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WAR GAMING TECHNIQUES APPLIED TO TRADE AND INDUSTRY*

MACON FRY

Operations Research Office, The Johns Hopkins University

THE SO-CALLED "WAR GAME" or "staff exercise" has long been an accepted vehicle for the training of military staffs. (Here, one should distinguish the war game from the "field exercise" or maneuver, which is primarily for training troops and field commands, not staffs.) Lately, it has been discovered that the war game, if properly designed and played, can also be made to tell something about the merits of various strategies, weapon systems and military organizations. In fact, some war games are now being played primarily, if not solely, for this purpose. Many repetitions of the same game are made, with controlled changes in some of the input elements. By statistical study of the results, it then becomes possible to determine the optimal strategies and weapons. In this respect the war game has become a very important tool in military operations research.

The great popularity of the late Dr. von Neumann's book** attests to the fact that it is widely recognized that the competitive (game) aspects of industry and trade have a tremendous effect on commercial success, just as they do in war itself. Therefore, it is reasonable to suppose that war gaming techniques likewise might find many applications in industrial or marcantile OR. In fact, your speaker has been informed that several prominent firms in Japan are already experimenting with gaming, and it is to be hoped that papers on their experiences will shortly be forthcoming. Consequently, it is thought that it might be of interest to examine some of the procedures used in military gaming, with a view to their possible adaptation to industrial use.

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** von Neumann and Morgenstern, "Theory of Games and Economic Behavior".

CONDUCT OF A WAR GAME

The war game assumes an encounter commencing on a certain day between a force to be tested (the "friendly" side) and a theoretical enemy force. The friendly side may be a single branch (e. g., ground troops), if the object is the testing of that one branch, in which case the co-operative contributions of other branches are inserted in routine ways. On the other hand, if the object is the testing of a combined strategy, the friendly side will have full participation of army, navy and air forces to the extent that would occur in actual war. Or again, the object of the game may be the testing of, say, an air defense system, in which case the friendly side would consist of ground anti-aircraft weapons, air force interceptors, and the detection network, while the enemy force would consist of bombers and escort aircraft. The scale of the game may range from a theater command or continental defense system down to a division engagement. In other words, the "pieces" in play and the design of the game are fitted to the object in view. The results of small unit games are used as building blocks in playing the larger scale games.

The commander of a military machine has three main variables at his disposal: strategy, organization, and weapon systems.* Of these, the most important, and in fact the only truly independent variable, is the weapon system. The commander who fails to adapt his strategy to his (and the enemy's) weapons, or who rejects an improved weapon because it does not fit his existing organization is doomed to defeat, unless his enemy is equally blind.

The design of the game and the manner of play are dictated by which of the three variables is to be studied. If the objective is optimal strategy, successive plays are made varying that element only; similarly, with organization. In examining weapon systems, however, it may be necessary to re-establish the optimal organization or strategy for each new weapons array tested, especially if the changes are extensive. This may require some additional gaming.

* When "weapon systems" are mentioned, the associated *tactids* are also implied. One should keep in mind the distinction between *tactics* and *strategy.* The determination of optimum tactics for each weapon may also be a phase of war gaming, or (more likely) it may already have been reached by analysis.

GAME ORGANIZATION

The participants in a typical war game comprise the friendly and enemy players, the umpire and evaluation group, and the direction or control group. If the object of the game is to test the efficiency of the existing military staff, the friendly players will be the actual staffs of the various headquarters, down to the level that is being played in detail. In any event, the friendly players will represent staff headquarters of the form of organization comtemplated in the game. Each participating headquarters will have players representing each of their staff sections, and will be in contact with each other and higher headquarters through the channels that would be used in actual war. If the object is to test communication networks, the various headquarters might be their "home" locations; usually, however, the players are assembled at one place, and communications delays are inserted at random in the play in accordance with estimates and experience.*

The enemy players are similarly organized. However, since the enemy is theoretical, his potentialities must be assumed, supported by the best intelligence and scientific judgment. The aim is usually to give him slightly more power than any conceivable enemy could muster, so as to err on the safe side. (In an industrial war game, it should be possible to make a more exact assessment of "enemy capability"; knowledge of competitors' activities is not so thoroughly hidden by security!)

The umpire and evaluation group has the task of assessing the results of various actions taken by the two opposing player groups. The umpires alone have full knowledge of what is taking place on both sides. They release to each side only that amount of intelligence regarding its opponent that it would be likely to obtain actual war. For example, if the friendly side announces an aerial reconnaissance flight, the umpires determine the probability of its success and make a random decision based on this probability.

Where pertinent, the umpire group takes into account such factors as terrain, weather and time of day. Frequently, a real weather cycle is used, taken from some period in the past. Assessments are based on

* The injection of various random elements will be discussed later on.

actual weather, but the players are given only the weather *predictions* for planning theiractions.

The direction or control group acts in a supervisory capacity over the game, insuring that the play goes in a way which will test the desired elements. In a "free play" game, which is the type of greatest interest from the operations research standpoint, the function of the control group is chiefly administrative; it interposes only to prevent players from proposing actions which they manifestly have not the means to execute. In games intended principally for staff training or exercise, the control group will often make arbitrary alterations in the play in order to bring out salient points; suchga mes do not, of course, really test the merits of the various input elements and it is very dangerous to draw conclusions from them, a point which, alas! sometimes escapes their sponsors. It is postulated that the "free play" type of game is the only one that would be useful for industrial OR.

RANDOM ASSESSMENTS

For weapons used in quantity, for example, small arms fire and most artillery, casualty assessment can be made according to various formulas.* Certain important actions, however, may happen uniquely, and must be assessed in some manner in accordance with their probabilities. The words of the Australian poet, A. L. Gordon, truly apply to the "game of war";

"No game was ever worth a rap
For a rational man to play,
Into which no accident, no mishap,
Could possibly find a way." (*Ye Wearie Wayfarer*)

For example, the point of fall of a single bomb aimed at a vital airfield may need to be determined. If it strikes dead center, the airfield may be out of action for a week or more; if it misses by a few hundred meters the airfield may be relatively undamaged. For intermediate impacts varying degrees of damage will be produced. To assess this, the umpire uses three tools: (1) the damage-distance function of the bomb; (2) the bombing accuracy expressed according to some convenient

* The well-known "equations of force" of F. W. Lanchester being an example.

statistical measure, which takes account of such factors as visibility andheight of the bombing aircraft; and (3), a roulette wheel with a suitably graduated scale. Figure 1 shows a scale graduated for the normal probability law, with miss-distance expressed as a ratio of probable error.* The umpire spins the wheel once for the longitudinal miss-distance ratio, again for the lateral ratio, multiplies them by the corresponding probable errors for the given bombing conditions, and locates the point of impact on a map of the target. From this location and the damage-distance function, the amount of damage and the time out of action can be determined. Naturally, other scales can be placed on the wheel, to match any distribution law. In emergency, even a pair of dice can be substituted for the roulette wheel, since a table of "points" can be prepared which will give probability increasing by intervals of 1/36. (In this connection, it might be mentioned that a very elegant die in the shape of a regular icosahedron has recently been devised by the Operations Research Group of the Ground Staff Office; it permits the use of the more convenient increment of 5%.) Many other chance procedures are often used by umpires in dealing with probability questions-drawing lots, flipping coins, use of random number tables, etc. In games which employ computing machines this feature can often be "built in" automatically in the programming.

Thus, it will be seen that a large part of the play of a war game employs the so called "Monte Carlo" method. Clearly, the number of repetitions that would be necessary to arrive at an estimate of the merit of any variable would depend upon the frequency and relative importance of these unique actions. If they are duplicated many times throughout the game they tend to "smooth out", so that the end results of all games will be about the same (although the internal patterns might be quite different). On the other hand, if the unique actions are few in number and of transcendent importance, many repetitions may be necessary to establish absolute expectancies.

RELATION BETWEEN SCALE AND OBJECTIVE

Mention was made earlier of the three general variables, or in-

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* Probable error means the distance from the aiming point within which 50% of the bombs will fall. Obviously, there is both a ***longitudinal*** probable error and a ***lateral*** probable error. Sometimes they are equal (circular bombing pattern) but more often they are not (elliptical pattern).

puts, to the war game: strategy, organization, and weapon systems. Games designed to test one or the other of these variables will differ in scale. A strategic game will usually be on a large, even world-wide, scale, and will be concerned with making a choice between relatively few alternatives. Such a game, for example, might seek to determine whether it is better to maintain a chain of naval bases throughout the world or to equip the navy with very long-range vessels. Few repetitions would be needed because (1), the choices are so limited, and (2), the smoothing effects of large-scale actions make them less sensitive to small variations, as already mentioned. The need for strategic games is not likely to occcur in industrial operations, except perhaps in a struggle between huge international cartels.

Organizational games are conducted on smaller scales, generally from theater command size on down. Such a game might have as its object the best size of battalion, or the relative amounts of artillery to assign to corps or division.

Weapon systems games frequently use still smaller scales. They need only be of a size which will include typical representation of the

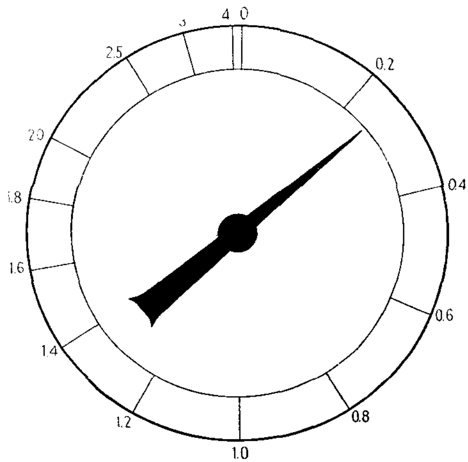

Fig. 1. Roulette wheel graduated to yield readings distributed according to the Normal Law. Unit is ratio of Probable Error.

weapons to be tested, together with terrain and climatic conditions that might have bearing on the test.* A game of this sort might be intended to discover the best size, speed and relative numbers of destroyers in the navy, or the best proportions of various kinds of artillery in the army. It might also be designed to test to what extent a new or improved weapon should replace existing types.

MECHANIZATION OF PLAY

The necessity for frequent repetition of the game to achieve worth while results has been referred to several times. This is chiefly the case with the smaller scale games, especially those concerned with weapon systems evaluation. Fortunately, these are the sort that require a minimum amount of military judgment but a maximum amount of mathematical juggling, which is readily adapted to programming in present-day computing equipment. Practically all the gaming of weapons is now being done with these machines, and a start has been made toward solving organizational problems in this way, also.

COMPARISON OF INDUATRIAL AND MILITARY PROBLEMS

Having taken this panoramic but rather sketchy look at the theory of the war game, let us now see how industry and trade resemble, or differ from, the art of war, and to what extent war game techniques might be applied

1. An industrial firm differs from an army in that it usually faces not one enemy (competitor), but many. However, these competitors are not acting in concert against it (not legally, at any rate!), and are equally competing with each other. Thus, each competitor's response to actions by the firm concerned will be independent of others' (no joint staff work) and will be intended for protection or betterment of itself alone.

2. An industrial firm is in competition not only with those firms which produce the same commodities, but also with firms seeking the same consumer's yen. In this sense, for example, a manufacturer of air conditioners is in competition with a manufacturer of television sets, where a customer could afford one or the other, but not both.

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* However, note that some weapon systems, such as air defense, might embrace a whole continent in geographical extent.

3. The results of executive error are not as extensive or disastrous for a firm as for the military. A mistake by the General Staff can cost a nation its independence, but a similar mistake by company management might cause only moderte financial loss until it could be detected and corrected.

4. An army actually fights for only a few years at a time, with long intervals of peace in between. The war game enables assessments of weapon improvements to be made during peacetime which might in wartime be tried on the battlefield. The business firm, however, is always at "war", so that usually a new product or sales approach can be cautiously tried out in the marketplace at modest expense. An exception might be a change that would involve great expense and lapse of time, so that an actual test on the market would be risky.

5. Competitors are not the only "enemies" of the industial firm. Raw material supplies, general business conditions, tightness of money, changing public tastes are equally important factors. With certain commodities the possibility of radically changed statutory requirements might have great influence, as, for example, a change in the motor vehicle horsepower tax, or in the building code relating to plumbing fixtures. However, it should be possible to deal with these factors in gaming the problem.

THE FIELD FOR THE TRADE OR INDUSTRIAL GAME

It is clear from the foregoing that the area for worthwhile use of gaming techniques will be somewhat narrower in the industrial field than in the military. As an alternative to experimental methods, they will be useful mainly in cases where (1) a small-scale experiment will not produce accurate results; (2), the nature of the problem is such that a scaled-down experiment cannot be designed; (3), the problem deals with circumstances that will exist in the future but do not at present; (4), the time or expense required to run an experiment would be excessive compared with gaming; (5), an experiment would reveal company plans to competitors.

However, the above situations still provide a considerable range for the employment of game techniques. It is suggested that some of the following problems might be amenable to attack by gaming methods :

1. Railway systems: re-routing or expansion; location of station stops and freight depots; type of motive power; prediction of traffic.
2. Electric systems: location of generating plants and load centers; routing of transmission lines and determination of transmission voltages; selection of energy sources; estimates of future requirements.
3. Shipping: routes; vessel size, speed and design. (Similarly for air lines.)
4. Manufacturing: selection of line (number and quality of items); prediction of volume.
5. Distribution and merchandising: number and location of wholesale and retail outlets; promotional methods.
6. Highway planning: location of throughways, interchanges and feeders; capacity.
7. City planning: zoning; prediction of urban growth; traffic control.
8. Municipal services: water supply; sewerage; police and fire protection; waste disposal. (Related to above.)
9. Monopoly corporation operations.

ORGANIZATION FOR INDUSTRIAL WAR GAME

The organization for an industrial war game would probably be much smaller and simpler than that described for the military game. For one thing, it would certainly not have staff training as one of its purposes! In fact, the regular company staff should not be concerned in gaming at all, except perhaps to furnish technical advice occasionally on request. The game should be conducted by a special group of player drawn from the OR staff, and should be no larger than is necessary to operate effectively. Maximum use should be made of computing machinery, where suitable, to supply routine and repetitive inputs.

CONCLUSION

It is hoped that this brief description of military gaming, together with suggestions for industrial applications, will help to put the subject in proper perspective. The war game is certainly not a universal tool, but it is worthy of consideration by operations analysts, along with direct analysis and actual experiment.