Chapter (Draft Version)

Complexity Studies and Security in the Complex World: An Epistemological Framework of Analysis

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1. Introduction

The impact of systems thinking can easily be found in numerous security-oriented research, beginning from the early works on international system: Pitrim Sorokin, Quincy Wright, first models of military conflict and war: Frederick Lanchester, Lewis F. Richardson, national and military security (origins of RAND Corporation), through development of game theory-based conflict studies, International Relations, classical security studies Morton A. Kaplan, Karl W. Deutsch [Mesjasz 1988], and contemporary studies on broadened concepts of security proposed by the Copenhagen School [Barry Buzan *at al.,* 1998]. At present it may be even stated that the new military and non-military threats to contemporary complex society, such as low-intensity conflicts, regional conflicts, terrorism, environmental disturbances, etc. cannot be embraced without instruments taken from modern complex systems studies.

Unfortunately, in many instances, validity of applications of ideas and methods deriving from complex systems research in security-oriented studies are weakened by insufficient understanding of contemporary social sciences and complex systems ideas. During the Conference "Complexity, Global Politics, and National Security" held at the National Defense University, Washington, D.C. on November 13-14, 1996, [Alberts & Czerwinski, 2002], Murray Gell-Mann [2002] in his introductory speech, made an attempt to identify the links between security-related issues and broadly defined complex systems studies. He stressed that one of the obstacles in the

discussion during the Conference was that too broad definition of security made it difficult to identify the links between security studies and complex systems research.

The aim of the paper, treated as an introduction to a broader research, is to provide some answers how to understand and to overcome conceptual barriers challenging applications of complex systems concepts in security-oriented studies. These answers should allow to develop an epistemological framework for applications of the ideas taken from complex systems research in security-oriented discourse and practice.

2. Concepts of Security

According to the most popular etymological interpretation, the term security derives from Latin *securus* safe, secure, from *se* without + *cura* care - the quality or state of being secure or as a freedom from danger (freedom from fear or anxiety). In the classical sense security - from the Latin *securitas*, refers to tranquility and freedom of care, or what Cycero termed the absence of anxiety upon which the fulfilled life depends [Liotta 2002: 477].

The traditional meaning of security is deriving from foreign policy and international relations - “objective security” "military security". Security is treated as an attribute of situation of the state, equivalent to absence of military external conflict. Such an approach was proposed in theory of International Relations in realism and neorealism and can be linked with classical security studies and strategic studies.

This sense of security can be extended by the concept of internal security i. e. absence of threats to the state system and to the everyday life of its citizens caused by political and or military disturbances within the borders of a country. After September 11, 2001 a broadened concept of Homeland Security embodying both external and internal threats was institutionalized in the USA in November 2006.

The second term, military security can be to a large extent associated with both traditional meanings of security – external and internal. In numerous cases all combat-related military activities are given security context in its traditional sense – national security.

In the realist, and later, neorealist approach, military security is an attribute of relations of a state, a region or a grouping of states (alliance) with other state(s), regions, groupings of states. Security is viewed as an absence of threat or a situation in which occurrence of consequences of that threat could be either prevented or state (region, alliance) could be made isolated from that.

Broadening the neorealist concept of security means inclusion of a wider range of potential threats, beginning from economic and environmental issues, and ending with human rights and migrations. Deepening the agenda of security studies means moving either down to the level of individual or human security or up to the level of international or global security, with regional and societal security as possible intermediate points. Parallel broadening and deepening of the concept of security has been proposed by the constructivist approach associated with the works of the Copenhagen School [Buzan *et al.* 1998].

These characteristics can be called the core of the concept of security and can be used as a point of departure for elaborating a survey of systemic attributes which appear in any discourse on security [Mesjasz 2006].

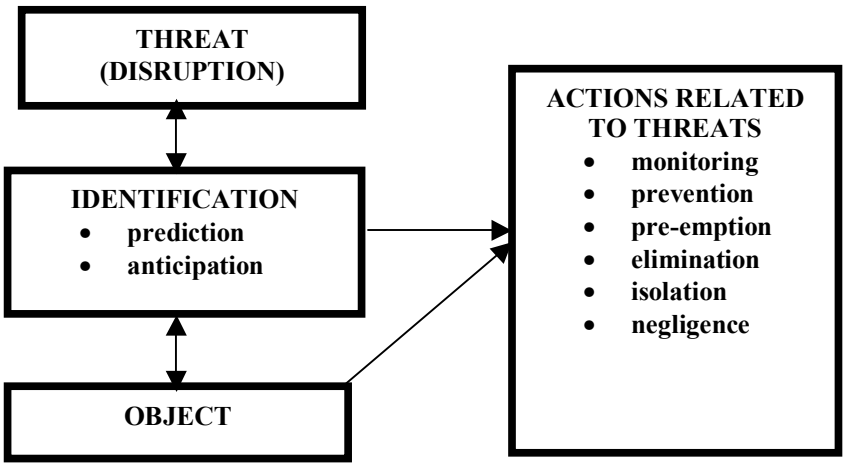

Fig. 1. The core of the concept of security

In order to preserve and develop analytical properties of the concept of security, a specific "middle-of-the-road", eclectic approach is proposed. It combines at least declarative objective value of widened neorealist broadened security concept with the constructivist, and at the same time "deepened" idea of security viewed as an "act of speech" [Buzan *et al.* 1998].

In the eclectic approach security is referred to the following sectors: military, economic, political, environmental and societal. Following Buzan *et al.* [1998] the concepts of existential threat and securitization are used. Any public issue can be securitized (meaning the issue is presented as an existential threat, requiring emergency measures and justifying actions outside the normal limits of political procedure). Security is thus a self-referential practice, because it is in this practice that the issue becomes a security issue - not necessarily because a real existential threat exists, but due to the fact that the issue is depicted as a threat [Buzan *et al* 1998].

A mirror concept of desecuritization can be defined as a process in which a factor (threat) which under one "speech act" compels extraordinary measures in another "speech act" is presented as not requiring such measures [Wæver 1995].

The proposed approach to security allows to find a compromise between a neorealist assumption of predictability of objective threats, and constructivism's denial of any possibilities of prediction. Inspiration for solution of this dilemma can be found in other normative social sciences, especially in economics and management. Possibility of reconceptualisation of prediction in those disciplines was mainly resulting from abandonment of mechanistic views of social processes. Instead of refining extrapolations, computer models, scenarios and forecasts, stress is being put on the mechanisms of learning which result in making predictions, like in

management [van der Heijden 1996], or in refining methods applied in forecasting like in the future studies [Glenn & Gordon 2006].

3. Complexity and security

3.1. Defining systems and complexity

There are various interpretations of relations between cybernetics and systems thinking but we can agree with Ludwig von Bertalanffy [1973] that the former can be regarded as a part of the latter. As to avoid unnecessary typological considerations, it is also assumed that complex systems studies are regarded herein as a part of systems thinking [Mesjasz 1988], [Midgley 2003].

Even more difficult problems arise in defining terms associated with "studies of complexity", "complex systems studies", or the like. The author refrains from using the terms "complexity theory", or "complexity science" although an idea of "emerging sciences of complexity" has been already proposed [Waldrop 1992]. The challenges were even reflected in the article of John Horgan [1995] titled: "From Complexity to Perplexity". There is not any commonly accepted definition of complexity and such a definition seems neither needed nor achievable.

The first attempts to study complex entities go back to the works of Weaver [1948] (disorganized complexity and organized complexity), Simon [1962] - the Architecture of Complexity, and Ashby [1963] – the Law of Requisite Variety. In his search for explaining the meaning of complexity Seth Lloyd [1989] identified 31 definitions of complexity. Later, according to John Horgan [1997: 303] this number increased to 45. In other writings numerous definitions of complexity have been formulated and scrutinized – [Waldrop 1992], [Gell-Mann 1995], [Kauffman 1993, 1995], Holland [1995], [Bak 1996], [Bar-Yam 1997], [Biggiero 2001].

Impossibility of decomposition of such an entity and incomprehensibility are also treated as important facets of complexity. Gell-Mann [1995], shows that complexity can be treated as a function of the number of interactions between elements in a system. Nicolis and Progogine [1989] prefer measures of complexity based on system "behavior" rather than on any description of system interactions. Similarly, behavior is also a foundation of analysis and description of CAS (Complex Adaptive Systems) [Holland 1995].

Complex systems exhibit non-linear, "chaotic" behavior. During unstable periods, such as chaos, non-linear systems are susceptible to shocks (sometimes very small). This phenomenon, called "sensitivity to initial conditions" and popularized as the Edward Lorenz's "butterfly effect", exemplifies the cases, where a small change may generate a disproportionate change [Gleick 1997].

One of most recent ideas of complex research are the scale-free networks discovered by Albert-László Barabási in 1999 [2003]. After finding that various networks, including some social and biological networks, had heavy-tailed degree distributions, Barabasi and collaborators coined the term "scale-free network" to describe the class of networks that exhibit a power-law degree distribution, which they presumed to describe all real-world networks of interest..

Complexity can be also characterized by multitude of other ideas such as artificial life, fractals, bifurcations, co-evolution, spontaneous self-organization, self-organized

criticality, chaos, edge of chaos, instability, irreducibility, adaptability, far-from-equilibrium-states which are extensively depicted in a large number of writings quoted and not quoted in this paper.

The above ideas can be called "hard" complexity research as an analogy with "hard" systems thinking[1]. The "soft" complexity research, also coined per analogy with "soft" systems thinking, includes the ideas of complexity elaborated in other areas – cybernetics and systems thinking, social sciences and in psychology. Initially, they were developed independently but after the growing impact of CAS and chaos, their authors began to treat the "hard" complexity concepts as a source of new ideas.

Subjectivity is the first aspect of complexity in the "soft" approach. Following this line of reasoning, from the point of view of the second-order cybernetics, or in a broader approach, constructivism [Glasersfeld 1995], [Biggiero 2001], complexity is not an intrinsic property of an object but rather depends on the observer.

As to identify a genuine epistemological meaning of complexity, based on some properties of the relationships between observers (human or cognitive systems) and observed systems (all kind of systems) Biggiero [2001: 3] treats predictability of behavior of an entity as the fundamental criterion for distinguishing various kinds of complexity. He proposes three classes of complexity: (a) objects not deterministically or stochastically predictable at all; (b) objects predictable only with infinite computational capacity; (c) objects predictable only with a transcomputational capacity.

The typologies presented by Biggiero lead to two conclusions important in studying social systems. Firstly, self-reference characterizes the first class, which relates to the many forms of undecidability and interactions between observing systems [Foerster 1982]. This property in some sense favors the subjective interpretations of complexity. Second, human systems are characterized by the presence of all sources and types of complexity [Biggiero 2001: 4-6]. It may be then summarized that human systems are the "complexities of complexities".

In social sciences, and particularly in sociology, special attention is given to the concepts of complexity of social systems proposed by Niklas Luhmann. First of all, as one of a few authors, he made an attempt to provide a comprehensive definition of a social system based solely on communication and on the concept of *autopoiesis* (self-creation) of biological systems. According to Luhmann, a complex system is one in which there are more possibilities than can be actualized [Luhmann 1990: 81].

The idea of complexity of Luhmann is also used in defining risk in social systems. The large amount of elements in a given system means that not all elements can relate to all other elements. Complexity means the need for selectivity, and the need for selectivity means contingency, and contingency means risk [Luhmann 1993].

Complexity of social system developed by Luhmann is strongly linked to self-reference since reduction of complexity is also a property of the system's own self-observation, because no system can possess total self-insight. This phenomenon is representative for epistemology of modern social sciences, where observation and self-observation, reflexivity and self-reflexivity, and subsequently, self-reference are

[1] The term soft complexity science is used, among others, by Richardson and Cilliers (2001).

playing a growing role. According to this interpretation, social systems are becoming self-observing, self-reflexive entities trying to solve arising problems through the processes of adaptation (learning).

An interesting definition of complexity was proposed by biologist Robert Rosen, who also elaborated the concept of anticipatory system, i.e. a system containing a predictive model of itself and/or its environment, which allows it to change state at an instant in accord with the model's predictions pertaining to a latter instant [Rosen 1985: 341]. According to Rosen, a system is simple if all its models are simulable. A system that is not simple, and that accordingly must have a nonsimulable model, is complex. [Rosen 1998: 392][2].

Using the concept of Luhmann's complexity, Qvortrup has put before the concept of hypercomplexity. He linked Simon's "bounded rationality" as a limitation to choice (selection) with the complexity resulting from impossibility to make that selection. Hypercomplexity is complexity inscribed in complexity, e.g., second-order complexity. As an example, hypercomplexity is the result of one observer's description of another observer's descriptions of complexity, or it is the result of a complex observer's description of its own complexity [Qvortrup 2003: 7].

3.2. Complexity and security: Mathematical models, analogies and metaphors

While systems thinking sought for holistic ideas and universal patterns in all kinds of systems, complexity research defined its goals in a more specific manner. A common theoretical framework, the vision of underlying unity illuminating nature and humankind is viewed as an epistemological foundation of complexity studies [Waldrop 1992: 12-13]. This claim for unity results from an assumption, that there are simple sets of mathematical rules that when followed by a computer give rise to extremely complicated, or rather complex, patterns. The world also contains many extremely complicated patterns. Thus, in consequence it can be concluded that simple rules underlie many extremely complicated phenomena in the world. With the help of powerful computers, scientists can root those rules out. Subsequently, at least some rules of complex systems could be unveiled.

Although such an approach was criticized, as based on a seductive syllogism [Horgan 1995], [Richardson & Cilliers 2001], it appears that it still exists explicitly or implicitly in numerous works in the hard complexity research.

Another important epistemological contribution of complexity, and of non-linearity in particular, is if not impossibility, then at least very limited capability of prediction and control which are viewed as the most important characteristic of complex systems.

Although security studies cover a very broad area, including also purely technical issues, they can be treated as a part of knowledge about society, sharing numerous

[2] Despite expectations towards the anticipatory systems of Rosen (1995, 1998), not any directly or indirectly security-related research applying those ideas model has been identified.

components with social sciences. Ideas originated in systems thinking and complexity studies are used in security-oriented research as models, analogies and metaphors. The term "models" is used only for mathematical structures.

Models, analogies and metaphors deriving from systems thinking and complexity studies are gaining a special significance in social sciences. For mathematical models it is quite obvious that they are associated with “objective” research. Analogies and metaphors taken from complex systems studies are related to ideas drawn from "rational" science. They are treated as "scientific" and obtain supplementary political influence resulting from "sound" normative (precisely prescriptive), legitimacy in any debate on security theory and policy.

In applications of models, analogies and metaphors in social sciences the following approaches can be identified: descriptive, explanatory, predictive, anticipatory, normative, prescriptive, retrospective, retrodictive, control and regulation.

Bell, Raiffa and Tversky [1988] have proposed to discern between the normative approach resulting from mathematical models, predominantly game models, and prescriptive approach reflecting recommendations resulting from decision analysis, including also qualitative aspects.

Following the distinction from traditional cybernetics, control and regulation approach can be also proposed. In management this approach is expressed in a way the dominant analogy or metaphor influences control of a system, i.e. they differ for mechanistic, evolutionary or learning system, e.g. [Senge 1990], [Palmer & Dunford 1996]. Limitations of prediction of behavior, design and control of complex systems impose also other ways of to complex systems. Axelrod & Cohen [1999: xvi] proposed to “harness” complexity of social systems:”…to convey a perspective that is not explanatory but active – seeking to improve but without being able fully to control”.

Another lesson non-linear dynamics and complex systems teach us is that social changes, or in a broader sense, evolution, are produced by both deterministic historical factors and chance events that may push social phenomena to new patterns of behavior. Thanks to better understanding the confluence of chance and determinism in social systems we may better learn what kind of actions we have to undertake, or even perhaps, what kind of norms we have to apply.

It must be also reminded that analogies and metaphors of rather loosely interpreted non-linearity, chaos, complexity, self-organization, etc. in many instances have become the backbone of the post-modernist (post-structuralist) new science. Reaffirmation of limited predictability has become an epistemological foundation of the discourse-based science. Numerous examples can be quoted but as an illustration a it is worthwhile to recall synthesis of Braudel and Priogogine made by Wallerstein [2000: 160-169].

The above epistemological links between complexity research and social sciences are predominantly associated with the “hard” complexity. The input to this area exerted by the “soft” complexity research is equally significant. Reflexive complexity of society has become one of the foundations of post-modern social theory.

Unfortunately, various abuses and misuses may occur, when analogies and metaphors drawn from “hard” complexity research, and to a lesser extent from “soft” complexity research are treated too carelessly even by eminent social theoreticians of

post-modernism/post structuralism. Several examples of such abuses are mirrored in the so-called "Sokal Hoax" and other examples widely described by the originator of that hoax [Sokal & Bricmont 1998]. The warning message conveyed in that book is of a special importance since broadening and deepening the concept of security contributed to the development of critical security research frequently referring to post-modernism, and sometimes directly or indirectly, to complex systems research. [Albert & Hilkermeier 2003].

3.2. Complex systems in security theory and policy: Can expectations be fulfilled?

An overview of security-related expectations towards complex systems studies should open from a brief sociological survey in which the following question will be answered: Who and what is expecting from whom? What can be delivered by those whom the expectations are addressed to?

Most frequently expectations towards complex systems research are articulated by specialists in International Relations and in associated areas – security studies and peace and conflict research. All those disciplines eclectic, thus complexity studies naturally enrich epistemology of those sciences. It is interesting to observe that complex systems are applied equally by representatives of the mainstream security studies, who treat it as a kind of extension of rational choice-based considerations [Axelrod and Cohen 1999], and by the so-called critical approaches in security research, and in a broader sense, in International Relations [Albert and Hilkermeier 2003].

Policy makers are the second group who, rather indirectly, through the academic research and/or advisors express their hopes, to ameliorate their understanding of the world with the use of complex systems ideas.

Close to policy makers the military community can be placed. A part of their expectations are similar to those of the policy makers, especially at the strategic level. However, numerous expectations of the military are deriving from their will to adapt complexity methods at all levels to the situations in which military units can be used. Not only in classical military conflicts but also in the post-conflict situations as well as in various emergency situations.

It is also necessary to mention the media and the societies, or the general public, the last social actors awaiting new insights from complexity research. Increasing complexity of the surrounding world enhances natural curiosity of the phenomena directly and/or indirectly influencing the life of the individuals. Who is the addressee of those expectations and questions. First and foremost, it is a very incoherent community of academics, advisors and other professionals. The second group is professional military analyst, who are involved in developing new methods of accomplishing functions of military systems at all levels of their hierarchy.

Due to a very wide scope of meaning of security, and to a multitude of complexities, it is obviously impossible to enumerate all expectations towards the complex systems research. The fundamental expectation is simple. Although increasing complexity is viewed as a law of nature and society, but after the end of the Cold War the process of "complexification" of the world system has accelerated substantially. Social systems of the turn of centuries are more complex and are

labeled as chaotic society, or risk society [Beck 1992]. Reflected in all prognoses, uncertainty, speed of change, and complexity of political and economic affairs as well as environmental challenges contribute to the incomprehensibility of the world at all levels of its internal hierarchy [Glenn & Gordon 2006].

Widening and deepening of the sense of security also contributes to increasing real, or perceived complexity of the world. Since its very beginning, the complexity research was perceived as a source of a certain promise, a source of a new language, and at the same time contributed to such perception, that there were some patterns in complexity, which could be disclosed by the mathematics models taken from a new field of science. This intellectual and at the same time emotional impressions of incomprehensibility and at the same time an appeal for new approaches are well-reflected by the metaphor of "The Ingenuity Gap" proposed by Homer-Dixon [2002]. Assuming that security is always associated with an unusual disturbance undermining the existence (functioning) of an individual/system it may be assumed that in all security-oriented theories and policies, three basic human desires are expressed:

1. Reduction of uncertainty by enhancing predictive capabilities and strengthening potential of anticipatory activities.
2. Identification of patterns of functioning of the social systems and their components, allowing to enhance protection against the disturbances, ex ante and ex post.
3. Elaboration of norms and methods allowing improve functioning of social systems and of their components. .

This triad reflects the essence of any normative social discipline, yet for studies of security it has a special meaning due to the fundamental sense of security.

In a traditional state-centered security studies based upon "simplicity", expectations if not hopes for enhanced capabilities of prediction were the main goal of applications of "scientific" methods, including the ideas borrowed from early systems thinking - stability, polarity, hegemonic stability. More sophisticated descriptions and analyses based on systems thinking, e.g. bipolarity-multipolarity dispute of the 1960s and 1970s were to a large extent refined by applications of traditional systems thinking. Concepts drawn from the "older" systems thinking had and still have multiple applications in security-related considerations, e.g. the discourse on the sense of international stability [Mesjasz 1988].

The question is thus arising what are the peculiar advantages and disadvantages of applications of complex systems research in contemporary security-oriented discourse, and in policy making. Below an attempt to give a preliminary answer to this question is presented.

Description and explanation

Due to the fact that description and explanation of causal relationships are difficult to separate both approaches are discussed simultaneously. Broadly defined security studies employ complex systems concepts as analogies and metaphors, and mathematical models.

Analogies and metaphors drawn from complex systems research have significantly enriched the language of security discourse. It is now commonly accepted that only in a limited number o cases mechanistic explanations of functioning of social systems can applied. Such as utterances complexity, self-organization, the edge of chaos and the like have diffused into the language of security discourse. Of course, in most of such considerations it is not clearly stated what is truly chaotic (what attributes of social systems?) but undoubtedly such metaphors are a heuristically valuable instrument. As it was already stated, the notions taken from complex systems studies have substantially enriched hermeneutics of security discourse based on non-mechanistic interpretations of social systems.

In this point it is almost impossible to distinguish between the impact of "hard" complexity and "soft" complexity. The latter one, based referring to reflexivity, opens up the possibility to study cognitive aspects of social systems and the processes of communication. It is the basic instrument of applications of learning systems in security studies.

A closer look at the ways of communication allows to disclose an interesting link between complex systems research and the contemporary security policy On the one hand politicians, scholars, general public and journalists seek for utterances reflecting their perceptions of uncertainty and incomprehensibility. Emotionally laden term "chaos" may serve is the best example being at the same time a well-known metaphor and used at present to reflect some properties of non-linearity. At the same time the scholarly community, not completely incidentally offers the works with the titles responding to that demand: "Hidden Order" [Holland 1995], "The Origins of Order" [Kauffman 1993], "End of Certainty" [Prigogine 1997] and quite a few similar ones.

The need of understanding by the lay readers, and the demand for marketable titles are obvious, but recognized scholars presenting such concepts, voluntarily or not, have become the participants of the specific social discourse. An open question remains to which extent such new terms allow to name new social phenomena. It is only certain that such terms significantly enrich the language of social discourse on politics and security.

As an example the metaphor :order out of chaos" can be quoted. The meaning of chaos the Greek term *Χάος*, is associated with disorder, as well as chasm and void. This word has a very strong emotional appeal and almost immediately was applied in security discourse. It is worthwhile to remember that "order out of chaos" may have two meanings. The first one may mean emergence of order while the second could be interpreted as disclosure of a hidden order concealed by irregular patterns of behavior.

Another interesting link between widening security research and the concept of self-organization can be made. In the discourse on self-organization and emergence attention is shifted to the behavior of the elements and the mechanisms of emergence and self-organization.. It may be then hypothetized that such an approach could in the future provide some methodological solutions to already disputable definitional limitations of human security and on its development into a more precise concept. .

Complex systems research has provided a new understanding of explanation. It especially concerns possibility of explanation/prediction of the phenomena at the macro-level from the behavior of the elements at the micro-level. A good example of

this strategy is the Sugarscape project where the question “can you explain it?” as “can you grow it?” [Epstein & Axtell 1996: 177].

It is also worthwhile would like to pay attention on relation between the notion "complexity" and notion "the order parameter" introduced by L. Landau and "slaving principle" formulated by H. Haken in his works on synergetics. When a complex system is close to unstable point, the behavior of this system can by described and understood in terms of order parameters (the most unstable variables of the system). Since the number of order parameters is much smaller than the number components of the system, an enormous compression of information takes place. Therefore we can describe behavior of self-organizing complex system only with a few equations. This may support some expectations for security studies that perhaps some of those parameters can be identified in social systems in the studies of risks, threats and vulnerabilities.

Prediction

Enhanced capabilities of prediction, or even early warning, are undoubtedly the most important desire of security policy, and subsequently of majority of strands of security-related studies. Therefore the term stability borrowed from control theory has become of the buzzwords of security theory and policy. Stability in its original sense can be treated as equivalent to increased predictability.

First of all it is necessary to recall that predictability is dependent on an observer while determinism is not. In most radical form prediction implies connections of necessity, not of probability, between non-perfectly well-defined states, of the system separated by finite time intervals. It means that in order to predict future of the system we must know its present state. But present knowledge is never perfect and there are always the measurement errors in any determination of the present state [Saperstein 2002: 38].

It should be also mentioned that the divide linear is predictable and non-linear is not predictable, is a simplification. For instance, Newton’s equations for the two-body Kepler problem (the Sun and one planet) are non-linear and yet explicitly solvable. It means that non-linearity not always leads to chaos. At the same time the fundamental equation of quantum mechanics, the Schrödinger’s equation is absolutely linear [Sokal & Bricmont 1998: 144-145].

Saperstein [2002] using a relative simple model of bipolar arms race shows how including disturbance in such a model with may help in predicting occurrence of unpredictability in a (model) situation which was to some extent predictable beforehand. It means that in such situation s non linear models provide a specific additional knowledge about the limits of predictability.

The complex adaptive systems (CAS), the basic idea of complexity theory have numerous applications in modeling behavior of social systems. Since the results of CAS simulations are to a large extent not replicable then more advanced methods can be used to improve their usefulness in prediction. It can be achieved directly by improving data gathering, relevance of parameters, better understanding of the links between micro- and macro-levels although it is always of limited validity.

The CAS models are also helpful as an instrument supporting heuristic processes. Not all paths of developments can be predicted by qualitative human reasoning.

Therefore new patterns of phenomena achieved thanks to complex systems can add new solutions difficult to develop, or unachievable otherwise. Complex Adaptive Systems, or in a broader sense Agent Based Modeling, have another advantage in prediction. They can simulate learning processes both at the level of elements as well as at the level of entire systems.

Discourse on predictive capability of complexity ideas and their limitations is predominantly built upon mathematical models. However, it is not the only advantage of complex systems research. The language of analogies and metaphors used for explaining the mathematical models and deriving from those models can be also seen as a significant tool allowing to enhance cognitive and heuristic capabilities of academics and political actors. The non-Newtonian thinking with more attention paid not to general solutions, but for local equilibria undoubtedly strengthens the predictive capabilities of policy makers by enriching their mental models with new, less plausible counterintuitive options, which could have been otherwise omitted in the decision making process. This phenomenon has been very popular in management, where training management in (complex) systems thinking is an important instrument of increasing efficiency [Senge 1990].

Normative/prescriptive approach

Security studies and associated domains have a strong normative bias. Norms in security can be analyzed at several levels. They may result from ideology, interests, epistemological determinants and purely individual motivations and rules. Norms in security studies concern: (1) prediction of threats (What is the threat, risk, danger?), (2) prevention and preemption of emergence of threats, (3) rules of behavior when threats are affecting the system (individual), and finally (4), what to do as to minimize the consequences of the materialized threats.

Similarly, as for all approaches, normative consequences of applications of complexity models in security-related theory can be found in two areas. In general security considerations and in military aspects of security.

In general security theory and policy complexity studies were the final impulse for abandoning search for any universal and stable patterns. It was a natural consequence of limited predictability resulting from non-linearity. The central norm is at present not how to protect against the impact of a broadly defined environment but how to adapt to it dynamically in a most efficient way. The norms of behavior are identified with the rules of social learning.

In military applications complex models contributed to changing approach to combat which is perceived in non-linear terms, not as a clash of hard balls, but rather as an interaction of swarms. In consequence the centralized visions of command are replaced with decentralization and commend is viewed as one of the stimulants of self-organization [Moffat 2003].

Retrospection and retrodiction

Retrospection, or *post hoc* explanation as the basic instrument of methodology of historical studies is not a frequent approach in security discourse. Only when the need for better understanding of the current status is needed explanations of examples

from the past are used in helping to understand better the present phenomena. Although from the epistemological point of view retrospection and retrodiction are different but in preliminary methodological considerations the differences are not so important

Similarly as retrospection, retrodiction, or "what if?" approach is not too widely approved in security theory. It is always treated as too speculative for scientific considerations.

An opposite tendency can be observed in military thought. Retrospection and retrodiction are indispensable in case studies and/or war gaming and complexity-based models have become one of most efficient instruments of studying achievements and errors of command in historical battles [Ilachinski 1996a], [Czerwinski 2003], or within the framework of the Project Albert run by the Marine Corps Warfighting Laboratory [www.projectalbert.org].

Control and Regulation

Although in classical cybernetics control and regulation are separated in this survey they are discussed together. Similarly to prediction, any expectations that results of complexity research might help in significant improving control of social systems proved unjustifiable. Strive for rigid, centralized control has been replaced by approaches aiming at improvement of learning processes. Hierarchies are replaced by networks and it is common both in non-military security considerations as well as in military theory and practice.

A shift from hierarchical to distributed command and control. In general security theory, it is mirrored both in more skeptical views of traditional security – awareness of limits of capabilities, even of the superpowers. Widening and deepening of security, and especially the impact of post-modernism on security theory (security as a result discourse or of "securitization"), can also be viewed as a sign of resignation from expectations for far-reaching control at all levels of societal hierarchy.

4. Conclusions

The fundamental but rather obvious conclusion is that complex systems studies have become an indispensable part of epistemology of security theory and eventually a useful instrument of security policy at the cognitive (language) level. It concerns both the impact on action and the impact on the processes of social communication although it would be rather difficult to measure that impact. The uses of complexity-related mathematical models and analogies and metaphors have broadened the epistemological foundations of security research. It does not obviously mean that complex systems studies directly responded to the expectations of security studies in reference to prediction, explanation of causal effects, prediction, prescription, normative approach, retrospective, retrodiction and in enhancing (always limited), capabilities to influence the social phenomena.

The applications of complexity ideas in security discourse have two basic weaknesses. First, too high expectations from security theory and policy, and second, mutual misuses and abuses. Security specialists, journalists and politicians too often treat the complexity-related utterances as an element of the new, modern and to some

extent “magic” language. By the same token, scholars familiar with complexity models reduce social phenomena to very simple patterns, irrelevant to reality.

Reference to non-linearity, self-organization and chaos allows to deepen understanding of all social phenomena. But they are of a special significance in security-oriented research where they provide some response to the need for prediction and normative, action-oriented studies.

The significance of complex systems models is especially visible in deepening the knowledge of prediction and of its limitations in social sciences. The traditional security studies, represented by realism and neo-realism, were built upon the positivism and rational choice theory, which included expectations towards increased predictive capabilities of security studies. The constructivist approach denies the role of prediction in security discourse – how to predict categories constructed in the discourse? Therefore the ideas drawn from complexity may have a special twofold function in security theory. On the one hand they teach rational choice advocates about the limits of prediction, but at the same time they enrich the discourse of constructivists with the terms which in an implicit form assume a certain degree of prediction. Predicting chaotic behavior from nonlinear complex models is also a form of prediction both in qualitative and quantitative terms.

The discussion in the paper shows that some attention must be paid to efficiency, if not legitimacy of applications of complex systems in security theory and policy. Thanks to the ideas of associated with variously defined complexity epistemology of security studies has been enriched with instruments helpful in description and explanation. New social phenomena in the Information Society have received the names facilitating their understanding and the processes of social communication about them. Some causal relations could have been also better described with the conceptual apparatus of complexity research, e.g. consequences of non-linearity. At the same time, the language, if not the “jargon” of complexity, by permeating the language of security policy has a strong impact on activities taken in the fields. The examples of such terms as stability, turbulence, non-linearity, self-organization, chaos, edge of chaos, etc. used in the language and in practice of policy making strengthen the argument favoring the use of complexity ideas for explaining and shaping security.

Although complexity studies provided the final argument of impossibility of any far-reaching predictions in security research, at the same time it showed the methods of enriching predictive capabilities either with the use of mathematical models, or with applications of heuristically stimulating analogies and metaphors.

It is much more difficult to assess the value of applications of complexity research in purely military applications. At the general epistemological level the advantages are as above – better understanding of the surrounding world. It would be, however, worthwhile to study to which extent the new ideas presented in the works referred to in the earlier part of the text can help in achieving combat superiority, or at least parity, against an enemy not using that conceptual apparatus.

And finally, an interesting socio-political observation can be made about the applications of complexity-related ideas in security discourse. As can be seen from the earlier parts of the text and from the Bibliography, studies in that area are absolutely dominated by specialists and institutions from the USA. Representatives from other areas are less numerous, or are absent at all. It concerns both civilian, non military security discourse, and purely military considerations.

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