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Meteorology—Vital Element of Naval Planning and Operations

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METEOROLOGY—VITAL ELEMENT OF NAVAL PLANNING AND OPERATIONS

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by

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INTRODUCTION

For centuries, weather and climate have been a factor in the prosecution of wars, but in the last fifteen years their importance has increased markedly. In Naval strategic, tactical, and logistical planning and operations, the meteorological factor can almost never be ignored and may sometimes be decisive.

As the result of great technical strides and scientific achievements, the Navy—as well as the other Services—has greatly increased its sensitivity to the meteorological environment. And along with this, the advent of the nuclear-missile-space era has precipitated a seeming inconsistency of no small magnitude. Today, from the standpoint of nuclear, chemical, or biological warfare, a nation surrounded by its allies is much more vulnerable than a nation surrounded by its enemies! And this adds greatly to the complexity of the tasks confronting the modern decision-makers.

The United States is surrounded by friendly nations. Consequently, the Soviet Union could unleash large-scale nuclear devastation against the United States heartland with little concern for lethal contamination of South America, the Caribbean area,

Mexico, or Canada, by radioactive fallout. And the same applies to the employment of chemical or biological techniques.

The Soviet Union, on the other hand, is largely surrounded by neutral or uncommitted nations, by United States allies or countries friendly to the United States, and by countries which have been coerced into joining the "bloc of tyranny" (and whose peoples are largely anti-Soviet). And herein lies one of today's many problems.

Under a variety of meteorological conditions, a large-scale nuclear retaliatory attack against the heartland of the USSR would also constitute a concomitant attack against United States allies, neutral nations, and anti-Soviet citizenry geographically situated in the "rimland" of the Soviet Union and beyond. The magnitude of the concomitant attack—the fallout of radioactive debris—would depend in large measure upon weather conditions. And in particular, upon wind patterns extending from the lower levels to extremely high levels in the atmosphere.

Which of these countries would be subjected to radioactive contamination? To what degree? When? The answers to these and many related questions must be provided to Naval planners and operational commanders. For many reasons, competent and timely meteorological information is no longer "desirable." It has become *mandatory*.

WEATHER SERVICE, A TWO-SIDED COIN

Naval commanders at sea have always taken the weather factor into account whenever possible. Before the days of steam, commanders were constantly forced to alter position in order to take advantage of the wind. They constantly attempted to "gain the weather gauge"—to get to windward of the enemy so that the enemy could be approached when desired. And if a

strategic retreat was a likely course of action, the shrewd Naval commander maneuvered his force to leeward so that he could turn and retreat without having to penetrate the enemy's line.

Before the birth of military weather forecasting in the 1850's, Naval commanders were limited to an anticipation of future weather conditions on a very general basis. Constant operational readjustments to the specific meteorological situation were required as that situation unfolded. But since the Crimean War (1854-56), the meteorological factor has never again been viewed with palsied fatalism.

Today, in addition to competent leadership, a highly mobile, flexible, efficient, and punch-packing Navy demands a specialized meteorological organization to meet specialized requirements extending from the depths of the hydrosphere to the great heights of the stratosphere and beyond. This is why the navies of almost all major countries have their own organization of weather scientists, forecasters, and technicians to provide, if at all possible, the requisite information, data, and studies to meet the diverse requirements of Naval planning and operations. And in this complex era, this is far from a simple task.

Some Scientific Facts of Life. In many instances, the Naval meteorologist is not able to effectuate *exactly* the data and information which the planners and operators state as requirements. The fault lies primarily with the tenuous nature of the earth's envelope of air and the difficulties encountered in observing, measuring, and describing the weather and oceanographic parameters inherent in Naval problems.

Naval meteorologists—like other meteorologists—are unable to observe weather and oceanographic elements with 100% accuracy. Limitations on their ability to do this stem primarily from restrictions inherent in sensing equipment and the "representativeness" of

the particular observation as it relates to a specific plan or operation. In other words, does the observation really define the requisite parameters? Also, how relevant is the observation to what *should* be observed?

In general, it can be stated that the capability of the Naval meteorologist to meet requirements for weather and oceanographic information is satisfactory for most purposes. Exceptions to this are those parameters lacking precise physical definition, such as "visibility."

Shortcomings similar to those inherent in the observation of certain weather elements are also encountered in the provision of climatological information for operational or planning purposes. And these shortcomings result primarily from the paucity—or complete lack—of data for remote land areas and the vast oceanic expanse. For, whenever the distribution of weather or oceanographic parameters must be extrapolated from data at a distant point, precision is drastically reduced.

With regard to the *future* state of the atmosphere or the hydrosphere, weather and oceanographic predictions possess all the uncertainties inherent in both the observational and climatological aspects, and in addition, a variety of other factors peculiar to the process of forecasting. Forecasts are derived either from the solution of an initial value problem in which the predicted element is defined in terms of its initial value or its time derivatives, or the values are determined from an extrapolation of a time series of the particular element. The basic difficulty stems from the fact that the atmosphere and the hydrosphere are media in which cause and effect are *always* multiple and complex relationships. These are the scientific facts of life, at this writing, and no solution appears imminent.

Current Fleet Requirements. Even though geographical, meteorological, and oceanographic considerations have always played a role in warfare at sea, it has been only within the last fifteen years or so that nature has subtly influenced and affected instrument and equipment design—particularly that of undersea warfare. The distribution of salinity, temperature, and pressure within the sea govern its sound-transmitting properties. And even the character of the bottom is an important factor. Consequently, oceanography (a responsibility of the Naval meteorologist) has become a vital factor in weapon systems studies, as well as in "routine" plans and operations.

The "environment" of undersea warfare varies both geographically and seasonally. And what is happening in the earth's atmosphere—the actual weather—strongly affects the temperature gradient in the hydrosphere which, in turn, determines acoustic paths. As a result, it is extremely unlikely that any one weapon system will ever be optimal under all circumstances. Obviously, then, advance knowledge of probable detection ranges by various techniques can significantly increase the efficiency of barrier, hunter-killer, and large-scale ASW operations.

This, of course, applies to the performance of radar equipment in the atmosphere, as well as to sonar equipment beneath the surface of the sea. For both radar and sonar are extremely sensitive to their environment in their effectiveness of operation. And the Naval meteorologist must be Johnny-on-the-spot with these predictions to assist the operational commander.

The numerous weather and oceanographic variables influence the different types of Naval operations in many ways. Consequently, in the planning or conduct of these operations, it is necessary to thoroughly consider all weather and oceanographic requirements, arrive at the best possible balance, and define the

minimal requirements on an overall operational basis. This analysis is a difficult procedure, requiring judgment of the highest calibre. And in no type of operation is the analysis more difficult than in amphibious operations, which involve the effectual coordination of sea, air, and land forces.

Despite many predictions to the contrary subsequent to World War II, amphibious-type operations have again assumed prominence in the warfare-technique arsenal as the result of the birth of "limited war." And while amphibious craft are sensitive to wind speed, wave height and period, the vertical assault technique is highly sensitive to wind speed, gustiness, and turbulence. Thus, prior knowledge of these, and other, conditions is mandatory for the efficient conduct of these types of operation.

Carrier Task Force operations with high-speed, high-altitude jet aircraft; sustained operations at sea, including the underway refueling and replenishment of units; the complex procedures and decisions inherent in the selection, delivery, and escape techniques concerning special weapons; mercy missions and search and rescue operations; the prediction of intricate radioactive fallout patterns, for offensive and defensive purposes; optimum ship-routing operations (which save the Navy more than ten million dollars per annum); all demand a highly-specialized weather and oceanographic service.

The advent of missiles and their incorporation into the Navy arsenal have served to increase, rather than decrease, the stringent planning and operational requirements placed upon the Naval Weather Service. At the present time, there are missiles of all types and ranges, performing offensive, defensive, and special missions. Many of these streak at supersonic speeds to their target. But regardless of the type of missile, the nature of its guidance system, or its speed, as long as the missile is within the earth's

atmosphere, its performance will be influenced by one or more of the many weather elements.

Missiles cannot correct for unexpected circumstances. Stratospheric clouds can blot out the stars. Radar beams can "bend" considerably. Most unusual changes in air density can—and do—occur. Stratospheric winds in excess of 350 knots are frequently encountered. This factor alone could result in a Mach-3 missile detonating 20 miles off-target. For, such a missile can be thrown off course in the last few minutes before homing, without sufficient time to correct for the deflection.

Only the true ballistic missile, because of its fantastic speed, will be relatively free of the weather elements during flight. But the effects during and subsequent to the warhead's detonation are still determined largely by weather conditions. Snow cover and cloud cover, humidity, vertical distribution of temperature, precipitation, and wind patterns will continue to determine the efficiency of the blast, thermal, and radiation effects, and the distribution of radioactive fallout.

Chemical and biological warfare techniques are perhaps the most weather-sensitive techniques of all, demanding a precise and accurate knowledge of existing, and especially of future, weather conditions.

Thus, current Fleet requirements for meteorological data and information are as numerous as they are diverse. And it is incumbent upon the Navy's weather organization to provide this vital information at all cost, subject only to scientific limitations.

Naval Weather Service Requirements. In order that the Naval Weather Service may provide the requisite data and forecasts to the best of its ability in meeting Fleet requirements, it is essential that the Fleet do its part.

During the initial stages of the planning process, the meteorological and oceanographic aspects and implications should be closely examined. A Naval meteorologist should be invited to act as a "consultant" to all new plans, programs, and operations at the earliest practicable stage, for the proper use of this type of data requires a finite recognition and assessment of the indeterminate character of the earth's envelope of air. The uncertainty factor is as important as knowledge of the weather and oceanographic elements, themselves. The meteorologist should be encouraged to carefully examine the flexible factors in order to determine the combination of operational factors which promises optimum chance of success.

Detailed briefing requirements should be clearly specified by Naval planners and operational commanders and data content and format requirements should be well-defined. As in any field of science, the degree of success is largely a function of accurate observations. Air, surface, and subsurface Naval units, therefore, should conscientiously make these observations in accordance with existing instructions. Equally important, timely reports of these observations should be made by Fleet units to the proper Navy weather activities. Such was the case during World War II. And Fleet units should forward complete weather and oceanographic records to designated activities for climatological, statistical, and research purposes, if the Naval Weather Service is to provide the calibre of support which the Fleet of today requires. Thus, the provision of efficient weather and oceanographic service to the Fleet is, indeed, a two-sided coin.

METEOROLOGICAL IMPACT ON MODERN DECISION-MAKING

Even though mankind is now in a simultaneously wondrous and appalling scientific and technological era, human intelligence remains the most vital single

entity. The human brain has not been replaced by the electron tube, nor is it likely to be for a long, long time. And the capacity for sound decision remains all-important.

Despite tremendous strides in the world's push-button technology, it is still man and his decision-making ability that really counts, not the button. And never before in the Naval and military history of mankind has the weather factor entered so forcefully into the decision-making process.

Earth satellites, rockets, missiles, manned aircraft, nuclear and CBR weaponry, and surface and subsurface ships are all weather-sensitive. It is only a matter of "degree of sensitivity." For, all operate within the earth's atmosphere, at least a part of the time.

Perhaps one of the most difficult decisions confronting today's Naval planner and operational commander is that of the optimum weapon system—to accomplish a particular mission, in a designated distant geographical area, at a specified time, with minimum risk to own and friendly forces or areas. For today, this must be accomplished under whatever weather and oceanographic conditions may envelop one's own forces and whatever conditions may cover target areas at the specified time. One thing is certain. Making such a decision without competent meteorological advice could easily be the prelude to failure—and perhaps disaster.

An unmanned vehicle of destruction with a radar guidance system should not be utilized if electrical storms are indicated or predicted in the troposphere or the ionosphere, for the vehicle will miss its target by a wide margin. A missile with infrared homing should not be used if it is forecast that the target is, or will be, obscured by multiple cloud layers, or even a single heavy cloud layer. For, the

water droplets comprising the cloud masses absorb up to 75% of the target's emitted infrared in the critical wave-length bands. Under these conditions, it would be almost impossible to calculate in advance the point of impact.

Even the extremely sophisticated missiles containing autonavigation systems are not invulnerable to the effects of the weather. And the efficiency of an orbiting reconnaissance satellite is highly vulnerable to the stratospheric and tropospheric clouds comprising an undercast.

Less exotic than missiles, perhaps, but much more effective for certain purposes, the sensitivity of manned aircraft to conditions of dense fog, severe storm, extreme turbulence, and the like, is all too well known. In addition to these meteorological factors, information relating to the three-dimensional structure, movement, and intensity of the jet stream; atmospheric layers in which contrails are likely to be generated; and many other weather factors too numerous to mention must be carefully considered by the planner and operator prior to making the final decision.

The tremendous effects of weather conditions on nuclear detonations are now well known. Temperature inversions near the ground and at great heights in the atmosphere, a strong increase of wind speed in the vertical, and a concentration of ozone in the upper atmosphere, all cause the blast effect to be magnified at various distances where successive reflections cause the addition of different wave lengths.

On the other hand, heavy precipitation and fog reduce the effect of the lower overpressures by as much as 50%. A cloud layer below the detonation seriously reduces the thermal radiation. But a cloud layer above the burst will increase the thermal radiation on the ground by as much as 80%. Snow on the ground is also an excellent reflective surface. Only

the initial gamma radiation, attenuated solely by the density of the medium through which it passes, is independent of atmospheric conditions.

The radioactive fallout subsequent to the detonation will settle upon the earth's surface—and will be scavenged from the air by rain, sleet, snow or hail—in a huge pattern of death whose orientation, length and width will be determined by the circulation of the wind. And it matters not whether the detonation results from a bomb delivered by a manned aircraft, the warhead of a surface-to-surface or air-to-surface missile, or Polaris. The weather-determined fallout will ensue and must be carefully precalculated, just as the other parameters can and must be predicted—and taken into account prior to the decision.

The exact times of aircraft or missile launch and detonation may, too, be largely dependent upon the weather picture; even the "Go" or "No Go" decision, itself. Of equal importance are Task Force formations, defense measures, and evasive maneuvers, in the event of enemy attack. These should be predicated largely on forecast local weather conditions and the predicted local fallout pattern.

It is self-evident that the operational effectiveness of any vehicle utilizing the earth's atmosphere or hydrosphere as a medium depends upon the accuracy of theoretical design and performance studies utilizing standard and appropriate data. The actual performance depends largely upon the "matching" of actual conditions to the assumed conditions of theoretical studies, and large deviations from standard values can result in serious consequences. Thus, not only must accurate meteorological and oceanographic data be furnished to enable instrument, vehicle, and weapon system design decision, but minimum and maximum deviations from standard must also be furnished to preclude future operational catastrophe.

Despite the passage of time with its associated fantastic developments, the meteorological impact on modern decision-making was most clearly defined fifteen years ago, when CTF 38 included the following conviction in one of his reports: ". . . Those Naval commanders who fail to use weather properly when it is provided, need never fear of losing their amateur status in the game of war. The amateurish conduct of war operations will be in direct proportion to the importance of weather in these operations, regardless of the professional skills of the Command in other fields." And this statement is even *more* valid today than it was in 1945 when it was drafted.

BRIEF ANALYSIS OF THE METEOROLOGICAL FACTOR

So long as an adverse effect can result, meteorological and oceanographic data must be thoroughly considered. But the precise and gainful application of weather and marine aviso to Naval plans and operations requires a certain skill, and particularly an understanding, on the part of all personnel concerned. For, the demand for this information stems from the strong environmental influence exerted on Naval equipment, weapon systems, and personnel.

In some instances, weather information is neither adequate nor properly utilized, for the meteorologist is not always able to produce *exactly* the information which planners and operators state as requirements. Another difficulty stems from the fact that many plans and operations are designed in such a fashion that meteorological information can be applied only once. And the application is usually restricted to the time when operational flexibility has been minimized or eliminated. Thus, in many cases, the weather information must be "single-valued," and an entire decision may revolve around the weakest component.

Fundamentally, meteorological and oceanographic information have maximum value to the Navy only when related to a particular type of operation, and only when this information is transposed into operational factors. The *exact* degree of weather and oceanographic influence is usually difficult to predict. Perhaps in the not-too-distant future it will be possible to state atmospheric and hydrospheric effects with high mathematical precision. But that day has not yet arrived. When it does, it may be possible to transform Naval planning and decision-making into a quantitative mathematical operation—similar to game theory analysis.

Perhaps above all, Naval planners and operational commanders should remember that meteorology is not yet the exact science we would like it to be. The uncertainty factor most assuredly does exist, and should always be taken into account. Also, the value of meteorological and oceanographic information is directly proportional to the flexibility of the plan or operation.

Modern engineering technology can materially reduce the handicap of natural environmental factors. Therefore, meteorological and oceanographic effects on Naval operations should not be continuous. And the degree to which weather and oceanographic influences can be eliminated is largely a function of the Navy budget.

The indeterminacy of weather information has always been rather difficult to manage effectually. But the fact must be recognized that *all* physical systems are indeterminate to some degree. Recent advances in game theory, however, have provided methods for utilizing uncertainty in a completely intelligent manner. And weather data should be handled in the same way in order to exploit their operational and planning value to the fullest possible extent.

CONCLUSION

It goes without saying that this is an extremely complex political, scientific, and technological world in which mankind now finds itself. And perhaps the new and fantastic products of the inventive genius of man have already outdistanced man's proven capability to adjust to their traumatic impact.

Yet, this is the world in which the Navy must plan and operate in the cause of freedom—and must do so effectually and with precision.

One fact, however, remains crystal clear. Despite the continued and tremendous expansion of Naval planning and operations into the vast depths of the hydrosphere and the extreme altitudes of the atmosphere, and despite the advent of the nuclear-missile-space era, the element of weather remains vital to all phases of planning and operations conducted by the Navy. And consequently, the subject of meteorology should be of sound concern to *every* Naval officer.

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