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HOW TO WRECK THE ENVIRONMENT

Chapter from *Unless Peace Comes* by Gordon J. F. MacDonald U.S.A.
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[Abridged]

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 practised. Such a world might be one in which nuclear weapons were effectively banned and the weapons of mass destruction were those of environmental catastrophe. As I will argue, these weapons are peculiarly suited for covert or secret wars.

Substantial progress within the environmental sciences is slowly overcoming the gap between fact and fiction regarding manipulations of the Earth's physical environment. As these manipulations become possible, history shows that attempts may be made to use them in support of national ambitions. To consider the consequences of environmental modification in struggles among nations, we need to consider the present state of the subject and how postulated developments in the field could lead, ten to fifty years from now, to weapons systems that would use nature in new and perhaps unexpected ways.

The key to geophysical warfare is the identification of the environmental instabilities to which the addition of a small amount of energy would release vastly greater amounts of energy. Environmental instability is a situation in which nature has stored energy in some part of the Earth or its surroundings far in excess of that which is usual. To trigger this instability, the required energy might be introduced violently by explosions or gently by small bits of material able to induce rapid changes by acting as catalysts or nucleating agents. The mechanism for energy storage might be the accumulation of strain over hundreds of millions of years in the solid Earth, or the super-cooling of water vapour in the atmosphere by updraughts taking place over a few tens of minutes. Effects of releasing this energy could be world-wide, as in the case of altering climate, or regional, as in the case of locally excited earthquakes or enhanced precipitation.

WEATHER MODIFICATION

The Earth's atmosphere is an envelope of air which rotates, for the most part, at the same speed as the underlying continents and oceans. The relative motion between the atmosphere and the Earth arises from sources and sinks of energy which vary in location and strength but which have, as their ultimate source, the Sun's radiation. **The quantities of energy involved in weather systems exceed by a substantial margin the quantity of energy under man's direct control.**

For instance, the typical amount of energy expended in a single tornado funnel is equivalent to about fifty kilotons of explosives; a single thunderstorm tower exchanges about ten times this much energy during its lifetime; an Atlantic hurricane of moderate size may draw from the sea more than 1,000 megatons of energy. These vast quantities of energy make it unlikely that brute-force techniques will lead to sensible weather modification. **Results could be achieved, however, by working on the instabilities in the atmosphere.**

We are now beginning to understand several kinds of instabilities in the atmosphere. Supercooled water droplets in cold clouds are unstable, but they remain liquid for substantial periods of time unless supplied with nuclei on which they can freeze. Conversion of water droplets to ice through the introduction of artificial nuclei can provide a local source of energy. This released heat can cause rising air currents which in turn lead to further formation of supercooled water. This process may lead to rainfall at the ground greater than that which would have been produced without the artificial nucleation. A second instability may arise, in which water vapour condenses into water, again affecting the distribution of sensible energy. On a larger scale, there is the so-called baroclinic instability of atmospheric waves that girdle the planet. Through the imbalance of heat between equator and pole, energy in this instability is stored, to be released in the creation of large cyclonic storms in the temperate zones. There are other, less well understood instabilities capable of affecting climate; I shall return to them later.

As far as military applications are concerned, I conjecture that precipitation enhancement would have a limited value in classical tactical situations, and then only in the future when controls are more thoroughly understood. **A nation possessing superior technology in environmental manipulation could damage an adversary without revealing its intent.**

Modification of storms, too, could have major strategic implications. As I have mentioned, preliminary experiments have been carried out on the seeding of hurricanes. The dynamics of hurricanes and the mechanism by which energy is transferred from the ocean into the atmosphere supporting the hurricane are poorly understood. Yet various schemes for both dissipation and steering can be imagined.

At present we are a long way from having the basic data and understanding necessary to carry out such experiments; nevertheless, **the**

long-term possibility of developing and applying such techniques under the cover of nature's irregularities presents a disquieting prospect.

CLIMATE MODIFICATION

In considering whether or not climate modification is possible, it is useful to examine climate variations under natural conditions. Firm geological evidence exists of a long sequence of Ice Ages, in the relatively recent past, which shows that the world's climate has been in a state of slow evolution. There is also good geological, archaeological and historical evidence for a pattern of smaller, more rapid fluctuations superimposed on the slow evolutionary change. For example, in Europe the climate of the early period following the last Ice Age was continental, with hot summers and cold winters. In the sixth millennium B.C., there was a change to a warm humid climate with a mean temperature of 5ºF higher than at present and a heavy rainfall that caused considerable growth of peat. This period, known as a climatic optimum, was accentuated in Scandinavia by a land subsidence which permitted a greater influx of warm Atlantic water into the large Baltic Sea.

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 atmosphere to different forms of radiated energy. In the last connection, the effect of clouds in making cool days and relatively warm nights is a matter of familiar experience. But clouds are a manifestation rather than an original determinant of weather and climate; of more fundamental significance is the effect of gases in the atmosphere, which absorb much of the radiation in transit from the Sun to the Earth or from the Earth into space. Intense X-rays and ultra-violet from the Sun, together with high-energy atomic particles, are arrested in the upper atmosphere. Only the narrow band of visible light and some short radio waves traverse the atmosphere without serious interruption.

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 which might be manipulated many years hence. In a solar flare, for example, 1010 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. For the near future, however, modification will not be in the short-wave incoming radiation but in the long-wave outgoing radiation.

EARTHQUAKE MODIFICATION

What causes earthquakes? Over geological time, the irregular distribution of heat-producing radioactive elements in the rock layers gives rise to sub-surface temperature differences between various parts of the Earth. In the continents, granites and similar rocks have concentrated radioactive elements near the surface; no similar concentration has taken place in the sub-oceanic regions, which may as a result be more than 100ºC cooler than the corresponding sub-continental regions. Such variations in temperature along a horizontal line, due to the differences in the vertical distribution of heat-producing elements, give rise to large thermal stresses, causing strain analogous to that which cracks a glass tumbler filled with hot water. The strain tends to be greatest in regions of abrupt temperature change along a horizontal line through the Earth's crust. The strain may be partially relieved by the slow convective flow of material in the deep Earth which is thought by some geophysicists to push continents about. But the strain can also be relieved by sharp fractures or by movements along previous faults in rocks near the surface. Movement along a fault radiates energy outward, which results in an earthquake. Each year approximately 200 megatons of strain energy is released in this fashion, the largest earthquakes corresponding to energy of the order of 100 megatons.

Major earthquakes tend to be located along two main belts. One belt, along which about eighty-five per cent of the total energy is released, passes around the Pacific and affects countries whose coastlines border this ocean, for example Japan and the west coast of North America. The second belt passes through the Mediterranean regions eastwards through Asia and joins the first belt in Indonesia. Along these two belts, large earthquakes occur with varying frequencies.

The use as a weapon system of the strain energy instability within the solid Earth requires an effective triggering mechanism.

MODIFICATION OF OCEANS

We are still in the very early stages of developing the theory and techniques for predicting the state of the oceans. In the past two decades, methods have been devised for the prediction of surface waves and surface wind distribution. A warning system for the tsunamis (tidal waves) produced by earthquakes has also been developed.

Certain currents within the oceans have been identified, but we do not yet know what the variable components are; that is, what the weather within the ocean is. Thus we have not been able to identify any instabilities within the oceanic circulation that might be easily manipulated. As in the case of the solid Earth, we can only speculate tentatively about how oceanic processes might be controlled.

One instability offering potential as a future weapon system is that associated with tsunamis. These frequently originate from the slumping into the deep ocean of loosely consolidated sediments and rocks perched on the continental shelf. Movement of these sediments can trigger the release of vast quantities of gravitational energy, part of which is converted in the motion of the tsunami. For example if, along a 1,000-kilometre edge of a continental shelf, a block 100 metres deep and 10 kilometres wide were dropped a distance of 100 metres, about 100 megatons of energy would be released. This release would be catastrophic to any coastal nation.

BRAIN WAVES ROUND THE WORLD?

At heights of forty to fifty kilometres above the Earth's surface, substantial numbers of charged particles are found which make this part of the atmosphere, the ionosphere, a good conductor of electricity. The rocks and oceans are also more conducting than the lower atmosphere. Thus, we live in an insulating atmosphere between two spherical conducting shells or, as the radio engineer would put it, in an Earth-ionosphere cavity, or waveguide. Radio waves striking either conducting shell tend to be reflected back into the cavity, and this phenomenon is what makes conventional long-distance radio communication possible. Only recently, however, has there been any interest in natural electrical resonances within the Earth-ionosphere waveguide. Like any such cavity, the Earth-ionosphere waveguide will tend to sustain radio oscillation at certain frequencies in preference to others. These resonant frequencies are primarily determined by the size of the Earth and the speed of light, but the properties of the ionosphere modify them to a certain extent. The lowest resonances begin at about eight cycles per second, far below the frequencies ordinarily used for radio communication. Because of their long wavelength and small field strength, they are difficult to detect. Moreover, they die down quickly, within 1/16 second or so; in engineering terms, the cavity has a short time constant.

The enhanced low-frequency electrical oscillations in the Earth-ionosphere cavity relate to possible weapons systems through a little understood aspect of brain physiology. Electrical activity in the brain is concentrated at certain frequencies, some of it extremely slow, a little around five cycles per second, and very conspicuous activity (the so-called alpha rhythm) around ten cycles per second.

The Brain Research Institute of the University of California is investigating the effect of weak oscillating fields on human behaviour. The field strengths in these experiments are of the order of a few hundredths of a volt per centimetre. Subjects show small but measurable degradation in performance when exposed to oscillating fields for periods of up to fifteen minutes.

The field strengths in these experiments are still much stronger, by a factor of about 1,000, than the observed natural oscillations in the Earth-ionosphere cavity. However, as previously noted, the intensity of the natural fluctuations could bc increased substantially and in principle could be maintained for a long time, as tropical thunder storms are always available for manipulation. The proper geographical location of the source of lightning, coupled with accurately-timed, artificially-excited strokes, could lead to a pattern of oscillations that produced relatively high power levels over certain regions of the Earth and substantially lower levels over other regions. In this way, one could develop a system that would seriously impair brain performance in very large populations in selected regions over an extended period.

SECRET WAR AND CHANGING RELATIONSHIPS

As economic competition among many advanced nations heightens, it may be to a country's advantage to ensure a peaceful natural environment for itself and a disturbed environment for its competitors. **Operations producing such conditions might be carried out covertly, since nature's great irregularity permits storms, floods, droughts, earthquakes and tidal waves to be viewed as unusual but not unexpected. Such a 'secret war' need never be declared or even known by the affected populations**. It could go on for years with only the security forces involved being aware of it. The years of drought and storm would be attributed to unkindly nature and only after a nation were thoroughly drained would an armed take-over be attempted.

In addition to their covert nature, a feature common to several modification schemes is their **ability to affect the Earth as a whole**. The environment knows no political boundaries; it is independent of the institutions based on geography and the effects of modification can be projected from any one point to any other on the Earth.

Because environmental modification may be a dominant feature of future world decades, there is concern that this incipient technology is in total conflict with many of the traditional geographical and political units and concepts.

Political, legal, economic and sociological consequences of deliberate environmental modification, even for peaceful purposes, will be of such complexity that perhaps all our present involvements in nuclear affairs will seem simple. Our understanding of basic environmental science and technology is primitive, but still more primitive are our notions of the proper political forms and procedures to deal with the consequences of modification. All experience shows that less significant technological changes than environmental control finally transform political and social relationships. Experience also shows that these transformations are not necessarily predictable, and that guesses we might make now, based on precedent, are likely to be quite wrong. It would seem, however, that these non-scientific, non-technological problems are of such magnitude that they deserve consideration by serious students throughout the world if society is to live comfortably in a controlled environment.

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extended by his participation in national science policy-making. He is a member of President Johnson's Science Advisory Committee.

Author's note:
In the section on weather modification I have drawn heavily on Weather and Climate Modification (National Academy of Sciences, National Research Council, Washington, zg66). A. T. Wilson's paper on 'Origin of Ice Ages' appeared in Nature, vol. aox, pp. z4y-g (xg64), and J. T. Hollin's comments in vol. ao8, pp. ra-16 (r 965). Release of tectonic strain by underground nuclear explosion was reported by F. Press and C. Archambeau in Journal of Geophysical Research, vol. 67, pp. 337-43 (1962), and man-made earthquakes in Denver by D. Evans in Geotimes, vol. to, pp. rr-rp. I am grateful to J. Homer and W. Ross Adey of the Brain Research Institute of the University of California at Los Angeles, for information on the experimental investigation of the infiuence of magnetic fields on human behaviour.