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MODELING OF SOFT FACTORS IN THE
RAND STRATEGY ASSESSMENT SYSTEM (RSAS)

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PREFACE

This paper was developed independently by the author for a conference entitled "Human Behavior and Performance as Essential Ingredients in Realistic Modeling of Combat—MORIMOC II," sponsored by the Military Operations Society (MORS) and held February 22-24, 1989 in Alexandria, Virginia. The paper draws on extensive published work by the RAND Strategy Assessment Center, which is part of RAND's National Defense Research Institute (NDRI), a Federally Funded Research and Development Center funded by the Office of the Secretary of Defense. Comments and questions are welcome, and should be addressed to Dr. Paul Davis, Director of the RAND Strategy Assessment Center, The RAND Corporation, 1700 Main Street, Santa Monica, CA, 90406. Electronic mail can be addressed to pdavis @rand-unix.arpa.

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SUMMARY

Reflecting "soft factors" has been a major objective since the early design of the RAND *Strategy Assessment System* (RSAS) in 1982. *This paper discusses how selected soft factors have been and could be represented in combat models, theater-level decision models dealing with command-control issues, and national-command-level models dealing with issues of national policy, strategy, and controls. The paper also discusses the (limited) empirical basis for the assumptions used and speculates about the degree to which the empirical and subjective basis could be improved. Finally, it notes several recent examples of policy-level analysis that have been strongly affected by assumptions about soft factors involving human and organizational issues—notably factors involving readiness, surprise, national fighting quality, the break-point phenomenon, and command-control adaptability.*

The paper includes references to reports describing modeling and programming methods developed for the RSAS that could be used in a broad range of other problems involving human and organizational issues.

ACKNOWLEDGMENTS

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I. INTRODUCTION

BACKGROUND

One of the most unsatisfactory features of most current-day military analysis is its treatment (or, rather, its nontreatment) of many so-called *soft factors*. This is not a minor consideration affecting only the second or third significant figure of some prediction, but rather a fundamental problem constituting in some cases a fatal flaw. This paper discusses several types of soft factors and argues that it is often straightforward to reflect them in analyses if merely one decides that doing so is essential, and illustrates this by drawing on experience gained in the development of the RAND Strategy Assessment System (RSAS).[1] One purpose of the paper is to convince readers that modeling soft factors can and should be a routine part of military modeling and analysis. Interestingly, when one accepts this view and begins incorporating them, the soft factors quickly become less abstract and less soft, and the very issue of soft factors slips into the background. An outside observer, however, might detect a paradigm shift having taken place.

DEFINING SOFT FACTORS

Although it is common for people to talk about soft factors, usually in the context of lamenting or rationalizing their exclusion, there is no common basis for deciding what a soft factor is. Some of the more obvious definitions fail under scrutiny. For example, it is *not* the case that soft factors are identical to qualitative variables, if by that one means variables that are not measured numerically. Many features of "hard" combat models have long been qualitative—e.g., distinctions between meeting engagements and assaults on fortified defenses. Nor is it the case that soft factors are those that have not been measured or determined accurately, since anyone familiar with combat models knows that they are stuffed with variables that would then be considered soft (e.g., the attrition rates to be expected in the next large war are probably uncertain by a factor of 4). Nor are soft factors necessarily associated with human or organizational factors, although this

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[1]The RSAS is a system for analytic war gaming developed by the RAND Corporation under the sponsorship of OSD's Director of Net Assessment, Mr. Andrew Marshall. It is an integrated system for studying both conventional and strategic-nuclear issues in individual theaters and on a global basis. It includes both combat models and decision models, the latter including optional political-level models. The RSAS is currently being used by about a dozen government agencies and by a sizable number of RAND projects. For a short overview, see Davis, Bennett, and Schwabe (1988).

paper focuses primarily on examples of that type. Ultimately, *factors are considered soft if they have not yet been reflected explicitly and comfortably in analysis, and if they are not yet well understood.* This is a disappointing definition, but it has much to recommend it. If this definition seems unreasonable, imagine how scientists in earlier centuries probably dealt with the concept of friction before there were empirical or theoretical concepts for treating it explicitly. Falling bodies were said to obey the equation $V(t) = g\, t$, where g is the constant for gravitational acceleration. If $V(t)$ turned out not to quite obey this law in practice, especially for bodies of matter such as feathers, then it was because "there are always some complications and imperfections" (one can almost see hands waving as these "soft" matters were discussed). After a theory of friction existed, however, then one could write something like $dV/dt = g - f\, V$ and seek to measure f for the body of interest. And, after the appropriate aerodynamic theories developed, one could estimate f from the size and shape of the body itself. The concept of friction was then no longer "soft" with respect to falling bodies.

In this paper we shall be discussing a particular set of soft factors determined, *at least in significant part*, by peculiarly human or organizational factors:

- The **qualitative fighting capability** of different forces with similar or identical equipment

- The **frictional processes** in military operations such as maneuver, command and control, and the use of weapons under combat, rather than test-range, conditions; and

- The **political, strategic, and operational-level decisions** and decision processes that have so fundamental a role in determining the outcome of wars.

These factors are commonly regarded as annoyances and imperfections by a large part of the analytic community.[2] By contrast, many military people in the western world consider them fundamental, but use them as a basis for avoiding rigor in preference to an

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[2]This point should not be overdone. For example, analysts have to some extent reflected frictional processes in terms of parameters such as decision time, reaction time, or the like. Also, the possibility of very different decisions is often treated explicitly. Nonetheless, it is unusual for analysts to take on these subjects with the diligence and enthusiasm they demonstrate in, say, the modeling of strategic mobility, Lanchesterian attrition battles, or strategic nuclear exchanges. For a survey of early-1980s models, see Battilega and Grange (1984), in which soft factors are only infrequently mentioned (one exception is the discussion in Chapter 8 of the VECTOR-2 concept, which includes explicit modeling of perceptions and intelligence).

emphasis on the *art*, rather than science, of war. The Soviet approach seems to be more like that of engineers, who have to cope with complications of process and people in all walks of life and who try to accomplish this by safe-siding whenever possible in their designs and construction plans over time. Western operational planners must also deal with these "engineering problems," but they must often do so without the benefit of an appropriately technical and comprehensive textbook (hence, the common emphasis on "art"). Our challenge, in a sense, is to begin defining how that textbook should deal with factors such as those above. The impression that military science can reasonably aspire to the precision and rigor of the physical sciences would be misplaced, especially when dealing with human and organizational issues, but we can surely go much farther than is customarily attempted.[3] In the following sections, I shall discuss work of the RAND Strategy Assessment Center (RSAC) in each of the above areas of so-called "soft factors." Nearly all of this work is at a relatively high level of aggregation, because we have focused on issues of policy and strategy, but the ideas and techniques should have broader application.

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[3]The most notable exception to the widespread tendency in the West to avoid dealing with "soft factors" was, for a long time, T.N. Dupuy, whose work strongly influenced my thinking in 1982-1983 while conceiving much of the work reviewed here. I am pleased to note the increasing number of analysts who now read, use, and refer to Dupuy's books, even if they disagree with some of his arguments and models. See Dupuy (1987), which updates his earlier *Numbers, Predictions, and War*.

II. REPRESENTING QUALITATIVE CAPABILITIES OF UNITS

PHILOSOPHICAL APPROACH

In laying down principles for the RAND Strategy Assessment System (RSAS) in the early 1980s, my colleagues and I in the RAND Strategy Assessment Center (RSAC) decided to deviate from normal procedure and to include as many high-level qualitative factors as possible in our combat models, while recognizing that our ability to measure them might be highly limited. The reasoning on this was essentially that argued earlier and persuasively in Jay Forrester's work on Systems Dynamics at MIT: [4]

> Much of the behavior of systems rests on relationships and interactions that are believed, and probably correctly so, to be important but that for a long time will evade quantitative measure. Unless we take our best estimates of these relationships and include them in a system model, we are in effect saying they make no difference and can be omitted. It is far more serious to omit a relationship that is believed to be important than to include it at a low level of accuracy that fits the plausible range of uncertainty.
>
> If one believes a relationship to be important, he acts accordingly, and makes the best use he can of the information available.

If one *really* believes this, then one is comfortable using subjective inputs from experienced people, including historians and psychologists. One is also comfortable about writing down postulated relationships that *appear* right intuitively, and then asking people to help estimate the coefficients. Dealing with human and organizational realities is seen as necessary and important.

MEASURING THE CAPABILITY OF UNITS

The Usual Approach: Measuring Equipment-Limited Capability

Policy-level analyses dealing with such subjects as the military balance, conventional arms control, and high-level resource allocation decisions depend heavily on highly aggregated models. At the extreme, but a very useful extreme indeed, analyses are based on the effects of proposals on the theater-level force ratio over time, ignoring attrition. Force size is usually measured in one or another variant of Armored Division Equivalents (ADEs), where a given unit's raw score is calculated by a "WEI-WUV method" or something comparable, and then ADEs are obtained by dividing by the score

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[4]See, for example, J. W. Forrester, *Urban Dynamics*, The Massachusetts Institute of Technology Press, Cambridge, Massachusetts, 1969.

of a standard division (see, for example, U.S. Congressional Budget Office , 1988, or Posen, 1988). A modern U.S. armored division is often counted as 1.0 in such a system. It is usually assumed that these ADE scores measure force capabilities. In fact, they measure the capability of equipment, not units,[5] making no allowance for the quality of the people manning the equipment, nor for the quality of doctrine, command-control, and unit mix.

The next useful level of sophistication involves simulation models of combat. These also require measuring the capabilities of opposed forces. Some of these involve weapon-on-weapon calculations, while the more policy-oriented models often employ a dynamic version of scores comparable to ADE scores. In the past, both the weapon-on-weapon-level models and more aggregated models largely ignored human factors and depended almost entirely on equipment-limited measures of capability. To my knowledge, there was no *systematic* effort to do otherwise until the development of the RSAS.

Unit Capabilities in the RSAS

Consistent with the more general philosophy indicated earlier, the RSAC approach required attempting t least a first-order treatment of non-equipment issues. With this in mind, we introduced a new measure of capability into the RSAS: effective strength, as measured by effective equivalent divisions (EEDs). Effective strength (EEDs) is related to strength (EDs) by multipliers, which can be either exogenous parameters or variables:

Effective strength (EEDs) = Strength (EDs) * Multiplier 1* Multiplier 2...

The multipliers we currently use deal with (Bennett, Jones, Bullock, and Davis, 1988):[6]

- **Level of training** (roughly speaking, "readiness")

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[5]Even the characterization of equipment-limited capability is highly controversial and there are long-standing and sometimes bitter and mindless arguments about whether such scoring systems are even useful, let alone which system to use. Those controversies are irrelevant to the current paper, but there has been considerable RSAC research devoted to understanding and improving scoring methods.

[6]In the current RSAS, the multipliers for surprise and chemical effects appear only within calculations of attrition and movement rather than in calculations of the sides' separate effective strengths. This should logically be changed in future versions of the model, but it seldom has much effect on results.

- **Cohesion and effectiveness problems caused by** attrition in combat (which can be offset to some degree by withdrawing the forces from combat for a rejuvenation period)[7]

- **National fighting effectiveness**

- Unmodeled effects of **shortages in supplies** or support (some effects are modeled explicitly)

- The potential benefit in morale and determination from **fighting in one's homeland**

- The reduced efficiency arising from **interoperability problems** when forces of different nationalities are operating in the same corps (or army) sector

- Certain indirect **rear-area effects:** reduced effectiveness of divisions at the Forward Line of Troops (FLOT) when opponent forces are loose in the corps' rear area

- Temporary **surprise effects at the tactical level** (e.g., effects reflecting likely problems of disorganization)

- Temporary **chemical-attack effects at the tactical level** (e.g., reflecting likely problems of disorganization and reduced effectiveness due to using chemical garb)

This list is eclectic, to say the least, and the factors reflect phenomena involving a mix of human, organizational, and "physics" effects. The discerning reader will appreciate that there are numerous theoretical problems in having these multipliers. For example, having several multipliers less than 1 might overestimate the combined effects of the several problems and there are potential interdependencies. Nonetheless, having the multipliers has proven very useful: first, in reminding us to consider what are often dominant factors; second, in encouraging us to develop reasonable estimates of what the multipliers should be as a default; third, in allowing us easily to do excursions of considerable interest in both war games and analysis; and, last, in encouraging us to develop approximate models replacing exogenous parameters by dynamically calculated variables.

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[7]As documented in a recent historical study (Fain, Anderson, Dupuy, Hammerman, and Hawkins, 1988), forces typically break off battle at much lower levels of attrition than might be expected. The reasons are many and complex, often involving maneuver issues such as the danger of being outflanked, but it is reasonable to assume that the effectiveness of a division decreases faster than linearly with increasing attrition, even if there are no absolute "break points."

Readers dubious about the desirability of having such soft factors should bear in mind the following:

- It seems impossible to understand combat results in historical conflicts such as WW II and the Arab-Israeli wars without applying factors for the qualitative effectiveness of the different nations' forces. For example, German forces were more than twice as effective at the tactical level as Russian forces in WW II and Israeli forces have been at least twice as effective as Arab forces (see Dupuy, 1987, p. 281). Indeed, "everyone knows" these facts at some qualitative level. Hence, it seems downright foolish to analyze the battles of these wars without including the factors explicitly, although many statistics-oriented analysts have long and obdurately done so. It is unsurprising that they tend to find few correlations between battle outcomes and force ratio.

- "Everyone" would agree that if the ultimate simulation model existed with perfect data, then Israeli ground forces would do better on average than Arab ground forces with the same equipment, because of better tactical-level prowess by both officers and enlisted men, better support, and perhaps because of better doctrine for their theater. In the absence of such an ultimate model, we must "guess" the net effects of unmodeled considerations. The best guess would surely not be a multiplier of 1.

- If one does apply such corrections, then it is far easier to make sense out of a vast range of historical data as Dupuy has argued for some years. [8]

In practice, we ordinarily assume a multiplier of 1 for several of the variables listed above, including the national-effectiveness factor. However, doing so is clearly not a best estimate and we *experiment* with corrections such as reducing in some scenarios the assumed tactical effectiveness of reluctant Pact allies such as the Poles and Czechs, increasing the assumed tactical effectiveness of Federal Republic of Germany (FRG) forces, and lowering the assumed effectiveness of other NATO forces that have special problems not reflected in their equipment scores. This can substantially alter one's view of where NATO's warfighting problems lie.

How Visibility Hardens Soft Variables

It is instructive to illustrate how what starts as an ad hoc multiplier for a "soft factor" can become just another "hard" variable. Consider the case of training effectiveness. So far as I know, models prior to the RSAS assumed that forces would

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[8] In unpublished work, I have shown that the attrition models used in the RSAS appear to be reasonably consistent with Eastern Front experience of the Soviet Union as described by Stoeckli (1985), if one assumes that German forces were approximately twice as effective tactically as Soviet forces.

fight as effectively as their equipment dictated, regardless of training time. Training readiness was reflected only indirectly *if at all*—by withholding forces from the simulated battle until such time as it was deemed reasonable to assume they could be used effectively.

In any case, the first step in our procedure (1983) was to recognize the need for a multiplier. The second step was to build an analytically trivial model of how effectiveness might increase with training time. As one might expect, the equation was (Bennett et al., 1988):

$$TE = TE_0 + Rate * Time$$

That is, we assumed that the training effectiveness multiplier increased linearly with time, increasing at a rate treated in the model as a parameter. However, while the analytics are trivial, the results are not. Half the Pact force structure, after all, is at a very low state of readiness. This can have a profound effect on simulation results. Also, having this issue highlighted immediately suggests that for the Soviets to achieve surprise in an attack of Europe they might have to raise their initial levels of readiness in peacetime—well before formal mobilization began. Thus, the very meaning of "surprise attack" is sh ... d from one akin to a bolt from the blue to one better described as attack after a short-mobilization subsequent to extensive premobilization preparations to which NATO has not fully or cohesively reacted (Davis, 1988a and b).

After working with this simple model of training's effect on overall force capabilities for several years, it became necessary to extend its sophistication (Davis, 1988b) to explain qualitatively some of the major discrepancies one finds in the literature regarding the time required for Soviet Category III forces to prepare for combat (roughly 20-120 days, depending on the source) . The essence of the approach is simply to recognize that a given unit's effectiveness depends heavily on its mission and that the training time required for effectiveness must also depend on that mission. In particular, it is only reasor ... ble to assume that forces can fight rather effectively when they are fighting from static defenses to protect something critical to their homeland (e.g., Soviet units defended on the outskirts of Moscow in WW II with only minimal training). By contrast, it is likely that effectiveness increases more slowly when preparing for attacks on difficult defended positions. Figure 1 illustrates these concepts with essentially notional numbers. *It remains a difficult and unsolved problem to go from such objective variables as training frequency and cadre levels during peacetime to output measures such as how*
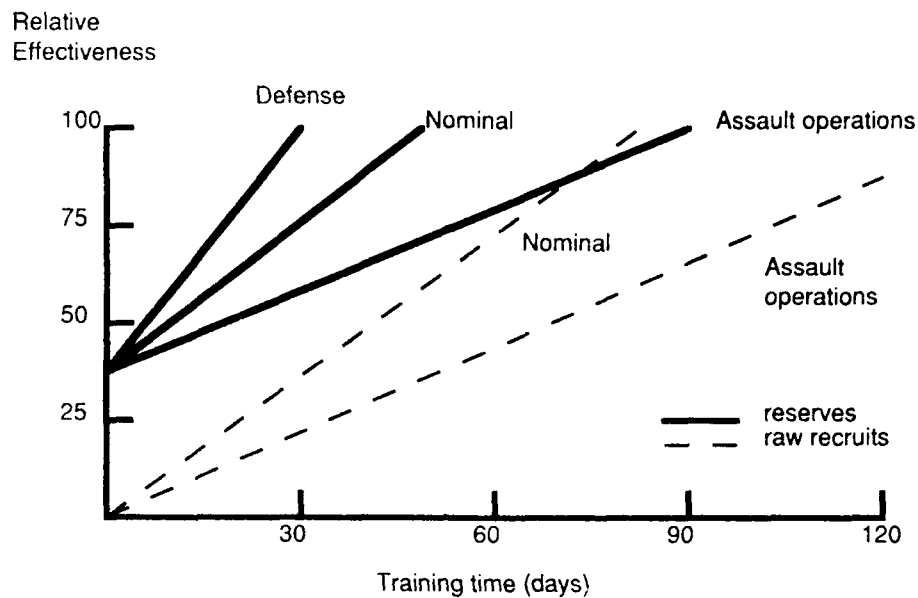
Relative
Effectiveness

Fig. 1—Notional buildup of effectiveness with training for low-readiness reserves

quickly the unit in question can be prepared for combat once mobilization begins.
Human-factors experts surely have a role in doing better on such matters.

The example illustrates how what starts as a soft and fuzzy concept later becomes
just another "hard" part of a quantitative model, although the parameter values may
remain uncertain and sensitivity analysis may be essential. At this stage, government
sponsors and military officers with whom I have discussed these matters no longer regard
the training readiness factor to be any "softer" than other variables (e.g., the terrain
factors routinely applied in theater-level models on a zone-by-zone basis).[9]

Speculations

Similar strides could probably be made with respect to estimating future national
fighting effectiveness. As background here, I suspect that Israeli military leaders were
not surprised when their air force quickly cleared the skies of Syrian aircraft over
Lebanon (with an exchange ratio of something like 80 to 0 or 1). They *knew* they had
both better pilots and a decisive advantage in command and control. Nonetheless,

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[9]This treatment of readiness still captures only a portion of the human-factors issues,
however. For example, it omits discussion of divisional leadership, which in some cases appears to
have been the dominant factor in a division's performance (see discussion of the 88th Infantry
Division in Dupuy, 1988, pp. 114 ff, which also indicates that in retrospect "objective" indicators
of that division's probable excellence could be found in its records). See also Van Creveld (1985)
for much relevant discussion, unfortunately not quantitative.

standard combat models would have sought to predict the results of the battle over Lebanon with complex calculations that are the rough equivalent of the Lanchester equations of ground combat or, in more detailed models, with "physics" calculations involving acquisition and kill probabilities and the like, but with acquisition probabilities calculated without fully accounting for the issues of quality and command and control. Surely we can do better. A good recipe in such situations is to focus first on itemizing the critical factors differentiating one battle from another *qualitatively*, and to then try to predict outcomes for each type of battle using *all* the objective and subjective information at one's disposal, including calculations when appropriate, but also including the currently "soft" factors such as pilot capability and command-control issues. In many instances, one will conclude that it is better to forego detailed calculations and rely on judgments and rules of thumb using techniques such as those described in Allen and Wilson, 1987. This, of course, is precisely what operational commanders have often done over the years, but without the benefit of analytic techniques designed for the purpose.

III. REPRESENTING FRICTIONAL EFFECTS OF MILITARY OPERATIONS

Defining what one means by "friction" is notoriously difficult. It was difficult for Clausewitz, who did not succeed, and it is difficult for us today. Indeed, the word "friction" is as ambiguous as the adjective "soft" used here. Both words refer to factors on which it is difficult to get a clean hold.

Let us discuss three examples here, not all of which readers may agree should be referred to as frictional examples, but which are instructive nonetheless in discussing soft factors driven in significant measure (but by no means entirely) by human and organizational factors rather than laws of physics. The three examples involve: (a) the effects of air interdiction on ground-force movement, (b) the movement of large armies over long distances, and (c) effectiveness of assaults on prepared defenses.

AIR INTERDICTION AS AN ENHANCER OF FRICTION

For decades, the predominant mechanism by which modelers have attempted to reflect the effects of tactical air forces on the ground war has been direct attrition. In one common approach ground-attack aircraft fly sorties and kill, on average, some number of armored vehicles per sortie (see, for example, CBO, 1988, and Posen, 1988). A division may be assumed to lose effectiveness in proportion to its loss of armored vehicles. The image, then, is that air forces add *firepower* to the battle. Indeed, many analysts have taken the next step and translated ground-attack sorties per day into an increment of equivalent division score so that a side's total equivalent-division score is the sum of that from ground forces and air forces.[10] What happens next is interesting if one is an anthropologist observing analysts rather than someone concerned about the validity of defense planning. Because close-air support aircraft are specifically tasked to attack ground forces and fly at a relatively heavy sortie rate, and because they can have rather significant killing potential in terms of kills per sortie, analyses often conclude that A-10s are extraordinarily cost effective with respect to both other types of aircraft and divisions—even if they have high attrition rates. Further, the analyses indicate little or no value to other tactical air missions such as battlefield interdiction and air interdiction (BAI and AI, respectively).

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[10]Using fictitious numbers merely for illustration, suppose that a standard division kills 0.10 enemy equivalent divisions (EDs) in a typical day's battle and that 400 air sorties kill 100 armored vehicles. If a division has approximately 1000 armored vehicles, then it can be argued that 400 air sorties per day is equivalent to 0.10 EDs.

There are many problems with this type of analysis, but I would mention two, both of which can be regarded as involving friction in war:

1. Virtual attrition and the pucker factor . The kills per sortie typically ascribed to ground-attack aircraft in models are assumed independent of the air-defense environment under the reasoning that air defenses are accounted for indirectly through the attrition of ground-attack aircraft. Nothing could be farther from the truth, but those who dislike treating soft factors seem not to notice. Consider the experience of the Israeli air force in the Yom Kippur war of 1973. In the first days of that war the Israelis did not actually suffer an especially high attrition rate by the standards of simulation models, but the environment was so hostile to aircraft that the air force was ineffective initially and had to refine drastically its tactics. Anecdotes from both aircraft and helicopter pilots tell a similar story: if the environment is hostile enough, one must expect mission effectiveness to be very low even for those pilots who complete the mission alive. *The conclusion I draw is that close air support effectiveness has been greatly exaggerated in many studies.*

At a modeling level, reducing estimated effectiveness this way corresponds to *virtual attrition.* Some might say it represents the *pucker factor.* In our work with the RSAS we have included a factor reducing the per-sortie effectiveness as a strong and nonlinear function of the attrition rate, using attrition rate as a measure of the environment's hostility to such missions. The parameter values we currently use in the model are highly judgmental, although historical research could probably improve on them and it seems plausible that a more detailed model could be developed that would be explicitly dependent upon the density of air defenses, their rate of fire, and the difficulty of the attacker's mission. Such a model *might* be calibratable from history and field tests or man-machine simulations that included simulated defenses and pilots with high incentive to avoid being "hit" by the simulated fire (e.g., laser beams or simulated missiles).

2. Interdiction-induced friction. Next, consider what anecdote and history would indicate are important effects of tactical air forces on the ground battle even though they have played a modest role in many analytic studies: (a) delaying and disrupting the movement of enemy tactical units while one's ground forces execute attacks on enemy forces that these units are attempting to reinforce; (b) disrupting rear-area movements generally (of supplies, support forces, and maneuver units), often in unanticipated ways; (c) slowing and disrupting the enemy's movements after he has achieved a local breakthrough, or speeding one's own movements in exploitation of a

breakthrough; and (d) delaying and disrupting the movement of operational-level enemy units en route to the front. Of these, the first two have clearly been important in past wars, and correspond well to both anecdotal and historical accounts, especially by army officers. Mechanism (b) is emphasized in the historical review by Dews and Kozaczka (1981), which brings home the image of tactical air forces increasing the friction of the *opponent's operations as a matter of first-order significance. Mechanism (c) is largely* postulated, but is highly plausible. Mechanism (d) is at the heart of deep interdiction concepts, and is highly controversial.[11]

To summarize now, consider first that it is conventional wisdom among senior professional officers and historians that control of the air is extremely important to the ground war, and, second, that there have been *no* wars as yet in which close-air support aircraft were effective in terms of killing armored vehicles. Clearly, these people are either wrong or the *principal* effects of tactical air on the ground war have been precisely the effects that have traditionally been left out of aggregated (and some detailed) models, those dealing with the effects mentioned above rather than close support. Unfortunately, these effects are usually considered to be difficult to model accurately.

The heart of the difficulty is that we have long visualized the problem with frictionless models. Even when we try to model delays in columns caused by strafing, the mental image is often something like this: "Hmm, well, the vehicles would have to get off the road for a spell and then get back into column and start up. Let's see, how long would that take? Well, if I saw some attacking aircraft coming then . . . ." This type of imagery invariably leads to very short estimates of delay and disruption because it starts with individual small units and omits random and systematic complications characteristic of the whole organization rather than the part. These include human and technical command and control disruptions at the tactical level, logjams caused by damage to a particular bridge, increased timidity, the time required to shift back and forth from a relatively fast-moving posture to a defense-emphasizing posture, and the fact that equipment that could clear up problems quickly if available may be in the wrong place— i..e., a mix of human, organizational, and "physics" issues. To resort to a physics analogy, one might say that there are separate coefficients of friction for static and

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[11]RAND colleagues Ted Parker, Richard Hillestad, and Lou Wegner have developed a very detailed model of interdiction affectiveness addressing some of these mechanisms assuming that unit-level delays and disruptions are specified functions of attrition. Their work is especially suitable for looking at adavanced munitions, but probably underestimates the value of older munitions and effects on Army- or Front-level strategy.

moving bodies, and that overcoming static friction is much more difficult than one might expect from seeing the body move after it has achieved momentum. *Some* of the factors determining the coefficient of static friction here are human and organizational in character.

There are no obvious solutions for this problem as yet, but my colleagues and I have introduced some postulated relationships into the RSAS, where they can be experimented with systematically. The first cut at mechanism (c) asserted the following:

$$V = \max \{ (V_0 - a*S/F), V_{min} \} \text{ if } V_0 >= V_{min}$$

$$V = V_0 \qquad\qquad\qquad \text{if } V_0 <= V_{min}$$

where V_0 is the movement rate one would predict based on the type of battle, force ratio, and so on, S is a CAS, BAI, and helicopter "equivalent sortie rate" against the forces in question, F is the size of the force against which the sorties are operating, a is a parameter, and V_{min} is a minimum speed that could be maintained even against heavy air attack. Thus, the image postulated was that if a breakthrough occurred and the attacker was moving at a speed of, say, 50 km/day according to standard ground-combat equations, then by applying enough sorties against the breakthrough force, it might be slowed down substantially, perhaps to a speed of 5-15 km/day.[12] Note that this effect is in addition to tactical air forces killing of armored vehicles, to the extent the kills in the previous time period did not change the force ratio enough to slow down the movement to Vmin.

MOVEMENT OF LARGE ARMIES

Another excellent example of frictional effects is in the movement over large distances of large armies. To a naive civilian analyst it is often very puzzling why movement rates cannot be calculated assuming that tanks should be able to move at least 20 miles per hour for at least 12 hours a day for a total of 240 miles (400 km) a day. Even sophisticated analysts often greatly overestimate likely movement rates over sparsely occupied networks subject to interdiction. They may, for example, assume that each and

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[12] The next level of sophistication requires accounting for the movement *enhancing* value of offensive air support, which was quite important in both German and Soviet large-scale operations in World War II. This has not yet been incorporated in the RSAS, but it should be, although the movement-slowing effect can plausibly be assumed to be more dramatic than the movement enhancing effect.

every "cut" can be repaired in the nominal time required for that type of repair (e.g., repair of a bridge). This, however, tends to ignore such effects as: (a) engineering equipment being in the wrong place, and having great difficulty getting to the problem area because of traffic jams; (b) resource-allocation problems and associated confusion when there are multiple problem areas; and (c) the delays and disruptions caused by attacks on support units. Again, it might be more productive to approach the problem with explicit concepts of frictional coefficients, and to then seek ways to estimate those coefficients from history and field experiments capable of demonstrating some of the human and organizational complications one sees in large-scale operations.

EFFECTIVENESS OF ASSAULTS ON PREPARED DEFENSES

As a final example of how frictional processes are both important and underappreciated, let us consider how to simulate the effectiveness of attacker and defender in Central Region scenarios that begin with the forces postured in ways constrained by arms control agreements such as withdrawal zones or thin-out zones. There are currently many proposals for such constraints being discussed in both government and academic circles throughout the U.S., Western Europe, and the Soviet Union. As one example, deliberately simplified to avoid going too far afield here, suppose that the Soviet Union withdrew to the Western Soviet Union fifteen divisions from the Group of Soviet Forces, Germany, and also withdrew a substantial fraction of its forward deployed ammunition. Assume no other changes occurred. If we now analyzed the significance of this change with most models, it would be difficult to see much effect at all on the results of combat, except with respect to eliminating the feasibility of extremely short-mobilization attacks, because the models would predict that the Soviets could redeploy their forces and ammunition quickly. It can be argued, however, that the effect (as measured in time required for the Soviets to restore the previous situation) would be much greater than ordinary analysis would predict. Those familiar with the complexities of assault operations, especially assaults on prepared defenses, tend to argue that orchestrating the redeployment and subsequent marshalling for the attack would be a nightmare for Pact planners if they were trying to do it quickly, especially if they feared early interdiction attacks by NATO's air forces. Their description of the attacker's problems translates naturally into friction as represented by units who can't find their sister units, communication problems, massive traffic jams, and many low-level mistakes with higher-level consequences. In any case, better progress might be made with models

developed from the start from a perspective emphasizing such soft concepts as friction rather than the image of frictionless interactions and theoretical network capacity.[13]

The reason for raising these issues in a paper oriented toward soft factors involving human and organizational behavior is that a good fraction of the "friction" would in fact be due to human and organizational inability to approximate theoretical performance given the equipment and road networks available. Actual performance would depend on organizational structure and doctrine, planning, and such low-level factors as the prevalence of individual initiative.[14, 15]

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[13]It seems plausible that extremely detailed simulation models could demonstrate in the aggregate many if not most of the frictional effects, at least if those models included appropriately chosen and interrelated stochastic features. Experience suggests, however, that research and analysis with such models is very costly, time consuming, and vulnerable to forest vs trees problems. Hence, my preference for a more engineering-level approach coupled with field testing.

[14]See Van Creveld (1985) for material highlighting the significance of such factors (e.g., Chapters 5 and 6).

[15]One of the difficulties in improving our understanding of these matters is that there appear to be few appropriately trained scientists working to collect relevant information about *organizational* performance in military operations. The people needed might be better served by a mix of some factory-floor experience in operations research, business theory, and the social sciences than by knowledge of biology, psychology, or the brand of statistics that eschews theory.

IV. REPRESENTING DECISIONS AND DECISION PROCESSES

The third "soft" area to be discussed here involves decisions and decision processes by military commanders, U.S. and Soviet political leaders, and third countries.

POLITICAL-LEVEL DECISIONS AND DECISION PROCESSES

Superpowers

Clearly, higher-level military analysis should be concerned with the likely and possible decisions of political leaders on strategic objectives, grand strategy, operational objectives, operational strategy, nuclear escalation (arguably part of strategy but so important as to merit separate mention), and miscellaneous constraints not clearly part of any strategy. They should also be concerned about decision processes, or at least the external consequences of them such as the decisions themselves, delays, ambiguities, and message garbling.

As one mechanism for varying and understanding the political-level dimensions of possible war scenarios, the RSAS includes optional National Command Level models (NCLs), often called Ivans and Sams, which follow a human-like decision process (the original version of which is shown in Fig. 2, adapted from Davis, Bankes, and Kahan, 1986) and consider variables of likely interest to decisionmakers rather than only the variables more familiar to modelers and quantitative analysts. While research in this domain is still very new, the NCL models demonstrate that some of the most important and complex issues of concern can be illuminated and studied analytically. Recent work, for example (Davis, 1989), discusses first-strike stability in some depth, arguing that the issues most likely to determine actual decisions in a nuclear crisis are only weakly related to what is usually focused upon in strategic nuclear analysis, and even in nuclear war gaming. This argues for much improved decision aids that deal explicitly with the issues likely to be of concern. As one element in an effort to improve our understanding of stability issues and to increase first-strike stability, the report recommends more extensive research and analysis based on filling out the RSAS' NCL models to better reflect some of the cognitive limitations of human beings that are known empirically to cause flawed reasoning. We are indeed pursuing research on the matter in the RAND Graduate School.
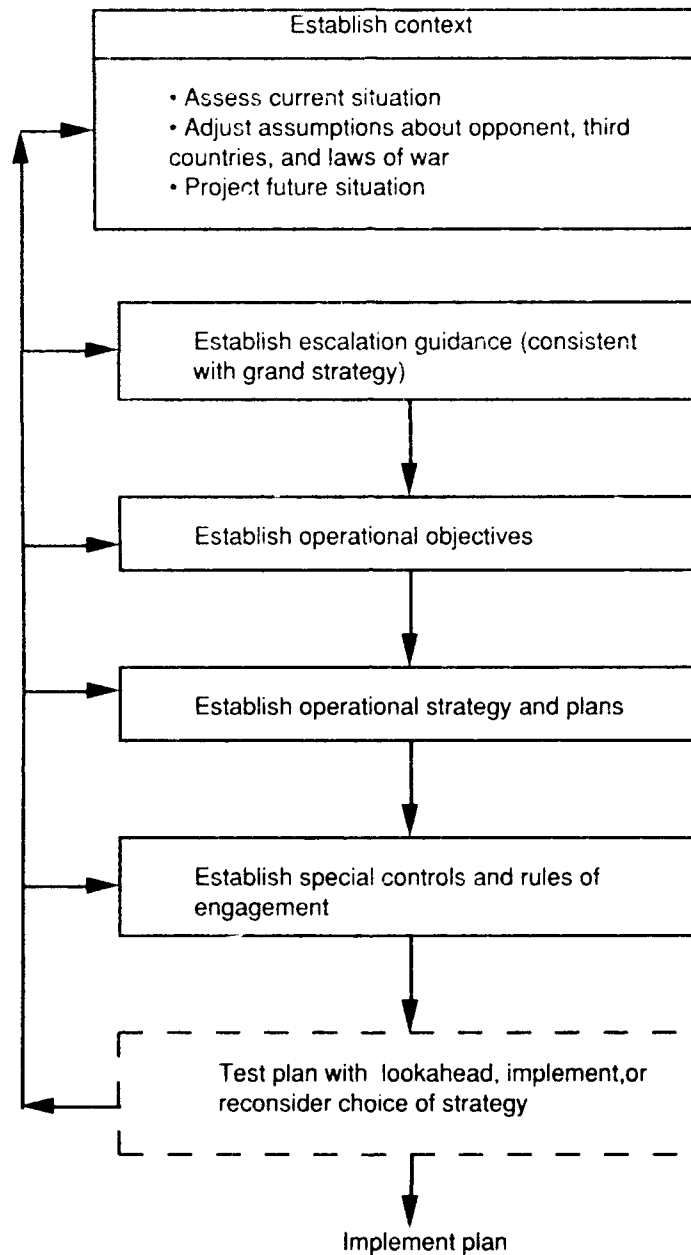
Fig. 2—Process model of original national command level models in RSAS

The most relevant aspects of this for the current paper are probably intellectual and technological:

- It is now feasible to build highly understandable and fast-running computer models mimicking important aspects of human decision processes and

focusing on the kinds of high-level qualitative variables and tradeoffs so critical in real-world decisionmaking. Such models are fundamentally different in character from the utility maximizers of traditional decision analysis, and can be readily understood, reviewed, and improved by people who are not themselves expert programmers.

- Such models can reflect both volitional and nonvolitional aspects of human decisionmaking.

- Such models can be built to deal with issues at any of many different levels of decisionmaking, using much the same techniques technically (e.g., knowledge-based modeling that includes such concepts as a process model for decision, hierarchies of variables, qualitatively driven tradeoff decisions in the midst of conflicting considerations, explicit treatment of perceptions and changes thereof with respect to the environment and prospects).

Interested readers may wish to see an overview report (Davis, Bankes, and Kahan, 1986). They may also wish to consider use of the RAND-ABEL® programming language, which we have now used extensively for several years in building both decision models and knowledge-based combat simulation models. This language (see Shapiro, Hall, et al., 1988) is especially suitable for work in which differentiating among situations is a large part of the challenge. Fig. 3 illustrates actual code, and demonstrates certain features such as the ability to use English-like variable names and the cognitively natural use of decision tables to express tradeoff issues. The language depends on a C/UNIX environment and has been used almost exclusively on Sun work stations. It is fast (only about three times slower than C), strongly typed, and part of a larger environment for modeling called the RAND-ABEL Modeling Platform (RAMP) developed by colleague Ed Hall. RAMP should be available to other researchers by early spring, 1989, at no or nominal cost.

Models of Nonsuperpower Decisionmaking

The RSAS also includes models to represent the behavior of nations other than the United States and Soviet Union in war games and simulations.[16] These models, collectively known as Green Agent (Scenario Agent in older publications), have outputs such as the cooperation and involvement of individual nations. For example, Green Agent will determine whether a given nation provides basing rights to a requesting superpower, or whether a NATO ally would go along with a request to authorize NATO's

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[16]The most relevant documents here are Schwabe (1983), Schwabe and Jamison (1983), and Shlapak, Schwabe, and Ben-Horin (1986)

From NCL models
Decision Table

Current-situation	Warning-of-escalation	Time-since D-Day(Eur)	Presumed-opponent	/Presumed /opponent
Eur-gen-conv	None	long	--	Blue1
Eur-gen-conv	None	short	--	Presumed-opponent
Eur-gen-conv	Eur nuc	--	Blue-1	Blue3
Eur-gen-conv	Eur-nuc	--	>Blue1	Presumed-opponent
Eur-gen-conv	>Eur-nuc	--	--	Blue6.

[long means greater than 10 days]

From S-Land (now called CAMPAIGN-ALT) model (Allen and Wilson, 1987)

Decision Table [Air drop lift losses]

DCA-sorties	esc-sorties	local-degree-of-surprise	/ /	lift-loss-rate	frac-lost-on-ingress
<50	>=(0.25*DCA-sorties)	High		0.02	0 30
<50	<(0.25*DCA-sorties)	High		0.03	0.35
++	>=(0.25*DCA-sorties)	High		0.07	0.40
[lines deleted for brevity]					
++	<(0.25*DCA-sorties)	--		0.10	0.60.

Fig. 3—Examples of RAND-ABEL computer code

(Variables to left and right of "/ " sign are independent and dependent,
respectively, and one reads a given line as: If...and...and...and.... Then...)

Supreme Allied Commander in Europe (SACEUR) to use nuclear weapons. The models are parametric to reflect fundamental uncertainties. So, for example, one specifies such input variables as the side, orientation, and temperament of each nation. The values of temperament indicate predisposition to go along with the relevant superpower's requests (e.g., values include Reliable, Reluctant, and Initially-Reluctant). In addition, as with all the RSAS models written in RAND-ABEL, it is especially easy to review and change interactively even the lowest-level decision rules. Thus, the rules are very much like data in a practical sense.

Among the many reasons for having such models in RSAS work is that they are constantly reminding us of problems we would prefer to sweep under the proverbial rug. Even good allies will simply not roll over and cooperate immediately and fully with their superpower's requests, and in some cases it is nearly inconceivable that they would acquiesce at all—despite the many studies that assume otherwise. Another reason is that such models can highlight and illuminate the importance of the British and French independent strategic nuclear deterrents. Analytically, it has proven useful to study subjects such as launch under attack and flexible response theory with a combination of NCL models and Green-Agent models.

MILITARY-COMMAND-LEVEL MODELS

One of the most important features of the RSAS is that it allows and encourages analysts to make explicit their military strategies. The technique involves something called analytic war plans (Davis and Winnefeld, 1983; Davis, Bennett, and Schwabe, 1988), which can range from a mere script of orders comparable to what analysts have long put in data files at the outset of their simulations to a model of how the relevant commander might adapt his orders in response to circumstances, some of which he has anticipated with explicit branches in his plan, and others of which he must be able to respond to at any time. The analytic war plans also impose a structure forcing the analyst to confront the many dimensions of strategy. For example, in global analyses, there must be RSAS war plans for the various military theaters, as well as coordinating plans at higher levels. Even within a given theater, a truly adaptive plan must be able to cope with complications such as apparent changes in the enemy's strategy (e.g., a shift of main-thrust axes or a surprising use of air forces). By forcing military officers and analysts to confront such issues as part of the modeling process it has proven possible to inject substantially greater operational realism into both simulation and analysis. Further, discussion of military strategies has become more systematic and sophisticated and the

methodology has proven useful in war-college courses dealing with operational art and combined arms planning.

For some readers it may be desirable to mimic rather directly the approach we have taken in developing and using "analytic war plans." More generally, however, the technique should be understood as a mechanism for representing in simulations complex and only moderately adaptive organizational processes. This technique is for people seeking to reflect *realistic* cybernetic behavior, which may include local feedbacks and optimization, but which is seldom optimizable from the top-level viewpoint. Analogs to analytic war plans could be developed to represent mobilization, logistics, or the strategies for and operational procedures of concern at many different levels of human activity.

The relevance of this to a paper on soft factors in combat modeling will probably be more evident if we change vocabulary and talk about command-control rather than strategy. Command-control issues are widely considered as "soft" ("Who knows what the enemy commander would do at that point? Who knows whether the authorizations would be granted?"). Consider, for example, the problem of simulating the effects of delay and disruption on a Pact front commander being subjected to air interdiction with advanced weapons. It is easy enough in traditional models to compute attrition, and perhaps to estimate some delays that might or might not be correlated to attrition, but how do we reflect disruptive effects on the commander's entire strategy? If it means something to attack the enemy's strategy, as emphasized by Sun Tzu, then how do we see that in simulations? One way to do it is by having adaptive plans that attempt to represent explicitly the opponent's plans *and* the changes that real-world commanders would be likely to make as a function of how the war develops, rather than allowing the simulation to proceed with scripted orders. And, indeed, that is precisely what analytic war plans allow us to do, at least in principle. In practice, we have not yet exploited this feature to the extent possible because of our focusing on other issues.

It has been especially fruitful to approach such "soft" subjects as surprise attack and deception with the method of analytic war plans. Many analysts over the years have castigated those who write about the importance of surprise and deception because there appears to be no content in the discussion. What does it *mean* to achieve either, and how can either be possible in the modern world in which the superpowers have lavish systems for warning and intelligence? In fact, however, it is straightforward to construct attack (or defense) strategies that incorporate both, and then to test them interactively or in analytic war games—primarily because the methodology forces explicitness in a

comprehensible form. Surprise and deception remain as important to warfare as they have been in the past, which is very important indeed (Davis, 1988a and b).[17]

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[17]At this point let me post a very large caveat. While the RSAS has all the features described in this paper, it also has many limitations and problems. Moreover, we have only begun to tap the potential of the underlying approach and many of our submodels, as described here candidly, are much simpler than will eventually be desirable. As the experienced reader will have suspected, we have no panaceas yet.

V. ILLUSTRATIVE IMPLICATIONS OF SOFT FACTORS IN CURRENT POLICY-LEVEL ANALYSIS

To conclude this discussion it may be useful to cite some examples demonstrating that treatment of soft issues is a matter of first-order importance, even for policymakers. My examples draw on published RAND work using the RSAS, but many more examples could readily be constructed.

1. Assessing the threat. The very way one *views* the Central Region balance, the relative importance of short- and long-mobilization scenarios, and the value of various conventional arms control measures depends *strongly* on how one takes into account such issues as readiness, breakpoints, likely real-world force employment (rather than the more optimized force employment often assumed), political-level decisions by independent nations, and the likely differences in perspective between a Pact commander contemplating invasion and a NATO-conservative U.S. analyst (Davis, 1988a and b).

2. Tradeoffs among forces. The tradeoffs between ground forces and airforces, or between different types of air forces, depend sensitively on how one models such soft phenomena as the pucker factor and the friction enhancing effects of air attacks that go beyond the usual estimates of delay. Similarly, assessments of concepts such as FOFA depend on such phenomena, and also the degree to which FOFA could force changes in the operational concepts of commanders in the course of war.

3. Crisis decisionmaking. The issues that seem most important to deal with in improving first-strike stability involve *perceptions* and decision processes limited by aspects of human decisionmaking that are highly effective for coping with most situations in life, but potentially very ill suited for coping with life-and-death nuclear decisions in crisis (Davis, 1989). None of these are dealt with explicitly in traditional modeling and analysis. Nor are they properly reflected in today's decision aids, whether those be information displays on naval cruisers or briefing charts used in nuclear war games.

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