety and security.

The discussion will be based on the presentation of Morin's "complex thought", and case studies presented in previous papers which develop these ideas but also from past and current research (since 2000) for the environmental French ministry as well as consulting works for the industry currently carried out by INERIS. This paper will therefore specifically address the issue of modelling (describing, explaining, interpreting, predicting) complex systems for safety and security purposes.

1. INTRODUCTION

1.1. Complexity

Complexity is more a problem than a solution, however it helps a great deal in asking some relevant questions. The developments of philosophy of complexity, and of science of complexity, as developed for example by Morin, find their root in some questions raised after some main scientific revolutions. As the literature dealing with the status of science has shown it, some key questions have been raised following revolutions in natural science as in relativity, quantum physics but also following the assumption of big bang in cosmology (introducing the history of cosmos). Earlier, thermodynamics had created a breach in the deterministic view of the world (especially by questioning the reversibility of time that the Newtonian science implied). Thermodynamics led to further developments as for example in chemistry with the second thermodynamics dealing with dissipative structures (revealing properties of self organisation of matter) and later chaos theory, both introducing questions regarding the status of determinism and reversibility of time.

In science of life, open systems were opposed to the thermodynamic principle of entropy (maximum of disorder) because biological systems exhibit organisational patterns (as dissipative structures in chemistry do) when "fighting" against entropy (leading to maximum of disorder, dispersion). These systems are open to their environment, organised and have purpose, for which feedback principles are key for understanding their non-linear behaviour, and circular causality. They were therefore opposed to the principle of external causality, by introducing teleology (goal, purpose) and opposed to the principle of decomposition (found in the reductionist perspective and also in the analytical principle). They imply control and command and information (both quantitative theories of information and symbol treatment). These were features introduced and also therefore found in engineering, with cybernetics[2].

All these developments were made earlier or in parallel with the principles of self organisation, explaining better the creative side of the biological world, but also being the result of emerging features ("the whole is more than the sum of its parts") without external written plan, or without centralised control dictating behaviours of parts.

[1] It is rather difficult to distinguish clearly epistemology (in the French context epistemology concerns science, and not knowledge in general) and philosophy of science (Soler, 2000). In that article we will use both terms with the idea of talking about these disciplines having a reflexive approach on the developments of scientific concepts, models, theories. The epistemology or philosophy of complexity is one of them.

[2] Early in 1948, Weaver in a key article « Science and complexity », suggested distinguishing *simplicity* from *disorganised complexity* and *organised complexity.*

This type of understanding is linked with the idea that the atoms, the cells, the organs, the brain, the human and the societies, are emergence of levels of organisation that can't be reduced and deduced from the level before, but reveal themselves through self organisation and evolutionary principles. The systemic approach (rooted in cybernetics and general system theory) and complexity ideas (more rooted in self-organisation) are therefore intrinsically linked. These ideas of self-organisation and systems were and are also developed in a century where the Darwinian theory of evolution flourished in many ways along with the concepts of ecology starting with the concept of *Umwelt* (environment) and then of Ecosystem.

In social and human sciences, all these themes obviously echoed and echo strongly today. These ideas have of course spread (but also were originated for some of them) in the development of cognitive sciences (starting with cybernetics, linguistic, artificial intelligence, neuroscience…), in cognitive psychology but also in sociology, sociology of organisation for example but also in philosophy and epistemology, with the field of philosophy of complexity, as developed for example by Morin.

Morin is seen as a leading thinker on the matter of philosophy of complexity and his thought is very influential in the contemporary debate in science in general. The use of his epistemology of complexity (what is called "complex thought") serves the purpose of defining appropriate and useful mental frameworks, or method, to think[3], to organise knowledge. As we will see in this paper, Morin's philosophical and epistemological work has been highly influenced, but not only, by cybernetics, system theory and self-organisation (linked with the key concept of emergence), and these are also major features of the human and social science literature on major accidents.

1.2. Self organisation - emergence of pattern - and major accidents

Indeed, as described by many authors in the field of major accidents: history, interactions between actors (located at different levels[4]) and finally the concept of emergence do matter. Such an approach is therefore important and can therefore be understood through self-organisation principles, emphasising the emergence of patterns[5] - that are created without centralised control - leading to accidents.

We find therefore emergence and self-organisation, although not defined as such by this author, at the heart of the accident modelling (or theorising) of Vaughan, with the idea of emergence of a dynamic pattern of construction of meaning (normalisation of deviance, 1996) over the O-ring behaviour following many years of feedbacks on that specific topic at NASA. This patterns consists in 5 steps:

1. Signal of a potential problem arise,
2. Behaviours deviating from a performance norm of safety criterion were treated as a serious sign of danger,
3. Investigation of the evidence,
4. After discussion the deviant behaviours of the joint was often "normalized" – thereby defining parameters for a revised working norm too,
5. The risk could then be judged to be "acceptable" according to the new norm.

There is no written plan that people followed but instead the emergence of a pattern. It emerged from people interacting over the years, in a specific social-cultural-historical-political-economical context (NASA's institutional context, NASA's culture of "can do" …) and technological context (the specific behaviour of the technical O ring components)[6]. We also find this idea of emergence of organisational behaviour for Snook

[3] Offering some ideas for scientific research strategies.

[4] "Levels" is used here as a way to identify different type of actors (at the local level we would find operators, and managers, then authorities, market at higher levels etc). The interest is to put in light the problem of micro meso macro links, but can also lead to a graphical representation bringing some limitations (as any graphical representation does). Indeed it can bring a "vertical" vision where levels do not link directly with each other although links and influences are everywhere between actors, irrespective of the levels drawn. The diffusion of this vision of the socio-technical as been emphasised by Rasmussen (1997) and then used in different works (e.g. Hopkins, 2000, Leveson, 2004). A network of people interacting, creating systems of interactions, is probably a good alternative/complementary expression for emphasising the complexity/interactivity of these systems.

[5] "Pattern" is an important idea in epistemology of complexity, emphasising "processes" and "shapes" rather than elements, which is a key thing as we will see in the next chapters, especially for thinking the self-organising properties of levels of reality.

[6] We could say that there were some *possibilities* of emerging patterns under specific *constraints* (here it took the shape of a "normalisation of deviance" under the analysis of Vaughan), as Ceruti discusses about the knowledge of evolution and evolution of knowledge in his book "*Constraints and possibilities*"(1994). Ceruti uses the genetic epistemology of Piaget for stressing the subject/object relationship, and the possible emergence of specific pattern between a biological organisation and its environment. This pattern is not deterministic, but results

(2000), but also from human factors scientists as Rasmussen (1997, 2000), Hollnagel (2004). These authors are interested by an emerging behaviour, although without focusing as much as Vaughan on the idea of collective construction of meaning and sense about a single phenomenon over the years (as with a normalisation of deviance regarding the O-rings behaviour). Instead, but also because of the nature of the accidents that he studied, for Snook (2000), there is an emergence at the global level, generated by individuals, each of them independently "self organising" their own tasks around predefined rules and creating a global "practical drift", implying a coordination failure (due to loose coupling between actors and their tasks) leading to the accident. The following pattern is described by Snook this way:

1. An organisation is designed, defining procedures and a tight coordination between activities defined through the formal procedures for the worst case scenario.
2. Actors implement the organisation, but in reality the actors have loosely coupled activities between each other in a normal operations, and they slowly drift from rules defined by formal procedure to task based activities.
3. The organisation behaves according to this principle.
4. The organisation fails when the drift creates a "resonance" when drifting activities align with each other.

Emergence of patterns (linked with self-organisation, but also with adaptive systems and evolution, as we will see) seems therefore a key concept for understanding accidents (Lecoze, 2005). These patterns could be called "**emerging self organised incremental patterns**"[7]. Vaughan has recently used the idea of "slippery slope" for defining with an image or metaphor[8] the type of pattern that she is thinking of when dealing with major accidents and organisational dynamic. The challenge is therefore today, from the "practical drift" of Snook (2000) , to the "Normalisation of Deviance" of Vaughan (1996) , through the 'incubation period" of Turner (1978), from the type of "behaviour towards accidents" of Rasmussen (1997, 2000), to understand the conditions (which are cognitive-social-cultural-political-economical[9]) of the emergence of these accidental patterns. Doing so consists today in organising the relevant knowledge to help us detecting, anticipating, and preventing, thanks to proper organisational design, the potential emergence of these patterns before they lead towards a major accident.

This presentation of patterns and emergence in accident brings us to what Morin did with the idea of self-organisation and emergence in his epistemological and philosophical work.

1.3 Self organisation and "complex thought"

Self-organisation (emergence) is indeed a powerful concept that is thus at the core of the work of Morin and his "complex thought", and also, early, at the core of the complexity ideas in general (e.g. in physics Prigogine and Stengers, 1977, in biology Atlan, 1979, in neurosciences, Foerster) from where Morin has been looking at, to "feed" his thought. It seems therefore appropriate for the theme of this conference to see how Morin had elaborated on these ideas for the development of his "complex thought", defining consequently a field of epistemology or philosophy of complexity (Ceruti, 1994), and to see how this can be helpful to think prevention. The "complex thought" of Morin is however a very atypical kind of thinking that can sometimes meet difficulties in being understood as it doesn't fall into any categories of today's academically established, but also fragmented, knowledge[10].

The ideas generated in the several books of "La méthode" (from -1977 to 2004[11]) are therefore not standing very easily in any discipline, which makes it either repulsive or either very attractive (especially attractive for those

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from a construction due to an active interaction between a subject (here we could assimilate the subject to several people interacting) and an object (here the joints behaviours).

[7] We have recently used this concept in an accident investigation for pointing out some local but also more global self-organised incremental patterns, combining themselves, undetected by the organisation, and leading toward a weakening of the organisation in terms of major hazard prevention.

[8] Metaphors or analogies more anchored in the natural sciences have already been used for giving some images of what a major accident "could be". Rasmussen (1997) suggested using the Brownian movement to stress the exploratory dimension of individuals within organisation as a source of risk. More recently Hollnagel (2004, 2006) has used the magnetic resonance phenomenon as a source of analogy for facilitating a type of understanding related to organisations behaviours leading to accident.

[9] Each of these dimensions should be considered before concluding on the predominance of one over the others (it is often tempting to conclude quickly that accidents are due to economical constraints).

[10] Morin articulates knowledge from science (science of nature and life), philosophy, anthropology (Branchi, 1990), but not only (cognitive science, psychology, ethology…).

[11] In this paper, we will only use the 4 first volumes of Morin's work (1977-1991).

who believe that reality does not know scientific boundaries[12], believe that meta-models or meta theories are not to be found for tomorrow and that interdisciplinarity is a key process for treating multidimensional problems).

It is an extremely stimulating thought and gives strong scientific strategies for thinking prevention and research, but not only for "thinking it" in a common sense, as we don't need, for instance in the field of major hazard, the powerful intellectual work of Morin to realise that we have to put together engineers, psychologist, sociologist or economists to work out the patterns leading toward accidents[13]. It is rather because he tackled the epistemological question of our knowledge about reality from the physical, the biological and the anthropo-sociological views and tried to produce some ideas and concepts of organisation of knowledge for coping with the complexity of reality that his work is valuable. Lemoigne (1977 then 1999, 2001, 2002, 2003) has actively[14] used Morin's work to define a constructivist approach of knowledge, a constructivist epistemology, following a tradition of works such as Piaget (1970), leading to a circular representation of science and justifying the status of interdisciplinary researches.

The two next parts attempts to introduce the principles of Morin's "complex thought" (this presentation must however really be understood as an attempt but also as what the author of this paper was able to understand and to extract from Morin's work!).

Essentially, it could be said that two key principles are important to be understood for getting into his work, which are the concepts of emergence and the value of science[15]. Emergence (self-organisation) has already been introduced in this paper. It implies that although organisational levels are not understandable from the understanding of the levels before, there is however a continuum between all of them levels (from the physical, biological and anthropo sociological one) from which human, societies to knowledge (concepts, models, theories, ideologies) are, through evolution, the products. The other one, the value of science, is about the status of objectivity that is defended in scientific developments (and that is often associated with the positivist attitude), and our relationship with reality. Do we see the world as independent observers? Or do we co-create the world that we see in interaction with it? If yes, then do we have to address the situation of the observer? How do we do so?

It appears that Morin's "complex thought" is consequently trying to find a way between the traditional oppositions of:

- **the subject (the observer) and the object (the observed)** - addressing the value of science (or also the "subjective" side of the scientific adventure)
- **nature and culture**[16] - addressing the relationship linking the physical, biological and anthropo sociological levels.

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[12] As Von Foerster (1995) stated it when questioned about his transdisciplinary background, "I don't know where my expertise is; my expertise is no disciplines. I would recommend to drop disciplinarity wherever one can. Disciplines are an outgrowth of academia. In academia you appoint somebody and then in order to give him a name he must be a historian, a physicist, a chemist, a biologist, a biophysicist; he has to have a name. Here is a human being: Joe Smith -- he suddenly has a label around the neck: biophysicist. Now he has to live up to that label and push away everything that is not biophysics; otherwise people will doubt that he is a biophysicist. If he's talking to somebody about astronomy, they will say "I don't know, you are not talking about your area of competence, you're talking about astronomy, and there is the department of astronomy, those are the people over there," and things of that sort. Disciplines are an aftereffect of the institutional situation.", interview available at http://www.stanford.edu/group/SHR/4-2/text/interviewvonf.html.

[13] Turner for example already stated these needs for investigating disasters in 1978 *" the study of the nature and origins of disasters is the kind of inquiry which is naturally a multidisciplinary one and co-operation between psychologists and sociologists, epidemiologist, engineers and managers is needed to understand the complicated relationship between different kinds and levels of event which lead to the development of disasters"*, and this has been done early after accident, following for example the Three Mile Island accident by putting together various human and social scientists, (Sills et al, 1982) but also today very recently, following the Columbia accident, with a book released in 2005 (Starbuck and Farjoun, 2005) and also following the natural disaster Katrina on a website created by social scientists http://understandingkatrina.ssrc.org.

[14] The website www.mcxapc.org dealing with the modelling of complexity is very active in that respect and freely provides a rich documentation on epistemology of complexity.

[15] These two themes were respectively the subject s of two last special issues of a scientific journal in France ("l'énigme de l'émergence", "*the enigma of emergence*" 07/2005 and "Les valeurs de la science" " *the values of science*", 10/2005 from "Science et Avenir"). It is quite interesting to see that these are two central ideas that Morin articulates into his "complex thought".

[16] A first attempt to link the emergence of our human culture (that led to today's societies) with our natural side is found in "le paradime perdu: la nature humaine" (1973) which was a precursor of Morin's work on his research for a method of "complex thought". That first work was the product of a series of conferences organised by Morin in 1972 in Royaumont, around the theme of "l'unité de l'homme" (The human unity). In his book Morin links works from ethology, prehistory and anthropology through the concept of self-organisation and evolution, in order to show the possibilities of articulating these pieces of works together (from different disciplines) to imagine a possible scenario of a human culture emergence. 30 years later the ideas contained in the project are still relevant and can be thought with the new

The basic principles are that we must understand our reality through its physical, biological and anthropo sociological dimensions, without having one that would be dominating the other, or reducing the others to their "truth", such as saying that everything is physical, that everything is biological or that everything is anthropo-sociological[17]. Thinking our world is therefore about thinking the three together, but in a way that is consistent, through principles that link these levels in a circular relationship. Morin's research strategy has been therefore to look at the key scientific developments of science of nature and science of life to question our human and social "nature", and "life". These questions are contained in the two first volumes[18] of "La méthode".

2. THE PHYSICAL AND BIOLOGICAL DIMENSIONS OF HUMANITY

2.1 Some key scientific ideas of our contemporary world

Thus, in a dialogue between philosophy and science, in the two first volumes of "La méthode" (1977, 1981) Morin put together a lot of material from science of nature and science of life. His approach is a circular one, starting with the physical to the biological nature of human and societies. Here are some of these (this is not a comprehensive list):

- Cosmos studies and new trends (big bang following Hubble's discoveries of an expansion of the universe[19]),
- First and second thermodynamics (the dissipative structures and the philosophical discussions from Prigogine),
- Micro-physics (quantum physics and philosophical discussions from Heinsenberg, Bohr…),
- Cybernetics and system theory (and epistemological discussions from Bertalanffy, Wiener, Von Foerster, Bateson…),
- Self organisation, recursivity, autopoësis, emergence and principles of "order out of noise" (with epistemological discussion from Von Foerster, Maturana, Varela, Atlan),
- Evolution (Darwinian, neo darwinian developments),
- Ecology and *Umwlet* (from Von Uexküll),
- Ecosystem (from Tansley).

2.2. Concepts extracted from « The nature of nature »

All these insights are discussed and articulated to produce a number of principles such as (from the volume 1):

1. The presence of **order/disorder/interaction/organisation** as an underlying basis of the emergence of our world (instead of a strict principle of order but also instead of a strict principle of deterministic laws[20] and instead of matter as a elementary unit, the last point stressing the importance of patterns over elements).
2. **Emergence** as a principle for understanding the properties of systems that can't be deduced (and reduced) from the parts.

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advances obtained in various disciplines since, like paleoanthropology, prehistory, genetics, theory of evolution, ethology (Picq, 2005). One of the problem consequently concerns the way, the method, in which the various disciplines together are articulated. This raises the question of interdisciplinarity and of the method supporting this process.

[17] Dupuy (1982) has argued that reductionism and simplistic assumptions would always have the last word over a more complex, such as Morin's "complex thought", vision of reality.

[18] « The nature of nature » (1977) and «The life of life » (1981).

[19] In a recent dialogue (2003), between Morin and Cassé, an astrophysician, some of the ideas about our universe and on the cosmos extracted from the first Volume of "la méthode" are discussed.

[20] Determinism and consequently the search for laws is one feature that has been seen as a foundation of the scientific approach, as Ceruti notices (1994) "particularly during the Nineteenth century, the search for "laws" progressively becomes the way in which the regulating ideal of omniscience becomes normative in the building of human knowledge. The notion of law is interpreted as a fundamental place of description and explanation of phenomena. The discovery of a law gives access to the Archimedean point, a necessary and sufficient condition for the control and exhaustive explanation of phenomena. It allows for both the dissolving of the particular into the general, the predicting of the past and future course of event, and allows us to conceive of time as the simple unfolding of an atemporal necessity. These epistemological schemata took shape in the interpretation of the great successes attained by rational mechanics throughout the course of the 18th century and the beginning of the 19th, and in that attitude we tended to conceive of this science as being paradigmatic of the tasks of scientific explanation in general. Subsequently, even the great scientific events achieved by the emergence of both sciences of evolution and history (whether natural or social) were shaped by an ideal of scientific quality pivoting on this notion of law. The problem thus became that of determining laws of history characterised by the same necessity, invariance, and atemporality as the laws of the physical universe."

3. **A systemic principle** to be linked with an ecological vision of the world (developed in the second volume). The systemic principle stresses the fact that any organisational phenomena is embedded and in interaction within other systems.
4. **Recursivity and autopoïesis** (although the principle of closure from the autopoïesis theory is thought by Morin with a principle of openness) as a common "organisational" feature of the physical, biological and anthropo-sociological world through the concept of self - producing "machine" .
5. **Openness** as a key principle of intelligibility of reality (a concept that has *empirical*, *methodological*, *theoritical*, *logical*, *paradigmatical* impacts leading to a complex vision of the world).
6. A principle of **complex causalities** (little cause can have big effects, same cause can have different effects, leading to counter-intuitive effects through feedbacks, and exogenous -endogenous principles of open systems and interactions of systems), which makes **emerging patterns not predictable**.

2.3 Concepts extracted from "The life of life"

In volume two, a certain other number of principles are discussed and articulated from science of life developments (here are some selected ones):

1. **Oikos/autos** and the concept of ecology (environment) and of **ecosystem**, where the parts (autos) and the whole (oikos) are linked together in a complex relationship of **recursivity** (parts are the products of the whole but also the producers of the whole in a dialogical relationship).
2. **A concept of evolution** with a discussion of the notions **of adaptation and selection within an eco-organisation** through the use of **self-organisation of eco-systems**, and the introduction of **order/disorder/interaction/organisation** as a principle functionning of eco-systems (and also a principle of **variety as a principle of resilience**).
3. A principle of a **ecological science**[21] as the first "*scienca nueva*" introducing the **importance of the context**, the **importance of putting together separated disciplines** in a systemic approach, the link between nature and culture, and the necessity of a communication of science and the value of science as the future of our world and humanity depends on it.
4. The consequences of this general ecological type of thinking are the following concepts: **ecology of action** (supported by a principle of complex causalities developed in the first volume[22]), **ecology of ideas**[23], **social ecology**.
5. The **genotypic and phenotypic** relationship of the living, where both must be thought interacting with each other, and not separately (**endogenous-exogenous dynamical type of relationship**).
6. The emergence of two types of entities: **second order** (polycellular organisms) and **third order** (societies of polycellular organisms).
7. The **paradigm of auto-eco-re-organisation** (*self-eco-re-organisation*), as a universal principle for understanding the living (including humans). This paradigm indicates that phenomenon are self organised, but also eco-dependant (they are always open and embedded in a larger eco system, a milieu) and re organised (they constantly maintain but also transform themselves in a recursive manner).

3. THE CONDITIONS OF KNOWLEDGE

3.1 Some key ideas about knowledge from the third and fourth volumes

After exploring the physical and biological dimensions of the emergence of our human and social nature, in the third and fourth volumes of "La méthode", to which we could add the epistemological work of "Science with consciousness" (1990), Morin explores the possibilities for the emergence of human knowledge. He explores the relationships of our knowledge with reality and the possibilities, limits, constraints and resources of our ability to answer various types of questions, leading to various types of investigations. As similarly with the two first volumes, Morin uses again a circular approach. This circular approach starts in the third volume from the

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[21] Capra (who was initially a physicist) , have recently used similar sources as Morin (cybernetics, general system theory, self organisation, ecology, quantum physics, dissipative structure autopoïësis) to reach similar conclusions on the necessity of developing an ecological and systemic type of thinking (Capra, 1996, 2002),

[22] In « System effects, complexity in political and social life », Jervis (1997), quoted recently in Vaughan (2005) and Roberts (2005), offers - through a conceptual framework developed from science of complexity and grounded in empirical data of political events - an illustration of this type of « ecology of action » and complex causalities principle.

[23] The ecology of ideas (as also developed for example by Bateson, 1977) concept will be developed in the fourth volume of « la méthode » (1991).

biological nature of knowledge, to the cognitive through the psychological and anthropological dimensions of knowledge. In the fourth volume, the approach is historical, political, sociological and finally "*noological*"[24]. Various works are therefore put together, articulated and discussed. Here are some of these works (again, this list is not comprehensive):

- Genetic epistemology of Piaget, approaching knowledge through its biological side,
- Neuro-science insights on knowledge from Maturana, Changeux,
- Epistemological, philosophical and historical works on science such as of Popper, Kuhn, Lakatos, Farayebend, Hanson, Holton, Bateson …
- Logic from Gödel, Tarski, Russel, Whitehead …
- Philosophical works about knowledge from Kant, Husserl, Heidegger, but also Habermas, Adorno …

3.2 Concepts extracted

Some important ideas and concepts can be extracted from the discussions and developments contained in these three books[25]:

1. The intrinsic difficulty of understanding knowledge because of the communication difficulties between its **natural dimension** [information, computing, articifical intelligence], its **biological dimension** [central nervous system, phylogenesis/ontogenesis of brain], **its human and social dimension** [linguistic, cognitive psychology, psychologies, psychoanalysis, psycho sociology, cultural anthropology, sociology of culture, sociology of knowledge, of science, history of culture, of beliefs, of ideas, of science], **its philosophical side** [theory of knowledge], **its "in between" science and philosophy dimension** [logic, epistemology].
2. The cognitive **analogical/logical** duality and **explanation/understanding** duality of our relationship with reality, as well as a cognitive duality between a **simple/complex** approach of reality.
3. A strong influence of a **great western paradigm**, separating a philosophical thought (meant to be reflexive) and a scientific one (meant to be based on observations and experiments)[26], although both can't be simply summarised as such. This great paradigm is also developed by Morin around the traditional oppositions of **subject/object**, **spirit/body**, **mind/matter**, **quality/quantity**, **finality/causality**, **feeling/reason**, **freedom/determinism**, **existence/essence**.
4. Although science is developed under four independent legs (empirism, rationality, verification and imagination), there is however **a subjective side of the scientific objectivity,** hidden for example under *paradigms* (Kuhn), but also *schemata* (Holton), which are metaphysical statements, which organise preferences and define some of the values of the scientific works
5. Knowledge is therefore a **product of a biological, cognitive, psychological, historical, sociological, economical and political** conditions **allowing deviancies** and **new theories** to be generated, tolerated and expressed themselves, to allow new visions. This of course can't be seen as deterministic, there is a **principle of endogenous/exogenous process** (micro/macro) generating novelties, that can't be predictive in terms of what will be the new scientific ways of looking at the world, and radical changes are always possible.
6. **There exists systems of ideas**: scientific, philosophical, ideological (the last one supported by doctrines) where science is an extension of philosophy and where ideologies and doctrines differ from science and philosophy (offering the possibilities of debating) as they re not opened and "**bio-degradable**", as scientific and philosophical developments are. Science must be thought philosophically, epistemologically, but the reverse is also true, philosophy must be thought scientifically.
7. A **principle of uncertainty about knowledge and reality**, and the importance of the awareness about our **mistakes and illusions** in the process of generating knowledge, based on models that must be understood as mediations between the world and us, not a definite understanding of things, but as evolving.

4. COMPLEXITY, SAFETY AND SECURITY

Managing safety and security is about dealing with complexity.

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[24] Morin suggests, following Popper, Bateson, Monod, Dawkins … that ideas, theories, myths have their own autonomy, evolving as self organised entities and systems, under principles of evolution. This type of approach is currently being developed, following Dawkings book ("the selfish genes", 1976) through the field of "memetic".

[25] As for the previous parts, these are very limited extractions of what these volumes contain!

[26] This distinction is the result of the dualistic philosophy of Descartes.

The concepts extracted from Morin's work come naturally as macro-concepts for guiding, organising and thinking the problems and events related to security and safety issues.

From the Columbia explosion commission report to the 9/11 terrorists attacks reports[27], we see in both domains the **ecological/systemic** dimensions of theses events, but also the complex **causalities/ecology of action** principles as key concepts for understanding these failure of foresights at the global level[28].

Jervis (1997) has extensively used the domain of science of complexity and systemic perspectives for demonstrating this in the political and social worlds. Vaughan quoted his work for supporting her statement about the nature of complex social systems, and the nature of accidents. Our own experience in investigating accidents (e.g. Lecoze et al 2005) have shown us how people taking decisions (which can be regulatory decisions, as well as corporate decisions) "*shaped the landscape in which the accident unfold*" (Rasmussen and Svedung, 2000).

What can be also interesting to notice regarding this aspect is that often we find that impacts of changes and decisions (either technological or organisational) are thought through quantitative type of indicators. Organisational performance is often dominated by quantitative indicators for managing purposes and for continuous improvement type of thinking, where referencing points are needed for following trends in improvements. The insistence on quantitative indicators can be seen as a influence of the **great western paradigm** as described by Morin for which all qualities tend to be shadowed, tend to disappear in favour of only quantitative dimensions. In companies, it is often that only quantifiable indicators are primary used over more qualitative ones. It is true in the accident of Challenger (Vaughan, 1996) where engineers only had their intuition for arguing against the launch of the shuttle, so that in a positivist and engineering culture, these could not be used as strong enough proof.

In the report of the 9/11 we find similar type of problem regarding the way the FBI organisation was assessed: « *First, performance in the Bureau was generally measured against statistics such as numbers of arrests, indictments, prosecutions, and convictions. Counterterrorism and counterintelligence work, often involving lengthy intelligence investigations that might never have positive or quantifiable results, was not career-enhancing."*

There is a strong **quality/quantity** opposition in our paradigm of science that make qualities difficult to be expressed and taken into account as much as quantitative ones, although a lot of the dimensions of our organisations can only be expressed qualitatively, and not under quantified indicators. Hopkins (2000) has stressed in major accident also the misleading occupational health and safety indicators when it comes to major accident trends[29]. However, the task for defining suitable major accident indicators is a difficult one, as dimensions such as or example collective mindfulness (Weick and al, 1999), which can be seen as features of reliability of organisation, are difficult to put in numbers.

Principles of **self-organisation** and of **recursivity** are also key concepts for understanding that control of all organisational dynamics is an illusion[30]. Systems self-organise themselves in unpredictable ways. They create patterns sometimes sustained and detrimental to safety. But for understanding these patterns it is impossible not to open them to the **context** and the **history** of these phenomenons being revealed with the favour of hindsight. They are also the products of **order/disorder/interaction/organisation** principles within sociotechnical systems where "*failures comes from either a loss of order, something always suspected, or from an increase in order, a newer suspicion that is consistent with what is known about phenomena such as vicious circle, excalations and anti tasks*" (Weick, 1998).

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[27] We mention these two as they are examples of in depth investigation. Without such investigations it would be very difficult to learn, and find better ways of preventing catastrophic events. We have made (Lecoze and Dechy, 2005), based on the 9/11 report, a comparison between safety and security in order to show the relevance of the concepts of safety for the issues of security, as they share some common system, human and organisational issues. Of course, reports can be reviewed, completed and in some cases contradicted, but they are the basis for an in-depth understanding of systemic events.

[28] We apply these concepts (systemic/ecological, complex causalities/ecology of action, self eco re organisation…) as meta-mental frameworks for guiding accident investigation but also developing auditing (lecoze et al, 2005). These meta principles must be completed by disciplinary based works from psycho cognition, psycho sociology, socio logy, safety management. A list of some of the concepts existing in these fields is suggested in the next part.

[29] We have also found similar pattern in our investigations.

[30] We can suggest here a quotation from Meadow (2001) «*People who were raised in the industrial world and get enthused about system thinking are likely to make terrible mistakes. They are likely to assume that here, in system analysis, in interconnection and complication, in the power of the computer, here at last, is the key to prediction and control (…). I assumed that at first too (…), it was going to make systems work (…), but self organizing, non linear, feed back systems are inherently unpredictable. They are not controllable (…), we can't optimise (...), we can't keep track of everything (…), we can't control systems or figure them out (...)*". Rasmussen has also stressed this (1997) "*Often we found that attempts to improve the safety of a system from models of locals features were compensated by people adapting to the change in an unpredicted way."*

These patterns (such as normalisation of deviance, practical drift etc) are therefore self-organised, but also eco-dependant of their contexts in which they are maintained and transformed. The paradigm of **self-eco-reorganisation**, is therefore useful for thinking the open, self organised and evolving nature of these patterns. These concepts extracted from Morin's ideas help visualising the dynamical aspects of safety and security.

The accidents and attacks also reveal often new worldviews[31], a worldview that was not held possible before the events by a number of people. In that respect, the **ideologies and doctrines** maintained about the world, ideologies not opened to other debates, often configure the organisations into blind systems, not ready for what was thought as impossible by some, before the events. People having conflicting worldviews with others, and especially official worldviews (held by people at high position, with power) but also under cultural type of influence, and willing to express them require as much as for new scientific theories that some conditions exist for them to first express these conflicting views but secondly to be heard by the others. The "wisthle blowers" often play these roles. They appear in reports following disasters. We often find that ideas about the possibility of events can be found to have been already discussed, or even sometimes written at some points by people belonging to the organisations in charge of preventing accidents or preventing attacks. There is a need therefore to ask what are the favourable conditions[32] for these views at odd with the common beliefs (or ideologies, doctrines) to be expressed and listened to[33]. A type of requisite variety[34] is required for a complex world, where possibilities, emergence of unpredicted configurations are intrinsic features.

This requisite variety face the cognitive process based on the duality of **simplistic assumptions** (used for action[35]) and **complex ones** (which are more time consuming, requiring conflicting views to be expressed but also requiring a level of expertise about problems encountered). Weick (1998) noted that "*In order to act collectively, people adopt simplifying assumptions. Simplification limits the precaution people take and the range of undesired consequences they envision. These simplifications states the stage for surprise*". But the cognitive dimension is not the only one, and it is therefore a multidimensional approach that is needed, which requires articulation of various disciplinary based knowledge about safety and security, as the epistemology of complexity suggests us.

We have started (lecoze, 2005) to try to put together such a research strategy by looking at available works about safety and accident in cognitive science, psycho-sociology, sociology, management and political perspectives. This approach can be used for accident investigation but also for offering new perspectives of auditing and designing or "engineering" (see Hollnagel et al, 2006) the reliability or resilience of socio-technical systems.

As examples, works from

- Psycho-cognitive scientists such as Hollnagel (1993, 2004), Amalberti (1996), Reason (1993, 1997), Rasmussen (1997), Rasmussen and Svedung (2000),

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[31] In the terrorist attacks, the possibility of having planes crashing into towers in New York was quite a shocking and improbable scenario, a scenario difficult to imagine before the events for a lot of people. The Columbia accident report reveals also the difficulty to make sense and realise the risk potential of the foam strikes until the events occur. We find here the Turner vision of disasters (1978), that transform our worldviews, a bit similarly as science and new theories transform our worldviews at one point.

[32] For Morin (1991, 52), a certain number of conditions are favourable to a weak cultural determinism and possibility of the autonomy of knowledge : sociological conditions (exchanges, commerce, social plurality, international relations, democracy or enlighten despotism…), cultural conditions (pluralities, cultural commerce – communication, exchanges -, conflicts, disorder, regulation of debate, empirico-logic verification– science, freedom – tolerated deviance…), paradigmatic crisis (revolution in principles of knowledge…). Similarly, it could be interesting to try to find out the conditions in which "whistle blowers" are taken into account, and allow risks at odd with the official views and under the weight of the cultural influences to be identified and controlled when necessary.

[33] An idea in that sense is presented in Admonton et al (2005), with a "learning by doing" approach, as explained in the following: "*Through a "probe and learn" approach that is creative and iterative in nature, exploratory experimentation seeks to "try it and see". Investigators collect and interpret feedback rapidly and then design new trials. The goal is to discover new things, to generate new hypothesis about how the world works. In contrast the formal hypothesis-testing experiments, "proof is the desired end, not discovery (…) In the challenger hearings, physicist Richard Feynman used a simple experiment to demonstrate the relationship between cold temperatures and O-ring malfunction. By submerging a piece of O-ring rubber of iced water, Feynman revealed that the now frigid material returned to its initial shape slowly, imply that O-rings could not form and effective seal under cold launch conditions".* Of course, the initial beliefs held for technical systems can be experienced but the "ideologies" regarding the way human and organisation behave is another problem. Managers can tend to see human and group as behaving a certain way until the accident reveals something else about these behaviours. These can't be experienced in the same way that technological systems behaviour can be experienced as suggested.

[34] Some have developed the ideas of requisite imagination (Westrum et al, 2003) for that purpose of thinking of the impossible but also accepting it and acting on it.

[35] Psycho cognitive scientists, such as Amalberti (1996), have shown at the individual level, how making complexity "simpler" is a meta-cognitive strategy used by operators for dealing with their tasks, and having suitable models (explaining and predicting) to perform their specific tasks. Reducing complexity is a key strategy for them. It has strong implication for individual and collective actions.

- social scientists (Weick, 1993), Weick et al (2001), Turner (1978), Vaughan (1996, 1997, 2005), Snook (2000, 2005), Perrow (1984),
- political scientists (Laporte, 2001), Sagan (1993, 2004)
- safety engineering scientists (Leveson, 2004, 2005, Johnson, 1978),
- safety management (Hale, 1999)

provide conceptual supports and need to be articulated together for a better appreciation of incremental patterns detrimental to safety and security.

These works offer interesting concepts such as incubation period, organisational learning, redundancy, system effects, power and culture[36], to which we could add concepts of reliability of cognition, of requisite imagination, of collective mindfulness, of structurally induced inaction etc. Of course, the difficulty is to embrace an organisation within its context in one "motion", the dynamic of the system as a whole is very difficult, or impossible to capture totally. It raises empirical and methodological difficulties of collecting, but also interpreting data.

CONCLUSION

Morin's "Complex thought" strategy is a powerful instrument for approaching in a circular manner the disciplinary based knowledge and for thinking the nature of safety and security issues. In this paper, concepts extracted from Morin's work and some of them have been used for discussing the nature of disasters.

Disasters are the result of a **ecological/systemic dynamics** principle resulting from **complex causalities/ecology of action** principle, both principles leading investigation and auditing to a multidimensional and global approach. Disasters should therefore be understood as the results of **biological-cognitive-social-cultural-historical-political-economical** dynamic. They require a complex approach, for which the **self-eco-re organisational** nature of the incremental patterns leading to them should be detected and prevented in time. This is a challenging conceptual and empirical task implying the collaboration of several disciplines together.

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