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DEPARTMENT OF DEFENCE
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Combat Entropy as a potential MOE in land combat: early developments

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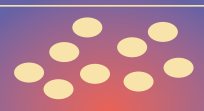
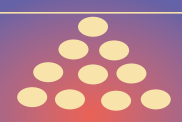


Disordered or Uncohesive System

Combat Entropy (S)

What is Entropy? A measure of disorder/order

What do we mean by it? The amount of order or "cohesion" in a force



Ordered or Cohesive System

Background

About 10 yrs ago, Carvalho-Rodrigues, Dockery and Woodcock [1] used Shannon's Information Theory ("entropy") to "predict" combat outcomes as part of their C2 investigations. It was solely attrition based.

They used $\Delta S = S_{blue} - S_{red}$ and an "entropic phase space" to do these predictions.

This "entropy" has been implemented in the cellular automata tool EINSTein as part of Project Albert.

We have determined that this description is too simple for combat.

The entropic phase space they used has no meaning.

We need something better for both EINSTein and for use as a metric elsewhere.

$$S = \frac{c_i}{N_i} \ln \frac{N_i}{c_i} [1n]$$

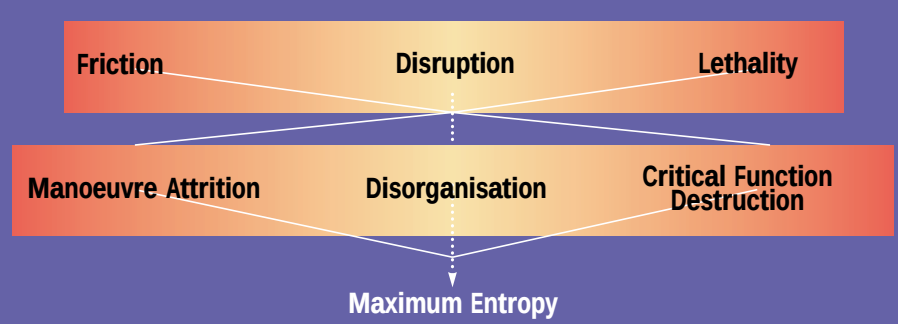
i=red or blue

Ci = casualties at time
N = force size (Ni = N - Ci at time)

We wanted a measure which accounted for various optempo scenarios and which incorporated intangibles as well as attrition, to give a more realistic tool.
We still wanted this measure to be based on the entropy concept but which covered the "cohesion" of the force.

RMA Entropy Based Warfare Elements [2]:

These are what act to break down cohesion in a force - and attempt to make it more ineffective. In this way the OPFOR can attempt to cause maximum entropy in its opposition.



Cohesion Intangibles [3]:

Intangibles which allow a force to be homogenous and cohesive and allow it to adapt to threats such as those above and cope with attrition situations.

Discipline
Communications
Initiative/Motivation
Trust
Leadership

To tackle the problem we are using 1) an analogue from a physical system and 2) some novel approaches.

1. Take a statistical representation/analogue from thermodynamics:
   $S = k1n\Omega$ Ω = the density of states and is what we want to represent. k is a constant of the system and for now can be ignored.

Ω is some combination of Physical (phys) and Intangible (coh) states of the force.

2. Novel approach: we consider that this combination of Ω might be represented by the following sum: $\Sigma_i phys_i(^l + coh_i)$

This is a simple sum to allow the physical and intangible aspects to be incorporated and will still function when there is little or no attrition.

We know how to quantify attrition (eg c_i/N_i) , but how do we quantify the cohesion intangibles and what weightings are important?

This is the model we would like to test - we can use it in a purely attrition form ie $\ln\Sigma phys$ - against historical data to validate the function as [1] did. Then we can use tools such as EINSTein and appropriate weightings to factor in the intangible aspects as a function also to test it's validity in those circumstances and if it holds attempt to apply it to experimental wargames to further test its validity.

This entropy measure will feed a meaningful tool back into EINSTein and Project Albert and will also potentially supply another post analysis tool which can be used in real time if it is kept simple and reliable enough and which will allow cause and effect analyses to be performed.

Further Work.....

This work is also coupled with investigations into self-similar behaviour or cellular automata models within LOD. In that work cohesion (as described here) is being investigated as a source of self-similar behaviour for combat organisations. The two streams of work are working together to develop and refine both concepts even further and allow more rigorous testing of both models.

References

[1] Carvalho-Rodrigues, F., *A Proposed Entropy Measure for Assessing Combat Degradation.* Journal of the Operational Research Society, 1989. 40(8): p. 789-793.; Carvalho-Rodrigues, F., J.T. Dockery, and A.E.R. Woodcock, *Using Casualty-Based Entropy to Predict Combat Outcomes,* in *The Military Landscape - Mathematical Models of Combat.* 1993, Woodhead Publishing. p. 195-230.; Dockery, J.T. and A.E.R. Woodcock. *Use of Complex Systems Inspired Measures to Describe Combat.* in *Land Warfare and Complexity.* 1996. Center for Naval Analyses. [2] Herman, M., *Entropy Based Warfare: Modelling the Revolution in Military Affairs.* Joint Force Quarterly, 1999. Autumn/Winter 1998/1999: p. 85-90 [3] Bergeman MJR R, USMC Studies & Analysis Division, MCCDC, Presentation to Project Albert 2001