

# A MODEL OF THE DYNAMICS OF THE THIRD WORLD WAR - An Exercise in Technology Transfer

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## ABSTRACT

The paper discusses two scenarios for a Third World War in Europe, and argues that it is often convenient to supplement a scenario by a formal model. The problems of creating such a model are examined, and a model is formulated for land, air, and sea combat in Europe and the Atlantic, using the System Dynamics approach, which has not hitherto been widely employed for military analysis.

The model confirms the results of the two scenarios, and its use for the analysis of alternative force configurations is illustrated. Some implications in the interpretation of Soviet military literature are discussed, and the paper ends with speculations on the role and value of such models.

## BACKGROUND

Recent books, edited by Hackett<sup>1</sup> and Bidwell,<sup>2</sup> described hypothetical land conflicts in Europe in the 1980's. Hackett's scenario leads to a planned Soviet attack, which the strengthened NATO conventional forces manage to defeat. Bidwell's war opens with a sudden Soviet attack, which the NATO forces are unable to stem, and ends with submarines 'hurling their ICBMs into the fiery ruin of the Northern hemisphere'.

Scenario writing is far from new in military and political analysis and has many attractions, not least that of vividness, but a scenario requires much skilled work which has to be repeated if a major factor changes. Anyone disagreeing with an assumption (or a conclusion) has the choice of doing a vast amount of work to trace his own ideas, or unconstructively rejecting the whole thing.

A more fundamental weakness of scenarios is that it is hard to incorporate the factor of *control*, or the continual adjustments to the state of affairs in the light of events to attempt to make them proceed, as far as practicable, in the direction desired by the 'manager'. For example, Hackett's naval battle depends on the assumed priorities of the Soviet Navy in the event of war, but they might change and rechange as the war progressed, according to the Soviet command's perceptions of the state of affairs and their requirements for what that state ought to be.

A scenario traces events as time passes under the influence of external factors, such as the state of weapon technology, and internal policies, as exemplified by the allocation of Soviet naval resources. A control engineer would call this the analysis of the dynamic behaviour, or controllability, of the system, and this essay is an attempt to demonstrate that the dual analysis of a scenario, plus a control study, contributes more to understanding than either taken alone.

This paper examines the prospects for the transfer of system dynamics 'technology' to and in the study of business policy. It is, however, particularly interesting that Druzhinin and Kontorov<sup>3</sup> argue, in the words of their American Editor, that "the current phase (of the revolution in military affairs) is concerned with military cybernetics — the science of effectively controlling the armed forces".

There are some rather serious theoretical and practical snags in attempting to apply engineering control theory directly to non-engineering problems, but various adaptations have been evolved for the analysis of controllability and dynamic behaviour in socio-economic problems. One, which has been particularly successful in studying practical problems of corporate strategy, is system dynamics, first developed by Forrester<sup>4</sup> and further described by Coyle.<sup>5-8</sup>

This paper examines the prospects for the transfer of system dynamics 'technology' to defence analysis. The method will be to describe the nature and results of a system dynamics approach, so as to display, for evaluation by the defence community, just what the method has to offer. To do this, a computer simulation model of NATO strategic options in a 'European' theatre of operations was formulated, using the system dynamics technique. We make no claim for a penetrating analysis of NATO strategy and seek only to show what a model of this type could do if it were constructed by people who fully understood the problems and had access to information at which we can only make guesses. The method is, however, computer-aided thinking, *not* computerised generalship.

This paper is fundamentally an essay in imagination in that we invite the reader to visualise whether or not, and we by no means regard it as a foregone conclusion, such an analysis



would be of value if it had, say, 6 man-months of work by well-informed experts.

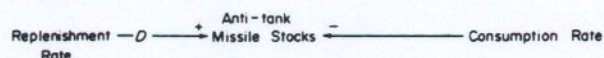
## THE MODELLING METHOD

Since the system dynamics approach to management problems is comparatively novel, we must give a *brief* discussion of it.

Mathematical modelling in the Services has a long and distinguished history. Indeed, the classical Lanchester equations are a dynamic analysis using differential equation theory, which was precisely the point of departure for the evolution of system dynamics. There have been a few applications of our method to defence matters: Lopez and Watson<sup>9</sup> studied manpower planning, and the US Navy has analysed shipping policies in a period of intense submarine threat, though the report itself is secret.

Apart from directly military work, Wallace,<sup>10</sup> using similar computer methods to those we employ, has modelled arms races but, while he is a scholar of political science concerned to 'understand' the world, we attempt to throw light on specific military problems. The modelling methods we use are far more sophisticated than those Wallace had available, and the modelling technique is not limited to his very simple model.

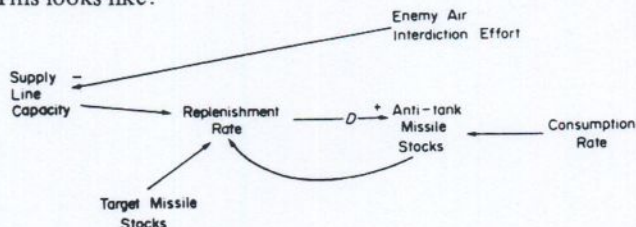
The first step in system dynamics modelling is to draw up an influence diagram, which merely shows what affects what. A very simple example is:-



Obviously, anti-tank missile stocks are depleted by firing them and increased by new supplies brought forward. The *D* denotes a time delay. The diagram shows only a so-called Conservation Relation, which expresses the idea that 'what goes in, must go somewhere'.

The next stage is to consider *what causes the flows*. We might, for example, find from expert military opinion that the replenishment rate depends on the need to build up missile stocks in the field to some target level and the supply line capacity as affected by enemy air interdiction effort.

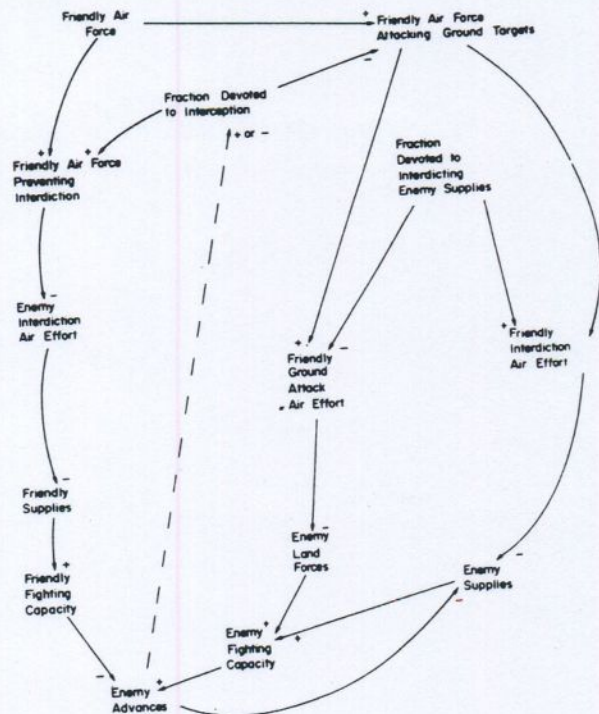
This looks like:



The negative sign on the link from Enemy air interdiction to Supply line capacity shows that an increase in air attacks would reduce the capacity. The form of this relationship could be derived from combat experience, assessments of ground attack technology, the use of detailed combat models, field exercises, and so on.

We can extend our example even further by considering the use of the Friendly Air Force to intercept enemy aircraft, to

interdict enemy supplies or to attack enemy ground forces:



For brevity, we have suppressed some of the detail in the previous diagram, but all we are doing is tracing the quantifiable factors in the situation and their interactions. With enough time, a large enough piece of paper and access to expert opinion, one could realistically trace out the interactions which have to be considered by senior commanders and their staffs, including both sets of land, naval and air forces.

Once the diagram is drawn and suitably simplified, it demonstrates very clearly some rather important factors. For example, the dashed line from Enemy Advances to Fraction Devoted to Interception denotes a military policy issue in that Friendly Interception Air Effort might be increased as the enemy advanced to try to protect friendly supplies, but at the expense of the ability to mount air attacks on the enemy. Alternatively, one might do the opposite. The model could trace the consequences of this particular problem in inter-service command and control.

Such issues arise in many contexts. Thus, three RUSI papers<sup>11-13</sup> on NATO strategy and the battlefield use of helicopters discuss what might be done in different circumstances. The very fact of such debates creates a need for a means of resolving such exceedingly complicated issues.

The diagram is more than an over-complicated representation of what everyone already knew. Thus, it is significant that the dashed line leads from Enemy Advances up to Fraction Devoted to Interception and then back down to Enemy Advances via Friendly Fighting Capacity. This closed sequence of cause and effect is called a Feedback Loop and its 'power' (technically called its gain and delay), which depends on the strength and speed of its links, will influence the outcome of the battle. The power of the loop can be adjusted by the nature and strength of the policy used to regulate the Fraction



Devoted to Interception and the constraints which have been placed on the freedom to change that fraction by the choice of aircraft types which has been made.

The previous diagram contains four loops, but our model contains very many. The salient point for strategic analysis is that feedback theory helps to identify the key factors and design control strategies which will most effectively regulate the behaviour of the system. We might, for instance, create two new loops by reducing the Fraction of the Friendly Ground Attack Air Effort devoted to interdicting enemy supplies as the enemy advances, and, if the loop through Friendly Ground Attack Air Effort is faster acting than that through interdiction of enemy supplies, this might be a more effective inhibitor of enemy advances, though perhaps generating different problems later.

We cannot answer such questions by reasoning, because the problem is too complicated. The computer will have to provide the answers and assess their reliability through sensitivity analysis. The human role is to tell the computer what to take into account by specifying, in the proper degree of detail, the influence diagram and the direction and strength of its links, and to translate it — a representation of *human* thought — into computer grammar. This is quite easy to do in the DYSMAP simulation language (see Ratnatunga<sup>14</sup>). Technically, this modelling language can easily handle high-order, severely non-linear, differentially sampled data, difference equation models, incorporating distributed lags, complex logical operations and random effects.

#### THE FACTORS IN THE MODEL

The model represents a war between NATO and the Warsaw Pact in Europe and the North Atlantic. A full technical account of the model will be published in due course, if this initial research is continued, and we limit ourselves here to indicating the salient factors.

On land NATO have 7000 'units', and Warsaw have 20,000, though time is required to build up to these full strengths. A 'unit' means some chosen combination of all arms, such that the combination governs the fighting effectiveness of that unit. The land battle depends on the numbers on each side and their respective combat effectiveness, which is a measure of the ability to destroy the other side's units.

The combat effectiveness depends on factors such as the force composition, the tactical doctrine, weapon technology and, in practice, would be estimated from field trials, judgement or detailed combat models. On both sides, the basic effectiveness is modified by availability of weapon stocks and the consequences of combat losses.

In passing, this suggests one of the ways in which this model could be used, that of strategic evaluation. If a given amount of money was added to the defence budget, which could be spent on improving tank armour to reduce the WARSAW combat effectiveness by 10% or on improved Anti-Tank Guided Weapons (ATGW) which would increase that of NATO by 12%, which would be the better prospect? Alternatively, should that amount be spent on additional land forces, on air forces, or where?

The WARSAW forces can, in the model, advance at a rate which depends on their relative preponderance over NATO. In the model, 'preponderance' means the ratio of the fighting powers of the combatants, which in turn means their respective numerical strengths multiplied by their combat effectiveness. The outcome of the 'war' is measured, as we shall show below, by their cumulative advance.

The NATO air force is allocated to ground attack on land forces, interception of Soviet air attacks or reduction of the capacity of the Soviet supply line. The WARSAW air force, which is numerically somewhat stronger, has corresponding tasks. Both sides lose aircraft in air combat and from ground anti-aircraft (AA) fire, depending on specific combat effectivenesses as for the ground battle.

The naval sector represents the transport of land reinforcements from the U.S.A. NATO naval forces are allocated to convoy protection or to preventing Soviet submarines from reaching the Atlantic via the Greenland-Iceland-U.K. (GIUK) gap. The WARSAW naval forces, on mobilisation, attempt to reach the North Atlantic to attack the convoys and their escorts.

Perhaps the best way to explain what is in the model is to use it to examine a few outcomes, and we now turn to that task.

#### RESULTS FROM THE MODEL

A model of this type can be made to analyse very many cases simply by changing parameters, but we can present only a few scenarios from the model, mainly to show how it might be used. The computer's graph plotter provides clear and detailed output from the model, and in practical system dynamics, one would normally consider many variables. Space considerations restrict us to examining only a few, even at the risk of oversimplification.

For each of the following graphs, the horizontal axis is time in days. The name, dimension and definition of each variable is printed under the graph, and from the left of the name, a line of a distinctive pattern moves to the left and then up to point to a scale for that variable drawn in the same pattern. The graph of the variable is again drawn in that pattern.

The war starts on day 12 to allow time for mobilisation in the Hackett scenario, and the graphs show the dynamics of the first three weeks. The main variable of interest is the Cumulative Warsaw Gain (CWG), measured in miles and taken to be in the most critical direction, as our model implicitly assumes that the NATO commander behaves intelligently in the detailed allocation of forces. The basic rationale is either that CWG will reach 100 miles, at which point Bidwell suggests that a general nuclear war starts, or that the Russians do not bring about the collapse of NATO within the three weeks — the Hackett scenario. On the attainment of one of these states the model ceases to have whatever validity it ever possessed because it is not intended to represent total nuclear war, nor does it include anything to do with peace-making, sudden Russian withdrawal or the social and political disintegration of the Eastern bloc.



The first computer experiment is for a Hackett-type scenario in which the Warsaw Pact mobilises in advance of an attack. After a few days, NATO realise what is happening and, after a further day for political consultations, NATO mobilises. Land reserves assemble in Europe and convoy vessels start to accumulate in North America. Warships are activated and despatched to convoy escort or the GIUK gap, and Soviet submarines move towards the North Atlantic.

These processes can be seen in Figure 1, where NLF and WLF, the respective land forces, build up from Day 4 (i.e. D-8) onwards, as does WSFIA, the Warsaw Submarine Fleet in the Atlantic.

The war actually starts on day 12 and we see, from day 13 onwards, a progressive build up of convoy vessels in the danger area of mid-Atlantic. The sudden jumps in the graph of Convoy In Danger Area (CIDA) indicate the arrival of new convoys in the Atlantic, a total of four being despatched. The reduction in CIDA matches the rise in the Cumulative Convoy Arrivals in Europe, CLCA.

The submarine fleet rises to a peak and then falls off from combat losses at sea, losses eventually reaching 45%. This last value is read off from the print out and is not shown in the graphs, but we can see the rising trend of the NATO Convoy Loss Ratio, NCVLR, which eventually reaches 19%, a value which agrees very well with Hackett's assessment.

On land, the battle starts on day 12, and the graph of CWG shows a fairly sharp advance, a slackening around  $D + 3$  and

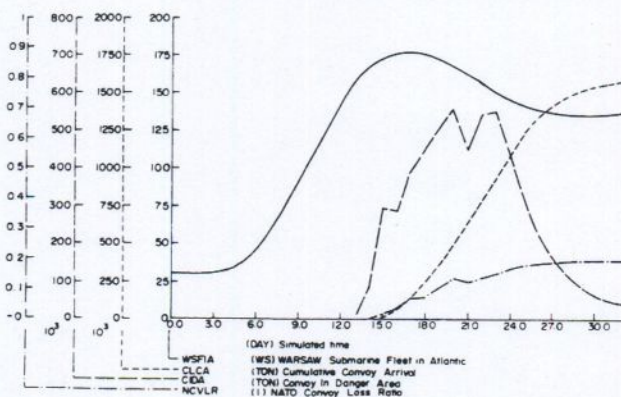
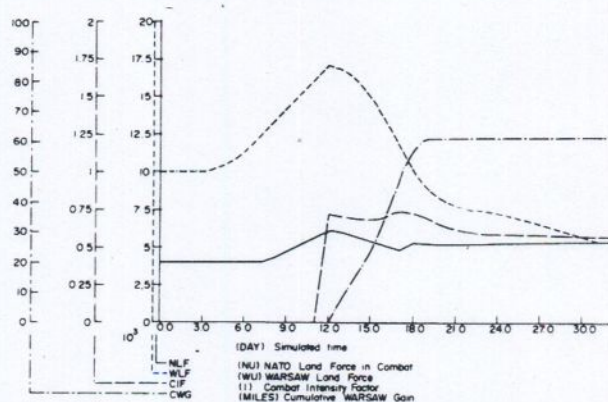


Fig. 1. Advance warning—The Hackett Scenario for the dynamics of World War III.

a further advance coming to a halt on  $D + 7$ , with a total gain of some 60 miles. The agreement with Hackett is remarkable (and we stress that we have *not* tuned the model to fit Hackett). From the maps in General Hackett's book we measured the advance on the line Leipzig—Bonn and found gains of 20 miles, 37, 51 and 54 miles on  $D$  day,  $D + 4$ ,  $D + 8$  and  $D + 11$  respectively. The corresponding figures from the computer are 18, 34, 61 and 61.

The curve for the Combat Intensity Factor, CIF, represents a hypothetical Russian doctrine of attacking all out when they perceive the odds to be 3:1 in the favour but easing off to a lower tempo as the odds move against them, until they have built up again, whereupon the tempo increases. The fall-off in CIF until  $D + 3$  represents the effects of combat losses; from  $D + 3$  to  $D + 5$  the tempo increases as the supply line capacity becomes free from moving up reinforcements and can build up weapon stocks from the initial heavy consumption, and then the combat tails off to low-level skirmishing as the Russians perceive they cannot win.

What happens after  $D + 9$  or 10 is another matter. The model cannot show the answer, as it is not designed to do so. Hackett offers a political analysis, and it is fairly certain that the petering out of the Russian attack represents a point at which models may not help very much and other methods have to take over.

Figure 2 shows the Bidwell scenario of a surprise attack. The graphs for the sea war are essentially the same but moved to the right because everything happens that much later.

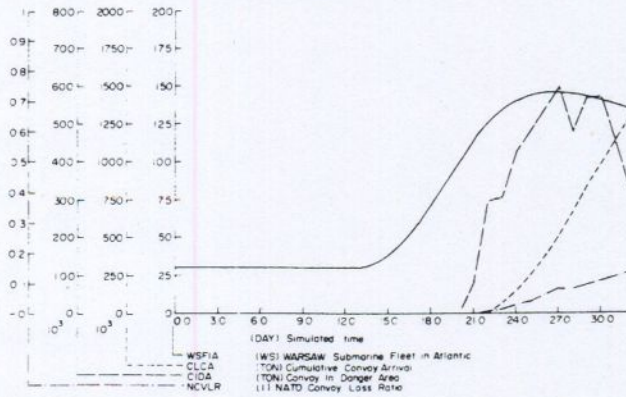
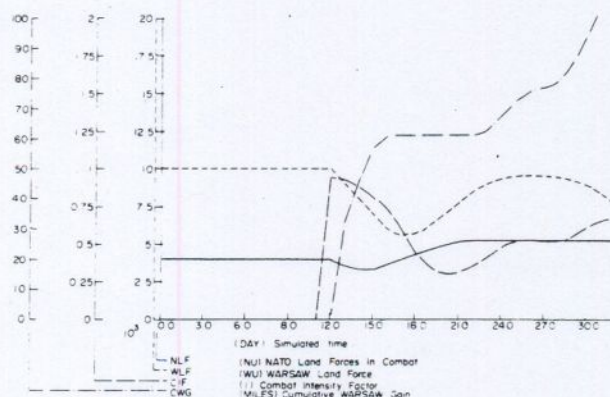


Fig. 2. Standing start—The Bidwell Scenario for the dynamics of World War III.



The land battle is fundamentally different. It opens with a very rapid Warsaw Pact advance of 60 miles by  $D + 4$  and then a period of quietness. This agrees quite well with Brigadier Bidwell<sup>2</sup> who says, on p.165, that by  $D + 2$  the Warsaw Pact advance had come to a halt. In Figure 2, however, the quiet period lasts for 7 days while Soviet reinforcements and supplies build up, followed by two more periods of severe fighting until the Pact reach the 100 mile mark by  $D + 20$ . At this point we have hypothesized that general nuclear war breaks out and the model ceases to say anything relevant. In the Bidwell scenario, this happens on  $D + 10$ .

To explore the characteristics of the model we looked at three further versions of the Hackett scenario, for which we do not have space to show the graphs.

In the first one, the Soviets abandon their policy of regulating the tempo of their attack according to their perceived superiority and simply go all out all the time. This would presumably be military idiocy, and the model does indeed show that, despite an initial gain of some 30 miles in the first 6 days, the Warsaw forces are thereafter progressively obliterated by NATO. This is not a realistic case but it does confirm something of the validity of the model in the sense that it seems to produce what would happen in the real world.

Finally, to test the model against defence policy issues we looked at the case in which a given amount of money might be spent on bringing NATO air force strength up to Soviet numbers or on increasing the combat effectivenesses of NATO land forces by 20%. We realise that this oversimplifies a complex set of difficult questions, but the model does not purport to do everything.

Both of these options prove to be highly attractive in that the limit of the Warsaw Pact advance is reduced, respectively, to 44 miles and 47 miles by  $D + 6$  in both cases. The 3-mile difference is not significant.

Having now run the model, we can make the technical comment that Lanchester's square law would require NATO to be 9 times as combat effective to offset the Soviet 3:1 numerical superiority. The non-linear effects in our model suggest that NATO could 'win' against a planned attack, whatever that would mean to an inhabitant of West Germany, with a combat effectiveness, much of which is conferred by the tactical properties of being the defender, about 4 times as great as that of the Soviets.

To withstand a sudden assault, combat effectiveness would have to be much higher or there would have to be more troops and aircraft in place.

#### NORMS AND 'EFFECTIVNOST'

Erickson,<sup>15</sup> discusses the setting of combat 'norms' in the Soviet Forces and says "the process of settling 'armament norms' is related to a huge, systematic, investigation of wartime operations at large". This seems to be very close indeed to what we have tried to do here. The difference may lie in that we have added the time dimension very explicitly to the calculation and have used a modelling technique which seems to be rather well suited to the problem.

In particular, we suggest that the type of computer output typified by the graphs in the previous diagrams is useful for appraising the outcome of a choice of norms, whether they be any or all of weapons technology, tactical doctrine, logistic scales or combinations and deployments of forces. It seems likely that, if the performance of the system is assessed simply as some kind of probability of 'winning', then matters will be grossly oversimplified but that the plotting of graphs of several, or many, variables will enable the judgement of commanders and politicians to come more widely into play.

In the same source (p.24), Erickson discusses the difficulty of translating the Soviet term 'effectivnost'. We do not think that it is *intended* to mean the dynamic behaviour displayed in our computer graphs, but it does seem to come down to meaning something very like that. If, indeed, effectivnost is supposed by its users to mean something like 'the outcome of events under the influence of our inputs and objectives, in the face of counter-actions and deployments by NATO', then that is precisely what is shown by the graphs, except that in system dynamics we use the term 'dynamic behaviour'. It may be that such is the intended meaning, though not the translation, of this elusive Russian term.

#### THE USES OF A STRATEGIC MODEL

The model we have described here cannot be used for anything other than its stated purpose as an exploration of the modelling technology, and in this section we refer to any future model which might be developed along these lines.

The first use of a model is as an aid to understanding. It seems that managers, including generals, air marshals and admirals, know the structure of their system very well. They cannot, however, think of more than a fairly small part at once. If, however, the whole can be displayed, the process of thinking *between* a group of people is greatly facilitated. A very simple but perhaps valuable, exercise could therefore be for a politician, a couple of civil servants and a very few officers from each of the Services to spend a day or two away from interruptions with a large blackboard simply arguing their way through an influence diagram. Despite its simplicity, this has proved in real life practice to be a very fruitful source of insight and understanding.

The second use of a strategic model is for contingency planning as a supplement to the normal staff methods. The advantage of our method is that the computer produces the answers practically instantaneously, displaying its graphs on a computer screen. In this role one could pose rather complicated questions. For example, there might be many possible NATO counters to the deployment of the Backfire bomber and their evaluation could be supplemented by a strategic model of the type we propose. Alternatively, a NATO development in Anti-Submarine Warfare (ASW) technology raises many options to do with convoy sizes, escort vessel assignment, the allotment of naval forces between Joint Allied Command Western Approaches (JACWA), the GIUK gap and convoy protection.

A third, longer range, possible role is the use of the model at the heart of a Command and Control ( $C^3I$ ) system, operating practically in real time. The purpose of having information is to improve one's management of a system, but too many information processing projects concentrate heavily on the hardware



and software of information processing and virtually ignore the question of how the information is used to manage the system.

Finally, we see the approach as being of potential benefit in academic defence studies.

In no case do we suggest that our method could, or should, replace 'traditional' analysis. We do see it as a useful additional tool which enables an analyst to address certain types of problem rather well and others, especially those of morale and psychology, not at all.

### THE VALIDITY OF THE MODEL

Every model must be examined to see if it is 'valid'. This is a most difficult concept and we cannot treat it in full but, broadly, it involves a decision-maker assessing how much confidence he should place in the model's answers. One measure of this is how well those answers fit the real world, but in our case the Third World War hasn't happened. The best that we could hope for would be for the model to reflect approximately both the Hackett and Bidwell scenarios. Even this would be no more than a test by Respectable Association and might be of limited value, as the Hackett scenario is by no means universally accepted. For example Halperin<sup>16</sup> refers to the "implausibility at every step of the argument".

We can never actually validate any managerial model in the sense of 'proving' it to be 'right' by any process of scientific investigation, and it is a logical nonsense to attempt to do so. All we can do is to say that, if, after the model has been tested, criticised and refined (and subjected to some purely technical tests), it still stands up, then we may take some notice of it.

If a model cannot be validated, what possible use can it be? The question arises from too great an expectation of a model. A model can never be a substitute for thought but can only be the product of thought. Modelling consists of a disciplined, ordered, framework for analysing the information about a problem, including knowledge about how the system works, as exemplified in the influence diagrams we discussed earlier. If the modelling is correct in the sense that the information has been accurately translated into the model, then the model cannot do other than trace out the consequences correctly, in more detail, more quickly and far more accurately than the mind could do unaided, if the mind could do it at all. A model is therefore only an extension of thinking, albeit a remarkably powerful one, and to ask whether it is 'valid' is a meaningless question. One should ask whether one's own knowledge and thinking were valid and whether they were correctly transcribed into the computer (there are sophisticated, purely technical ways of checking the transcription), or take on trust the analyst's assertion that they were. Best of all, the manager can learn to build his own model, so that he has only himself to blame.

We leave the reader to judge of the validity of this model. For our part we make no claim, other than that we think that, given a fairly small effort of a few man-months, the model could be brought to a point of being useful and illuminating. This is an interesting contrast with other models of which we are aware, where the modelling effort has been measured in man-decades. It is a property of the modelling method rather than our own skill.

### CONCLUSION

We have tried to show how a method of analysis which is of proven success in the field of business planning might possibly be applied to some aspects of defence studies. Our demonstration has been a simple model in the sense that we have no access to information which would improve it. The model is comprehensive in that it includes most of the factors mentioned by Hackett and Bidwell, and, in our view, there would be no particular technical problems in making it as realistic and detailed as one wished.

The reader must judge the potential of this form of analysis for defence studies. Our view is that being technically able to build a model and the model being of any value at all may be very different things.

Finally, we remark that there may be models of the type we have described already in existence. We have, however, not heard of any such. This may mean that such models are so good that they are secret, or that they are so bad that they are pointless, or that they have not been tried.

### ACKNOWLEDGEMENTS

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10. M.D. WALLACE (1976) Arms races and the balance of power: a mathematical model. *App. Math. Modell.* 1.
11. See, for example, comment by Air Chief Marshal Walker about the need to reduce the enemy's air threat and preponderance of armour, in *The Role of the Helicopter in the Land Battle* (1971) RUSI Seminar, p.41.
12. MAJOR-GENERAL J.M. ALLEN says "The order in which we would assign our tactical air power in combat would depend on the demands of the battle at the time, be it air or ground" (*A Conventional Strategy for the Central Front in NATO* (1974-5) RUSI Seminar, p.11). This is precisely the point exemplified in a very simple case, in the preceding paragraph of this paper.
13. P.H. VIGAR and C.N. DONNELLY, writing in the March 1975 *RUSI Journal*, p.72, comment on changes in Soviet tactics as a result of the Yom Kippur War. We feel that our model could throw some light on the likely effective-



ness of NATO responses to apparent, or possible, changes in Soviet military doctrine.

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