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A SCIENTIFIC FORECAST OF NEW WEAPONS

EDITED BY

Nigel Calder

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this limitation will often result from inhibitions produced by nuclear deterrence and the risks of escalation, as well as by the pressure of world opinion. Nevertheless, to consider conventional warfare as being humane could in many circumstances prove dangerously wrong as the risk of catastrophic destruction becomes even greater. I shall return to this crucial question of the humanization of warfare in my conclusion.

To review the possibilities in conventional warfare in the 1980s, I shall examine first the prerequisites for conventional war to recur within the strategic framework determined by the existence of nuclear weapons, then the technical characteristics that one can envisage for future conventional warfare, and finally the operational features of these wars as we can imagine them today.

The Scope for Conventional Warfare

The existence of nuclear weapons has created altogether novel dangers. On the one hand the risk of destruction entailed by war is now of an order of magnitude quite disproportionate to our experience. A medium-sized thermonuclear bomb of one megaton produces an explosive force equal to a salvo of 200 million "75s"—the gun that was "modern" in 1914! Not only are the destructive effects of a nuclear war difficult to compute rationally, but also there is, so far, no reliable means of self-defence. In these conditions, nuclear war involves the combatants in the certainty of mutual destruction, which completely dispels any adventurous illusions about the outcome of the conflict. On this certainty rests the effect that the nuclear deterrent imposes on the use even of conventional weapons.

But this nuclear deterrence is neither absolute nor spread evenly over the whole globe. The enormous risks of nuclear

warfare make it an implausible threat in minor conflicts. Moreover, in areas of the world where the interests of the nuclear powers are not vital, nuclear deterrence does not apply—for instance, in Vietnam at the time of writing. Even in the regions where these interests are vital, it is difficult to imagine that nuclear war could be unleashed in response to local incidents of secondary importance. In the present strategic nuclear situation, therefore, the normal field of action of conventional war is in those parts of the world not covered by nuclear deterrence—virtually the whole world outside the United States, the Soviet Union, and Europe. Furthermore, the possibility of very limited and doubtless very brief conventional military actions cannot be completely excluded in the zones covered by nuclear deterrence, for example in Berlin or in Eastern Germany. But such confrontations should not normally become more than local incidents if the risk of escalation to the nuclear level is to be avoided.

Nevertheless, the present strategic nuclear situation can be modified, either by the effect of innovations such as antiballistic missiles, or by disarmament agreements that neutralize the nuclear weapons. In this context, the possibility of minor or major conventional wars could reappear in Europe as the result of political events.

These different possibilities involve widely different kinds of conventional conflicts. If it is a matter of taking advantage of a favorable situation to achieve an object in spite of the existence of the nuclear deterrent, the war will take the form of a swift military action designed to achieve some kind of *fait accompli*, as did the 1956 Israeli campaign in the Sinai Desert. If, on the other hand, the conflict takes place outside the comparatively small zone affected by nuclear deterrence, conventional warfare can manifest itself in more or less important military interventions, of which

recent examples are not lacking—whether to occupy or defend a country against invasion (Korea), to uphold a government against subversion (Vietnam, Yemen, the Dominican Republic), or to defend national interests (Suez).

Finally, suppose that in Europe or on the Chinese frontier, the nuclear deterrent came to lose its power. Then we might witness the development of classical military conflicts gradually increasing toward major importance until they regain the intensity of the World Wars of this century, wherein the nations exhausted their strength in attrition and threw everything they had into the fight. This is fortunately not the most likely hypothesis, since the nuclear deterrent will retain enough of its menace to limit the scope of warfare for a long time to come. But it is a very dangerous possibility. World Wars I and II, waged only with conventional weapons, caused great enough turmoil in Europe and the world; another great war involving the use of conventional weapons of the future could be immeasurably more devastating. Certainly, humanity is still sensitized by its recent terrible experiences, but memories fade fast from one generation to the next. In the 1980s, the coincidence of a reckless head of state and a people inflamed by a great passion—racial, nationalist, or ideological—could reproduce the phenomena that twice in thirty years devastated the world and led Europe to her eclipse.

General Trends in Conventional Weapons

These anticipations lead one to consider possible progress in the realm of conventional weapons. They have developed spectacularly since the beginning of the century, but since World War II the process has been accelerated by the scientific discoveries and technical innovations of all kinds that characterize our times. Speeds and ranges, for

the psychological character of the struggle makes the political circumstances supremely important.

But what amounts to an important innovation in recent counterguerrilla wars comes from the considerable improvement in guerrilla tactics and strategy, under the Soviet and Chinese influence. In learning systematically to refuse to fight whenever he is not in a markedly superior situation, and in operating a highly coordinated system of dispersal, infiltration, and terrorism, the guerrilla has acquired a miraculous capacity for survival and for maintaining his hold over his people. In this situation, conventional forces are in the position of a lion attacked by mosquitoes; they can go anywhere they like, almost without a fight, and they can defend the points they occupy in force, but because of the extent of the terrain and its natural obstacles they cannot be everywhere at once. Vast areas will thus necessarily escape their permanent control, and there the guerrilla can persist. As a result this kind of conflict can last for years, often finishing with a compromise born of weariness in the more powerful adversary. Such a pattern occurred in the Algerian war, and it may repeat and grow in the future.

To put down the guerrillas, the most powerful conventional weapons have been tried in Vietnam; in the future perhaps even more modern weapons specially designed for the purpose will be brought into use. It is certain, for example, that developments in air-to-ground fire, the great tactical and logistic mobility made possible by the helicopter, day-and-night surveillance of the terrain by radar, the use of electronic or chemical methods to "label" the friendly population and the guerrillas in some discreet way, and the use of chemical incapacitants will give military forces increasingly effective means of action. But the essential difficulty in guerrilla warfare still stems from the physical impossibil-

ity of simultaneously controlling the whole terrain, even with greater and greater resources. That is why psychological methods are most often the only decisive ones. By contrast, the use of all these increasingly powerful modern weapons can mean subjecting the general population to almost inhuman stresses. With these massive and often blind techniques, counterguerrilla warfare comes to look more and more like a war against the population, the opposite of its declared objective. Personally, I believe that more subtle methods—and more political ones, as I have mentioned—are the only ones that will achieve results. Failing that, counterguerrilla warfare is simply an extremely costly means of postponing political solutions, which will impose themselves sooner or later.

The idea of a conventional war between adversaries of technically comparable strength is luckily not very realistic. As I have said, this situation could result only from a conjunction of grave political disagreement between two developed nations and the neutralization of nuclear deterrence. If these two conditions coincided, then we should witness the rebirth of the conventional "great war." What form such a conflict would take in the future is extremely conjectural, for it would depend directly on the relative value of the technical systems favored by the two sides. According to circumstance, one might be faced with a *Blitzkrieg* entailing the quick and complete defeat of one side, or with a prolonged war resolved by the exhaustion of the weaker or less determined party, or ending with nuclear escalation or some kind of revolutionary war.

Blitzkrieg (lightning war) in modern guise presupposes that one of the opposing parties has managed to gain complete ascendancy in power and mobility while driving his opponent out of the air. The touchstone here is the right solution of the counterinterception problem. If this result

is largely a matter of improvisation and opportunism. As I have mentioned, greater importance attaches to conserving manpower than to holding ground. With this principle in mind, the guerrilla is always ready, if need be, to run away and hide. Consequently, when regular ground or air forces attack with powerful modern weapons, the guerrilla makes it his business not to be present. It is possible that areas of open country which are regularly patrolled on the ground or surveyed from the air will be entirely denied to him, unless he moves in the guise of a civilian. The use of chemical agents to defoliate trees may rob the guerrilla of cover in some places. A massive sweep through a particular area by the regular forces may force him out of it, temporarily. The important point is that, unless the regular forces are prepared to lay waste to the entire country, with nuclear weapons for example (which cannot correspond with any rational political goal), there will always be somewhere for the guerrilla to conceal himself from attack by modern weapons systems. From his hiding place he can emerge at a moment of his own choosing to attack the enemy at a vulnerable point. The only strategy open to the regular forces is to attempt to eliminate the guerrillas, one by one, in infantry engagements over a huge area and a long period of time. The war becomes uncontrollably large and costly in lives and materials for the regular forces.

If the guerrilla movement (by our earlier definition) is supported by a large section of the population, it has a reservoir of manpower on which to draw. Clumsy, destructive, and impatient action by the regular forces will always tend to drive civilians into the guerrilla camps. A characteristic of advanced and powerful weapons systems by land and air seems to be that, despite the allegedly "sophisticated" electronic systems for fire control, the impression at the target is of clumsiness and purposeless destruction. For this reason advanced weapons systems may be much more of a liability than an asset in antiguerrilla warfare. And even if some highly lethal new weapon, such as a nerve gas or an infectious microorganism, were used effectively against the guerrillas, that local military victory of the regular forces would be bought at a price of moral catastrophe that would make political victory utterly impossible.

A secondary consideration about the use of advanced or novel weapons against guerrillas is that, as the guerrillas rely largely upon captured arms, these weapons, too, are quite likely to fall into their hands and be turned upon the original owners.

To sum up, guerrilla warfare is likely to remain militarily viable, whatever weapons are used to combat it, unless those weapons are so morally indefensible or indiscriminately destructive that the user forfeits all his political purposes. The well-organized guerrilla movement in a country of reasonable size, based on popular support, is indestructible except by enormously costly and protracted infantry warfare which is almost beyond the resources of even the biggest nations. In this sense, it represents the eternal truth that you cannot destroy a political belief without killing, one by one, all the people who possess it. That is something that no scientific advances in weaponry can alter, even though they make the killing easier to accomplish.

persing radioactive fission products derived from such a source rather than by dropping nuclear bombs. The problems of shielding the radiation of the fission products in aircraft, or in rockets before launching, would be formidable. They can therefore be neglected as potential weapons.

Proliferation and Nonproliferation

Unfortunately there are many countries in the world that could afford to develop nuclear weapons and minimal delivery systems, particularly if they became convinced that national security depended upon doing so and if they believed that they could economize in other military expenditure. Although competent scientific manpower is required and the relevant engineering is not trivial (especially for the production of uranium-235), there are no "secrets" inaccessible to an industrial nation prepared to carry out the necessary research and development.

To speculate about which nations might seek to acquire nuclear weapons during the next few decades is somewhat invidious and must depend on many political and economic assumptions. Alignments of nations in alliances and in conflicts plainly exert restraining or provocative influences. From a global viewpoint, the chief cause for anxiety is the likelihood of a chain reaction in which the acquisition of nuclear weapons by one new country would provoke other nations to follow suit. For example, if three nations made nuclear weapons for the first time in the 1970s, ten might do so in the 1980s and thirty in the 1990s.

The chance of nuclear war breaking out, and possibly engulfing a large part of the world, must inevitably increase with the number of nations possessing nuclear weapons. The risk is aggravated by the suspicion that smaller

countries acquiring nuclear weapons would be unlikely to develop the sophisticated command and control systems of the kind possessed by the United States, the Soviet Union, and Britain. These systems are strongly biased against the possible delivery and detonation of the bombs as a result of false information, unauthorized action, or an engineering fault. The lack of such systems would greatly increase the risk of nuclear war by accident. Another important factor is the likelihood that some nations acquiring nuclear weapons would have a less responsible form of government, or be susceptible to revolutions that might bring reckless men to power. In that connection the use of nuclear weapons in civil war cannot be entirely excluded.

We have several examples of powers that are mutually hostile at present, for example Israel and Egypt and, to a lesser extent, Pakistan and India. The tensions that have been generated in the past would be enormously increased if they had the possibility of dropping only a few nuclear bombs on one another.

There are also strong economic arguments against the development of nuclear weapons by underdeveloped countries while their standards of living are so low. They need the whole of their scientific and technological effort for the development of their economy rather than devoting a large proportion to nuclear weapons programs.

A further argument is the complete uselessness of nuclear weapons for any purpose other than mutual destruction. They would have been of little effect if India had possessed them and used them to try to stop the Chinese incursion over their border.

At the beginning of 1967 the risks and costs of the spread of nuclear weapons were sufficiently plain, the main nuclear powers in sufficient agreement, and the military am-

motor response (weapon). Modern "systems engineering" was born. The obvious if crude parallel to the functioning of the human being was immediately noticed by men like Norbert Wiener, who coined the word "cybernetics" to cover the complete range of biological, mechanical, electronic, and social systems that appear to operate according to the same general systemic principles.

Soon the problem of directing antiaircraft fire was replaced by the problem of guiding missiles, both for offence and for defence. As the more sophisticated intercontinental ballistic missiles (ICBMS) and space vehicles were developed, more advanced sensory and electronic machines were also produced, leading to "real-time, on-line" weapons systems. Missiles and space vehicles could not be guided with the accuracy now possible if we did not have the contemporary high-speed computer. Similarly, defence against ballistic missiles could not be contemplated if advanced computers were not available to control and guide the necessary systems. There may be, at best, only fifteen to thirty minutes' warning that an enemy missile is approaching; action and reaction must both occur in the same time phase. In the past, for any type of warfare, a counterstrike did not have to occur at exactly the same instant as the inaugural strike. A threatening battleship detected one day would still be there to receive a counterattack the next day, or even later. There could even be enough time to make official inquiries or protests through the traditional channels of diplomacy. But the blinding speed and the cataclysmic destructiveness of contemporary offensive weapons requires the "real-time" deployment of defensive weapons, if they are to have any effect at all.

The practical meaning of a "real-time" system of control depends upon the time span within which perception, decision-making, and action, the three elements of the com-

plete system, may be operated effectively. Compare other types of time systems. A philosopher like Immanuel Kant, deliberating speculative problems posed by David Hume, operated in a time span that could occupy generations. For a politician like Charles de Gaulle, pondering how to make the diminished power of France effective under the novel conditions of the Cold War, his effective time span may comprise a whole year, or even a decade. For the pit crew of the lead race car at the Indianapolis speedway, the effective time span may be less than twenty seconds. For a missile defence system, real time is closer to three millionths of a second. This kind of time scarcely existed at all, in any meaningful sense, for previous generations. Now, the need for instantaneous analysis and control is showing up in all sorts of circumstances, from complex manufacturing processes to traffic control at busy airports. An ever-increasing variety of tasks require something like the split-second analytical capacity and the high accuracy pioneered in missile control systems.

Two types of control systems are possible: DDC (Direct Digital Control) and SC (Supervisory Control). Under DDC the system is completely computerized. Under SC there is an intermediary stage between computer and motor response in which human intervention may occur. Most complex systems provide elements of both. A missile defence system, for example, possesses DDC components, but the over-all system is SC, because the final decision is preserved in the hands of the Commander in Chief. Where a system involves discrete operations that may be irreversible, like the launching of a nuclear-armed missile, some of the speed of response offered by DDC should be sacrificed to insure certainty about the information presented; in such cases, human intervention through an SC system is obviously required.

processing on the present scale was impossible before the computer; even if as much information could have been collected, it could not have been processed by paper-and-pencil methods within the time span relevant to the decisions on which it bore. Nowadays the President can be given, each morning, a composite, up-to-the-minute intelligence report on every critical event in the world.

The President, as Commander in Chief, thus has more complete information than can be acquired by anyone else in his entire system of command and control, including commanders on the spot. The first result has been the progressive sublimation of tactical considerations into the strategic sphere. Given sophisticated techniques for gathering and analyzing information, the discontinuity and discreteness once possessed by remote events gives way to an over-all interconnectedness. For example, a small-scale air strike by American bombers on Hanoi might be related to a whole series of larger problems of which no field commander could possibly be aware. A bombing mission could affect the internal strife between belligerent and conciliatory factions inside the Hanoi regime. It could also bear upon Soviet decisions on the quantity and quality of assistance to the Viet Cong. It could also affect Peking's calculations as to whether the United States had aggressive designs on China herself, and hence Chinese decisions about whether to enter the Vietnamese war directly. It could influence Britain's decision whether or not to support the American effort. It might reactivate the protest movement inside the United States, and so on, through a vast network of ramifying issues.

As was widely reported in the press, President Johnson personally pinpointed each day's bombing targets in Vietnam and received the same night direct reports of the results. This centralization of decision-making takes place not

just because it is now technologically possible, but because, being technologically possible, it has become politically necessary.

In previous times the same events could not have had the same strategic or diplomatic implications because they could be discounted as the autonomous, unwitting acts of local commanders. Now, however, each side must assume that the other is aware of the secondary implications of all military actions. This means that each is forced to assume responsibility for the secondary as well as the direct effects of every military operation. Authority, in such a case, follows responsibility. The Commander in Chief must take a direct decision-making role in remote and seemingly minor tactical operations.

The process that converted tactical problems into strategic ones did not stop there. It went on to convert them both into diplomatic problems. This is one of the most revolutionary of the host of novel developments that has grown out of computerized warfare. With the outbreak of war between Israelis and Arabs in 1967, President Johnson sat at his White House controls with one hand guiding his Sixth Fleet and the other on the hot line to Moscow. The integral nature of these functions was verified when an Israeli attack on the American intelligence ship *Liberty* forced activity by American carrier-based aircraft. Moscow was also monitoring every radar blip, just as was Washington: would the Russians interpret the changing and converging flight patterns as an act of aggression? This was where the hot line came in, as Washington immediately explained its actions and reassured Moscow.

In previous times the general, the diplomat, and the statesman employed different tools and plied different trades. Computerized warfare has congealed war, diplomacy, and politics into one overarching art. Clausewitz's fa-

mous dictum has been superseded. War is no longer the continuation of politics by other means. Both now take place in a simultaneous synthesis.

Administration and Management

The third set of developments in computerized warfare concerns administration and management. This does not necessarily mean the over-all management of war. Rather, it refers to the management of such things as weapons development programs, logistical support operations, and problems associated with organizing and training troops. Similar problems occur in the management of large civilian operations. If it is necessary to know how many Portuguese-speaking licensed ham-radio operators there are in the Air Force, or to know almost anything else, the answers can be obtained quickly. This provides a capacity for management in detail that would not be possible without computers. It has, in effect, created a new field of activity, which might be called "support management."

For example, it was always known that, in order to support a regiment in the field, certain back-up services and supplies were also required. However, the information was terribly imprecise, and troops in the field were always plagued by supply imbalances and bottlenecks. This was partly because needs simply could not be accurately analyzed and calculated. Nowadays, in sending a fresh division into battle it is possible to estimate, with high accuracy, the number of physicians, cooks, or mechanics, and the quantities of every kind of material, reaching into thousands of categories. For example, in the American operation in Santo Domingo in 1965 it was possible to know in advance that the ultimate troop level would be 120,000 men, and to know the sizes, types, and rates of flow with which troop

segments and supplies were to be dispatched. In previous times it might have been decided, for example, to commit 50,000 troops to such an operation without being aware that before it was over 120,000 would in fact be needed.

In short, the administration of military operations has been raised to a level of precision previously unimaginable. The perfection of this managerial skill is one of the products of the Vietnam war, and it has permitted a much finer adjustment between international policies and the use of force; the danger of overextending foreign commitments is correspondingly reduced. At least, it is possible to know in advance when the risk of overcommitment is present. Again, however, this is a development whose benefits result in the ever-increasing centralization of decision-making.

Instant Crises and Artificial Men

Already, then, computers and the massive flows of information they make possible have altered the conduct of combat operations. In the future, the systems can only become more powerful and "all-seeing." Not only are computers becoming bigger and faster, but the intelligence links feeding them can exploit such new techniques as surveillance satellites and communications satellites. This trend raises a series of more fundamental questions about the changing nature of warfare and military decision-making.

Consider, for example, one hidden consequence of the fact that we possess systems for the instantaneous communication and analysis of information from throughout the world. The short statement of the case is: instant information creates instant crisis. That is, the "existence" of a crisis, like the existence of anything else, depends in part on its being perceived. Until recent years border eruptions, riots, depositions of rulers, and so on might occur and then be

more and more sophisticated, more and more leaders are preserved to wield authority under conditions of near senility. Considerations of age alone raise such questions about Roosevelt, Stalin, Churchill, Adenauer, Eisenhower, Mao, and de Gaulle. The typical national leader of the future may be a man with a chemically induced artificial personality, maintained in authority beyond the time senility normally sets in, and then served up with a daily diet of stress-producing crises. It is a situation that any systems analyst would describe as gravely dysfunctional. In plainer language, it is a prescription for disaster.

The Militarization of Politics

We have seen that one result of computerized control systems was to convert tactical into strategic problems. This led to the centralization of command in the highest political authorities. The consequence was to erode the distinction between the military, the diplomatic, and the political. Now, however, a further distinction is in order. The conversion process refers to types of authority rather than to types of problems. It is military authority and diplomatic authority that have been converted into political authority. It does not follow that an issue that is essentially military in character is thereby converted into one essentially political. On the contrary, the alarming thing is that the opposite conversion tends to take place: the system is biased to evoke military response to political issues.

In the past nations were seldom on a permanent war footing. Mobilization represented a threshold between peace and full-scale war; it was not to be entered into lightly over a minor incident, and diplomacy had its traditional scope. Nowadays the maximum military means, up to thermonuclear strikes, are held constantly at the ready. This

the leading theoreticians of postwar international relations. Earlier students of diplomacy had possessed little or no knowledge of the technical details of weaponry or of the intricacies of logistics. They had studied such things as geopolitics, diplomatic history, international law, the governmental and political structures of other nations, demography, international economics, and the goals of the world's countries. When they spoke of international power politics they meant an amalgam of all these things. Such factors were then believed to be primary. Military capacity was secondary. Indeed, it was a maxim that a military resolution in discord with the deeper cultural sources of national power could not be stable.

All this was transformed by computerized thermonuclear war. For when a few weapons could wipe out all other sources of national power in a few moments, the relationship between nonmilitary and military power was reversed. Henceforth, anyone who wished to deal with international relations was forced to master the new hardware approach and to know a great deal about the world's armament secrets. However, this information was possessed by only a few of the world's highly classified information agencies and research institutes. Diplomacy was not only militarized, it was also monopolized by those who could find out about and understand the arcane intricacies of the new means of warfare. One had to know the capabilities of the latest model of thermonuclear warheads, their number and distribution, and the range and performance of their delivery systems. Only then could one calculate the first-strike capabilities, the second-strike capabilities, and the theoretical state of the balance of terror—Churchill's phrase. Now there was spawned an entire family of calculations based upon access to classified information. How many would die in a strike against the major cities? What were the pos-

sibilities of a strike against another nation's thermonuclear installations? If each could be done, which was preferable? In the event of a surprise attack, how much reaction time would be available for a counterstrike?

Such questions brought the perplexing topic of deterrence into the language of international relations. This involved the issue of how, without using thermonuclear weapons, one could convince others that there were conditions under which they would be used. This was the credibility issue. With the Soviet development of ICBMs, American "brinksmanship" gave way to the doctrines of graduated deterrents and the rehabilitation of "limited" wars; but if this were to work there must be a fairly explicit agreement between the thermonuclear powers about the conditions under which graduated levels of military means would be employed.

At first thought all of this appears to involve little more than the rough and practical psychology of the gladiatorial arena. And often there is not much more than this involved in the more popular works on thermonuclear warfare. Grisly imaginary games are carried on containing speculations that if A does such-and-such, B must reply so-and-so. Then A has options x, y, or z, and so on. However, the deeper point is that a game really is at issue—one whose principles are the subject of a very sophisticated branch of applied mathematics known as games theory.

Mathematicians in research institutes program computers with all conceivable variables and play unceasing series of war games according to established games-theory models. The dialogue that once characterized diplomacy has given way to theoretical war soliloquies carried on by latter-day Hamlets who address their end-game questions to computers rather than ghosts. This is not to suggest that today's questions, to be or not to be, are "decided" by computers. They are not. They are decided by human beings, apparently just as they always were, even though the artificially preserved human decision-makers may not be just as they always were. It is not that computerized warfare has yet eliminated man, but rather that it has eliminated politics and diplomacy, as these have been known in all times previously.

Minimax and Mainchance

The rules of the new game of militarized international relations are now adopted in practice. The Cuba missile crisis was all made up of move and countermove, with each side in complete isolation from the other. Each sat at his computerized console, studying his radar-activated, computerized war map of the world. And each made his moves like an apocalyptic chess player whose heavily guarded queen was his second-strike missiles in hardened sites.

But in such a situation there is a paradox: if either "wins" it is the end of both. The whole purpose of the game is to achieve a stalemate. And yet the rules of the game make stalemate a very unlikely outcome. This is because competitive games that eschew political dialogue surreptitiously favor outcomes in which one player's victory is achieved at another player's loss. Politics and diplomacy are the opposite. They rest upon the proposition that the joint exercise of reason can resolve conflicts so that both parties come out better off than they were before. This intuitively persuasive conclusion is capable of theoretical demonstration if one follows the assumptions of war games theory to their end.

According to the new rules, everything depends upon the "rationality" (that is, the calculability) of the sequence of actions taken by each party. There is a special type of rationality favored by the rules of the new game of inter-

national terror—the so-called minimax calculation, which means selecting the move that will minimize one's own maximum possible losses. Many of the great military leaders of the past were impulsive and their actions much less calculable; if such strategical extremists as Caesar or Napoleon were at the head of today's armed forces, the new rules of international terror would be hard to apply. Accordingly, each side's interests are endangered if all-or-nothing mainchance leaders oppose them. Part of the minimax strategy of each side must be to select moves best calculated to reinforce the authority of minimax leaders among their opponents.

Another result of the minimax calculations deriving from computerized warfare is the need for preserving the maximum number of options as long as possible. In other words, given two alternative strategies, each with the same probability of producing maximum returns, the preferred strategy will be the one that preserves the largest number of options for the future. Old-time leaders were usually radicals, forced to make an irrevocable, all-or-nothing decision; strategy tended to come down to jockeying for a position from which a mainchance strike could be made. Computerized warfare produces a more "conservative" minimax decision-making leader; it favors the bureaucratic Eisenhower types over the mainchance Patton types. Here again, however, there is a point at which an insidious reversal sets in.

We have seen that computerized warfare politicizes military authority and then militarizes political issues. Now a similar reversal of minimax conservatism occurs. In ultimate situations, when total destruction appears to be inevitable, it turns into mainchance radicalism, and brings doomsday. And the reason can be traced directly to the special features of computerized decision-making that have produced the ascendency of minimax conservatism over

post-mortem experts are still debating. Was an Arab attack truly inevitable? Was the Israeli pre-emptive strike too limited in its scope? Was the result a "real" victory for the Israelis or is it reversible?

Everything depends upon the validity of the information processing system, for, as we have said, the logic of completely valid information is ultimately to convert minimax into mainchance.

How to Make War Inevitable

Computerized intelligence and war gaming can only grow and tighten their hold on human affairs, as techniques improve. The ultimate possibilities and risks are perhaps beyond our present capacity to forecast. But if we look at the most advanced ideas today we can at least see the likely trend of the next twenty years if military confrontations between nations continue. The place to look for these ideas is Vietnam.

The advances in information-processing technology may be the most significant contribution to warfare to come out of the Vietnam war. If, as is often claimed, Vietnam is the 1960s counterpart of the Spanish civil war, then computerized strategic information leading to pre-emptive strikes is the counterpart of the *Blitzkrieg* of World War II. The United States has been operating four intelligence analysis centers in Saigon, with computers reportedly operating twenty-four hours a day. Over a thousand workers add to their computerized files more than 100,000 items each month. Supplementation comes from the "Big Eye"—four converted Super Constellation aircraft constantly watching and reporting on everything from the air. Raw information is collected from every possible source.

The long-term aim is nothing less than to account for

And the result — the Offensive Tet as a complete surprise

all enemy material and troops. Ultimately the system will be able to apply to enemy forces the same procedures of accounting and analysis that computerized inventory systems in industry use to account for the amount and location of production items. Then field troops can be given accurate information about the size and location of enemy units and weapon emplacements. One operation was said to have been furnished with intelligence location maps whose plotted items were later found to have been eighty per cent accurate. In at least one case a prediction by the system of an enemy attack was ignored by the field commander with disastrous results. If the ultimate aim is realized it will produce such a high degree of accuracy that the predictions cannot be ignored. ? ?

For example, the system aims at compiling critical military information about each individual among the enemy ground forces. Then, day-to-day variations in the information about given individuals can serve as reliable indicators of enemy tactical intentions. It is not far-fetched to suppose that sufficiently accurate information would make it possible to project probable enemy maneuvers even before the enemy himself had made his decisions. ? ?

If military information processing ever produces truly reliable projections of probable enemy actions, the consequences are clear. In the first place, decision-making will leave the hands of both field commanders and political authorities to become an adjunct of the information-processing system; then the computers may indeed take charge. Secondly, the tendency will be to make all military operations pre-emptive.

It requires but little imagination—and available hardware—to project for the entire world the application of the advances in information processing about enemy activities that have been achieved in Vietnam. Already the

sensory devices. Information will be continuously acquired about the complete environmental state of the ocean as well as about the man-made vessels and installations it contains, both on and beneath the surface.

In the 1980s it will no longer be possible to speak meaningfully of antisubmarine warfare or even of undersea warfare. The development of new carriers and other surface vessels, and the better technological adaptation to the environment from the bottom of the ocean to the surface and the air immediately above, will lead to a new concept of total naval warfare in which all the elements are engaged at once. From a narrow point of view, we can sum up by saying that, in this concept for the future, the submarine and its opponent have maintained an even match. A closer look would indicate that while the submarine has lost tactically, because of the new technology, it has gained strategically. However, this viewpoint is indeed too narrow. What transpires in the concept is that the various elements of naval warfare fuse into one global war at sea in which all the elements are brought into play to greater or lesser degree depending on the nature of the confrontation. We have a vast "no man's land" with fleets moving at will through each other and each other's installations. Major effort will be expended to obtain up-to-date and meaningful intelligence because of the shadowy nature of these operations.

Instabilities and Rivalries

Even with the best intelligence, the system as foreseen has grave instabilities. A limited war in so complex a system can raise naval activity to the point of overtly endangering the security of a deterrent missile system. The

States Government. It is difficult to know exactly what the reasons were for this lack of interest. Probably the progress of physical methods of warfare related to the development of explosives was partly responsible for it, perhaps also the inability to produce and to deliver large enough amounts of the poisonous substances known at that time. Ethical considerations may also have played their part, poison being more or less synonymous with treachery.

The progress made by the chemical industry during the nineteenth century lessened some of the technical objections. And, faced with the dangers of chemical warfare, the Hague International Peace Conference in 1899 adopted a resolution "to abstain from the use of all projectiles the object of which is the diffusion of asphyxiating or deleterious gases," on the ground that this method of warfare was inhumane. Among the big powers, only the United States did not support this resolution—on the grounds that the inhumane aspects of this type of warfare were not clearly established. (This seems to have been a consistent viewpoint of the United States Government, except in the early 1920s, and in 1926 the Geneva Protocol repeating the ban on chemical weapons was buried in the Senate because of opposition by the American Legion and the American Chemical Society. Despite the declarations of Roosevelt [1943], Eisenhower [1960], and others, "riot-control" gas has been used in Vietnam together with "defoliants," the Defense Department stating that, due to recent research results, "some forms of the weapons . . . could be effectively used for defence purposes with minimum collateral consequences.")

During World War I gases were used for the first time on a large scale. Although the first use was probably the attack by the French in 1914 using a "riot-control" tear gas, the "official" date for the beginning of gas warfare is 22 April

sequences of mustard-gas inhalation was many times larger.

During World War I chemical weapons were used only against troops and never against civilians. The first to use mustard gas indiscriminately, by air bombs and aircraft spray, seem to have been the Italians during the Abyssinian war. The casualties among the unprotected Abyssinians are said to have been terrible. As effective—and for the same reasons—were the chemical attacks by the Japanese against the Chinese.

World War II was characterized by an absence of gas warfare, although (or perhaps because) both sides were prepared for it. Chemical warfare was limited to incendiaries and flame throwers. Incendiary bombs with white phosphorus were used on a large scale by both sides against cities. When exploded by the bursting charge, solid phosphorus disperses in the form of small particles that ignite by contact with the air. Ignited particles cause painful flesh burns that heal very slowly. However, phosphorus bombs had only a limited value and were superseded by metal incendiaries made out of magnesium and powdered aluminum mixed with finely dispersed zinc and iron oxides. The most efficient incendiary, usable both in fire bombs and in flame throwers, proved to be napalm—gasoline thickened by aluminum soap of naphthalenic and palmitic acids. It was used on a large scale by the Allied forces against cities and also against troops, particularly troops in trenches or bunkers. After World War II napalm was used by the United States in Korea and in Vietnam, and by the French in Algeria. It has a devastating effect on enemy forces, men being transformed into nearly inextinguishable living torches. Napalm seems to give entire satisfaction to the military and will probably still be used in the 1980s, perhaps with minor improvements.

Research on toxic gases accelerated during World War II

high-altitude explosions of H-bombs. Another possibility, as yet untested, would be the creation of a "hole" in the ozone layer of the atmosphere above enemy territory (see also Professor MacDonald's chapter). It is well known that the existence of this ozone layer, absorbing deadly ultraviolet radiation from the sun, is a prerequisite for the existence of life on land, since the spectral region concerned is absorbed by many organic substances, among them proteins, and leads to their decomposition. Since ozone itself reacts very readily with many organic compounds, it is possible that at least a partial destruction of ozone in the region where it is most abundant (twenty to forty kilometers above sea level) would be achieved by dispersing a convenient reagent at this height. It is not unbelievable that this could be achieved by the 1980s.

Psychic Poisons

Let us now examine the latest additives to the arsenal of chemical warfare, the so-called psychic poisons, or psychotomimetic compounds, often referred to in the military context as "incaps" (incapacitating chemicals). They are intended to act on the brain and produce "temporary" mental disorder among the opponent's military and civilian personnel.

Drugs exerting such action on the brain have been known for thousands of years in many countries as crude extracts from plants and mushrooms. It seems that these substances are widespread all over the world, but that they are particularly abundant in Mexico. In 1888 Lewin discovered that the chewing of "mescal buttons" or "peyotl" (dried tops of a cactus growing near to the Mexico-United States border) had long been a practice among Indians and produced strong hallucinations. The synthesis of mescalin,

or so of LSD is, in principle, sufficient to render temporarily schizophrenic the entire population of London, in the ideal case of even distribution. But even assuming that only a thousandth of the LSD distributed is taken in by the population, the quantity necessary is only one ton. Although the most efficient method of distribution would be the poisoning of drinking water, inhalation of fine dust could also prove quite efficient. The whole population of a country could be poisoned by spraying LSD solutions over large areas, which seems technically possible today.

During a medical conference at SHAPE (the Supreme Headquarters Allied Powers, Europe), a newsreel was shown that gave an idea of the behavior of a battalion of soldiers "treated" by LSD added to their morning coffee. The soldiers were laughing without reason, throwing their guns away, climbing everywhere, screaming, weeping just like children—behavior far from normal in an army. Gay war, funny war, humane war . . . ? At first glance, perhaps. Looked at more closely, it is not as funny or humane as it seems.

The schizophrenic state induced by LSD seems to be reversible if the drug is taken under the control of a physician, provided the dose is low enough. But grave, not completely reversible, effects have been observed with LSD users in cases of overdoses. Used in a war, where it is intended that everybody should get an effective dose, most of the population will have to receive a large overdose. Such an overdose may either drive the victim mad for the rest of his life or simply kill him. And what is an effective dose for a man may be deadly for a child or for a pregnant woman. In addition it was recently announced that LSD possesses teratogenic, i.e., monster-producing, properties.

Again, many people receiving LSD will not be sitting quietly

at home. They will be driving cars, trucks, and trains, directing traffic, handling deadly weapons, giving orders. And animals will go wild. Reactions to LSD are unpredictable, and it is hardly likely that there will be no loss of life in the ensuing chaos.

Other classes of compounds such as atropine and tropane derivatives, and the closely related piperidyl esters, such as "ditran" (1-ethyl 3-piperidyl cyclopentylphenylglycolate), have also been investigated as potentially psychotomimetic drugs. It is obviously very difficult to obtain accurate data for these drugs because of military secrecy.

All the compounds mentioned so far are alkaloids or derivatives therefrom, that is to say, nitrogen-containing substances. However, there is also a class of nitrogen-free chemicals, which shows a rather potent activity: the cannabinols. Under the names of marijuana (the Americas), hashish (Middle East), or kif (North Africa), cannabinol-containing drugs have long been recognized as able to induce a feeling of well-being, distortion of space, and double consciousness. The active dose is far greater than for LSD, but progress can be made and present knowledge enormously widens the field of potential "incaps."

All these drugs act like LSD, causing to some extent a state of temporary schizophrenia. The details of their action are not yet firmly established. They are supposed to interfere with normal metabolism of 5-hydroxytryptophane, a precursor of serotonin. But it is also suggested that they could have an effect on adrenalin in the body, and there is some evidence that some psychotomimetic substances may well act by modifying the balance of the essential material, acetylcholine, in the brain. But whatever these biochemical explanations may be, the fact remains that it is now possible to poison a whole country, creating

tive statements like: "The offensive use of biological agents is feasible," and "Biological agents exist which can be used strategically to cause casualties in an area the width of a continent." A Russian colonel in 1959 went as far as to say that "from results of comparative studies of the losses of life from conventional weapons, war poisons, and atomic energy on one side and losses from biological weapons on the other, it is believed today that a biological war would have the greatest effect of all." Biological warfare has in fact given us the most forceful instance so far of the truth of Isador Rabi's observation that "the combining of military techniques and science makes it easy to apply scientific principles to kill people—who are not strong structures."

Very little has been published about the Soviet study of biological warfare, but a high level of civil defence preparedness indicates that it has attracted much attention; that would hardly have been the case were there no first-hand information on the offensive potential. In fact, it was claimed that, when the American program started to expand in 1959, the U.S.S.R. led the United States. The American level of expenditure for research and development in chemical and biological warfare then climbed from around $35 million per year to about $150 million by 1964, so it is conceivable that the supposed gap has now been closed, particularly if one adds the British and Canadian investments of funds and personnel.

Simple competition may partly explain the biological arms race, but technical factors have provided fuel for it. In the first place, strategy is becoming more and more dependent upon civil defence, and microbiological weapons are well suited for large-scale civilian targets. Some of their inherent characteristics, such as the incubation period and the possibilities for protection of one's own forces, add a certain amount of freedom to their strategic use and also

hard to dismiss as unrealistic an example given by Dr. Brock Chisholm, formerly head of the World Health Organization. He has speculated about a hypothetical nation making an attack on the United States by 100 vaccinated agents using botulinus toxin as the weapon. Each would import a few pounds in a body belt and proceed to one of the major cities, power sites, or military centers. At a prearranged time each would take a small private plane from the local airport and then dust his target from the windward side with the aid of a small, easily made apparatus. Fatalities after such an attack might range from forty to nearly one hundred per cent, and the attack might well be blamed on the U.S.S.R. Nuclear weapons would then be fired, and retaliation from the U.S.S.R. would be automatic and immediate.

Why Defence Is Difficult

The microbiological agents that might be used for offensive purposes represent a whole range of weapons systems rather than a single type of weapon. Antipersonnel, antianimal and anticrop agents all pose different defence problems; an open aerosol attack would represent one weapons system and a covert dissemination of infected insects another, quite different system. The situation is further complicated by the various means an enemy might employ in order to enhance his attack. Radiation from nuclear fallout would aggravate the results of an aerosol attack on man or animals by lowering natural resistance. Carriers like crystal needles might help viruses to penetrate plants. Elimination of chlorination would permit or simplify an attack on water supplies. And so on.

Specific prophylaxis, by vaccination for example, or cultivation of disease-resistant crop plants, has a very severe

by air of substantial quantities of vaccines, antibiotics, and chemicals in the event of an attack.

Several of the United Nations specialized agencies have a certain competence in the biological defence area. The World Health Organization (W.H.O.), for instance, can be expected to have an interest in the public health aspects. The Food and Agriculture Organization (F.A.O.) should be concerned with the protection of plants and animals, while the relevant microbiological research, documentation, and science policy falls within the scope of UNESCO. In view of the political dangers of impromptu international committees appointed to study allegations of biological attack, the establishment of an independent International Microbiological Agency as a parallel to the International Atomic Energy Agency (I.A.E.A.) has recently been proposed. This would tie a control function in biological warfare to the peaceful applications of microbiology, in the same way as the control of reactor fuels is tied to the peaceful uses of nuclear energy within the I.A.E.A. Since biological warfare could well upset the delicate power balance that now affords a precarious stability in the world, the superpowers should have a very real interest in biological disarmament and control. They are in the best position to know that the biological weapons are likely to remain erratic and difficult to handle as part of military games theory, the more so the cruder the technology. The superpowers should also know that a comprehensive defence program would involve almost prohibitive costs; they should also be conscious of the drain of such a program on a professional group (the microbiologists) that has many vital functions in society and is of considerable significance for the technical aid to developing countries that is now an important part of their foreign policy.

Microbiological weapons come from some of the largest

als for general and complete disarmament, to the effect that biological and chemical weapons should eventually be subject to control. Insurance against the use of biological weapons in a disarmed world might, however, prove to be impossible owing to the many delivery systems available to the potential user. Inspections to check on the possible manufacture of biological weapons also involve severe problems. Techniques include registration of scientific personnel, accounting of materials, fiscal controls, and visits to conceivable production and testing facilities. If an efficient system for the regulation of research and development, and for preventing testing and clandestine stockpiling cannot be proposed, it is unlikely that nations will be prepared to disarm. The Pugwash movement early recognized this problem and in recent years has operated a special study group on biological warfare, which has organized a series of experimental inspections in four countries, in order to gain practical control experience. This study has not yet been completed, but the inspectors have come to the conclusion that the possibilities of arriving at a reasonably effective control system are better than originally expected.

Control and inspection are hardly possible with regard to "sabotage" quantities of biological weapons, but large-scale military efforts are probably not easy to hide. For instance, the Pine Bluff Arsenal in Arkansas, where biological weapons are produced, as well as toxic-chemical and riot-control munitions, covers some 15,000 acres. Facilities for field testing would seem to be even more difficult to conceal. The Dugway Proving Ground is an example, occupying an area in Utah larger than the state of Rhode Island. Strong sunlight might help to accelerate the biological decay in a testing ground, but animals might harbor the microorganisms, and some bacteria might be so resistant that they would be detectable by normal sampling techniques

over long periods and at considerable distances from the test site. A high degree of resistance has, for instance, been observed in the case of anthrax, which was used for biological warfare experiments on the small island of Gruinard, off the northwest coast of Scotland, during World War II. After a recent study, it was stated that this island "may remain infected for one hundred years."

Nevertheless, control and inspection problems remain daunting because there is nothing about a production facility that would necessarily show on the outside of the buildings, and extensive field tests might be staged covertly on foreign soil. Consequently an intelligence activity would have to be part of the effort. For that to be fully effective, unorthodox supporting initiatives might also be required —perhaps internationalization of the microbiological profession, or provisions for diplomatic immunity and awards for disclosure of military preparations contrary to international agreement.

Fortunately, from the political point of view it might not be necessary to have an absolutely "leak-proof" system. The most important aspects would be found in side effects. The preparations for a control and inspection system would require contacts that would help to reduce the mistrust among nations, and they would tend to reinforce the international conscience in the field. International and regional agreements aimed at neutralizing the political dangers of allegations of biological attack and at limiting the spread of weapons technology would then logically follow.

Moral and Military Thin Ice

Discussions of the relative moral merits of napalm burning, saturation bombing, and nuclear warfare versus the use of infectious aerosols seem pointless without a care-

ful balancing of the long-range interests in terms of self-expression and happiness as far as both the attacker and the target population are concerned. Such a type of penetrating analysis is difficult for anybody to perform, particularly for the military man or the average politician. Superficially the microbiological weapons might seem preferable, because they include a wide range of agents that temporarily incapacitate rather than kill human beings and they do not have the obvious genetic effects that we associate with nuclear weapons. However, this is hardly enough to open the door to their use, since the young, the elderly, and the infirm may be killed by so-called incapacitating agents and there is in any case no clear dividing line between those weapons and other agents giving a very high mortality. Once the use of microbiological weapons became acceptable, the supposed "humane" aspects would be offset by an almost inevitable escalation.

Future conflicts are likely, in short, to breed weapons modeled upon nature's own ecological system. Man's success with biological control of insects and other pests indicates a road that is certainly appalling. Our dismay should not be aroused merely because microbiological agents are invisible and lack smell and taste, or because a perfect defence will never exist except in the minds of some theorists. What should determine our attitude is rather the fact that these weapons, like other weapons of mass destruction, will never be selective enough to spare individuals who are not responsible for the situation that breeds them. Meanwhile, the war gamesmen who balance the costs of antiballistic missiles (ABM) against "acceptable" megadeaths seem to walk on thin ice in presuming fair play or Expected Gentlemanly Behavior (EGB) by the opponent, as far as biological weapons are concerned.

vehicle, would make the human soldier completely obsolete. One robot would perform all the functions of the crew of a bomber or tank or submarine and can be built in as part of the unit, requiring no space for moving about.

The application of such robots to war purposes will plainly change the whole character of war. The main effect will come from the development of "suicide" bomb carriers of incredible accuracy and ranges of thousands of kilometers. Before we consider those, we can look at the use of robot soldiers in more conventional war situations.

Robot Soldiers

The traditional function of a soldier, whether on foot or in a vehicle, is to find the enemy soldier and destroy him with a weapon. To do so he must propel himself across the land until he is close enough to detect the enemy by sight and aim his weapon. All these functions can be performed far better by a compact armored robot with a sophisticated walking mechanism. It can be equipped with light and infrared vision, radar, and sonar; it can carry a built-in weapon such as a gun or rocket launcher, directed by computer to an exact range and aim on an enemy; and the same computer can steer the robot, even across terrain requiring circumambulations, to the desired point, and maneuver it so as to search for the enemy. With a laser or plasma-torch light spot it can blind all human eyes looking at it. The armored robot can carry enough fuel to run for a week without stopping, and it can operate with comparative impunity in highly radioactive regions. Sensitive parts such as the computer and the sensory detectors can be placed in well armored compartments close to the ground to make them almost invulnerable. The light and other signals can, if

appropriate, reach the shielded detectors via tall periscopes or external aerials.

A regiment of such robot soldiers could be controlled by a human officer in a tank who remains several kilometers behind them in a well-protected spot. A line of such robots spaced twenty meters apart might be deployed to move at fifteen kilometers per hour through a jungle and destroy all men encountered there. A bigger robot vehicle could carry a horizontal chain saw in front of it and cut down all trees and push them to either side so as to clear a straight track ten meters wide through the jungle, which could then be patrolled by robot soldiers to ensure that no man would be able to cross the track. The robot soldiers might be refueled and rearmed by service robots traveling along such a track once a week.

In conditions where antipersonnel weapons and radioactive fallout make battlefields untenable by human troops, robots may be the only means of carrying out the traditional military task of occupying and holding ground. They will also be immune to chemical and biological poisons, to napalm, and most other weapons intended to kill humanity. One can envisage battles, or whole campaigns, waged between opposing robot armies, with comparatively little human participation.

The task of policing a terrorist-ridden town might be left almost entirely to specially designed robots that would patrol the streets, send television pictures of any event to a central control station, and fire an explosive shell at any gunflash with a delay of only a fraction of a second.

Robots Instead of Heroes

Manned fighting vehicles have reached a very advanced stage of development: they include the tank on

sion away from the target but still on his own territory. My belief is that everything else would be tried, in a frenzy of improvisation, and that many of the "tanks" would reach their targets.

The very slowness of the "tanks," compared with attack by rocket or bomber, alters a common assumption about nuclear weapons—that there is a bi-stable situation in which the bombs are either held back or delivered more or less instantly, with virtually no time for second thoughts on either side before the bombs go off. We can now see an intermediate state of affairs, in which the bombs are plainly and relentlessly on their way, constituting a threat of the gravest kind but still allowing perhaps several hours for the political decisions that can halt them before the first reaches its target.

Other Robot Weapons Systems

Compared with the walking "tanks," other robot weapons systems will have over-all characteristics less unfamiliar to us. They will generally enhance the performance of systems at present falling within the scope of guided weapons on the one hand and manned aircraft and submarines on the other, by combining the advantages of both: giving the guided weapon something of the reasoning power of men or, conversely, giving the systems at present operated by men the fast response, compactness, and expendability that characterize the guided missile.

Present ballistic missiles are crude compared with the robot-controlled nuclear warhead of the future. It will be steered about its general ballistic path, using ancillary rockets, by a miniaturized computer responsible for navigation, evasion of antiballistic missiles, and eventual target identification. It will constantly reckon the fuel and time remain-

to sink every surface ship or other submarine in fixed areas excluding narrow lanes for use by friendly ships.

War of the Robots

Present-day automatic guidance and control systems for weapons are still comparatively primitive, and lack the versatility and capacity for tactical judgment of human servicemen. It is therefore still possible to argue the importance of manned aircraft, of infantry soldiers and traditional warships. Within a very few years this situation will be completely altered. To the already indisputably faster response of electronic control will be added as much capacity for information storage, decision-making, sensory input, and pattern-recognition as operational staffs care to specify. Men will cease to be valued in battle; on the contrary, they will be recognized as a grave complication in systems design, introducing great penalties of volume, weight, and vulnerability. Indeed, once the assumption that war is an affair for humans has been shaken, the military incentives to develop robot weapons will become irresistible. Robot soldiers immune to flying metal and to nuclear flash and radiation are simply a better military proposition than human troops, however brave and resourceful. Aircraft that need not get home, submarines that require no pressure-proof hull, and yet which can carry out all the maneuvers and opportunistic functions of the corresponding manned fighting vehicles, can have a performance in relation to cost that the latter could never match.

As the chances of human survival in battle dwindle toward zero, with the deployment of weapons that leave little to chance, humans are likely, in future wars, to stand helplessly by as a struggle rages between robot armies, navies,

HOW TO WRECK THE ENVIRONMENT

BY

GORDON J. F. MacDONALD
United States

Professor MacDonald is associate director of the Institute of Geophysics and Planetary Physics at the University of California, Los Angeles. His researches have embraced a remarkable diversity of natural phenomena, and his professional interests are further extended by his participation in national science policy-making. He is a member of President Johnson's Science Advisory Committee.

AMONG FUTURE MEANS of obtaining national objectives by force, one possibility hinges on man's ability to control and manipulate the environment of his planet. When achieved, this power over his environment will provide man with a new force capable of doing great and indiscriminate damage. Our present primitive understanding of deliberate environmental change makes it difficult to imagine a world in which geophysical warfare is practiced. Such a world might be one in which nuclear weapons were effectively

banned and the weapons of mass destruction were those of environmental catastrophe. Alternatively, I can envisage a world of nuclear stability resulting from parity in such weapons, rendered unstable by the development by one nation of an advanced technology capable of modifying the earth's environment. Or geophysical weapons may be part of each nation's armory. As I will argue, these weapons are peculiarly suited for covert or secret wars.

Science-fiction literature contains many suggestions of how wars would progress if man indeed possessed the ability to change weather, climate, or ocean currents. Many of these fictional suggestions, and other more serious discussions, fail to take into account the limitations of nature. Jules Verne gave a detailed discussion of displacing the earth's polar caps, thus making the world's climatic zones more equitable (*Les Voyages Extraordinaires; Sans Dessus Dessous*, Metzel, 1889). Verne's proposal was to eliminate the twenty-three-degree tilt in the earth's axis, putting it at right angles to the sun-earth plane. However, as Verne correctly pointed out in a subsequent discussion, the earth's equatorial bulge stabilizes our planet, and even the launching of a 180,000-ton projectile would produce a displacement of only one-tenth of a micron. Senator Estes Kefauver, Vice-Presidential candidate in the 1956 American election, rediscovered Verne's original proposal and was seriously concerned with the tipping of the earth's axis. He reported that the earth's axis could, as the result of an H-bomb explosion, be displaced by ten degrees. Either Senator Kefauver or his scientific advisers neglected the stabilizing influence of the earth's bulge. The maximum displacement that can be expected from the explosion of a one-hundred-megaton H-weapon is less than one micron, as Walter Munk and I pointed out in our book, *Rotation of the Earth* (Cambridge University Press, New York, 1960).

The climatic optimum was peculiar. While on the whole there was a very gradual decrease of rainfall, the decrease was interrupted by long droughts during which the surface peat dried. This fluctuation occurred several times, the main dry periods being from 2000 to 1900, 1200 to 1000, and 700 to 500 B.C. The last, a dry heat wave lasting approximately 200 years, was the best developed. The drought, though not sufficiently intense to interrupt the steady development of forests, did cause extensive migrations of peoples from drier to wetter regions.

A change to colder and wetter conditions occurred in Europe about 500 B.C. and was by far the greatest and most abrupt alteration in climate since the end of the last Ice Age. It had a catastrophic effect on the early civilization of Europe: large areas of forest were killed by the rapid growth of peat, and the levels of the Alpine lakes rose suddenly, flooding many of the lake settlements. This climatic change did not last long; by the beginning of the Christian era, conditions did not differ greatly from current ones. Since then climatic variations have continued to occur, and although none has been as dramatic as that of 500 B.C., a perturbation known as the little ice age of the seventeenth century is a recent noteworthy example. The cause of these historical changes in climate remains shrouded in mystery. The rapid changes of climate in the past suggest to many that there exist instabilities affecting the balance of solar radiation.

Indeed, climate is primarily determined by the balance between the incoming short wave from the sun (principally light) and the loss of outgoing long-wave radiation (principally heat).

Three factors dominate the balance: the energy of the sun, the surface character of terrestrial regions (water, ice, vegetation, desert, etc.), and the transparency of the earth's

may tend to accumulate, though the mixing time for this part of the atmosphere is certainly less than ten years and may be a few months. If a nation's meteorologists calculated that a general warming or cooling of the earth was in their national interest, improving their climate while worsening others, the temptation to release materials from high-altitude rockets might exist. At present we know too little about the paradoxical effects of warming and cooling, however, to tell what the outcome might be.

More sudden, perhaps much briefer but nevertheless disastrous, effects are predictable if chemical or physical means were developed for attacking one of the natural constituents of the atmosphere—ozone. A low concentration of ozone (O_3, a rare molecular form of oxygen) in a layer between fifteen and fifty kilometers altitude has the utmost significance for life on land. It is responsible for absorbing the greater part of the ultraviolet from the sun. In mild doses, this radiation causes sunburn; if the full force of it were experienced at the surface, it would be fatal to all life —including farm crops and herds—that could not take shelter. The ozone is replenished daily, but a temporary "hole" in the ozone layer over a target area might be created by physical or chemical action. For example, ultraviolet at 250 millimicrons wave length decomposes ozone molecules, and ozone reacts readily with a wide range of materials.

At present, we can only tentatively speculate about modifying the short-wave radiation at its source, the sun. We have discovered major instabilities on the sun's surface that might be manipulated many years hence. In a solar flare, for example, 10^{10} megatons of energy are stored in distorted magnetic fields. With advanced techniques of launching rockets and setting off large explosions, we may sometime in the future learn to trigger these instabilities.

human in the same sense that we are; we therefore have no need to treat them as if they were like us, or to be concerned with what they might be suffering if they were truly human beings. Throughout recent history racism of one kind or another has been the ally and support of dehumanization in this sense; *they* who are less than human may differ from us in inherited physical type (race) or in religion or language or national identity or ideology, or in any combination of these. The result is the same; we deny them a true humanity.

What I fear, and what I regard as highly probable, is that the robotizing of our weapons will greatly accentuate this process; one form of dehumanization will feed the other. The farther we, individual human beings, are from our target, the less we will be concerned about how others suffer under attack. Even under present conditions of conventional warfare, only a fraction of our military personnel comes into direct contact with the enemy; that is one reason why I have never been persuaded that personal aggressiveness played an important role as a motive for war. With these new weapons, however, the fraction will diminish even further; and there will be even less room for sympathy or empathy that might attenuate the suffering inflicted on others.

Another meaning to the concept of dehumanization has also been invoked, namely, that certain forms of warfare are contrary to human nature. This is a complex and difficult idea to apply in practice, because it assumes a knowledge of what kinds of military weaponry are "human" and what kinds "nonhuman" or "inhuman." I know of no body of scientific knowledge that would permit of a decision in this case. What is more "inhuman"—a submarine sinking, napalm, or sticking a bayonet through another man's belly? The human mind is a complex and fearful contradiction,

fensive!) Long ago Pascal wrote: *Vérité en deçà des Pyrénées, erreur au delà* (Truth on this side of the Pyrenees, error on the other). This kind of ethnocentric perception prevails, whatever the nature of the mountains that separate one nation from others.

This is nothing new. What is new is the intensity that characterizes nationalistic attitudes, so that the man who seeks a larger view, who tries to see the world as others see it, runs the risk of supreme condemnation as "unpatriotic." We are witnessing an outburst, a proliferation of nations and nationalism precisely at a moment in history when nationalistic attitudes should be considered anachronistic and lethal. The development of new weapons adds to the danger by giving to a nation the conviction that it now possesses the means to destroy the "enemy." Whether or not it will decide to do so will probably depend on its estimate of what the enemy will be able to do in retaliation, but the unrealistic nature of nationalistic psychology makes it equally likely that there will be an exaggerated view of one's own destructive capacity.

The growth of nationalistic attitudes is due to a variety of historical and political factors that I am not competent to identify or discuss, but there are also psychological aspects of considerable importance. Many observers of the contemporary scene are struck by a kind of pessimism regarding the future that is characteristic of many young people all over the world. There is a decrease in what has been called "future time perspective," the willingness to forgo a present gratification in order to obtain greater rewards at a later time. Many of these youths appear to be concerned only with the here and now. This may be associated with a feeling of rootlessness, of not belonging, of having nowhere to go, a feeling akin to what many sociologists have called "anomie." This in turn is not very different from the

description by psychologists of a lack of a sense of *identity*, of uncertainty as to who and what one is, of unwillingness to accept the self, with its failings as well as its virtues. The search for identity continues, however, and may take the form of bizarre and even antisocial behavior, sanctioned and supported by the peer group, symbolized by styles in dress, hair, vocabulary, and recreational activities. It may also lead, however, to seeking and finding a refuge in national identity, precisely because personal identity is so unsatisfactory. One may not know where one is going, but the nation remains, strong, noble, invincible, and indestructible.

This analysis is admittedly speculative and is based on impressions rather than on scientific data. I have no way of knowing how widely it would apply; obviously many young people would not fit the pattern just described. What does seem well established is that personal insecurity and concern with status are associated with ethnocentricism and chauvinism, and it is reasonable to conclude that, other things being equal, whatever makes people more insecure at the same time creates a propitious climate for the more extreme forms of nationalism. The circle is now complete; nationalistic attitudes lead to the development and acquisition of weapons, new and old, which create uncertainty and add to the feeling of personal insecurity, which in turn contributes to the encouragement of still stronger nationalistic attitudes. My fear is that this mechanism will make it easier for the chauvinistic leader to find followers and to carry public opinion with him.

Fear and Hope

One further fear is related to what has been called the self-fulfilling prophecy. If we expect certain events to occur, if we predict that they will occur, then (other things

being equal) they are more likely to occur. The example usually given is that of a rumor that a particular bank is about to fail. This results in a rush of people to the bank to withdraw their deposits, and because the bank is unprepared to meet all the demands on short notice, it actually does fail. Other things must be equal, however; Chamberlain's prediction of "peace in our time" was not exactly fulfilled.

The mechanism involved is actually quite simple, but it applies exclusively to those situations in which our own actions play a relevant part. If we—leaders as well as followers—regard a war as inevitable, and if as a consequence we do nothing to prevent it, then our attitudes and our inaction contribute to the likelihood of war. My fear is that the proliferation of weapons, new and old, may itself constitute a self-fulfilling prophecy. The weapons are there, of course, for defence, not for aggression; but who can define aggression? Who is more aggressive, the boy (or the nation) who puts a chip on his shoulder and defies the other to knock it off, or the boy (or the nation) who accepts the challenge? The very existence of the weapons constitutes the greatest temptation to their use.

In this chapter I have written of my fears; I have made no predictions. There is after all a considerable difference between being afraid that something *may* happen and prophesying that it *will*. Fear can be disruptive, leading to panic, immobility, an abdication of rationality in favor of blind emotion; it can also be constructive, creative in the search for ways of escape, sharpening the wits in order to avoid or overcome danger. One of the difficulties is that so many of us are too apathetic to be afraid, either trusting to fate to extricate us, or shrugging our shoulders at the prospect of "what will be will be." I can only express the hope that my own fears have a constructive aspect, that taking

tory of the repeated failures to achieve disarmament and avoid war.

The militarists have been much the same kinds of people, at least for the last hundred years. They have included military staffs who are deeply imbued with the belief that wars are inevitable, and that "human nature does not change." Another group has comprised the armaments manufacturers and salesmen who, encouraged by their national governments to accept a "patriotic duty," develop a vested interest in preparation for war and in promoting the export of arms. Thirdly, there have been the patriotic societies, dedicated to the cultivation of nationalistic ideals and the glorification of military strength. Again, the influence of technical and trade journals, with editorials favoring military application of industrial resources, must not be underestimated. The activities of these groups interlock to create "the military-industrial complex" of which President Eisenhower warned his fellow countrymen.

There is an additional militarist class, most sinister of all: the secret services and intelligence agencies, which operate outside normal governmental control, isolated by their secrecy and left to pursue what they regard as their nations' best interests by underhand means. The mentality necessary to carry out such work in peacetime ensures that these agencies will attract at least a proportion of men for whom all foreigners are enemies and all liberal thought an anathema. Most work of secret agents remains forever secret, but that which does come to the surface is plainly seen to be inimical to the cause of disarmament and peace. If one singles out the C.I.A. in this connection, it is only because conscientious Americans have brought some of its activities to light in recent years; other nations, including my own, have their secret services, just as they have their "military-industrial complexes."

1946 and 1955. At the first the Russians rejected out of hand, with extravagant attacks, generous American proposals for putting atomic energy under international control. In 1955 after three years' urging by the Western powers, the Soviet Union accepted their comprehensive proposals for disarmament. Thereupon the United States withdrew the proposals.

Militarism Today

The fact is that the world has not, since 1945, enjoyed even the brief respite from militarism that occurred after World War I. Instead, we have had a continuous arms race between the major powers, involving particularly nuclear weapons and delivery systems, and lesser arms races in troubled regions, particularly the Middle East and southern Asia, where the armament industries of East and West have found ready markets for their products.

Organized opposition to disarmament, most visible in the United States, but occurring also in the Soviet Union, Britain, France, and China, has triumphed. It is not difficult to see how these resolute minorities succeed. In the first place, comprehensive disarmament depends upon simultaneous good will from all countries in the negotiations; it is necessary only that the militarists secure the ascendancy in one major country to frustrate the discussions. Secondly, every failure and every increment in armaments adds fuel to the militarist flame.

Today, militarism assumes subtler guises than those of the bemedaled general gloating over his nuclear weapons, or the mad scientist of the horror film enthusiastically concocting new terrors for mankind; although it cannot be denied that some individuals fit these parts quite well. More typical is the bland civilian who reasons that a disarmed

world would be more dangerous, that the "other side" will agree to disarmament only as a temporary move in the game, that nuclear war may not be as insupportable as is generally supposed. Sir Solly Zuckerman, until recently Britain's chief defence scientist, has condemned the fashion for "abstract" modes of thought about nuclear war, and for replacing strategic judgments by numerical calculations. He has denounced the argument that nuclear war is "feasible," and that organized society could survive it, as "unrealistic mumbo-jumbo."

Echoes from 1911 and 1935 are still heard in the advertisements of armaments manufacturers, in the editorials of the aerospace journals, in the impatient utterances of patriotic societies. For the most part, however, the militarists in our midst are smooth and sorrowful in speech, yet in their purposes more savage and (because more sophisticated) more sordid than Attila the Hun.

Prospects for Disarmament

Are the prospects for disarmament improving or deteriorating? It is at least possible—and necessary—to remain optimistic. International relations are not markedly better or worse than in the past; deterioration in some parts of the world is offset by miraculous improvement in others, notably in Europe. The great cost and rapid obsolescence of weapons, characteristic of the present age of advancing technology, provide governments with a strong motive for calling a halt. The limited steps in disarmament since 1945 demonstrate the possibility of agreement.

It is customary nowadays to regard China as the greatest impediment. Not only the Americans, but the Russians, too, are fearful of China's growing strength and may be unwilling to disarm unless China does the same. The assump-

the World Health Organization, UNESCO, the World Bank and the International Monetary Fund, and several others. They have never had as much money as they really need, but their influence is felt all over the world, and affects the everyday lives of everyone. They operate according to international ideas and aims, without overmuch respect for narrow national interests.

The control of nuclear fuels for peaceful purposes, the regulation of broadcasting standards and frequencies, air-safety regulations, vaccination regulations for travelers, machinery for the conclusion of tariff agreements (for example, the Kennedy Round)—all these and many other practical functions of government have been willingly surrendered to international institutions. The technical and cultural requirements of our international society are sweeping aside the barriers between nations in almost every peaceful human activity, and eroding national sovereignty.

It is often said, even by many who earnestly wish for it, that the concept of world government is idealistic and remote. That is patently absurd, because we already have a great deal of world government. Woolf pointed out its existence more than half a century ago, and since then it has multiplied. We see it in action in the Security Council, the U.N. General Assembly, the International Court of Justice, and the specialized intergovernmental agencies. The question is not *whether* world government is possible, but simply how much we shall have, how strong we shall make it.

The Futile Race

This interpretation does not underestimate the obstacles to further development of world government at the political, legal, and military levels, least of all the continua-

[SUMMARY]

THE NEW WEAPONS

BY

NIGEL CALDER
United Kingdom

WHY A SUMMARY? Why restate the principal conclusions of the expert contributors to this book? The reason is that the accumulation of possibilities and risks from many kinds of warlike activity deserves at least as much attention as the specific forecasts within each field of expertise.

The weapons discussed range from some that exist already, through others under development or plainly plausible, to some that may seem farfetched. Right or wrong, these last must represent the weapons of the more distant future about which we can only guess, knowing that unforeseeable discoveries or inventions are likely to generate even stranger military applications. The impression this book is intended to make, and this summary to reinforce, is that military technology is a Hydra: for each weapon that seems familiar and containable, others rise up threatening to defy containment; for every problem, generated by the

military rivalries between nations, that attracts the attention of statesmen, others are looming scarcely noticed.

Even without the introduction of novel scientific principles or devices into warfare, technical improvement of "conventional" weapons, using projectiles, high explosives, and armor, is increasing their power to kill and to devastate. The chief reason is that the use of radar and other target sensors, of proximity fuses and of computers for fire control, greatly enhances the accuracy of each gun shot or missile round. Such techniques can probably deny a battlefield to infantry, deny the air to manned aircraft, and deny the sea to surface ships—unless countermeasures can frustrate the electronic systems. No one knows just how effective the competing techniques will be and, if a conventional "great war" were to break out between well-equipped nations in the future, it would be what General Beaufre calls a "truly enormous experiment." It could easily degenerate into bloody attrition worse than that of the two World Wars.

Such a major conventional war is in any case made improbable by the existence of nuclear weapons. Swift attacks, initiated by greatly superior forces and achieving their purpose within a few days, seem to be politically and militarily the only effective style remaining for conventional war. Against poorly equipped but well-organized guerrillas, on the other hand, the most sophisticated weapons systems may succeed only in "hitting air," and serve merely to postpone an inevitable political settlement.

Professor Dedijer takes the view that new weapons scarcely affect the principles of guerrilla warfare: guerrillas have always been at a disadvantage in firepower and they make it their business to be absent when a massive attack is launched against them. Dedijer characterizes guerrilla warfare as a politically motivated form of resistance in underdeveloped countries, nationalistic in nature and directed against foreign influences in the rule of the guerrilla's own country. If it matches the aspirations of the general population, it will tend to prosper and the only plausible strategy against well-organized guerrillas involves long and costly attrition in infantry engagements—destroying an idea by killing all those who hold it.

Here is the "poor man's power," the means by which underprivileged people can, when they feel driven to it, confront modern military forces with a good chance of success. With the poor of the underdeveloped countries tending to become poorer as populations explode, and with continuing interference by great powers in the affairs of nations within their "spheres of influence," the prospect is of an endless series of guerrilla wars, particularly in Latin America, Southeast Asia, and parts of Africa. The only way of averting such an appalling future, in Dedijer's view, is to remove the causes of social unrest, by massive aid and political reform. Neither in the scale nor in the manner of present aid is there much ground for hope.

The trend with which Sir John Cockcroft is chiefly concerned is the acquisition of nuclear weapons by countries not already possessing them—leading to greater likelihood of nuclear war breaking out, somewhere, between a pair of nations. The development of usable nuclear weapons and of their means of delivery is an expensive business, but within the resources of several nations, at least. For the manufacture of A-bombs, the cost of plutonium is really very low and the construction of nuclear power stations in many countries provides a ready-made source of nuclear explosive if international safeguards should fail or be disregarded.

Besides the existing nuclear powers, seven nations (Canada, West Germany, India, Italy, Japan, Spain, and Swe-

den) will have the potential to produce more than one hundred kilograms of plutonium per year, by 1971. Cockcroft expresses anxiety about a possible chain reaction, in which the acquisition of nuclear weapons by one new country would provoke other nations to follow suit. For example, if three nations made nuclear weapons for the first time in the 1970s, ten might do so in the 1980s, and thirty in the 1990s.

At present, the construction of H-bombs, rather than A-bombs, depends on uranium-235 as the triggering explosive, and the preparation of this material involves a very costly and cumbersome gas diffusion plant. As Dr. Inglis points out, the development of ways of obtaining uranium-235 more easily, or of using plutonium as a trigger, could greatly aggravate the problem of nuclear proliferation.

The laws of physics being what they are, Inglis believes with some confidence that there is no radically new principle for nuclear weapons to supplement the existing choice of fission and fusion bombs. Nor does he think that there is likely to be much extension of the choice of the materials used as nuclear explosives; for example, he dismisses the idea of a californium bullet as a "confusing fantasy." Existing nuclear weapons are as destructive as any military man could ask for. Variations and technical improvements are possible, of course, and even the hypothetical "doomsday machine," which would obliterate all life on earth, is not technically absurd, although it is almost certainly strategically absurd. A doomsday machine could plausibly be a series of extremely dirty H-bombs primed with cobalt. On the other hand, attempts will no doubt continue to make very "clean" H-bombs, which do not rely for detonation on the explosion of a fission bomb—fission products being the major source of fallout. But on the basis of present-day

porary madness such as could make soldiers throw away their arms or sit down and weep like babies. Fetizon and Magat strongly challenge, however, the suggestion from enthusiasts for psychic weapons that here is a humane, nonlethal means of waging war. They point out that if most people in the target population are to receive effective doses, many will receive large overdoses, which will cause permanent insanity or death. Moreover, the military administration of such drugs to armies or civilian populations in the midst of their normal business will create horrific chaos in which many people will die.

Microbiological weapons have even more fearful consequences for human targets, possibly exceeding the killing power of all-out thermonuclear warfare. Professor Hedén describes how a cloud of infective microorganisms could strike down by disease the human inhabitants of a whole province, or ruin their crops. Such weapons can be released swiftly from spraying vehicles over large areas or covertly by saboteurs against selected targets such as military staffs, crews of ships, or big public assemblies.

Biological weapons are easy to make and they may be especially tempting for nations unable to develop nuclear striking forces. Small groups of individuals may be able to upset the strategic balance. On the other hand, advanced microbiology may evolve novel forms of disease for military purposes. Defence against biological attack will be peculiarly difficult—most of all in the developing countries, which lack good public health facilities.

Biological attack may, in practice, be indistinguishable from epidemics—and vice versa—so that allegations of biological attack may become frequent, and it will be hard to tell whether they are well founded. Reprisals can lead to an escalation of the intensity and virulence of the attacks. It will scarcely be possible to confine the diseases so evoked

to the target areas. The very young, the very old, and the sick will be especially vulnerable to biological warfare.

The impact on weapons systems of electronics, and of compact computers in particular, may manifest itself in bizarre robots like the "walking bomb." Professor Thring forecasts the development of unmanned, expendable, and practically unstoppable tanks on legs, capable of finding their own way slowly but surely to their targets. Such a delivery system would introduce a novel psychological factor into the use of thermonuclear weapons, by allowing a rather long period for second thoughts between the launching of an attack and the first explosions.

More generally, robot foot soldiers, aircraft, and submersibles may displace men from the conduct of the battle once and for all, as such computer-controlled systems come to surpass men in tactical skill and reliability. Once a decision to exclude men has been taken, the traditional role of infantry units in controlling ground might reassert itself even in situations where men simply could not survive. Important limitations on the design and performance of aircraft and submersibles disappear when the crews' requirements for comfort and survival no longer figure in the calculations. By such developments some purposeless loss of life among servicemen may be avoided, but human populations will still be the targets of the robot strategic weapons.

The possibilities of geophysical warfare, aimed at producing subtle or catastrophic modifications in the condition of the earth or its atmosphere, are largely speculative. But it is important to understand that the impediments arise more from ignorance of natural processes, which leaves the long-term effects of particular actions incalculable, than from any basic incapacity for human interference with the environment. There is growing evidence that relatively modest action can trigger the release of much greater en-