COMPLEXITY THEORY: THE SIMPLE ANSWER TO ALL OUR PROBLEMS PRESENTED AT 15ISMOR, SESSION H, 3 SEPTEMBER 1998

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Complexity Theory *is the latest analytical craze, following on from catastrophe theory, chaos theory, fuzzy sets etc. It is suggested that complexity theory is likely to have as little practical impact on defence analysis as these other theories, in the long run, and that it would be better for us to realise this now rather than in 5 or 10 years time.*

1. [1-3] It was back in 2015, and World War III was about to begin. Despite its economic travails over the previous 25 years, research in the resurgent Soviet Union had not been idle, and they had a new secret weapon: the butterfly! Capitalising on chaos theory, the idea was to deploy the butterfly at a critical moment, and with one flap of its wings, totally disrupt the enemy. Unfortunately, however, NATO had not been idle either, and had a counter-force strategy: its own butterfly! I won't bore you with the details of the deployment technology, aimed at maximising the influence of wing-flaps on the environment while minimising vulnerability, or the massive investment in lepidopticide research. However, you may wish to note that, of the $43Bn rumoured to have been spent on NATO butterfly R&D, fully 37% was devoted to genetically engineering the NATO star on the wings, which had no effectiveness contribution whatsoever.

2. [4] This absurd example is mainly a metaphor for the existence of magic solutions to problems, which rarely exist. When faced by several hundred tanks appearing over the ridge, it is highly advisable to have some more substantial countermeasure than a butterfly. It also reflects the fact that most writers on complexity theory seem to make a rapid connection with chaos. However, complexity theory is about bringing *order* to our understanding of complex system behaviour: the connection with chaos is quite incidental.

3. [5] Complexity theory is the latest fashion in analysis, following on from catastrophe theory, fuzzy sets, chaos theory etc, none of which really fulfilled their initial promise. It is being touted as the answer to a maiden's prayer. If it's so promising then we need to know more about it. However, if real money is to be spent investigating its possibilities, then we have a responsibility to the taxpayer to have at least some confidence that the money will not be wasted. I have to say that the evidence to provide this confidence is pretty thin on the ground so far in the case of complexity theory.

4. [6] I hasten to add that I am not against complexity theory as such, since the work so far, as exemplified in Kauffman's excellent "At Home in the Universe", is highly innovative and impressive. My gripe is about its application to defence analysis.

5. [7] Let's start by considering emergent behaviour, the most distinctive feature of complexity theory. The fact that complex high-level behaviour *can* arise from simple low-level rules does *not* necessarily mean that:

   a. Any particular instance of real complex high-level behaviour *must* in fact have arisen from simple low-level rules; or that

   b. Simple low-level rules can be found which will generate any given form of complex high-level behaviour; or even that

   c. If some specific real complex high-level behaviour *does* in fact arise from simple low-level rules, it will be possible to deduce what these rules are (cf trapdoor encryption algorithms).

In fact, it is clear that a much richer range of complex high-level behaviours must be possible from *complex low-level rules and interactions*, which occur abundantly in systems involving human beings.

6. [8] The hope of the complexity theorists seems to be that, rather as in thermodynamics, the same high-level behaviour should emerge to a great extent *regardless* of the detailed nature of low-level interactions. However, this remains to be proven: both thermodynamics and the systems studied by complexity theorists so far are actually governed by *very simple* rules: much simpler than those which apply to military systems. We already know that the simplest statistical rules of combat - Lanchester equations - represent only a very crude approximation to real combat. Any claim that a given variety of high-level behaviour applies must be backed up by a causal model or a mathematical proof (cf statistical mechanics) and should be consistent with historical data: an act of faith will not be sufficient. There is also the serious problem of how to present complexity theory results to decision-makers.

7. [9] Conflict is a very messy business with many interactions in which most effects have a large random component, and for which simple rules are very unlikely to be a sufficient explanation. In simulation we try to get away with as simple rules as possible, but they still tend to be pretty complex. The idea that simple rules will nevertheless be sufficient to replicate any form of complex behaviour is pretty incredible. The idea that a relatively arbitrary set of simple rules "will do"in order to generate suitable high-level behaviour is even more incredible.

8. [10] Qualitative understanding of system behaviour is not sufficient: quantitative prediction and control, consistent with historical data, are required if analysis is to be useful. Kauffman doesn't seem to offer much hope from the point of view of prediction and control. On the contrary, there is a definite fatalistic element in what he has to say, in that complex systems tend to have decentralised "minds of their own" which are specifically resistant to control.

9. [11] It is a bit too easy to make a name for oneself in a new field. Eventually, really hard work will be required to make significant progress, at which point I suspect there will be a mysterious migration to another fashionable topic. By analogy with catastrophe theory, for example, it would be very useful to have a topological theorem identifying *all possible* types of interaction between different classes of command agent. This would be a great achievement, but it will probably be *very* difficult, and even if it were achieved, it is not clear how mainstream defence analysis would be affected.

10. [12] It is interesting to consider what features a new analytical craze should have:

a. It should have a catchy title designed to appeal to the layman (so although tantalisingly technical, it should have an understandable everyday meaning, and with luck will generate a lot of money from popular book sales).

b. Below the superficial level, it should be too difficult to understand by all but a few (even/especially including scientific/research fund holders?). This enables all critics to be accused of not understanding it, while most of the rest won't be able to tell who's right. In terms of these first two criteria, the title "complexity theory" will be very hard to beat.

c. It should contain an element of truth. Otherwise its practitioners risk being seen as mere charlatans. More charitably, all those concerned should sincerely believe that it holds promise. Past examples include chaos (weather); neural networks (pattern recognition); fuzzy sets (the efficient storage of multivariate response surfaces).

d. It should promise a (magic) solution to many of our problems.

e. It should be revolutionary:

(1) It needs to be new and different, to catch the imagination.

(2) It must sweep away all existing approaches, since to build it into an existing approach would be too much like hard work. It is much harder to make progress in a mature field, and easier to make apparent progress in an immature field. Complexity theory itself tells us this!

(3) However, this is also a major weakness since not only does it fail to take advantage of previous work, but it implies significant change, which any bureaucratic organisation will strongly resist, especially without good reason (which *does* have to be understood).

11. [13] It would be useful to anticipate any new crazes yet to hit us, satisfying the above criteria. How about "Perplexity Theory"?

12. [14] I next have a number of quotes from Jamie Macintosh, a leading light in the UK complexity theory world. They are all from a paper called "Complexity Modelling: Commanding a New Economy of Force", which was presented at a conference last year[1]. I must apologise to Jamie for quoting him in this way, but he will lead with his chin. First of all some serious misunderstandings:

a. Classical "ideal" maths is irrelevant, because it has been "dealt massive blows" by Gödel, Turing and Chaitin (para 2.3.1 in the original paper). This shows a deep misunderstanding of the state of mathematics, and also that a little knowledge is a dangerous thing. The 20th century work does not invalidate previous mathematics, but establishes more clearly the boundaries between what can and what cannot be proved given any specific set of axioms.

b. "Information cannot be valued for quantity but only quality..." (3.6.2) Information theory of course belies this claim. It is true that information theory tends to concentrate on the syntactic as opposed to the semantic content of data, but even the latter, in both quantitative and qualitative terms, is increasingly yielding to modelling attack.

c. "Humans...make computationally undecidable decisions...everyday...". (4.1.5) If you believe, as I do, that the brain is a form of computer, then this claim is simply meaningless. A deeper analysis of the claim leads to two conclusions: that there must be a serious mismatch between the problems the brain actually solves and those which it is accused of solving (the latter being those which cannot yet be solved by electronic computers); and that the brain's parallel processing still gives it a speed advantage over the electronic computer for certain types of problem. No form of computer, including the brain, can decide a truly undecidable problem.

13. [15] Now for some gloriously meaningless quotes from Macintosh:

a. "Yet, if confidence is not to be grossly misplaced, this cannot be what Poincaré called *analytically blind* nor merely compromise systems further with what Van Creveld diagnosed as "Information Pathologies", largely through a lack of critical scrutiny." (2.3.3)

b. "It is global markets that are making asymmetry far more innovative than those unencumbered by state procurement chains and risk assessment." (3.7.3)

c. "In summary, the ESA sweeps up systemic threats or "threats without enemies", in terms of globalised instabilities shared across sustainable yet fragile ecologies and economies but not merely INFOSEC as IT infrastructure." (3.7.3)

d. "Thereafter, connectivity is folding space into multiple dimensions that change relations from distant to proximal very rapidly". (5.2.1)

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[1]Modelling International Conflict: IMA conference held at Wadham College, Oxford on 13-15 April 1997

e. "However, if semiotics in Reflexive Control excuses massive rule bases to capture situation awareness, it will radically miss the point, commanding no influence metaphorically or otherwise". (5.2.1)

14. [16] There is a worrying mystical element in much modern science, or should I say popular pseudoscience, and especially in complexity theory. Even Kauffman and Hawking have fallen prey to this. For example: "The central issue we confront is to reinvent the sacred." (Kauffman p4). At its most innocuous, it may simply be overenthusiastic and injudicious PR, or the result of striving for comprehensible metaphors for what are truly complex ideas (far too complex for the lay reader). Or laws of nature may be appreciated for their genuine beauty (which generally equates to simplicity, á la Ockham). At its worst, some theorists seem genuinely to equate emergent behaviour with magic. Somewhere in the middle, which is where Kauffman seems to sit, is the idea that humanity is stumbling about, having lost the psychological crutch of religion, and is desperate for any form of spiritual uplift, however absurd. It would be better if complexity theorists stuck to theory, and kept their messianic fervour in check. Remember the Feynman quote (which I am quoting from memory, so it may not be 100% accurate): "It is better not to know, than to know and to be wrong."

15. [17] Research fund-holders should remember Arthur C Clarke's law that sufficiently advanced science is indistinguishable from magic, and not be conned by glib salesmanship. They should also remember Gresham's law as applied to OR (bad OR will tend to force out good OR), since bad work, in cutting corners, can always achieve a faster response time than good work.

CONCLUSIONS

16. [18] Complexity theory *is* innovative and impressive in improving our understanding of certain very complex systems (principally biological ones so far). *But* its application to defence analysis has been vastly oversold: it is unlikely to provide more that a qualitative sidelight on military affairs. There *is* a need to remain open-minded and to encourage lateral thinking, but this should be tempered in responsible research fund-holders by an incisive ability to separate the sheep from the goats, and to terminate research programs if and when they exhaust initial promise.

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