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THE REPORT TO THE PRESIDENT
BY THE
TECHNOLOGICAL CAPABILITIES PANEL
OF THE
SCIENCE ADVISORY COMMITTEE

FEBRUARY 14, 1955

VOLUME 2

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF DEFENSE MOBILIZATION
WASHINGTON, D. C.

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MEETING THE THREAT OF SURPRISE ATTACK

TECHNOLOGICAL CAPABILITIES PANEL
OF THE
SCIENCE ADVISORY COMMITTEE

VOLUME II



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PART III

NUCLEAR STRIKING POWER:
AN ELEMENT OF DEFENSE

How innovations in the technology of our striking power and reduction of its vulnerability can increase its value as a deterrent against surprise attack, and can help insure winning a general war if deterrence fails.



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NUCLEAR STRIKING POWER: AN ELEMENT OF DEFENSE

1. INTRODUCTION

Earlier sections of this report have emphasized the new importance and meaning of surprise in the evolving U.S. military-technological strength, and the central significance of more positive intelligence and warning in improving our effectiveness against a possible surprise attack. In this section, we discuss the nuclear striking power of the U.S., and ways in which innovations in the technology of our striking power and reduction of its vulnerability can increase its value as part of the defense of the U.S.

The importance to the defense of the U.S. of an offensive air striking force stems from its ability to attack the Soviet long range air force on the ground; in this role it is a necessary partner of the air defense force which attacks the enemy long range air force in the air. If the U.S. air striking force is to be a deterrent, and if it is to retain the offensive-defensive capability, it must be reasonably invulnerable to surprise attack, and must be continually improved to keep ahead of the Soviet defensive capabilities.

The nuclear striking capability of the U.S. has been considered in this study principally from a technical point of view; we are thoroughly aware of the broader organizational, management, and operational problems which determine to a large extent the effectiveness of technical innovation.

The task of the striking force is essentially that of transporting a bomb from friendly territory to a target in enemy territory, against the active opposition of an enemy. The effectiveness in performing this task can be roughly measured in terms of the probability of destroying an assigned group of targets with the available force during a specified time period. To accomplish this mission with a high probability of success, the striking force must be maintained in a continual state of readiness, with adequate foreknowledge of the assigned enemy targets; it must be capable of reacting quickly and reliably when called upon; it must survive the effects of enemy action both on the ground and in the air; it must have the range and the equipment to navigate to the target area; it must place bombs sufficiently near the assigned targets to wreak the desired level of destruction; and it must return safely to an assigned base for further missions. The striking force requires personnel, bombs, delivery vehicles, defensible bases, logistic support, communications, and intelligence. To weld these elements into an efficient striking force requires, above all, professional management of a professional force.

Attention in this study has been restricted to those parts of the military forces which, now and in the future, have some capability of inflicting damage directly upon targets in the Soviet homeland by means of air delivered bombs. In this context, our attention has been directed principally towards the Air Force and to appropriate parts of the Navy.

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The Mission of the Nuclear Striking Force

Towards recognition of the fact that the type and form of the striking force depends in part on the kind of job to be done, we summarize the mission of the nuclear striking force. In broad terms, this mission includes:

- (a) Bravo—to neutralize the enemy's airpower.
- (b) Romeo—to destroy the capabilities of his other military forces (primarily surface) to conduct operations.
- (c) Delta—to destroy his war supporting capabilities.

Neutralization of enemy airpower, which has first priority because of its importance to defense, requires attack on a number of target categories including aircraft, airfields, military command control centers, weapon stockpile sites, weapon production facilities, fuel and reserve fuel storage facilities, air depots, and air logistic support facilities.

Destruction of an enemy's other military capabilities are achieved by attacking the military forces themselves and the resource elements that enable him to supply and control those forces. Targets include concentrations of military forces, enemy war materiel, and logistic support facilities. Command control centers necessary for control of the forces involved are also included as targets.

Destruction of an enemy's war supporting capabilities is accomplished by subjecting his centers of logistic, industrial, general economic, and political strength to attack. Most of these centers coincide with centers of population so that with the exception of isolated industrial installations, an enemy's urban areas are in fact the targets which must be attacked.

We believe that a small scale surprise attack with relatively few nuclear bombs could do severe damage to the U.S. At the same time, we also believe that the U.S. needs a large offensive striking force capable of hitting many targets with megaton bombs. This looks like a contradiction, for does the U.S.S.R. indeed represent a larger, tougher, target system than the U.S.? This question prompted us to ask further questions.

A Symmetric Comparison of Certain U.S. and Soviet Bloc Potential Target Categories

How do the jobs of the U.S. and Soviet striking forces compare? What are the relative U.S. and Soviet air-atomic capabilities? Is our nuclear striking force more vulnerable to destruction in a surprise attack than the Soviets'? What can we say about the relative vulnerabilities of U.S. and Soviet war supporting resources? Are the basic industrial, population, and control centers of the U.S. more concentrated or more exposed to attack than those of the Soviet?

The overall analysis of the problems posed by the above questions is the task of a large part of the Department of Defense. Every aspect of these questions is studied by an appropriate agency. Generally, however, the studies have different terms of

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reference and include planning factors. And so, it is difficult to synthesize and integrate the various pieces into a single, consistent, comparison.

We have made a very crude attempt to make such a comparison of the Bravo and Delta target categories—primarily to get some feeling of feasibility. While it is clear such a comparison can not be made in a complete sense, some useful and interesting results do emerge. Examples are given below.¹ While we generally use the methods of target analysts, we did omit many of the factors which control selection of specific target systems.

BRAVO

Aircraft, total numbers.—The Soviet Bloc possibly² has three times as many aircraft as the U.S.

This is a limited comparison; it includes jet aircraft of all types and piston engine aircraft in the medium and heavy bomber class.

Aircraft, bombers.—The Soviet Bloc possibly has no heavy bombers in operational combat units; the U.S. has 300 B-36's.

On the other hand, the Soviet Bloc possibly has one and one-half times as many medium bombers operational as does the U.S. Most of the Soviet medium bombers are TU-4's (B-29 type); the U.S. has about twelve times as many jet medium bombers as the Soviets.

The Soviets have about three times as many jet light bombers as the U.S.

Bases.—The U.S. has significantly more surfaced runways potentially available, particularly for small aircraft, than the Soviets, but the U.S. has fewer bases in use by military aircraft. The average number of aircraft per home base is about the same for each country.

The Soviet Bloc has possibly twice as many bomber home bases, and three times as many jet fighter home bases as the U.S.—excluding U.S. overseas, rotational bases and aircraft carriers.

The Soviet Bloc has possibly four times as many alternate bomber bases as the U.S.

Atomic Capability.—About 75 percent of U.S. bombers are atomic capable—i.e., they are completely equipped and ready to deliver atomic bombs. In addition, a small (3%) part of the U.S. jet fighters are presently atomic capable.

On the other hand, analysis of intelligence data has not revealed which, if any, Soviet Bloc operational units are atomic capable. There is an implication that the Soviet operational atomic capabilities are small. However, their bomber aircraft could carry and deliver nuclear weapons—the bomb bay dimensions are appropriate.

Stockpile Sites.—It is possible that the Soviets have only a single stockpile site comparable to five U.S. National sites, but this does not preclude the chance that Soviet weapons are stored elsewhere. Nothing else is known to us about Soviet nuclear

¹ A copy of the complete study is on file in the office of the ODM Science Advisory Committee; the title is: "A Symmetric Examination and Comparison of Certain U.S. and Soviet Bloc Potential Target Categories, 4 Jan. 1955."

² Possibly is used here and in what follows in the sense given it by the intelligence analysts who attach ratings to their estimates of *firm*, *probable*, or *possible* in descending order of validity.

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weapons storage. Thus we have no estimate of the number of operational storage sites containing weapons in custody of the Soviet military services.

Command Control Centers.—The U.S. and Soviet Bloc have about the same number of first echelon control centers for the direction of combat air units. In the case of the U.S., the control centers at the headquarters of JCS unified and specified commanders are included.

The Soviet Bloc has about three times as many command control centers in the next lower echelon. There are also geographical differences. In the case of the U.S., these subordinate centers are with or near the subordinate combat air units; in the Soviet Bloc, the similar centers are located in cities.

Bravo Summary.—We have been able to summarize no more than general impressions—and even these impressions may have only limited validity.

- (a) The target array presented by Soviet Bloc total airpower is significantly bigger than that of the U.S.
- (b) The target array of the Soviet atomic capability, particularly intercontinental, is smaller—and significantly so—than that of the U.S.

DELTA

What follows is a comparison between the U.S. and the whole Soviet Bloc including China and satellite countries. It would be appropriate to compare (a) the U.S. and USSR, and (b) the U.S. plus NATO and the Soviet Bloc.

Industry.—The productive capacity of the Soviet Bloc is significantly lower than that of the U.S. in nearly every category except military end items.

Ten sample industries were selected for comparison; they were chosen because of their obvious importance for sustaining a war effort. In the U.S. 154 urban areas account for about 80 per cent of the capacity of every one of the 10 selected industries; in the Soviet Bloc the comparable number is about 180. By and large about the same number of targets are presented.

Population.—The industrial labor force is drawn from urban population. The numbers of people in the 200 largest cities is not very different in the U.S. and Soviet Bloc; because of the large differences in total population, the percentage of the population in the 200 largest cities is greater for the U.S. than for the Soviet Bloc.

We conclude that:

1. It would be profitable to compare on a common basis the Bravo, Romeo, and Delta target systems of the U.S. and USSR and such a symmetric study would be useful to a net capabilities estimate.

We recommend that:

1. As a first step in comparing the capabilities and vulnerabilities of the U.S. and USSR in a possible nuclear air war, a comprehensive comparison of U.S. and USSR Bravo, Romeo, and Delta target systems be undertaken in the context of a single symmetric study, using common terms of reference, and a common framework of analysis.

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2. NUCLEAR BOMBS AND FALL-OUT

Nuclear Bombs

Nuclear weapons have materially improved the military position of the U.S. and the importance which they have assumed in our military planning makes it necessary for this study to estimate future improvements in them.

Following World War II the fission bomb developments have been primarily aimed at 1) increasing the efficiency of bombs in terms of kilotons per kilogram of fissionable material, and 2) making the atomic bombs more deliverable by means of ordnance engineering and by decreasing the size and weight of the bomb. Under ordnance engineering, applications to specific military problems have been made and will continue to be made. The small sizes of general purpose atomic bombs now available go down to about a half ton in weight and even smaller sizes are under development. These smaller fission bombs yield about; whereas the largest fission weapon yields around

The advent of the thermonuclear bombs brought about three things: (a) The maximum practicable yield of air delivered bombs was increased by about ten times over that practicable with fission bombs; (b) the comparable cost per megaton was decreased by a factor of about twenty, and (c) the yield per ton of bomb was increased to about

The steps in the future development of the thermonuclear bombs are very similar to those in the fission bomb program; namely, the making of thermonuclear bombs compatible with existing or programmed delivery systems and in this way, increasing the nuclear capabilities of the military forces. This program leads essentially to a variety of general purpose thermonuclear bombs which the military forces can apply to their needs.

The programs described above have centered attention upon the explosive damage, and rightly so, since the military effects of blast destruction are reliable and known. As yet little explored are the possible applications of the *techniques* of nuclear bomb design to military problems other than for the production of blast. For example, high explosives are used militarily not only for production of blast but in throwing fragments and in producing jets; perhaps nuclear explosives will be useful in similar ways. At times it could be militarily (and politically) desirable to deny to the enemy some specified area without destroying that area. Radioactive fall-out is at present unreliable for this purpose but possibly the application of nuclear bomb techniques might lead to a useful tactic.

In the previous paragraph we have indulged in speculation in the ways in which the techniques of nuclear bombs may be applied in the future. Being only speculations, we hesitate to make any specific recommendations in connection with them.

As noted earlier in this report, the past ten years have seen a significant increase in the explosive yield per ton of bomb. For reasons given below, comparable increases in this characteristic will not occur in the future.

The sources of energy (fission and fusion) now being exploited in thermonuclear bombs will allow an ultimate between 15 and 60 times more explosive power per ton

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of bomb than has now been achieved, depending upon the relative roles of fission or fusion involved in the bomb. This ultimate includes no allowance for bomb hardware, and is not likely to be achieved. The future can bring only small further increases in the explosive power per ton of nuclear bomb; a factor of two is achievable and a factor of ten might be attained, but certainly not a factor of sixty. Planners desiring a thermonuclear bomb or warhead yield of so many megatons will need to think of delivered weights of about the same number of tons.

These limitations, being imposed by nature, will not allow the Soviets to build nuclear bombs with significantly more megatons per ton of bomb than some already possessed by the U.S. A probable maximum to consider (for both the U.S. and USSR) is ten megatons per ton of bomb.

It is important to strive for the maximum in megatons per ton of bomb, because delivery is always made easier and cheaper with smaller weight. Only a very small part of the U.S. nuclear bombs have one megaton per ton of bomb; the other types have ample room for improvement in this characteristic.

With delivery by aircraft, the maximum payload is limited to a bomb yielding tens of megatons, but with delivery by ship or submarine the payload can be a bomb yielding a thousand or so megatons. Such heavy weapons are indeed feasible to make. Comparison of the U.S. and USSR seacoasts shows that the U.S. is much more vulnerable to ship-delivered weapons than is the USSR.

Clandestine introduction of nuclear bombs, either atomic or thermonuclear, is frequently thought to be limited to small size bombs. Complete atomic weapons do exist, having weights of a few hundred pounds and "suitcase" dimensions, although they are inefficient and have low yield. A perhaps more worrisome possibility is the megaton bomb of large size which could be disassembled into small pieces for clandestine transportation; after introduction the pieces could be assembled. It is feasible to make such a weapon.

We conclude that:

1. U.S. thermonuclear bombs using fission and fusion are already fairly close to their ultimate in terms of megatons per ton of bomb; in other type bombs and in other characteristics there is ample room for improvement.
2. The ultimate in megatons per ton of bomb, being a fact of nature, applies equally to the U.S. and to the USSR.
3. Now and for some time, the most efficient thermonuclear bombs will yield no more than about
4. For U.S. defensive planning purpose, the upper limit that should be ascribed to the Soviet bombs is a reasonable planning figure is two megatons per ton of bomb.
5. Present U.S. technology would permit the design of a costly weapon yielding a but the weight would be many hundreds of tons; we must assume that the Soviets can do the same.

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6. Present U.S. technology would permit the design of megaton nuclear bombs which could be disassembled into small enough pieces to allow clandestine introduction; we must assume that the Soviets can do the same.

We recommend that:

1. For planning purposes the maximum yield per weight of nuclear weapons be taken as:
2. For U.S. defense planning purposes, it be considered technically feasible for the USSR to deliver, by ship or by submarine, very large and heavy, though expensive, bombs having yields up to about 1000 megatons.
3. For U.S. defense planning purposes it be considered technically feasible for the USSR, to construct, for clandestine introduction into the U.S., nuclear bombs having yields as high as megatons.

Radioactive Fall-out

In this section we discuss the implications of fall-out for offense and defense; they differ significantly.

As is well known, the detonation of a nuclear bomb releases very considerable quantities of radioactive material which may result in significant military effects or may constitute a serious hazard to military or civilian people. At the present time, there are uncertainties as to:

- (a) where the radioactive debris will be deposited.
- (b) biological effects.

Both the Atomic Energy Commission and the Department of Defense have excellent and vigorous programs underway directed towards resolving the uncertainties. We have no suggestions for improving the programs either in direction or emphasis.

What follows is a brief résumé of these effects as they are currently known. There are two distinct cases of interest:

(a) *Short-Term Hazard (local fall-out)*

This case is generally confined to the radioactive material which falls out within a period between minutes and days after the detonation and at distances up to hundreds of miles from the point of burst.

(b) *Long-Term Hazard (global fall-out)*

This case is concerned with the potential, long term, biological hazard which may result from fall-out or more particularly from the *cumulative* activity which would fall to the earth, even at great distance and as the result of the detonation of many bombs.



The Short-Term Hazard

Air burst bombs do not contribute any local radioactive hazard. On the other hand, a large fraction of the radioactive debris from surface burst bombs does fall out within a period of minutes to days. The amount of radioactive fall-out is not

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quantitatively serious from the lower yield atomic weapons except in wartime when a great many might be detonated nearly simultaneously in one locality.

Large yield bombs—one megaton or more—burst on or near the surface of the earth can result in fall-out at places and in amounts which are not completely predictable. The mechanism of fall-out is moderately well understood, and fair predictions are possible if detailed meteorological information is available.

The activity dies off rather rapidly: within one day its intensity is down to 1/45th that which existed one hour after detonation; after 2 days it is 1/100th. Ordinary buildings offer considerable degree of protection from even the more penetrating components of radiation; an ordinary house can cut the intensity by a factor between 2 and 20. Even a relatively shallow, uncovered hole or trench can give a protection factor of 10 or more.

A surface burst 10 MT bomb can result in covering an area of 2500–5000 square miles with sufficient activity that a person in the open for one day immediately following detonation will receive a dose large enough to cause radiation sickness; an area of 700 to 1400 square miles would receive sufficient activity to cause death to most people who are similarly exposed. If shelter, such as basements, trenches, or ordinary buildings, is used for the critical one or two days, the area in which a person would be dangerously exposed might be as small as the area of primary blast damage. But it is essential that the person remain within shelter for one or two days, with no or few, brief, forays into the open. By waiting two days the rate will have dropped sufficiently that even for a person in the open for the next 24 hours, the dosage received would not be dangerous; it is comparable to the dosage from several deep medical fluoroscopic examinations. Decontamination, e.g., by flushing with water or by covering with soil, is an additional possible defense measure. Since an enlightened populace can make use of shelter and considerably mitigate the exposure rate, defense planning should take explicit account of fall-out.

The results of fall-out may be capricious: the effects may, in one case, be catastrophic—i.e., a large population might experience radiation sickness and fatalities; in another case, the results would only be to add a marginal number of casualties to those from immediate, direct effects. Though fall-out is important, it can not at present be depended upon for offensive planning. Necessary military and civilian functions can be carried out even though personnel may risk radiation sickness; there is no question that fall-out can make operations in the open difficult.

It is possible to prevent local fall-out completely by using air burst. However, there may be cases where surface burst is required because of the crater produced, and where the radioactivity may be an undesirable side effect. If there are many such cases, it may be necessary to develop thermonuclear bombs with substantially reduced radioactive yield. A major reduction in radioactivity can be accomplished at the expense of cutting the explosive yield by a factor of about four.

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The Long-Term Hazard

As already stated, after the air or surface detonation of a nuclear bomb, some fraction of the active debris goes into the upper atmosphere, whence it spreads out over a considerable fraction of the earth before falling out. Further, certain species of the active material may go into the upper air irrespective of the type of burst. There may then be cumulative, long term biologic hazard of a quite different sort. One such constituent, strontium-90, has a long radioactive and biological half-life, and because it seeks and deposits within specific portions of man, it may over a prolonged period lead to decreased life expectancy. Palliative measures which could cut the possible long term hazard are presently known.

The genetic hazard, while a possibility, is believed to be small, by comparison with the direct hazard already mentioned.

Estimates of the number of bombs which may be safely detonated are available. A full scale nuclear war would undoubtedly result in a very large number of direct casualties from blast and heat. There may be no long-term hazard, but even if the estimates were exceeded, the implications for the survivors are certainly less serious than those exposed to the direct effects.

We conclude that:

1. Radioactive fall-out from a surface burst megaton weapon can create a serious hazard to personnel over thousands of square miles; however, with appropriate defensive measures the area over which radioactive fall-out is dangerous need not be significantly more than the area that suffers primary blast damage.
2. The military effect of fall-out is probably not sufficiently predictable to be useful as a primary effect for military offensive applications.
3. Current estimates of possible long-term hazards do not indicate a need for limitations to current military plans for the use of nuclear bombs.

We recommend that:

1. Current studies directed toward better understanding of the radiological hazards which may result from the detonation of large numbers of nuclear weapons should be continued.
2. Plans for the military use of nuclear bombs should not at this time be restrained because of the long-term radiological hazard.

3. VEHICLES

The increases in the yield per ton of nuclear bombs have brought about corresponding increases in the power of our nuclear air striking force, but increases from this source will diminish as the yield per ton of bomb approaches its upper limit. Should the Soviets achieve a near equality with the U.S. in yield per ton of bomb, then a superior U.S. delivery system is necessary for the maintenance of a superior nuclear striking force.

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The significant problem of delivery is the active opposition of the enemy. If there were no problem of penetrating defenses, delivery would be a simple logistic job. Transport type aircraft capable of modest altitude and speed, but with truly intercontinental radius of action could be designed and built.

Up to the present, high speed and high altitude have been primarily exploited in order to avoid the defenses. The present state-of-the-art in airframe and engine design does not provide bombers of intercontinental radius of action along with the necessary adequate high speed and high altitude performance. It has, therefore, been necessary to balance these three characteristics and accept less than is desired in one or more of them in each specific bomber design. Greater emphasis on power plant research and design, as well as airframe design (for example: boundary layer control) would permit a better balance to be struck. It is clear that higher speeds and higher altitudes are worth further exploitation and should continue to receive support.

Defense systems can also be avoided by very low flying aircraft. The achievement of effective area defense against low level attack is basically difficult. As pointed out in another section of this report, the U.S. continental defenses have not yet solved this particular defense problem. For operational reasons very low altitude flying is not compatible with high speed and long range, and therefore the defense problem is somewhat moderated. There are additional disadvantages; such tactics are not well adapted to conditions of poor visibility; even with good visibility, navigation to targets presents a special problem; severe training problems must be solved. In order to increase the U.S. minimum altitude capability more effort on navigation equipment and training facilities is needed.

Quite aside from the relative advantages, there are reasons for achieving alternate capabilities for both low and high altitude penetration of defenses. The defense systems are essentially different for the two cases. As a consequence, if the enemy develops both, he either dilutes his defensive strength or dilutes his resources. There is also the possibility of thwarting our offense through the development of an unexpectedly good defense against one or the other capability. We believe that more emphasis should be given to the development of a significant minimum altitude capability of the U.S. nuclear striking force.

Evasion alone cannot be counted on to provide complete security for a striking force against a strong defense system. It follows that some measures may have to be taken to reduce the effectiveness of Soviet air defense through deception, confusion, or destruction. There properly is a strong bomber defense program embracing many approaches to this problem. We understand that these programs will continue to receive the support they deserve. We believe, however, that looking further into the future, a more general physical destruction of the defense system may become essential. It is our belief that the program towards this end should be expanded and strengthened. As a first step, a study should be made of possible tactics and weapons which may be needed in the attack of probable future air defense systems.

We have discussed a number of ways of improving the vehicles for the U.S. striking force. There are many other programs also directed towards maintaining superior

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nuclear striking power. In what follows, four major long range programs are presented which we believe can afford real jumps in delivery capability.

High Energy Aircraft Fuels (HEAF)

The Bureau of Aeronautics of the Navy Department is currently carrying on a program in high energy aircraft fuels which shows considerable promise. This program has recently made impressive gains.

The energy content per pound of the currently favored HEAF is almost 50% greater than that of conventional jet fuel (JP-4) and aviation gasoline. The gains which could be obtained if the fuel and engines were available and were used in certain bombers are shown in the table below:

Gross Take-off	Radius of Action (n. miles)	
	JP-4	HEAF
B-52C (10,000 lb. bomb) (450,000 lb.)	3,600	5,500
B-47E (10,000 lb. bomb) (221,180 lb.)	2,200	3,500
B-47E (10,000 lb. bomb) (221,180 lb.)	(3,200)*	(4,500)*
A3D (8,580 lb. bomb) (70,000 lb.)	1,200	1,800
A3D (8,580 lb. bomb) (70,000 lb.)	(1,800)*	(2,800)*

*One aerial refueling from jet tanker.

The increases in radii of action are about 50%, just as is to be expected from the ratio of energy contents. In particular the radius of action for the B-52C would be 5500 n. mi. This may be a way to get a chemically fueled intercontinental bomber without building larger bombers.

The discussion above has indicated the pay off in radius for existing bombers using HEAF. In new bombers designed to use HEAF, the pay off could be distributed among range, reduced size, increased combat altitude and, to a minor extent, higher speed in the combinations which best fit operational requirements. The superior combustion characteristics at high altitude of HEAF as compared to JP-4 will contribute to increasing the maximum altitude of bombers. Similar and striking increases in the performance of both rocket and ramjet vehicles would also occur. Gains for fighters and interceptors will be described elsewhere in this report.

There are some problems and disadvantages in the use of HEAF. While today HEAF can probably be used in after burners and ram-jets, there is a currently unsolved difficulty in turbo-jet engines because of the deposition of combustion products (boron oxide) in the engine which would decrease the engine efficiency. Solutions to this problem have been proposed, but they have not been tried because of the lack of sufficient HEAF. Another problem which might have operational significance is the white smoke trail left by engines burning HEAF.

Assuming that the technical problems were solved, there would need to be established a new industry of considerable size for supplying the HEAF. We believe the cost of HEAF will remain much higher than the cost of petroleum fuels, because the petroleum fuels come from the ground with the energy in them naturally, whereas the energy of HEAF must be put into the fuel during synthesis. However, the higher

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cost of the fuel could be countered to some degree by the decreased cost of the bomber fleet and elimination of some portion of the tanker fleet. Further, the military worth of achieving greatly increased performance of aircraft cannot be evaluated in terms of dollars alone.

As stated above, it is expected that even in large production the cost of HEAF will always be very large compared to JP-4. It is, therefore, important to plan to do most of the training with JP-4. For this reason the engine development program from the start should be directed toward a design permitting these fuels to be used interchangeably or in mixtures.

The status of the HEAF program is as follows:

a. Compounds of Boron, Hydrogen and Carbon have been synthesized which have satisfactory characteristics as a high energy fuel. These compounds are liquid over a greater range of temperatures than JP-4; their vapor pressure is low (which allows the use of these toxic materials); their specific gravity is slightly higher than JP-4; their stability toward water and air is satisfactory.

b. The problem of viscous or solid boric oxide deposits in some parts of turbojet engines is being evaluated by tests using very small quantities of actual HEAF fuels and large quantities of a simulated HEAF fuel which is not suitable for operational use. This is because of the extremely small quantities of HEAF now being produced. This procedure has, however, permitted component testing, tests of ramjet engines in flight, and some turbojet and afterburner tests on the ground. The results to date indicate a compatibility of HEAF in ramjet and afterburner systems as well as the feasibility of the development of modified turbojet systems for use of HEAF. It is believed that engines and equipment can be made to operate interchangeably on either JP-4 or HEAF.

c. Small pilot plants are in operation and produce about 150 lb. HEAF/Month at a cost of about \$20/lb. This amount is inadequate for engine and equipment development.

d. It has been estimated that the known boron reserves in the U.S. alone would be ample for large scale military use of HEAF, particularly since it is anticipated that training could be done with JP-4 and HEAF interchangeably.

The planned program involves continuing study of the chemistry of the boron compounds and great emphasis upon the engine and equipment tests and development. The chemical studies are on a moderate scale, but the engine tests must be expanded to include full scale tests with the HEAF in adequate quantities and to bring in the prime engine and equipment contractors. Those in charge of the HEAF program estimate that about 50 tons of fuel per day are needed to support a reasonable level of engine testing and development. At this production level the cost is expected to be \$2.00-\$3.00 per lb.

We conclude that:

1. Successful development of a propulsion system based on high energy aircraft fuels would furnish a means of appreciably increasing the performance of military aircraft and certain missiles.

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2. The present and projected program directed at development of propulsion systems based upon high energy aircraft fuels is technologically sound.

3. Further practical progress in the development of propulsion systems based upon high energy aircraft fuels requires that supplies of high energy aircraft fuels adequate for engine and equipment testing and development be provided.

4. An unrefueled intercontinental manned bombing system can probably be achieved earliest through the use of high energy aircraft fuels in conventional bomber aircraft.

5. Widespread operational use of high energy aircraft fuels would require the establishment of a large new industry.

6. It is important that the engines developed to exploit high energy aircraft fuels be designed to allow the use of these fuels and JP-4 interchangeably or in mixtures.

We recommend that:

1. The program for the development of high energy aircraft fuels, and propulsion systems capable of using them, be approved and receive strong support.

2. Supplies of high energy aircraft fuels adequate for development and testing of engines and equipment be manufactured and made available at an early date.

Aircraft Nuclear Propulsion (ANP)

Aircraft nuclear propulsion promises to provide radii of action which are unlimited when measured in terms of the dimensions of the earth. This would easily provide the 5500 miles radius required for intercontinental bombing of the U.S.S.R. from the U.S., or permit the bomber force to be based anywhere in the world, other considerations permitting.

Initially, the ANP Program was directed at a bomber propelled solely by nuclear energy. That goal was subsequently given up as being unlikely to lead to a useful vehicle within a reasonable time. The early program also suffered from considerable technical and organizational confusion which no longer exists, although some of the early stigma no doubt persists. The current program is mature, vigorous and well supported. The genuine and marked technical progress within the past few years has exceeded the predictions of many conservative observers.

The current approach is toward a bomber which would cruise subsonically on nuclear power, with chemical power augmentation for landing, take-off, and high speed-high altitude dash.

There are two approaches now being taken in the nuclear reactor-turbojet combination. One of these is the direct air-cycle in which heat for the engine is taken directly from the reactor by the air going through the engine; the other uses liquids to transfer the heat from the reactor to the air stream in the engine. The first air-cooled reactor is now under construction and a version of a liquid cooled reactor has been operated with encouraging results.

Some overall technical generalization can be stated:

a. In comparison to chemical power plants, the materials problem will be aggravated by the radiation flux in the reactor and by the fact that operating temperatures

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in the reactor need to be higher than in a chemical engine because of the temperature drop in the heat exchange between reactor and engine.

b. These power plants depend upon heat transfer of energy into the moving air stream, in contrast to chemical engines where energy is fed directly into the stream in the combustion chamber. As a result, special engine components are necessary and the high altitude performance may be inherently poorer.

c. Each of the reactor-turbojet combinations appears to pose unique aerodynamic and structural problems in any aircraft using these combinations. Consequently, prototype or operational aircraft must in all probability be designed around the specific reactor-turbojet combination.

While we cannot predict with any certainty the performance characteristics of the first generation of nuclear propelled aircraft, we do not expect it to have better speed or high altitude performance than conventional aircraft. On the other hand, it will have the one important characteristic of long range, even at low altitude.

The extended range will grant considerable independence of specific base and geographic location as well as flexibility in selection of routes and altitudes to and from enemy targets. It would also be possible to enhance the U.S. capability for attacking targets of opportunity deep in enemy territory. A number of other interesting uses have been visualized, such as for airborne carriers of fighters and bombers, and for general logistics. Our main interest is in the bomber application, where, in our opinion, a clear increase in offensive capabilities can and should eventually be realized by the use of nuclear power.

The story would not be complete without presenting some possible disadvantages of the nuclear propelled aircraft. It will no doubt be necessary to run the nuclear engine on the surface from time to time. Because the shield is not complete, this operation will require an area cleared of personnel, except for those in the aircraft, because of the high radiation. Portions of the power plant and airplane will become radioactive with operation, and there will be a dependence upon special handling and maintenance equipment at some bases for support of this type aircraft; this may result in some inflexibility of operation.

We conclude that:

1. There is a good probability of achieving a nuclear propelled aircraft in a militarily important and useful form.

2. The time required for the attainment of a nuclear aircraft capability depends both upon the solution of a number of vexing technical problems and upon the vigor with which the program is continuously sustained.

3. The achievement of nuclear powered bomber capability would result in a significant increase in the capability of the U.S. nuclear striking force.

4. The date of achieving a significant nuclear powered bomber capability is sufficiently uncertain that it would be wise to continue developing chemically powered bombers for the intercontinental mission.

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We recommend that:

1. The program directed toward development of aircraft-nuclear propulsion systems continue to receive strong support and that the program include a propulsion system for bombers.

Intercontinental Ballistic Missile

The technical problems involved in developing an intercontinental ballistic missile, while formidable, are considered within reach of solution. A development program is proceeding under high priority. When operational, such a missile will significantly increase the capability of the U.S. nuclear striking force.

The U.S. strategic bombers have exploited speed and altitude to thwart enemy defenses. An intercontinental ballistic missile, when available, will exploit these elements to a much greater extent; its speed while approaching its target will be so great (10,000 mph), and its altitude so high, that defensive measures against it will be exceedingly difficult. The time available for active defense measures would be so short that a complex and costly defense system would be required, assuming that a defensive system could indeed be developed. The time from launching to target would be so short that the U.S. could quickly get at the job of reducing the Soviet's capability to continue strikes against the U.S. The rate at which this could be accomplished would be determined by the launching rate, which would depend upon characteristics of the missile itself, and the number of launching sites as well as upon many operational factors.

In common with other missiles the intercontinental ballistic missile has a guidance problem. It is probable that the missile accuracy will be less than that obtained by manned bombers. The use of this missile depends upon knowing the accurate geographical location of the target whereas a bomber crew has the inherent ability to recognize the target somewhat independent of its location or motion. The bomber generally will be able to carry a larger yield weapon. For these reasons we believe there will be a continuing need for manned bombers even though the intercontinental ballistic missile would furnish an important increase in the capability of the U.S. nuclear striking force.

The intercontinental ballistic missile as now planned will have a range of about 5500 nautical miles, an accuracy at that range of several miles, will carry a warhead yielding a megaton or two, and have a flight time for 5500 n. mi. of about 30 minutes. It is expected to be 70-100 feet long and weigh somewhere between 200,000 lb. and 400,000 lb.

The development of such a missile requires the solution of a set of truly awesome technical problems. Its size alone is a problem; the atmosphere re-entry is a totally new problem; the firing of each test missile will probably represent an operation of great magnitude. A number of test firings will be required in the development of the missile. Good tracking and prediction equipment and techniques will be important for the testing program. (These same techniques are necessary elements of defense against ICBM.)

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As stated earlier, a development program is proceeding under high priority to solve these difficult technical problems, and we believe solutions are within reach. We have indicated reasons why such a missile would significantly increase the capabilities of the U.S. nuclear striking force. In the hands of the Soviets such a weapon would represent an even greater jump in capability, since it would to a considerable extent wipe out the present geographical advantage enjoyed by the U.S. With such a capability the Soviets could put pressure on much of the world outside the U.S., either by direct threat to them or by threat against the U.S. It, therefore, appears urgent to achieve this type of capability before the Soviets, in order to at least match threat with threat.

The present status of the program directed toward the development of an intercontinental ballistic missile is in our opinion satisfactory. The project is a going concern, it is being directed and carried out by competent organizations and it has a high priority. The schedules of future accomplishments in the program are optimistic, showing the first full scale test launching in late 1958. Following this there will be further development and test launchings, manufacture of small quantities, military suitability tests, full scale manufacture, military training as combat units and, in general, the entire shakedown required of a new system. Even though some of these steps can be done in parallel, we believe that planning should not count on having a militarily significant capability with the intercontinental ballistic missile before about 1965, although a small number could be operational before that date. This is said to point up the need and importance of vigorous support for this missile program so that the U.S. can achieve this capability at the earliest date.

We conclude that:

1. The achievement by the U.S. of an intercontinental ballistic missile capability would furnish an important increase in the capability of the U.S. nuclear striking force.
2. It is important that the U.S. have an intercontinental ballistic missile capability before the Soviets have a similar capability.
3. The technical problems involved in developing an intercontinental ballistic missile are sufficiently within reach of solution to justify the development program.
4. The schedule for the development program of the intercontinental ballistic missile, while optimistic, is possible of attainment, provided solutions are found for each technical problem without delay.
5. Significant military capability with the intercontinental ballistic missile is unlikely to be attained by the U.S. before 1965 although a small number may be operational before that date.
6. There will be a continuing need for manned bombers even after the achievement of a capability with the intercontinental ballistic missile.

We recommend that:

1. The development of an intercontinental ballistic missile (with about 5500 n. mi. range and megaton warhead) continue to receive the very substantial support necessary to complete it at the earliest possible date.

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Medium Range Ballistic Missile

In the previous section, we have discussed the importance of an intercontinental ballistic missile having a range of 5500 n. mi. A medium range missile would, of course, enjoy the same advantages over defenses as the 5500 n. mi. missile. With about 1500 n. mi. range it could cover a significant part of European USSR from advanced land bases and a significantly greater part of USSR if it were ship based. The proximity of the launching sites to the USSR would increase their vulnerability to attack.

In the hands of the Soviets, a missile of about 1500 n. mi. range could be nearly as important offensively as would an intercontinental missile. These missiles could be launched from the USSR and cover Europe. With launching sites in China and Eastern Siberia it would be possible to cover Alaska, Japan, Okinawa, and the Philippines. By launching similar medium range missiles from ships, the Soviets could cover most of the U.S.

We believe that the development of a medium range ballistic missile would be an easier development, more certain of success in a shorter time than that of the 5500 n. mi. missile. Thus the Soviets could achieve a medium range ballistic missile capability sooner than the U.S. could achieve an intercontinental ballistic missile capability. Therefore, it is important that the U.S. initiate a medium range ballistic missile program to increase the probability that the U.S. is first to achieve a ballistic missile capability.

We are aware that political considerations may place certain limitations upon the basing of nuclear striking forces upon foreign soil. These limitations do not apply to missiles based upon ships. It is probably more difficult to achieve a ship based system than a ground based system. However, the difference in difficulty between land and sea basing is considered minor in relation to the other problems in a ballistic missile system.

We conclude that:

1. It appears to be technically feasible to develop a ballistic missile of about 1500 n. mi. range with a megaton warhead for either land launching or ship launching.
2. The development of a ballistic missile of about 1500 n. mi. range should be easier, more certain, and faster than the development of a 5500 n. mi. ballistic missile.
3. The attainment of a strategic nuclear bombardment capability with a ballistic missile of about 1500 n. mi. range would increase the capability of the U.S. nuclear striking force.
4. Possession by the Soviets of a ground based 1500 n. mi. ballistic missile would constitute a serious threat to Western Europe; a ship based system would also threaten the continental U.S.
5. A land based system for the medium range ballistic missile would probably be easier to develop than a ship based system; however, ship basing probably would allow better coverage of Soviet Bloc targets and be free of political restraints.

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We recommend that:

1. There be developed a ballistic missile (with about 1500 n. mi. range and megaton warhead) for strategic bombardment; both land-basing and ship-basing should be considered.

4. GROUND VULNERABILITY OF STRIKING FORCE

Today the Strategic Air Command represents essentially the entire U.S. nuclear striking force. With large numbers of bombers concentrated on a small number of poorly defended bases, it is unacceptably vulnerable to even a small-scale surprise air attack. The Department of Defense, recognizing this, has various programs under way to reduce the ground vulnerability of the U.S. striking force.

There are many ways in which the ground vulnerability of the U.S. nuclear striking force can be reduced. These include: improvements in warning, reduction in reaction time to warning, reductions in the number of bombers at risk at each base, increased active defenses of the bases, and reduction in the physical vulnerability of the bases. All of these should receive proper attention.

Warning

Warning is most important for preventing the destruction of the Strategic Air Command by a surprise nuclear attack. This has been recognized by the Department of Defense and great effort properly is being put on improving the warning system.

Although strategic warning may be obtained from intelligence and may be properly interpreted and acted upon in time, history is not reassuring on this point and it would be imprudent to base plans on this source alone. However, as noted earlier the greater the geographical dispersion of the U.S. nuclear striking force or the larger the force the Soviets must commit to a surprise attack, the greater is the probability of obtaining strategic warning.

Our main reliance must be placed on tactical warning which is presently limited to detection by the perimeter radars. We have a maximum of two hours warning on some Strategic Air Command bases and a real possibility of no warning until the first bomb drops. Within two or three years tactical warning should be greatly improved through the introduction of distant early warning. We can then plan, at all bases, on a minimum of two hours warning of any air attack of substantial size.

Reaction to Warning

Of almost equal importance to warning is the reaction to it. The basic necessary reaction is bomber dispersal to the air within the warning time. However, if the bombers become airborne without the capability of going on to Soviet targets, base destruction would greatly reduce the immediate effectiveness of the Strategic Air Command. The desirable reaction is to be airborne toward target within the warning time, and thus achieve rapid retaliation. To achieve this objective adequate warning is needed coupled with base facilities and operational procedures necessary to permit reaction time to be less than warning time.

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Warnings will probably be of all shades from mere hints of air attack to the extreme of bombs exploding on the U.S. Consequently, the reaction of the Strategic Air Command will no doubt vary from mere standby to orders to attack the USSR. But at some level of warning the bombers must be airborne and within the warning time. With the bombers airborne there is additional time for interpreting the warning and for making the decision to attack the Russian homeland.

Base Requirements

Of the less than 30 bases available to the Strategic Air Command in the U.S., about three-quarters of them are presently used as heavy and medium bomber bases. Each of fifteen bases has two wings of heavy or medium bombers, or one heavy and one medium. Such crowding not only results in a large number of bombers at risk at each base, but also increases the time required to get bombers airborne were we attacked. The present plan of increasing the number of bases to 35 is necessary to care for scheduled new bombers and will not reduce the number of aircraft per base.

There are, within the Department of Defense, proposals for additional increases in the number of Strategic Air Command bases within the U.S. We understand that these proposals are aimed at matching reaction time to the expected warning time, and reducing the number of bombers at risk at each base. We did not study these proposals or the base structure and facilities required to accomplish these ends. We believe, however, more bases to be an operational necessity.

Availability of Nuclear Weapons

It has been recognized that bombs and bombers should be on the same bases. Two members of this Panel have been briefed, by special authorization, on the plans, present and projected, of storing and making available the stock of nuclear weapons. It is essential that these plans be carried through as promptly as possible.



Tanker Force

Since our tanker force is at present as essential to the intercontinental mission as the bombers themselves, it is necessary to plan for tankers and for their basing as carefully as we plan for the bombers. If we do not we will be dependent on the advanced bases for the first mission with all the uncertainties of vulnerability and political indecision that are associated with these bases. Aerial refueling has eliminated dependence on advanced bases for a first strike, but it has led to a dependence upon the availability of an adequate tanker force. This fact appears to be only partially reflected in current plans for the tanker force.

Seaplanes

In the future a considerable degree of dispersal and mobility might be achieved through the use of seaplanes. Recent studies show the possibility of designing seaplanes with performance characteristics comparable to those of land planes. Other studies have indicated that a seaplane striking force could use floating bases in protected water areas around Europe and Asia; with such bases medium bombers could cover most of the Soviet Bloc without aerial refueling and without dependence upon fixed foreign

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bases.. Further, the water basing would allow all of the other land masses of the world to be covered, should the need arise. The mobility of the floating seaplane bases imposes upon the enemy the task of locating and identifying them prior to attack. The advantages pointed out above make a seaplane bomber capability for the nuclear striking force appear sufficiently attractive that we conclude that the feasibility of such a seabased nuclear bomber force should be actively explored.

Emergency Measures

We have indicated means for future reductions in the ground vulnerability of the Strategic Air Command to surprise attack. None of these will be available during the next two or three years when warning is inadequate and the Soviets have some capability for neutralizing the U.S. nuclear striking force and destroying U.S. cities. There are emergency measures which could be taken during this period to decrease the ground vulnerability of the Strategic Air Command, which should be considered in relation to the immediacy of the threat. Some of these are:

- a. Additional bases for the Strategic Air Command could be built on an emergency basis in order to obtain them several years sooner than normal procedures would permit. Toward this end there would need to be a concentrated effort by the Congress, the Administration and the Department of Defense to make this a top priority program.
- b. There could be instituted for the Strategic Air Command an emergency dispersal program in which more airfields, including civilian, would be used, but very probably at the expense of the over-all operating effectiveness of the Strategic Air Command.
- c. More of the Strategic Air Command bases could be actively defended with local defenses. Since the gun and guided missile defenses now allocated or installed at important cities are all mobile, some could rapidly be located at bases of the Strategic Air Command. This plan requires the decision to defend the Strategic Air Command as against more defense for cities.

We conclude that:

1. Today the Strategic Air Command is the major U.S. nuclear striking force; it is essential that it be reasonably invulnerable to attack.
2. The Strategic Air Command is concentrated on so few bases that even a small-scale nuclear surprise attack could destroy the bulk of the U.S. nuclear striking force.
3. The ways in which the ground vulnerability of the Strategic Air Command can be reduced include: improvements in warning, reductions in reaction time, reductions in the number of bombers at risk at each base, increased active defenses of the bases, and reduction in the physical vulnerability of the bases.
4. Warning is most important for preventing the destruction of the Strategic Air Command by a surprise nuclear attack; its reaction to warning is of almost equal importance.

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5. Additional bases are necessary in order to permit the bombers of the Strategic Air Command to be airborne towards target within the warning interval as well as to limit to a reasonable number the bombers at risk at each base.

6. One serious delay in the reaction time of the Strategic Air Command will be eliminated when nuclear bombs are more immediately available.

7. At present tankers are as important as bombers to the intercontinental mission of the Strategic Air Command, unless it is to be dependent upon advanced bases.

8. In the future, seaplane bombers may have advantages which will make them an important part of the U.S. nuclear striking force.

9. During the next few years, when warning is a minimum, there are emergency measures which could be taken to decrease the ground vulnerability of the Strategic Air Command, which should be considered in relation to the immediacy of the threat.

We recommend that:

1. The Strategic Air Command be provided additional bases sufficient in numbers to permit its bombers to be airborne towards target within the warning interval, as well as to limit to a reasonable number the bombers at risk at each base.

2. The Department of Defense conduct further studies and experimentation to determine the feasibility of a seaplane nuclear bomber force.

5. SHORT-RANGE STRIKING FORCES

The availability of light weight thermonuclear weapons in quantity will give new significance to the striking power of small aircraft. Any light bomber, fighter bomber or attack aircraft capable of delivering megaton weapons has a tremendous destructive potential. While the small aircraft will be limited in range and will not be able to reach all of the Soviet targets as would the medium and heavy bombers, they, nevertheless would be able to reach a significant portion of the Soviet targets, even on an unrefueled basis.

The light bombers, fighter-bombers and attack aircraft as programmed for 1958 have the potential of carrying, on a single combined mission, about ten times the megaton load which could have been carried on a single mission in mid-1954 by the combined heavy and medium bombers of the Strategic Air Command. (The factor of ten is not an appraisal of the relative military worth of these two hypothetical missions.)

While this section presents a discussion of the short range striking forces, it must be emphasized that the availability of thermonuclear weapons in quantity will increase by a factor of about a hundred the mid-1954 megaton carrying capacity of the medium and heavy bombers. Thus the Strategic Air Command will continue to be the powerful concentration of nuclear striking power.

The short range forces, if equipped with megaton bombs and if deployed around the USSR, would be a force with which the Soviets would need to reckon in their planning for a surprise attack. The wide geographical dispersal of the short range forces would compound the Soviet problem of coordinating strikes in Europe, in the Pacific and in the continental U.S. By multiplying the number of targets, which the Soviets for

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their own safety would need to attack, the Soviet force required would be larger, thus increasing the difficulty of mounting a successful surprise attack.

Short range forces, to be an effective threat must be deployed near Soviet borders where they are subject to attack by even the short range Soviet bombers which exist in large numbers. The resulting ground vulnerability can be reduced, not only in the ways discussed for the Strategic Air Command, but also by achieving base mobility. Mobility introduces uncertainty of target locations in Soviet plans for attack. The carrier at sea gives an example of a short range force, all elements of which are mobile. While comparable mobility would be difficult to achieve in a land based force, improvements in mobility can be made. There are underway research and development programs aimed towards practical methods of achieving greater mobility for land based aircraft; these include: zero length launchers, mobile arresting gear, and vertical take-off and landing.

Political considerations may place certain limitations upon the basing of short range nuclear forces upon foreign soil. These limitations apply to land based aircraft which constitute most of the short range force. These limitations do not apply to carrier or sea based aircraft.

We conclude that:

1. The availability of lightweight thermonuclear bombs in quantity will give new significance to the striking power of small aircraft.
2. The presently-programmed light bomber, fighter-bomber and attack aircraft, if given a megaton striking capability, would be a force with which the Soviets must reckon when planning a surprise attack.
3. The ground vulnerability of short range striking forces can be reduced by achieving mobility of the forces.

We recommend that:

1. The new significance of the striking power of small aircraft, which would come with the availability of lightweight megaton bombs in quantity, be taken into account in future planning.

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PART IV
DEFENSE OF NORTH AMERICA



How improvements in our defensive measures can protect us against surprise attack and contribute to the prevention of war.

~~RESTRICTED DATA~~

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DEFENSE OF NORTH AMERICA¹

1. INTRODUCTION AND MAJOR CONCLUSIONS

Objectives of Defense

In our studies of defensive measures we have tried to recognize all major threats to the continental United States and to consider defense against them in the broadest possible terms.

Defense against these threats has two aims: to protect in the event of war and, by virtue of this protection, to discourage attack.

Pursuit of these aims is jointly shared with our offensive forces. Our striking forces must blunt attack at its source; defenses must protect our retaliatory power as well as our people and our cities. Together they provide over-all strength and a substantial deterrent to war.

In its role as a deterrent, the defense need not necessarily be capable of stopping all forms of attack completely, but must, in the enemy's view, make attack extremely hazardous. Faced by sure retaliation and by limits on his sustaining power he dare attack only with reasonable certainty of large initial success.

Problems of Defense

The requirements of defense are vast and complex. We must defend a huge area against a large, varied and changing threat of partly unknown nature. We must be prepared to do so at an instant's notice and with a degree of success beyond all previous demand. The tools are intricate and many of the problems are at the very limits of technology.

Unfortunately, assignment of the task does not fit naturally into the present organization of our military forces. Its various elements—distant warning and continental surveillance, interceptor forces and ground-based weapons, defense against submarines and destruction of their missiles—are shared among diverse groups from all three Services. Inevitably there are problems of responsibility, of command, and of the proper meshing of equipment.

The system now sketched out for continental defense is the largest integrated system ever conceived to perform a specific task. It is, unfortunately, not yet being planned as an integrated entity. There exists no agency with both the competence and the authority to do this planning. There is inadequate coordination between operating and development agencies. The development of specific weapons and equipments is often spread through a number of laboratories and contractors with insufficient attention to over-all system needs. The procurement and operational introduction of already-developed equipment is slow and cumbersome. Promptness and decisiveness are lost through wide dispersion of the decision-making process.

¹ In studying the defense of North America, the Panel has informed itself about the progress of Project Lamp Light, sponsored by the Departments of Navy and of the Air Force.

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In spite of all these problems, an important beginning toward an effective defense has been made by the military services and other agencies of government. Organizational improvements have been made. The creation of CONAD was a major advance and its growing effectiveness will greatly improve our defense. New and better weapons have been developed and procured. We have the beginnings of a continental radar net. Unfortunately, however, the nation was slow to recognize the need, the program was late in starting, and the system is as yet embryonic.

As a consequence of all these factors—the magnitude and complexity of the problem, the organizational readjustments required, and the lateness of our start—the United States is at present unacceptably vulnerable to surprise attack. Our military defenses are as yet numerically deficient and have serious qualitative weaknesses. These defenses could be avoided or overwhelmed and might not even be warned of an attack until the first bomb exploded. Under these circumstances our cities could suffer millions of casualties and crippling damage, and enough SAC bombers and bases could be destroyed to reduce drastically our ability to retaliate.

Many steps are being taken to improve this situation. A Distant Early Warning line is to be installed. Additions and improvements are being made or planned in the continental radar net to give better high and low altitude cover and to extend the system outward from our continental boundaries. New and improved weapons are being developed and procured. All of these steps we enthusiastically endorse. Even with these and other planned and programmed measures there will remain, however, great and continuing need for improvements to match and keep up with the increasing threat.

Some General Conclusions

The threats which exist now may continue for many years. They are primarily nuclear weapons carried by intercontinental aircraft, by mine-laying vessels and submarines, and by missiles launched from seaborne platforms. Refinements of the airborne carriers, and ultimately intercontinental ballistic missiles, must be expected in the future. We must also be alert to other still more obscure dangers—to clandestine introduction of nuclear bombs, to covert or windborne attack by biological agents.

We have considered the technical problems of defense against these threats. We have studied our present defenses and the programs to improve them. We have found great sources of strength and grave weaknesses and have examined measures for improvement. If our conclusions were to be put into a single sentence, it might be this:

Although technology is important, in the end our success at defending ourselves will depend upon the effort we put in and how well we organize that effort.

This generalization stands upon two others:

First, there is no unique perfect weapon or technical trick that is going to make defense an easy job. Against even the present threats we will need strategic intelligence, warning of—and surveillance of—a potential or approaching attack, the best of destructive weapons well deployed and efficiently brought to bear, protection of people by shelter and evacuation, and protection of recuperative strength

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by stockpiling and dispersion. There is no magic formula to simplify this list. We need every element and we need it in time.

Second, most of the basic technical problems raised by the threats of attack by manned bombers and from the sea have been solved; the rest seem solvable. It is the scale of our technical effort, and its planning and integration in detail, which need attention. Above all and throughout, we must strike a realistic balance between technical perfection and timeliness.

Granted solutions to the technical problems the question rises—Can we build *enough* defense and can we built it *fast* enough? The answer hinges on innumerable factors, many of an intangible nature. We have analyzed those within our competence, calculating some, and estimating others. We have concluded:

The nation can afford enough protection against the air and seaborne threats to create a serious obstacle to effective attack, an obstacle whose appreciation by the USSR would be a direct and forceful deterrent. To defend at this level demands an increased and balanced effort which must be matched to the increasing threat.

Our studies of the various aspects of defense have led us to the following conclusions of a more specific nature:

a. Adequate air defense requires effective early warning and surveillance and active defenses in depth. The system visualized and under construction by CONAD has these concepts.

b. It is imperative that an early warning system be completed as rapidly and as effectively as our ability and resources permit. The warning system must provide information in depth. It must detect potential attackers several hours from our boundaries; must give an unequivocal signal for action when attacking aircraft are still a few hundred miles away; and, in the later stages, must provide sufficiently detailed information to permit effective deployment of defensive forces.

c. In addition to numerical deficiencies, the present active air defense system suffers from serious high and low altitude gaps in the radar cover, inadequate interceptor capability at high altitudes, and grave weaknesses in all weapons at low altitudes.

d. Thermonuclear weapons demand strong active defenses and place a premium on destroying attackers long before they reach heavily populated areas where serious damage can result from a downed or jettisoned bomb; a defense which meets these challenges must include extensions seaward and northward, and eventually southward, several hundred miles beyond our continental boundaries. Realistic rules for identification and engagement must develop with the outward extension of the system.

e. Nuclear weapons are the most effective armament with which we can equip our air defense forces. They provide the most direct and reliable method of achieving the high kill probability against single aircraft that modern air defense demands, of creating a potent defense against saturation type attacks, and of actually destroying the enemy nuclear weapons. Recent studies have shown that



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the air-to-air atomic rocket can be made compatible with existing and programmed interceptors. The investment cost of fissionable material for nuclear warheads is a small fraction of the total cost of the air defense system. The radioactivity which would be added to the atmosphere by the large-scale use of nuclear defense warheads would be no more than that from a single large strategic weapon and would cause no dangerous fallout.

f. Nuclear missiles and mines transported by sea and delivered against our harbor and coastal belt could be important components of a surprise attack. Serious deficiencies exist in the present and programmed measures for defense against these threats. Our technological and economic resources are adequate to provide acceptable solutions, but traditional concepts of territorial waters and freedom of the seas must be amended to permit fully effective defensive controls.

g. An effective civil defense may be a major factor in national survival in the event of nuclear attack on this country; without effective civil defense, freedom of action on the part of the United States to adopt a firm peacetime foreign policy may be dangerously limited. Although the advent of thermonuclear weapons has radically increased the threat to our civil population and altered the protective measures required, a civil defense which would save millions of lives is technically and economically feasible.

h. In the event of atomic war, one of the most important elements in providing the requisite national resiliency will be the ability of the people to resume organized activity after the initial attack. We are concerned over the concentration of our essential civilian supporting industries in critical target areas and the lack of a positive national program designed to reduce this vulnerability.

The Threat of the Intercontinental Ballistic Missile

New and complex problems are raised by the threat of the intercontinental ballistic missile which may well face us in the 1960-70 decade. The enormous speed makes warning short at best, leaves little time for defensive or protective action and renders destructive measures extremely difficult. Nevertheless, we feel, the situation is not hopeless. As a result of our studies we have concluded:

a. Although the technical problems are extremely complex, the attainment of means for countering such missiles appears sufficiently promising to justify an expanded and accelerated program of research and experimentation. The recent formation of a special subcommittee of the Air Force Scientific Advisory Board is a significant first step toward the planning of such a program.

b. We believe it practicable to build a radar system providing approximately 15 minutes warning of the arrival of an ICBM, and giving a reasonably good localization of the expected target area. Such a system would be of great value to our retaliatory forces and in saving lives whether or not a successful defensive weapon system can be devised.

c. Attack by manned bombers will continue to be a threat long after the advent of intercontinental missiles.

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2. AIR WARNING

Required Warning System

Our study of defense against an attack by manned aircraft has convinced us that the most important single requirement is for an adequate and reliable early warning system.

A review of the needs for warning reveals that in order to prevent the destruction of a large portion of the U.S.-based nuclear striking forces, to insure that the regularly assigned air defense forces will be at full strength to meet an attack, and to allow time for implementation of non-military defense measures, it is imperative that the continental defense system provide at least two hours' warning of impending attack before enemy aircraft enter the combat zone. This amount of warning time is the minimum requirement; more warning would be extremely valuable, including strategic warning of the imminence of attack. In this discussion, however, we are concerned with tactical warning, i.e., warning obtained after the launching of an attack.

The minimum warning requirement of two hours could be satisfied by a single early warning line cutting across all possible bomber approach routes. It is clearly apparent, however, that a single line would not constitute a sufficient warning system. Additional components providing warning in depth certainly are required because the value of warning is measured in terms of the nature and certainty of information obtained as well as by the amount of warning. Ideally, of course, a warning system would be able to spot and identify an attack at the instant of launching and keep each aircraft under continuous surveillance until control is passed to tracking radars in the combat zone. Since this degree of warning is not feasible—although at some time in the future it may be—the warning system must be planned to provide as much information as possible taking into account practical geographical, technical and operational constraints.

A warning system which seems to be reasonably sufficient for the immediate future is one composed basically of two lines; an outer warning line to satisfy the minimum warning requirement mentioned above and an inner warning or "action" line about 500 to 700 miles out from perimeter targets. The outer line would give the alert of possible attack and provide some information on the characteristics and composition of the bomber force; the inner line would give an unmistakable signal of actual attack while the enemy forces were still far enough from the combat zone to permit interceptors to engage them as far away from the defense perimeter as the contiguous radar cover and the range of the interceptors will permit.

One reason for placing the outer warning line as far out as feasible is to force the enemy to carry out refueling operations on our side of the line. If this can be achieved, we believe that eventually it should be possible to harass and destroy enemy bombers during this critical portion of their flight.

The location and function of the inner warning line would be expected to change as the perimeter of the combat zone is pushed outwards. As stated earlier, its initial function is to furnish unequivocal warning and its location is set with respect to the

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planned depth of radar cover for tracking and interceptor control. As time goes on and as the depth of solid radar cover is extended further seaward and northward, the inner warning line may furnish part of this cover. It still would function as well to provide the "action" signal of attack.

In order to deploy interceptor forces most effectively, it is essential that the warning of attack be supplemented by increasingly more accurate information on the strength, location and disposition of the attacking forces as they come closer to the combat zone. The system of two fixed lines described above only partially fulfills this requirement. Close in, the information will be provided by the radar cover of the combat zone; as a general rule of thumb, this radar cover should be twice the depth of the fighting range. It is also desirable, we believe, to make use of individual high-power radar stations or fragmentary radar cover in selected regions, and of AEW "trailer" planes at appropriate locations along or near the outer warning line, in order to provide additional surveillance.

Bear Island and Spitzbergen are examples of areas where large radars could be usefully located. These islands, owned by Norway, would be appropriate sites for "navigation" radars to assist commercial and military transpolar flights. The U.S. might well subsidize such radars, getting, in return, information on all air traffic in the regions.

Bases for AEW "trailer" planes might be Iceland, the United Kingdom, Kodiak and Hawaii. These planes, called into action by the warning line, would trail overwater flights of suspicious aircraft, keeping the defense system continually informed on the position of the strike or "spoof." In addition, these planes could patrol likely overwater refueling areas at irregular intervals. When clutter-rejection circuits for AEW radars become sufficiently effective, the trailer planes could also be used over land to trail flights between the outer line and the inner line or the combat zone.

Current Status of Implementation

The warning system described above is partially programmed and installation of some components will begin this year. The programs call for a line of scanning radars across northern Canada and Alaska with seaward extensions (AEW planes and radar picket ships) from Newfoundland to the Azores in the Atlantic and from Kodiak to Hawaii in the Pacific, and an extension of the contiguous radar cover of the combat zone seaward a distance of about 300 miles from both coasts. Further, the Canadian Government is planning to install a "fence"-type line, supplemented in places by scanning radars, across mid-Canada at about 54° latitude.

We enthusiastically endorse these programs and urge that they be fully implemented as rapidly and effectively as possible. We think they can be brought to completion within two years unless unforeseen logistic difficulties arise. Acceptable detection and communication equipments for the lines are obtainable; delays for the development of better equipments would not, in general, be advisable. Of course, as time goes on, advantage should be taken of new and improved equipments as they become available.

The northern Canada or DEW line, with its seaward extensions, generally satisfies the minimum requirements for an outer warning line. The amount of warning obtain-

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able is somewhat deficient on the eastern approach, however, and we endorse the suggestion by CONAD that the overland portion terminate in Greenland, with the seaway extending from southern Greenland to the Azores.

The mid-Canada line would form the overland segment of the required inner or "action" line. Current programs do not include provision for the overwater portions of the "action" line. While the extension of radar cover to 300 miles offshore is absolutely essential for controlling interceptions, it does not go far enough to furnish the "action" warning. Unless this cover is pushed out about as far again (another 300 miles), extensions of the mid-Canada line will be required from Newfoundland to Bermuda in the Atlantic and at a comparable location off the Pacific Coast. These lines are additional to the planned seaward extensions previously mentioned; they must be provided to complete the "action" line.

Possible Additions or Changes to Programmed Warning System

In opening this discussion, we point out that Project Lamp Light, looking well into the future, is investigating in detail the over-all warning problem, locations and techniques for obtaining warning. Although we have kept in fairly close touch with the work of Project Lamp Light, and are aware of no major differences in thinking, we have not had time to examine all of that group's proposals in detail. We urge that close attention be given to the findings of Project Lamp Light as they pertain to the suggestions made here.

As mentioned earlier, we endorse the suggestion by CONAD that the eastern junction of the land-based outer warning line and its overwater extension be made in Greenland. This change in location seems essential to give adequate warning to the northeast heartland of the United States and Canada.

The need for overwater extensions of the "action" warning line has also been emphasized in the preceding discussion.

Further, we made some comments about the desirability of utilizing large radars in a few remote locations and AEW "trailer" aircraft to obtain more warning and flight path information on suspicious aircraft. We would add here our belief that both the intelligence and defense functions would benefit from the operation of small radar and passive listening posts located on the polar ice cap and wherever sites can be obtained near the periphery of Soviet territory. (This type of intelligence-warning activity is discussed in some detail in Part V.)

Lastly, we suggest that further consideration be given to a seaward extension of the outer warning line which would go from Greenland to Iceland to the Faroes and thence to Norway or the United Kingdom or both. The decision on location of the most easterly leg obviously should be made in collaboration with SHAPE. This line would have the advantage of connecting to the future NATO warning system. It appears to be an essential part of the warning system for the NATO countries as well. This line offers the technical advantage that the radars could be almost entirely land-based.

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The principal objection raised with respect to the Greenland to Faroes line is that it would be easy to "spoof." While it undoubtedly would be easier to spoof than the Greenland to Azores line, at no location is the outer line immune to spoofing. Our conclusion with regard to the spoofing problem is that it cannot be circumvented anyway, and that it should be treated for what it is—a real manifestation of enemy activity furnishing information which our offensive and defensive forces can make use of in practicing their missions. Moreover, as experience is gained with AEW operations, we are convinced that spoofing aircraft can readily be made to "show their hand."

Technical Problems in Obtaining Warning

Detection Radars.—Equipments in hand for use in the early warning lines, both ground and airborne, are reasonably satisfactory although far from perfect. The deficiencies that exist are not serious enough to delay the implementation of the lines. Improvements should be vigorously sought, and taken advantage of as quickly as they are realized in practical form. Once the lines are established, modifications or replacement of detection equipments which will enhance the value of the lines should be continually programmed.

Three technical improvements in detection radars are needed to obtain the most effective results from warning systems. These are:

- (a) Ground-based radars need more power and better high-altitude coverage.
- (b) Airborne search (AEW) radars need better means for rejecting clutter due to echoes from the sea.
- (c) Airborne search (AEW) radars need techniques for distinguishing aircraft moving relative to the ground over which both planes are flying. This is the so-called AMTI problem.

Development programs for attaining (a) and (b) are already well advanced; little progress is being made on (c).

A new ground-based warning radar, the Sentinel, has now reached the stage for prototype engineering. The computed vertical coverage of this set on a B-47 size target extends upwards to 140,000 feet; range on the same target is about 150 miles. It incorporates the latest techniques for automatic alerting and functions as a dual-channel equipment to insure continuous high reliability. We are informed that production of the Sentinel could begin in mid-1956. Ground-based radars under development for other applications, including the UHF long-range GCI set, may also have use in warning systems.

A UHF modification of the standard APS-20 AEW radar has been tested which substantially reduces the interference from sea clutter. We are informed that production prototypes of the modification kit will be available within a few months, so presumably production could begin late this year. The re-equipping of WV-2 or RC-121D AEW aircraft with these kits, as required, appears to be a relatively simple matter since much of the present radar installation would be retained. We believe this radar program should be given the maximum possible support since it promises

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very significant advantages both for aircraft used in the overwater warning lines and for "trailer" aircraft.

Unless the AMTI problem can be solved, effective use of AEW planes over land will perforce be extremely difficult if not impossible. At this time, operational concepts relying upon the use of AEW planes for warning, trailing or control of interceptions over land must be considered largely wishful thinking. Despite the fact that the AMTI problem has been present since radar was invented, it is our feeling that it has not received nearly enough basic research and experimentation. We do not think it unsolvable, but we doubt that it will be solved without an increased new and ingenious effort.

Communications.—Based on the tests of Project CORRODE and on experience with various types of communication circuits in the regions of interest, the communications requirements for the land-based portions of the warning system can be readily satisfied using existing equipments and well-proven techniques. There are enough different transmission methods, including VLF, HF, UHF tropospheric scatter, VHF ionospheric scatter, and wire, to assure reliable communications under any likely natural atmospheric conditions and to minimize the threat from jamming. This is not to say that the jamming problem can be ignored, for it could be serious indeed, but we think it is entirely manageable if the communications system is planned and operated with care.

We have not been able to examine the communication problems of overwater lines or of AEW planes operating independently of the lines. It is our opinion, based on what we have learned from briefings and from informal discussions with members of Project Lamp Light, that communications, air-to-air and air-to-ship, in a barrier line have been reasonably well tested and present no serious technical difficulties at the distances involved. Present means of ship-to-shore communications likewise are considered to be of sufficient reliability for handling warning information although the capacity is quite limited. An AEW plane operating independently will have the most difficult communication problem; the severity of the problem will depend in part on where the plane is flying. While this problem requires special attention, it is not expected to be a limiting one on the use of trailer aircraft.

Conclusions

1. To insure that defensive forces will be in readiness, that U.S.-based striking forces can be dispatched or deployed, and that non-military defense measures can be activated, requires at least two hours of warning of impending attack by manned bombers. At present, the defense system cannot provide this amount of warning.

2. It is imperative that an effective warning system be installed as rapidly as possible. The system should comprise the following basic components:

- a. An outer warning or "alerting" line.
- b. An inner or "action" line.
- c. AEW patrols and ground-based radar and passive listening stations in selected locations.

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3. The most critical component of the warning system is the outer line. In order to protect the U.S.-based striking forces, it must not be possible for the enemy to fly around the ends of the line. The inner line is only slightly less important because it must provide the unmistakable signal of attack on which SAC and CONAD will base their decisions for action.

4. Unless satisfactory AMTI techniques can be developed, the use of AEW planes over land, no matter how desirable, will be severely limited and should not be depended upon.

Recommendations

1. We recommend provision of an early warning system by (see Figure IV-I):
 - a. Installation of the programmed Distant Early Warning (DEW) line, including seaward portions, without delay for technical or geographic refinements.
 - b. Provision for a second "action" line approximately 500 to 700 miles out from the perimeter of continental U.S., either by extension of the contiguous radar cover or by installation of an additional radar line.
2. We recommend further development of the warning system by:
 - a. Early extension of the north-Canada line to Greenland and completion to the Azores by shifting the northern terminus of the overwater line from Newfoundland to Greenland, in accordance with the suggestion of CONAD.
 - b. Installation of a line joining the DEW line on Greenland (a above) and extending via Iceland and the Faroes to join the future NATO warning system at some point recommended by SHAPE. Long-range, land-based radars should be used wherever possible; they should be installed as soon as feasible, regardless of when the other parts of the line can become operational, since by themselves they could give satisfactory cover except at low altitude midway between stations.
 - c. Consideration of ultimate replacement of the Alaska-Hawaii line by a system of fixed radars along the Aleutians plus an overwater line to Midway. Such a system would increase initial warning and reduce the overwater link.
 - d. Determination of the effectiveness of AEW planes in trailing unknown aircraft crossing the DEW line, as a step toward developing a distant surveillance capability.¹
3. We recommend continuing, vigorous development of ground and airborne radar and communication equipments and techniques to enhance the effectiveness of early warning systems, and a dynamic program to take advantage of significant improvements as quickly as they are realized in practical form. As part of this activity, we recommend intensifying the effort to develop AMTI for AEW radars. (See also the Recommendations on pages 109-110.)

¹Project Lamp Light is studying the benefits to be derived from a "general surveillance" system, employing radars and suitable communications equipment placed on board friendly merchant ships and at inhabited locations in north Canada. Although time has prevented our studying this possibility in detail, we believe it sufficiently meritorious to warrant serious consideration.

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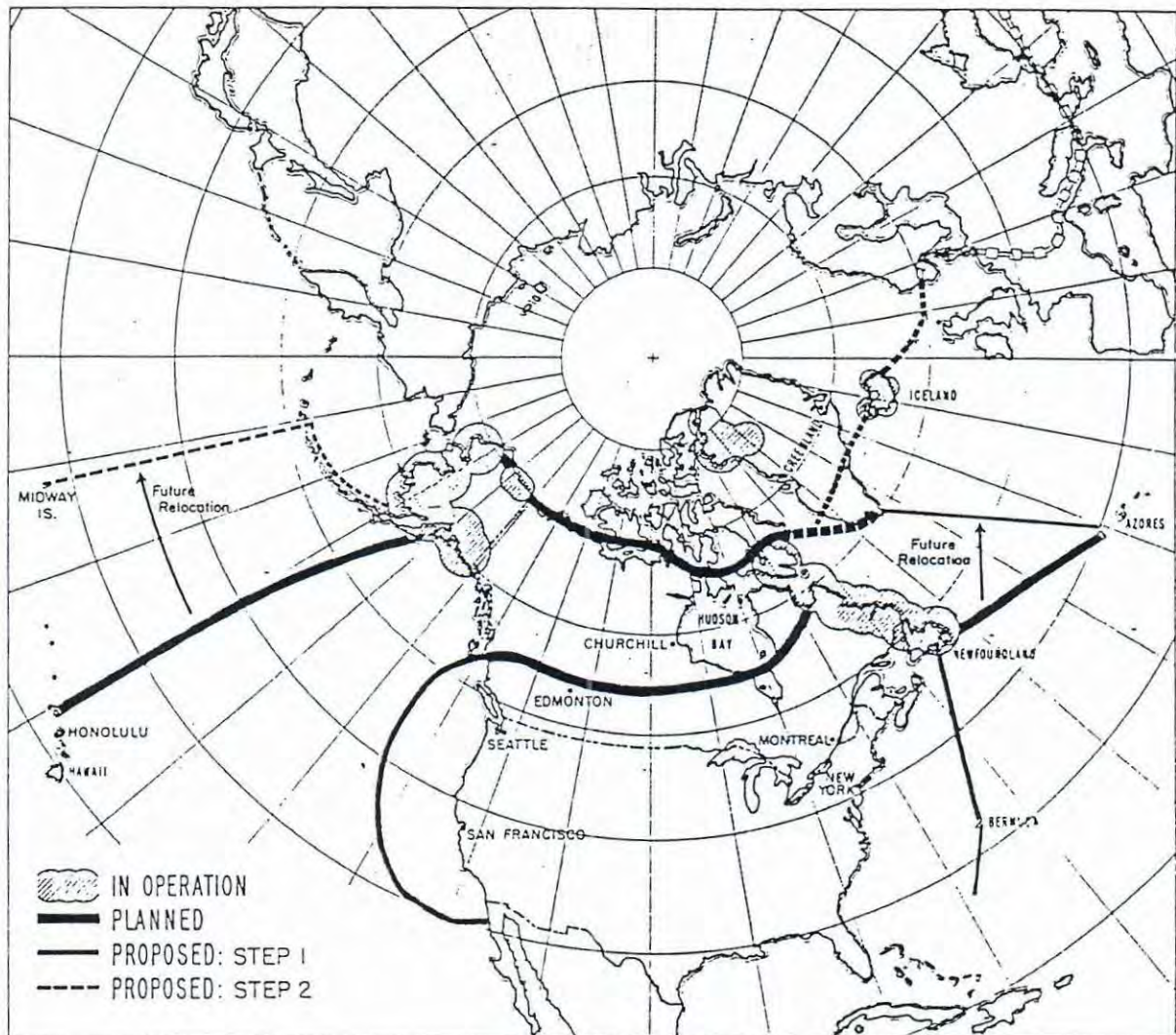


FIGURE IV-1
PROPOSED WARNING SYSTEM

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3. DEFENSE OF THE CONTINENTAL UNITED STATES AGAINST MANNED BOMBERS

General Conclusions

The aim of active defense is to destroy the enemy before he accomplishes his mission. Air defense encounters four complications in implementing this aim:

(a) Present defensive weapons meet difficulties at the extremes of high and low altitude where bombers can fly.

(b) The attacker, moving at high speed with the freedom to concentrate forces, can complete his mission before more than a certain fraction of the total defensive force can be brought against him.

(c) In a thermonuclear war, the defense needs a true superiority of weapons mustered at the point of contact to insure that only a few attackers finally escape.

(d) The essential electromagnetic aids to air defense—radio and radar—are targets for electronic jamming and destructive attack.

In the defense against manned bombers these factors are complications, not ineradicable weaknesses.

They do result in serious complications. To meet them demands technical and military effort on a scale and at a rate not yet achieved. In the last analysis we are in a race, a race which we have a good chance to win, and a race from which we dare not withdraw.

To state these conclusions more fully:

a. There are now no technical obstacles to designing a defense system which can meet bombers at the highest altitudes at which they can fly. There are promising ways to extend the upward reach of our present defensive forces.

b. To get a defense at low altitudes quantitatively comparable to that which is now possible at higher altitudes demands a practical solution of one important technical problem: the elimination of ground return in airborne and ground-based radars.

c. The problem posed to the defense by the attacker's speed, unpredictable choice of route, and tremendous potential lethality, is a quantitative one. It is solved by having *enough* defense. With an adequate warning system, a balanced and diversified force skillfully deployed, organized, and trained, and with reliable weapons and gear, the total force needed is not overwhelming: to build and maintain a defense force costs about as much as to build and maintain the bomber force which it defends against.

d. Warning, defense in depth, and the use of highly effective weapons, are the factors which can contribute most to the efficiency of a defensive force. Beyond these, efficiency is gained by meticulous attention to detail.

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e. The obverse to these last conclusions must be added: to get a defense of the efficiency suggested as possible demands that all elements of the force be simultaneously at a peak of effectiveness. A failure of warning, and individually small degradations in each of many operational factors, can easily increase the total defensive force needed by a factor of ten.

f. The problem posed by the vulnerability of radios and radars to counter-measures is largely quantitative. It is solved by ingenuity, care, duplication, and diversity. It is not now getting the attention it deserves. Whether the effort we can devote to it in the time available will win the race is the source of most doubt about the technical outcome of that race.

g. To solve in time the manifold problems implicit in the conclusions just listed takes a major engineering program in development, design, and procurement. To keep such a program moving, balanced in detail, and alert to technical innovations on either side, is a management task which probably exceeds the capacity of the present structure available to air defense. Solution of this management problem may be as difficult as that of any of the technical problems here considered.

The Air Defense System

Introduction.—Basically, the air defense system of the continent comprises a means for detecting and identifying aircraft flying over the United States, southern Canada, and nearby waters, means for recording and displaying the current positions (or "tracks") of those aircraft considered important, and means for directing killing weapons against those identified as hostile. The system divides roughly into two major functional components: (a) the weapons themselves, and (b) the ground environment. It is the latter system which provides the data upon which the weapons are assigned and dispatched.

The Weapon System.—The weapon system absorbs most of the cost of air defense. The weapons divide organizationally, and to some extent technically, into the ground-based weapons and the airborne weapons. At the present time, the ground-based weapon system comprises 49 battalions of 90 mm. and 120 mm. guns, 8 battalions of 75 mm. rapid fire Skysweeper guns, and 11 battalions of Nike guided missiles. The system is converting to a major dependence upon the guided missile; the guns will, however, continue in service, being manned by National Guard units.

The essential characteristic of present ground-based weapons is their short range. Because they must be fired at a predicted point of impact, guns are not effective beyond one or two miles; they can, however, deny the enemy easy access to critical targets. The Nike missile can engage targets out to twenty-five miles of range, at altitudes between 2,000 and 60,000 feet; it is steered all the way to impact.

Optimally employed, the total ground-based weapon system can now engage about 250 targets at a time. At very best, it might kill perhaps at a rate of 10 to 15 targets per minute. Such an efficient employment would occur only if the enemy foolishly

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chose to disperse his attacks against all targets simultaneously, and at medium altitudes.

The development of future ground-based weapons is centered around the guided missile; the aim is to produce missiles with ranges of 100 to 200 miles.

Longer ranges are provided by the airborne and air-launched weapons system. The backbone of this system is the mobile and maneuverable launching site: the interceptor aircraft. Historically, interceptors were first armed with machine guns or light cannon; those presently assigned to air defense forces are armed with rockets fired in clusters and detonating upon contact. Conversion to guided missiles is planned, but predicted fire will continue to be important for several years. An air-to-air rocket with nuclear warhead, Ding Dong, is under consideration. Table I describes the present interceptor forces of the air defense system, and their armament.

TABLE IV-1
INTERCEPTORS IN THE AIR DEFENSE SYSTEM

Type	F94C	F89D	F86D
No. of squadrons*	10	7	43
Combat speed, knots	481 kt.	459 kt.	524 kt.
“ “ , Mach	.84 M	.80 M	.91 M
Combat radius	347 n.m.	377 n.m.	332 n.m.
Effective ceiling**	45,200 ft.	38,600 ft.	46,400 ft.
Armament type	2.75" Folding fin aircraft rocket		
Armament load	48	104	24

* 25 A/C per squadron

** 1.5 G turn at combat weight and without loss of altitude.

This table does not list Canadian forces.

Of the 1,500 aircraft which are listed, about 150 are continuously in alert status (available in two to four minutes). Recent experience has been that a maximum number varying between 400 and 600 can be made ready for battle over a three-hour period. Optimally employed within these limits, they could engage 400 to 600 bombers in the first two hours. Neither this firing rate, nor that quoted for the ground-based system, gives a realistic picture of the degree of employment which would actually occur when the enemy exercises the option of concentrating his attack.

In addition to the 1,500 interceptors listed in Table IV-1, there are large numbers of Navy, Tactical Air Force, National Guard, and Air Force training aircraft some fraction of which can be mobilized for defense when there is several hours' warning of attack. Of these augmentation forces, several hundred of the Navy craft are, like the interceptors listed in Table IV-1, equipped with fire control (AI) radars and operate independently of visibility and weather. The rest depend upon optical sights and can be effective only in daylight.

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The Ground Environment.—Functionally, the ground environment of the air defense system must keep track of aircraft in the air, identify them, assess their threat, assign weapons to those identified as hostile, and guide (or "vector") manned interceptors to attack and back to base.

The data for the ground environment system derives from about 110 large scanning radars and a larger and growing number of auxiliary radars. These are deployed with considerable duplication of coverage (for reliability and continuity of service) over the populated and peripheral areas of the United States and Canada. Equipment for communicating and displaying data, and some computing aids, assist a complex human organization in processing and comprehending these data and acting upon them.

It is expected that in the ground environment system of the future more and more of the routine processing and transferring operations now done by people will be done by automatic equipment. By about 1960 a system will have evolved in which only critical decisions, and monitoring functions, are left to human beings. The basic features of this SAGE (Semi-Automatic Ground Environment) system are well described in the document "Operational Plan, Semi-Automatic Ground Environment System for Air Defense" (SECRET, draft dated 21 September 1954, Hq. ADC, Colorado Springs).

In the absence of a more remote warning system, it is through surveillance by the radar net that the first indication of an air attack will be received. All radar echoes look very much alike; the source of any given echo must be identified by inference. The basic problem is to know enough in advance about aircraft movements, and to tighten identification procedures at points of entry to the point where there are normally very few unidentifiable aircraft under surveillance. Then small or incipient raids can be recognized by an abnormal increase in the number of these "unidentifiables," before any aircraft are specifically identified as hostile.

Once it is recognized or believed that a raid is in progress, the ground environment must also assume the task of assigning weapons and controlling interceptors. Control is accomplished by assembling data on the current movements of an interceptor and its assigned target and computing steering orders which are transmitted by radio to the pilot of the interceptor. A second stage of radar enters the process as contact nears and the interceptor's radar seeks the target. Once the target is found, the fire control system directs the plane on a firing run. If an air-to-air guided missile is used, a third stage of seeking, that by the missile itself using radar or infrared, must be successful before a kill results.

Reliability.—The sketch drawn is of a large and complicated air defense system whose successful functioning depends upon the proper operation, simultaneously, of many interrelated technical and human components. The sheer intricacy of the system and the interdependences of its functional parts are important features; it is because of them that surprisingly stringent requirements must be met by each component individually.

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The Amount and Efficiency of Defense

The Force Needed.—The number of weapons needed in the total defensive force to be sure of killing any particular bomber before it completes its mission is generally very large, to account for the following factors:

A. Even the best of weapons are not perfect, so that repeated tries, rounds, or passes may be needed before a kill results.

B. If there is not time to assess the result of a first try before committing a second, "insurance" weapons must be dispatched in the first pass.

C. Further insurance weapons are needed if the bomber is in a formation which confuses the weapon assignment.

D. In a short battle, and because of threats elsewhere, only a fraction of the nation's whole ready force can actually be mobilized at a given point.

E. Only a fraction of the force in being, the exact fraction depending on the state of warning, is ready at any given time.

F. Only a fraction of the weapons called into battle actually get there because of gross failures of men and equipment.

One can express these effects by a simple formula:

$$(\text{Force needed}) = (\text{Attack expected}) \times A \times B \times C \times D \times E \times F$$

Here each factor, A, B, C, D, E, F, is a number, larger than 1, accounting for the correspondingly labeled effect. Few of these factors are known precisely for any given system. They all depend in exact value upon the conditions of battle. Table IV-2 suggests what appear from experiments, estimates, and map exercises to be reasonable upper and lower limits for them; conditions under which these possible extremes can arise are sketched.

This crude formula refers tacitly to a highly concentrated attack. The defense can handle several such attacks at the same time if they are separated geographically; more generally, as an attack of given size becomes less concentrated, the defense becomes more efficient because of the improved availability of defense weapons (Factor D).

Reliability and Probability of Kill.—With some exceptions soon to be noted, factors A ("firing errors") and F ("unreliability") refer specifically to the weapon system rather than to the tactical situation. The quantity $1/A$ is usually called the "probability of kill" of the weapon system. While it is clearly desirable to have a weapon with a high probability of kill (low value of A), and later discussion will emphasize this, it is important to recognize with respect to A and F that it is the product AF which is of final interest. If an improvement in A is achieved at too great expense in unreliability, that is, with too great an increase in F, the net effect may be a loss to the system.

The principal reason this Panel has recommended so strongly the use of atomic weapons in air defense is that we feel that they will improve *both* A (by their direct

TABLE IV-2

FACTORS AFFECTING THE EFFICIENCY OF DEFENSIVE FORCE

Factor	Cause	Practical Limits and Typical Conditions for Attainment			
		Upper	Condition	Lower	Condition
A	Firing errors: ballistic, guidance, fire control, fuzing	4	present air-to-air rockets, Nike	1.2	atomic rocket, Nike B
B*	No time to assess kill before committing another weapon	4	A=4 and time for only one firing pass before bomb release line	1.5	A=1.2 and time for at least two firing passes before bomb release line
C*	Over-commitment against incompletely resolved formations, or lack of coordination among firing units	3	very close formations	1	good coordination and formations resolvable by ground radar, or by probing and reconnaissance
D*	Impossibility of concentrating whole force at one point	5 to 20	if all weapons have short range or if there is no information to guide mobilizing of long-range weapons	3	defense of N.E. U.S.A. with 300-500 miles of radar cover outside periphery and medium range interceptors
E	Unreadiness	10	at peripheral targets without warning,	1.5	ultimate aim of present system with two hours of warning
		3 to 4	as national average in present system		
F	Unreliability, or "operational degradation"	4	present system	1.5	a triumph of morale and engineering

*Value decreases when defense is very weak. When there is an excess of targets, weapons may always be used efficiently.



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effectiveness) and F (by virtue of the fact that they remain effective even with simple fuzing and fire control).

The unreliability factor F depends upon the state of training of personnel, and the effectiveness of maintenance procedures, throughout the whole ground environment and weapon system. It is also influenced by the enemy's use of evasive and defensive tactics and countermeasures.

The factor E ("unreadiness") is also strongly influenced by the state of maintenance in the force. Currently, only about one-half to one-third of the interceptor force is flyable even after three hours' preparation, simply because of the difficulty of maintaining somewhat marginal equipment with the present level of manning.

Warning and Defense in Depth.—Three related themes are introduced in earlier parts of this Report: (i) provide warning, (ii) get data in depth, and (iii) move the battle out. Table IV-2 helps show in a quantitative way the importance of these elements to active air defense. It is useful here to consider them in an order reversed from that just given.

(a) The bomb release line:

First, there are two very important reasons for moving the battle out which do not appear directly in Table IV-2. One is the fact that large thermonuclear bombs are a hazard in populated areas even if not dropped exactly according to an attacker's plan. We must assume that bombs will be fuzed to burst if downed or jettisoned, and that bombers can be diverted to alternate targets. To destroy the enemy before he reaches a useful, if not ultimate, bomb release line, we must then strike him before he gets over our populated regions.

The second prime reason for doing battle outside the populated regions is that the defense is then freed for unrestricted use of nuclear weapons. This Panel has recommended use of Ding Dong¹ and the nuclear-armed Nike B wherever needed, but the desirability of exploiting their effectiveness before the battle reaches our shores is obvious. Furthermore, the potential of larger yield defense weapons
..... particularly against attacks at low altitude, cannot be realized except at sea or over waste land.

(b) Depth beyond that:

These seem to us to be compelling reasons for wishing to destroy as much as possible of the enemy's force before it reaches some peripheral line, for example, a contour of constant population density. Granting this as the aim of active defense, Table IV-2 shows the quantitative advantages of a battle in depth outside that line.

Basically, a defense in depth reduces the cost of insurance by keeping most mistakes from being fatal. If, for example, an enemy force is to be destroyed by a single sweep of interceptors, enough weapons must be individually assigned against each bomber to insure that it will not escape due to failures of weapons or equipment. For such a situation the factor B ("over-kill") may be 4 or more, and C ("over-commitment") may also be large. On the other hand, if there is time for probing,

¹ Air-to-air rocket with nuclear warhead.

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and time to reassign weapons against bombers not caught by the earliest passes, commitment can be more intelligent and weapons may be used more effectively to get the same total kill.

Table IV-2 is too condensed to make it fully clear, but enough repeated firing passes with kill assessment after each, that is, enough depth of battle, can reduce the over-kill and over-commitment losses and make the product BC as near to unity as desired. Unless the weapons used have reasonable effectiveness, however, astronomical numbers of firing passes are needed. In other words, though insurance is cheap when mistakes are not fatal, it is even cheaper when there are fewer mistakes. There is no substitute for effective weapons efficiently used.

(c) Data in depth:

Since all information about an approaching attack may be useful in assessing the attack and committing weapons against it, the importance of data in depth appears first in factor C (over-commitment). However, the most important quantitative effect of data in depth is exhibited in factor D ("geographical concentration"). Long-range weapons provide a potential defense at every point which they can reach from their bases. This potential can be realized at a particular point, however, only if there is time to marshal the forces there after it has become certain that the attack will be met there. This means that the defense battle cannot begin in force until the attacker has been under some kind of surveillance for the duration of the defender's flight to meet him, plus the time used for decisions and getting under way. Since modern bombers travel at speeds comparable to the cruising speeds of interceptors, this means that before the battle begins the attacker passes through a surveillance zone whose depth is comparable to the distance travelled by the first defenders to engage him.

If the full potential of long-range defense forces is to be realized, the battle zone must be surrounded by a surveillance zone whose depth approximates the range of the defending interceptors. The data provided in this zone must be adequate to give a track on each raid; if there is not adequate depth of battle after the first engagement, details of raid size and composition are also needed. Also, all available long-range forces cannot be shifted to a particular attack unless there is clear evidence from the data zone that some forces will not soon be needed elsewhere.

(d) Warning:

The value of warning appears in the "unreadiness" factor E in Table IV-2. Because of the difficulty of keeping personnel continuously ready, at present only about one-tenth of the air defense interceptors, and no local defense forces, are available within five minutes after an alert is sounded. The weapons which are not instantly available are themselves in varying degrees of unreadiness; during the first two to three hours following an alert, the practical limit of manning and readiness can be reached.

It is unrealistic to expect that all elements of the defense forces will be needed within five minutes of the enemy's first penetration of contiguous cover. Nevertheless, most of our important targets are peripheral. To provide them with two to three hours of warning, rather than the few minutes they now have, will improve our active

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defenses by at least as much as a three- or four-fold increase in total force. This effect of warning is of course in addition to its contribution to passive defenses.

The present dramatic impact of warning on the effective size of the defense force will diminish as the data and battle zones extend, but the importance of warning to passive defenses, to clearing the air of civil traffic, and to putting all elements into alert condition will never diminish.

Cost of Defense.—The crude relation already enunciated, that

$$(\text{Force needed}) = (\text{Attack expected}) \times A \times B \times C \times D \times E \times F,$$

can be used to make a rough estimate of the cost of an effective defense system.

First, examination of Table IV-2 suggests that a well-integrated, well-deployed, and well-trained defense force, equipped throughout with atomic weapons, could be expected to achieve a value of 15 to 20 for the product $A \times B \times C \times D \times E \times F$.

Second, let us remember that the enemy's bomber force has commitment problems, suffers operational degradations not unlike the defense's, and cannot be perfectly coordinated. Perhaps $\frac{1}{3}$ to $\frac{1}{2}$ of his total force of bombers is the most he is likely to be able or willing to bring in as a single highly concentrated raid. For applying the formula, this is the size of the "attack expected"; several such raids striking at different places could be handled by the defense simultaneously.

Putting these factors into the formula gives a value of "Force needed" which is 3 to 7 times the enemy's total bomber force. This quantity is not the number of interceptors needed, it is the number of atomic warheads which must be deliverable, if needed, against simultaneous enemy attacks.

Exclusive perhaps of its special ground environment, the system needed to deliver small atomic warheads against enemy bombers within a few hundred miles of our boundaries should not cost as much as an intercontinental delivery system for strategic bombs. A cost of half as much per deliverable bomb seems conservatively large, one-tenth as much is probably too small. Exclusive of ground environment, then, the defensive system might cost from about one-half to 3 times the cost of the force it must defend against, within the limits of accuracy.

With the large forces which modern warfare demands, adding the cost of the ground environment does not change the loose brackets just enunciated. In the CONAD plan ADR 54-60, for example, only 14 per cent of a six-year cumulative cost is assignable to the ground environment system.

Recommendation.—To exploit the full potentialities of defense in depth, to protect our peripheral cities, and to minimize the danger from large bombs anywhere within our borders we recommend continuing outward extension of the combat zone. In particular:

1. Providing a zone of radar surveillance for about 300 miles beyond the programmed extensions of contiguous radar coverage to seaward (Atlantic and Pacific); this depth of coverage would be provided by the inner warning line of recommendation 1 b, page 82.

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2. We recommend that plans and programs be extended to provide prime radar coverage northward to approximately the mid-Canada line and low-altitude coverage (gap fillers) to a distance well beyond the heavily populated regions of Canada; that steps be taken to enable our interceptors to supplement the Canadian defense forces in this region (i.e., by obtaining the necessary agreements and bases).

3. We recommend that future improvements in interceptor ranges be fully exploited by corresponding extensions to seaward of the full weapon control capability, and of the surveillance-only zone beyond. (Note: Eastward extension of the surveillance zone may ultimately justify elimination of the Greenland-Azores warning line, provided the Greenland-Iceland-Europe line has been installed.)

4. Immediate development and installation of effective data processing and transmitting equipment and procedures to integrate overwater surveillance information into a system linked with the land based "ground environment".¹

Defense at High Altitude

Introduction.—The Russians have recently displayed medium and heavy types of jet aircraft, the types 39 and 37. Intelligence studies indicate that it is entirely possible for aircraft of these general types to attack the U.S. on one-way missions at altitudes of at least 50,000 feet. Actually, aircraft especially designed for high altitudes, and not differing much from present Russian or U.S. types in appearance, could attack at altitudes up to 70,000 feet.

Our present area defenses are helpless at these altitudes; programmed additions may begin in 1957 to improve them. - We believe that the seriousness of the present threat and the extent to which it can grow demand further steps and alternative developments.

The Ground Environment.—The present ground environment system is based upon a search radar which was conservatively designed to see B-29 type aircraft at their maximum altitudes. Jet bombers are smaller and better contoured than the B-29, and the present radar cannot be relied upon to see medium jets at altitudes above 40,000 feet.

For the past several years, the Air Force has been examining alternative proposals to extend the coverage of the present FPS-3 radars upward to 50,000 or 60,000 feet on aircraft of the medium jet type. Production specifications for a program of field modifications to be completed by mid-1957 are now in preparation. We feel that it is essential to keep this a practical program of modification and to prevent further delays for technical refinements.

It is planned, in 1957, to begin replacing the present major radars by a more powerful type (FPS-7). If they perform as now promised, these new radars will see medium jet bombers well above 70,000 feet. Without prejudice to this program, the Panel feels that it does not meet the final goals set by the threat and by the necessity of operating with the SAGE system. We have accordingly included a somewhat detailed recommendation specifying that by 1960 the continental net should be capable

¹ Project Lamp Light has made an intensive study of this problem.

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reliably of tracking small aircraft at altitudes of 100,000 feet, and detailing some of the features essential to operation with the SAGE system.

We believe that there are no serious technical or development problems implicit in a radar program such as that recommended. The major problem in this proposal is exactly the one which has plagued the development of the continental net for several years: indecision. To succeed in the recommended program, it is necessary to make at the start a statement of needs and a firm plan to meet them, so that there is a clear guide to technical decisions when, inevitably as the program develops, they must be made.

The Interceptor Force.—The present interceptor force consists of subsonic jet aircraft of the F-94C, F-89D, and F-86D types, each carrying quantities of folding fin aircraft rockets. These aircraft have little maneuverability above 45,000 feet. Using their present weapons and tactics, they cannot be expected to attack jet bombers flying at or above 50,000 feet.

During the year of 1957, the F-102A aircraft should become available in quantity. Consideration is also being given to the F-101A as an interceptor to become available in 1957 and 1958. It is expected that at a later date improved types, the F-102B and F-101B, will appear. These aircraft will be capable of supersonic flight to a Mach number of about 1.3, but will not be capable of a 1.5 G maneuver at altitudes much above 45,000 feet. Other aircraft of the same period, such as the F-100 and F-104, will have generally the same ceiling limitation. Even these future aircraft, then, if they are to be effective at the altitudes which indeed now seem important, must turn for help to new terminal weapons and tactics. This has been well recognized in the program for the F-102, and the fire control system for the F-102B will permit aiming the Falcon missile for firing in an upward direction.

There is a new long range interceptor in the final stages of study. At the present time the various proposals of the aircraft industry are being evaluated by the Air Force. These aircraft will incorporate new engines and the latest aerodynamic advances. At a considerable increase in size over present types, they will give substantial gains in speed, range, and altitude. The specified performance requirements of M=1.7, combat radius of 1,000 miles, and a combat ceiling of 60,000 feet, appear possible with existing technology. However, it is unlikely that these aircraft will be available before 1960. At the time they are available the threat can have outpaced them unless, again, suitable weapons and tactics are used.

We endorse the interceptor program which has just been described, but we believe that it will not be adequate to meet the threat of the next few years; we feel that it is certainly not a plan adequate to meet the threat of very high altitude attacks in the future.

We cannot but concur completely in the conclusion which has been reached by the Air Force in specifying the F-102B and Falcon system: that the terminal weapon must begin to assume the burden of performance traditionally borne by the interceptor alone. Implicit in this conclusion is a concept of such importance for the future that we have devoted a separate discussion to it. We have, further, included recommendations to exploit the technique of upward firing throughout the present inter-

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ceptor forces. Recognizing, however, that with present and programmed weapons and interceptors this technique can at best give only a few thousand feet extension of altitude, we have also recommended a design and development program directed toward an interceptor and weapon system which will be effective at very high altitudes.

Upward Firing of Rockets and Missiles.—There is nothing in principle which prevents the launching of an air-to-air weapon on a trajectory which makes up for a difference in altitude between the interceptor and its target. If this is to be done with unguided rockets, the launch must occur while the interceptor is flying essentially along the desired trajectory: that is, while the interceptor is properly climbing toward the point of impact without excessive angle of attack. Such a maneuver must begin at an altitude at which the interceptor has adequate maneuverability and must be maintained by thrust, lift, and the expenditure of kinetic energy, long enough for the fire control system to set up a solution.

The requirements just stated set limits on the angles of climb which can be used in such a "zoom-up" maneuver. It is unlikely that within these limits the present small air-to-air rockets can give any effective altitude extension; their range at best is too restricted by their small lethal volume and large dispersion. The Ding Dong nuclear-armed rocket has intrinsically a much longer effective range because of its large lethal volume. It appears to offer promise of some altitude extension even under the limits which rockets impose upon the zoom-up maneuver. We have accordingly included a strong recommendation for its development and exploitation.

Present air-to-air homing missile designs, Falcon and Sparrow, are more tolerant than rockets of heading error and yaw at launch; but they still set limits on the zoom-up maneuver. The interceptor will not be fully freed of restrictions on its angle of attack and vertical heading at launch until it uses a missile which can be sent into a climb after launch. One attractive and rather immediate possibility in this direction is to incorporate rudimentary command guidance in a rocket of the Ding Dong type. Ultimately, of course, one seeks an air-to-air missile which at launch is tolerant enough of heading error in any plane to relieve the interceptor's burden of maneuver.

Ground-based Weapons.—The present Nike missile system can engage targets at altitudes up to 60,000 feet, and Nike B, which may become operational in 1958, is designed to engage up to 80,000 feet. Each Nike battery is equipped with a search radar adequate to keep the battery fully employed within its capabilities.

Present planning does not contemplate a Nike deployment, even in 1960, which will be more than a powerful supplement to longer range defensive forces. The Panel is not prepared to recommend extensive changes in this planning. In particular, we do not feel that it would be sound to plan an air defense system based exclusively upon local defense missiles. Nevertheless, in the period between now and the achievement of an interception system effective at high altitude, the Nike missile offers our only available high altitude weapon. Accordingly, we have recommended steps to insure that these weapons have some effectiveness against possible immediate attacks.

To the Panel, it seems important to deny the enemy *now* the luxury of unopposed approach at high altitudes to all our critical targets. We have offered our recom-

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mendation in full knowledge that, within present procurement schedules and installation plans, no area will be adequately defended against large attacks.

Several missile systems other than Nike are presently under study or development; all propose to engage targets at very high altitudes. Our present specific reference to the Nike system stems wholly from the fact that this system is now being manufactured and procured; our recommendation should not be interpreted as prejudicial to other systems arriving on the scene.

Recommendations.—We recommend continued and increased efforts to close the high altitude gap in our defenses on an urgent basis, and urge that the program include the following steps or directions of development:

1. We recommend that the present program of field changes in the FPS-3 radar be prosecuted without further delays for technical elaborations.

2. We recommend that, without prejudice to the plans for the FPS-7, the Air Force institute now an integrated, realistic, and determined program of planning and design for a radar net to be installed during the period 1957-1960 which will match the threat, will exploit the capabilities of the SAGE system, and will meet the needs of that system. By 1960 the continental radar net should

- a. be capable of tracking reliably small aircraft at 100,000 feet altitude;
- b. have around its periphery at least 300 miles range on such aircraft; and
- c. incorporate the MTI and clutter-rejection features which are essential to the operation with the SAGE system.

New radars added to the net in such a program should use a multiplicity of frequencies in the range from 100 to 1,200 Mcps.

3. We recommend that the Air Force be prepared to bring the F-101 type into the interceptor force as a companion and supplement to the F-102.

4. We recommend that the Ding Dong rocket be developed in time for use with the F-102A and F-101A, and that these aircraft be equipped for upward firing at high altitudes. We recommend further development of nuclear-armed air-to-air weapons including consideration of early missiles having rudimentary command guidance.

5. We recommend further studies of the fire control and stowage problems involved in putting Ding Dong rockets, and infrared Falcon or Sparrow missiles, into the present interceptor force or into interceptors of the present types for use in upward firing. These studies should be pursued until it is clear whether by field adaptation or by new procurement of modified designs it is possible to obtain substantial effectiveness at high altitudes in advance of full employment of the F-102 and F-101.

6. We recommend most strongly that the Air Force supplement its present and planned interceptor forces with an aircraft and weapon system capable of effective combat at altitudes above 60,000 feet. Consideration should be given to modifying present interceptor or bomber designs (for use as interceptors) by 1958 even at the sacrifice of traditional interceptor performance at lower altitudes. Further evolution in this direction is covered by the recommendation on page 102.

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7. We recommend that, as they are installed and until the ground environment can undertake the alerting function, the Nike missile defenses be kept in continuous readiness to detect and defend against high altitude attacks. It is essential in this to establish rules for all aircraft which will permit the missiles to remain in "guns free" status against all aircraft above some specified and appropriate altitude.

Defense at Low Altitude

The Threat.—The Russian TU-4 bomber is capable of flying even at sea level without significant loss of range. Although jet bombers suffer increased drag and fuel consumption at low altitudes, recent estimates suggest that the Russian T-37 could fly, unrefueled, for 4,000 miles at an efficient altitude and still be capable of a further 1,000 miles of flight at sea level. Whatever the present Russian jet capabilities, we know that their TU-4 force is large.

Piloting, navigation, and bomb delivery are difficult, and high-speed aircraft are often subject to buffeting from turbulence, at low altitude. Recent training experience, and World War II experience, however, show that these difficulties alone are not enough to prevent successful attacks by a determined and well-trained force at altitudes below 500 feet in good weather and below 2,000 feet in any flying weather.

Over targets which are well inland the natural difficulties of the attack at very low altitudes impose restrictions on the attacker's choice of formations and timing, restrictions which do not apply at higher altitudes. We can probably expect that attacks inland at low altitudes will involve fewer aircraft and looser formations than attacks at higher altitudes.

Targets near the seacoast cannot take this comfort. To drop to sea level well offshore and come in "on the deck" is scarcely harder than to remain at altitude. There is, further, the possibility that submarine- and ship-borne missiles will attack the coast at low altitudes.

Technical Difficulties in Defense.—The low-altitude attack is troublesome for two simple reasons:

1. Ground-based detection, surveillance, and fire control gear, and ballistic weapons are all limited in range essentially by the horizon. Because of the curvature of the earth, it takes a "carpet" of such equipment to cover the air at low altitudes over the same area that a single installation will cover at high altitudes.

2. Airborne and ground-based radars, and radar homing heads, receive such strong signals from the ground (ground clutter) when looking lower than the horizon that a target may be completely masked. To a considerable extent, all radars suffer in this way also when looking above but near the horizon because of unavoidable side-lobes in their antenna patterns.

Ground-based Weapons.—For the reasons just enumerated, and others, the Nike missile cannot effectively engage targets below about 2,000 feet. Even at short range, the present SKYSWEEPER guns suffer side-lobe returns (item 2 above) and appear now

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to be ineffective below about 2,000 feet; some hope has been offered for their early improvement.

Optically sighted rapid-fire guns are effective at short ranges, and even effective at night when visibility is good and they are given some advance information. While the United States has such ordnance left from World War II, and more modern equivalents, there are no plans to use these in air defense. It is expensive to encircle or carpet an area with such guns in useful quantities; nevertheless, this is a way of giving low-altitude defense now to critical targets.

The Porcupine weapon system now under development is designed specifically for low-altitude defense. It fires rockets sighted by a special fire control radar. It is designed for simplicity and a minimum of manual attendance. Its first field trials will be in April, 1955. If the Porcupine program continues at its present pace the weapon will not be available before 1958 or 1959; if the program were expedited, Porcupine might be operational in 1957.

Talos, Hawk, and Bomarc missiles all propose to engage low-altitude targets, and a modified Nike missile with homing head has recently been suggested for this purpose. It is unlikely that any of these systems can be in operation much before 1960. Furthermore, technical as well as operational problems will probably always limit the useful range of even the most sophisticated missiles against very low-altitude targets.

Unless material improvements in the SKYSWEEPER system are forthcoming, it appears that optically sighted guns and, later, the Porcupine system, are the only ground-based weapons to be available against low-altitude attacks before 1960.

The Interception System.—The great cost of providing a carpet of continuously ready ground-based weapons has fostered the hope that interceptors may some day give the same kind of defense at low altitudes that they now can at higher altitudes. To some degree this hope is not unfounded, but it will not be realized for several years, and not then without further special effort.

The situation is basically simple: a ground environment for interceptions at low altitudes is planned for completion in 1957 and 1958, there are a number of air-to-air weapons, including in particular the atomic rocket (Ding Dong), which promise good performance at low altitudes, but the interceptor still lacks an AI radar which will work near the ground.

Ground Environment.—The present net of large radars has little chance of seeing aircraft below about 2,000 feet. An extensive net of smaller "gap filler" radars is planned for installation between 1956 and 1958; according to present schedules the most important elements will be in by the end of 1957. These radars will be sited to give full cover down to 500 feet and partial cover well below that.

It is planned that these gap fillers will operate unmanned; transmission equipment (slowed-down-video links, AN/FSA-8) will carry the video pictures on telephone lines to control centers where they will be combined in a unified presentation (Vidicon combiner, AN/FSA-10). The SAGE system is being designed to accept these same data for use in its unified air picture; this system will not be generally operational before

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1960. It is expected that the gap fillers will have good moving target indication, suppressing ground clutter and enhancing signals from aircraft.

It is hoped that by these means the ground environment will be able to track aircraft flying at altitudes between 500 and 2,000 feet with the same ease as it tracks at higher altitudes. This low altitude tracking system is as yet untried, however, and the program must be kept under careful review to insure that difficulties now unforeseen do not delay the desired outcome.

At the present time, there is a Ground Observer Corps (GOC) which can provide a limited tracking ability in some areas of the country.

Interceptors and Fire Control.—Jet interceptors suffer the same range penalties, and the same effects of turbulence, as do jet bombers at low altitudes. Their most severe limitation, however, lies in the radar (paragraph "2.", page 97). Because of the masking effect of echoes from the ground, present pulsed AI radars have less range at low altitudes than has optical sighting in daylight, though perhaps somewhat more range than an optical sight at night. To some extent, this handicap can be overcome by good "vectoring" by ground control, but it seems certain that only tail approaches can be used when AI ranges are so short. The tail chase is the simplest approach to vector with high accuracy, though of course the most time-consuming.

Experimental twin-dish CW radars have recently demonstrated the ability to lock-on at 8 to 10 miles range, independently of altitude, in head-on approaches. These results are very encouraging and we have recommended vigorous prosecution of this program. It is unlikely that the CW radar will permit beam or tail approaches at low altitudes.

The present development effort on MTI for pulsed AI radars is very small, considering the importance and the difficulty of the problem. We have recommended an increase in this effort. We believe that the MTI problem for AI radars is solvable.

Air-to-Air Weapons.—Because of rough air near the surface, jet interceptors become poor platforms for predicted fire weapons at low altitudes. Despite this, it has been planned to equip F-102A aircraft to carry about 100 small rockets for low altitude firing. The Panel believes that this is at best a stop-gap armament.

Rough air will also influence the accuracy of Ding Dong rockets at low altitudes, but the
..... In addition there is the attractive possibility that a burst even well above or to one side of a low flying target may drive the target into the ground. For these reasons, with fire control which can see the target, Ding Dong will be very effective at low altitudes.

It seems possible that the large lethal radius of Ding Dong may permit firing without fire control (AI) radar, from ground control data alone. This may offer a straightforward solution of the low altitude AI problem; we have recommended a complete study.

Obviously these possibilities of using Ding Dong put a premium on moving the air battle out from populated areas.

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The standard Falcon missile has a homing head which is subject to the same kind of side-lobe and ground-clutter difficulties as other pulsed radars. Other guidance possibilities, however, are far from discouraging; in particular, the Sparrow III missile has a CW homing system which appears now to be able to home at all altitudes in attacks from the forward quarter. In addition, both the Falcon and Sparrow have infrared versions, and the Sidewinder, a somewhat smaller and simpler missile, is also an infrared homer. Infrared homing is effective only in tail approaches and in clear air; then, however, it is considerably better than radar homing at any altitude, and does not suffer interference at low altitudes.

In view of these guidance possibilities, and of the great potential of nuclear warheads, the Panel feels that the problem of the air-to-air weapon at low altitudes can be solved sooner than the AI problem.

Special Conditions at Sea.—Radar echoes returned from the surface of the sea depend upon the state of the surface but are always less severe than returns from typical terrain. This permits radars to work with some effectiveness on targets lower than the horizon. In particular, the present APS-20B airborne search radar can be used on low flying targets even at short ranges in light sea states. A UHF modification of the APS-20B appears to be similarly effective in considerably rougher weather.

It appears from this that search for and surveillance of low flying targets may be possible without a great multiplicity of equipment over the sea. The problem of assembling data from airborne search and of controlling interceptions with these data are not severe when the traffic is light; they will be more complicated if a seaborne system is ever to tie in with, and have the tracking and control capacity appropriate to, the SAGE system.¹ The problems raised by the lower resolution of UHF radars also need study.

Airborne fire control and homing radars profit somewhat from reduced clutter at sea, but it is unlikely that an interceptor and weapon system fully effective at low altitudes will be achieved over the sea with much greater ease than over land. The AI problem must still be solved.

One great advantage that defense has at sea is virtually complete freedom to use atomic warheads of any size.

Conclusions

1. The Russians are now capable of mounting a large air attack against the continental United States at altitudes well below 2,000 feet; there is no prospect that this capability will diminish as the USSR adopts jet bombers. Our coastal cities are more liable than inland targets to heavy attacks at low altitude.

2. We now have inadequate air defense at altitudes below 2,000 feet.

3. Optically sighted guns can be used now to give some defense to critical targets; there is no plan to do so. Planned coastwise AEW aircraft and ground-based gap-filler radars will begin in 1956 to provide radar tracking of low flying aircraft. The problems

¹ Project Lamp Light is studying this problem.

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of centralizing these data and using them for controlling interceptions need continuing attention.

4. An effective interception system to use the control data which will become available has yet to be developed. Nuclear-armed weapons promise great assistance in this direction. With or without them, it is the AI radar which needs most attention.

Recommendations

1. We endorse the present plans to provide airborne radar cover at sea and to install gap-filler radars on land. We urge that these programs be kept to schedule. We recommend that continuing attention be given to means for assembling data from these radars and using the data to control interception; a satisfactory solution to this problem must not await installation of the SAGE system.

2. We recommend that, as soon as possible, enough of the appropriate radar cover be made available to test the ability of airborne and gap-filler radar nets to vector interceptions at low altitude. We recommend extensive experiments to examine the problems of handling data, and to determine the feasibility of launching or directing air-to-air nuclear weapons directly by ground control, without the use of AI radar or homing devices. This study should recognize the possibility of using weapons of large yield at sea and over waste land.

3. We recommend that the development of a lower frequency modification kit for the current AEW radar be vigorously continued with the specific aims to reduce sea return, to provide improved AMTI, and to improve coverage; that the problems of controlling interceptions with these radars be studied; and that a development program for equipment to tie the AEW data into the ground environment system be initiated on the basis of the results of Air Force and Project Lamp Light studies.

4. We recommend enlarging the scope and increasing the intensity of the current program to develop AMTI for pulsed AI radars; alternative techniques should be studied in parallel.

5. We recommend that the Air Force and Navy jointly sponsor a program to explore and understand the possibilities of CW radars for use in air defense interceptors. This program should be carried to the point at which equipment weight and size, and location requirements applicable to various air defense interceptors, can be firmly estimated; complete weapons systems should be planned out and evaluated and experimental checks of technical and tactical feasibility made.

6. We recommend a thorough experimental study of the limitations of present infrared and CW homing missiles, with particular reference to performance at low altitudes. The study should be aimed at finding what requirements on vectoring, what tactics, and what fire control ranges are needed to employ these missiles effectively.

7. We recommend that broad and vigorous support be given to studying and developing the CW guidance techniques involved in the Hawk, Talos and the newly proposed modified Nike B missile systems; the program should be timed to permit an early decision on feasibility and to ensure at least one operational all-altitude missile before 1960.

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8. We recommend that the forthcoming trials of the Porcupine system be expanded to an adequate test of feasibility, to permit an early and informed decision on the pace and scale of the program.

9. We recommend re-examination of the possibility of concentrating optically sighted guns, and Porcupine if it proves satisfactory, for defense of critical targets against low altitude attacks.

The Interceptor and Its Missile

The tradition that the interceptor is a small and highly maneuverable airplane is founded on the weakness of predicted fire. Guns and rockets must be fired at short range if the quarry is not to have time to evade. Short ranges permit small weapons, but they demand speed and maneuverability of the carrier in bringing the weapons to bear. Within this framework our present interceptors have evolved.

This evolution has reached its limit. Unhampered by the need for maneuverability, the big-winged bomber can fly above any present interceptor. To fly at the bomber's altitude, an interceptor must sacrifice effective maneuverability: either it is sacrificed at low altitude to permit big wings for high flight, or it is sacrificed at high altitude because of the great speed needed to remain airborne on small wings.

It is time to exploit the intrinsically long range of guided fire. Present and forthcoming interceptors will soon be armed with guided missiles, but this is only a beginning. These interceptors are small and have radars of short range; they cannot fire missiles at long range because they cannot see the target soon enough. Armed with missiles, they are better weapons than when armed with rockets; but they still demand good placement from the ground environment and they still must maneuver for a kill.

Given a fire control radar of adequate range, and a missile to match, the interceptor need have no special maneuverability. In the Nike system, for example, the "interceptor" is a plot of ground. What this particular "interceptor" lacks, of course, is just what a good airborne platform can provide: the mobility needed to marshal forces against a concentrated attack.

We recommend that the Air Force undertake a study of the inherent possibilities of the airborne platform and its missile. This study should develop quantitative relations among the following important parameters: accuracy of the ground environment or search system in controlling position (in three dimensions) and heading at the moment of radar lock-on; range of AI lock-on; size of, and aerodynamic limits imposed by, radar antennas; speed and maneuverability of interceptor; speed, range, weight, lethality, and maneuverability of missile; weight, range, and altitude ceiling of interceptor.

In view of the particular vulnerability to jamming of ground-to-air communications, it is interesting to consider an extreme example of the missile-platform idea: the self-contained "dreadnought" with its own search radar. For example, an adaptation of the B-52, with a new wing which retains the high aspect ratio but has reduced thickness ratio, could be designed to cruise for thousands of miles at 0.9 of the speed of

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sound, carry large numbers of missiles, carry high-powered search and tracking radar, and fly at altitudes of from 55,000 to 65,000 feet, depending on fuel and armament load.

Electronic Countermeasures

When the Panel began its surveys, we decided not to enter into the problems posed to active air defense by the enemy's use of electronic countermeasures. This decision originated in a need to limit our explorations, and in a feeling that the necessarily superficial attention which we could devote to this field could not resolve any of its problems.

During our studies, however, we have become increasingly impressed by two things:

First, we are now so vulnerable that it is entirely within the enemy's power to deny us any air defense whatsoever.

Second, in a kind of panic search for a universal resolution of these problems we have ignored a number of direct, if inelegant, ways to help ourselves.

We feel that it is important, even within the limits we have put on this report, to enlarge briefly upon these observations.

Communications.—Although radars can be jammed or spoofed, the place to cripple our air defense system now is in its ground-to-air communications. These use omnidirectional antennas and low power. Exercises have repeatedly demonstrated the ability of our own SAC bombers to jam them. It is well known that the Russians are expert at jamming communications in Europe; we must assume that they can bring suitable gear with them.

Without ground-to-air communication, our present interception system can give us no defense. It is our impression that this problem is receiving little attention. A straightforward technical attack would include the use of (i) transmitters of much higher power, (ii) more transmitters, (iii) somewhat directive antennas, and (iv) rugged and broad-band modulation schemes. The use of widely separated alternate frequencies has the same value here as in all counter-countermeasure efforts; obviously diversity raises operational problems, but none that could not be solved by multiple receivers in the airplane.

We have recommended a vigorous experimental study of the usefulness of these technical items, and of the degree to which we can make our ground-to-air net difficult to jam. We may find that we have to abandon close control. It were better to find this out for ourselves than to have the enemy prove it to us.

The seriousness of the threat to our communications makes it imperative also to study and try to develop tactics which are less dependent on a complex ground-to-air net.

Radars.—Though they use highly directive antennas, radars are subject to active jamming from noise-modulated or pulse-modulated sources, to passive jamming from chaff, and to spoofing by transponders and decoys. We cannot add here to an already extensive literature on this subject. We feel compelled to point out, however, that,

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beyond some specifications for tunable components, there are now no plans to make real use of frequency diversity in our future ground radar equipment.

At the very least, our radar net should be able to draw its data from the S, L, and UHF bands. We have recommended study of the possibility of using several search radars operating simultaneously at each site, with synchronously rotating antennas. Since one display and data processing system would suffice for all the radars, the increase in capital equipment cost per station would be small and the increase in required manpower negligible. The wide separation of frequencies would make jamming by electromagnetic radiation much more difficult and expensive, and a comparison of echoes obtained with the different frequencies could help to distinguish between planes, chaff and decoys.

Diversity in both frequency and mode of operation is desirable in AI equipment. At present all AI equipment uses X band pulsed radar. Some could be S band instead of X, some could be CW instead of pulsed, and use could be made of other sensing methods, such as infrared.

General.—The use of homing on sources of jamming and other electromagnetic radiations is still in the experimental stage. It has the attractive feature that it converts a jamming signal from a hindrance to an aid, and the advantage that its action need not be dependent on the exact nature of the signal. Such devices might well prove to be the most effective counter to the high power barrage jammers which have recently been developed. Although the concept is simple, the development of a practical homing system is difficult and will probably require far more support than it is getting at present:

Direction-finding in general, whether used for homing or other purposes, is a useful technique for exploiting, rather than evading, active jamming. Jamming can be detected by a receiver at several times the range at which a target would be visible to that receiver by radar echoes. Our early warning and peripheral radars should be so organized that incoming jamming sources can be detected and localized.

Recommendations

1. We recommend that the Air Force begin now a quantitative study of the "jamability" of the present and planned ground-to-air communication system, and of the effects thereon of increased power and denser deployment of transmitters. Practical ways for diversifying frequencies should be considered.

2. We recommend a realistic parallel study of the tactical problems raised by the jamming of communications and of the innovations needed to fight an air battle in the presence of jamming and electronic cover.

3. We recommend that the planning of the ground radar net include the use of a wide range of frequencies in the range from 100 to 1200 Mcps. We urge careful study of the simultaneous use of several radars at different frequencies feeding common display equipment.

4. We recommend study of the tactical problems involved in using S band AI radars. We have elsewhere recommended further development of CW radars for AI application.

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5. We recommend increasing the present limited efforts to develop homing missiles, and homing devices in interceptors, for attacking jamming sources.

4. ATOMIC WARHEADS FOR AIR DEFENSE

Military Utility

Atomic warheads can provide a capability for increasing the kill probability to 90 per cent or greater from a single pass against a maneuvering enemy bomber. Because of the large lethal radius of these weapons, their terminal guidance can be simplified or eliminated, thereby increasing the reliability of the system and decreasing the vulnerability to electronic countermeasures. In addition, atomic warheads would force the separation of enemy targets and thus prevent close enemy bomber formations which tend to saturate and render ineffective defense systems using conventional explosives.

Ground-to-air missile systems, such as Nike B, have an altitude capability greater than 60,000 feet. If air-to-air rockets were fired from an aircraft in climb, they would provide a kill capability at altitudes above the ceilings of our present interceptors, i.e., up to 50-60,000 foot altitudes. Future air-to-air atomic missiles could provide a very high altitude kill capability even though the interceptor ceiling was limited.

These weapons not only destroy aircraft by air blast and gust, but the nuclear radiation also kills crews at ranges much beyond those at which the aircraft will be damaged. In almost any type of defensive attack, the probability of killing the bomber crew will be essentially 100%, a fact which should provide a strong psychological weapon. However, since even supra-lethal doses of nuclear radiation probably would not produce incapacitation in less than 2-5 minutes, the radiation could only be relied upon to prevent a successful attack when interception occurred at some distance from the target area.

The desirability of destroying an enemy weapon, in addition to the delivery aircraft, has taken on new importance in the age of megaton yields because of the potentially large area which would be covered with radioactive fall-out from a surface burst. More exact information on the vulnerability of enemy nuclear weapons is needed. However, if an atomic defense warhead were exploded so as to place the enemy aircraft within the fireball (400 foot radius for 2 KT at 40,000 feet), then the probability of destroying any nuclear weapon therein should be very high. No other defense weapon has this ability, since the probability of weapon destruction with an HE warhead is considered to be low. A further effect peculiar to atomic warheads is their ability to reduce the yield of presently designed megaton weapons to a few kilotons by preinitiation at ranges far greater than those at which physical damage would occur. Thus, if an atomic warhead had just succeeded in destroying an enemy bomber at 40,000 feet, the bomb being carried would fail to function properly as much as five minutes later if the plane crashed with the weapon intact, armed, and fuzed. This effect is an important consideration in planning defense against possible enemy ICBM's. However, the effectiveness of preinitiation against enemy weapons of unknown design will always be questionable.

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Operational Problems

The increased lethal range of nuclear warheads is not obtained without producing new operational limitations which must be overcome. For example, in the use of an air-to-air nuclear rocket at high altitudes, the nuclear radiation forces the attack to be carried out at a range sufficient to protect the interceptor pilot. As a result, some of the advantage of the larger lethal radius may be reduced by the resulting increased fire control error. For an attack with a 2-KT warhead at 50,000 feet, the launching range between the interceptor and the target must be about 4 miles in order to avoid all risk of injury to the attacking pilot. Because of this demand for remote launching, the air-to-air unguided rocket requires certain special fire control characteristics. Recent studies indicate, however, that the atomic warhead can be made compatible with presently available and programmed interceptors, such as the F-86B and F-102, with only minor modifications to the existing fire control systems.

Because of the denser air at low altitudes, the safe launching range will be shorter (less than 2 miles at sea level). Thus, no special fire control problems will occur for low altitude defense. However, for low altitude use over inhabited areas, care must be exercised in order to prevent damage or casualties to friendly personnel. A 2-KT weapon could not be detonated below 3,000 feet without producing important damage to residential structures. Careful consideration must therefore be given to the selection of optimum impact areas when atomic weapons are being used to defend against low altitude attack. In any case, such damage would be insignificant compared to the damage which would be produced if enemy weapons were detonated. Over the ocean, atomic warheads could be used at low altitude without any restrictions.

Fissionable Material Requirements

Atomic warheads can be produced at relatively low cost for inclusion in both air-to-air and ground-to-air armament. The major requirement is for yields of about 2 KT, but higher yields might be desired in some situations.

To establish an early capability, it might be possible to arm a defense force by 1957-58 with weapons employing of Orallloy equivalent of fissionable material. At a cost of, such a capability would cost between

To supply an expanded air defense system completely with atomic weapons such as that proposed in the ADC requirements plan for 1960 would require the allocation of about of Orallloy equivalent of fissionable material. A conservative estimate of the total investment cost of the fissionable material for such a program would be about This material, as is true of all nuclear weapons, would be recoverable in the event that the material were not used in warfare. Since the

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total number of enemy aircraft is not likely to exceed a thousand, and since the kill probability for these warheads is nearly 100%, only a small fraction of the total number of warheads would be expended in actual warfare. Thus, even further additions to the total allocation would increase only the investment cost, not the actual expenditure of fissionable material. If all the air defense weapons were actually fired, the total kilotonage would be approximately that of a single strategic weapon. Thus, the radioactivity which would be added to the atmosphere by the use of the warheads is of no consequence at all.

Development Programs

The Atomic Energy Commission has an active program for developing low yield, small diameter atomic warheads which would be suitable for use in the proposed air defense weapons systems. Effort is being placed on obtaining maximum nuclear efficiency, nuclear safety, and minimum maintenance. The use of new techniques, such as boosting, could still further reduce the fissionable material requirements given in the preceding paragraph on "Fissionable Material Requirements." The warhead development program should have no difficulty in providing satisfactory atomic warheads within the time schedules of the other components of the system.

At the present time, the Air Force is sponsoring a program to develop an air-to-air atomic rocket (Ding Dong) which might become operational in 1957-58. This program should be vigorously supported with a view to having at least a limited capability available by that date. Such a capability would have immediate psychological advantages in addition to their military worth. This weapon should be planned for use in the F-36, F-102 and all other suitable interceptors.

The Army and Navy have programs for development of surface-to-air atomic missiles (Nike-B and Talos-W) which could be available in 1958-59. These should also be expedited since they offer promise of materially increasing the U.S. air defense. The Air Force Bomarc program, which could produce a longer range atomic defense missile, has experienced considerable slippage. (See the November 1954 Progress Report to NSC 5408.) Every effort should be made to halt this slippage or to expedite the development of suitable alternatives.

Consideration should be given now to the inclusion of atomic warheads as the major armament in future air defense weapons systems. It may be possible not only to increase the kill probability but at the same time simplify and increase the reliability of the overall system. All interceptors should be made compatible with this type of weapon. Special consideration should be given to the value of atomic warheads in solving both the high and low altitude defense problems. Their relative usefulness in future air-to-air guided missiles is worthy of particular attention. Every effort should be made to determine and to exploit the capabilities of atomic warheads for actually destroying enemy weapons.

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Operational Doctrine

The effective use of atomic warheads in air defense requires a doctrine of instant use as soon as a hostile attack has been confirmed. To accomplish this, fissionable material must be allocated and deployed to a large number of different air defense missile and interceptor bases. The air defense forces must be granted advance authority for the instant use of the atomic warheads wherever needed over the land areas of the United States and Canada. This calls for the establishment of realistic rules of engagement, the conclusion of satisfactory treaties with Canada, and the realistic indoctrination of the public to the importance and relative hazards involved in their use. The forthcoming high altitude shot of Operation TEAPOT in the spring of 1955 will undoubtedly focus attention on this problem, so a public information program should be established using this as a point of departure. Such a program could have the dual objective of allaying public fears and informing our enemies and allies that we are using our atomic capability for defensive purposes.

Conclusions

Nuclear weapons are the most effective armament with which we can equip our air defense forces. They provide the most direct and reliable method of achieving the high kill probability against single aircraft that modern air defense demands, of creating a potent defense against saturation type attacks, and of actually destroying the enemy nuclear weapons. Recent studies have shown that the air-to-air atomic rocket can be made compatible with existing and programmed interceptors, such as the F-86D as well as the F-102. The investment cost of fissionable material for both ground-to-air and air-to-air nuclear warheads is a small fraction of the total cost of the air defense system. The radioactivity which would be added to the atmosphere by the large-scale use of nuclear defense warheads would be no more than that from a single high yield strategic weapon and would cause no dangerous fallout.

Recommendations

We recommend that nuclear warheads be adopted as the major armament for our air defense forces and that this step be implemented by:

1. Expeditious development, procurement, and deployment of sufficient weapons, initially the programmed air-to-air rocket (Ding Dong) and nuclear version of Nike B, to provide a high kill capability at an early date. (Note: The November Progress Report to NSC-5408 estimated that Ding Dong would become operational in FY '57 and Nike B in FY '58. Maximum effort must be made to maintain these schedules.)
2. Commencement of negotiations with Canada to provide defense forces with authority for instant use of atomic warheads wherever needed over Canada.
3. Use of the high altitude shot at the next atomic test series as a springboard for a public information program with the dual objective of allaying possible fears and informing our enemies and allies that we are using our atomic capabilities for defensive purposes.

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5. A RADAR PROGRAM

At many places in Part IV of this report we have had to discuss radars and to recommend study or development programs relating thereto. The importance of radar to our subject is not surprising: radars are literally the eyes of the defense force. What may be surprising is that we have had so much to say and to recommend about further developments.

There have been few significant improvements in early warning and GCI radar since 1945; there has been no broad effort to seek such improvements. Progress has been slow in the difficult problem of AI radar; the Panel feels that now is no time for complacency. To emphasize the importance, and the scale, of the total effort that we are recommending in the radar field, we summarize here our otherwise scattered references.

If our total program seems large, it must be remembered that the whole investment in radar gear for air defense now amounts to but a few percent of the capital cost of the air defense system. Yet every major function of that system depends upon some form of radar.

The main technical deficiencies of present radars are:

- (a) Inadequate cover at high altitudes,
- (b) Inadequate ability to reject irrelevant signals ("clutter"),
- (c) Inadequate average power,
- (d) Inadequate or marginal scanning rates,
- (e) Dangerous vulnerability to jamming and spoofing.

To overcome some of these deficiencies takes no subtlety: simple courage to recognize the problem and to face the rigors of its solution is enough. Other problems, notably rejection of clutter in both ground-based and airborne gear, require more study. Even about these latter problems we are hopeful. In fact, we are convinced that ingenuity and brute force together can bring radar technology up to the demands of modern warfare.

Our detailed recommendations, summarized below, describe a ramified program of study, planning, and developments directed toward important but rather immediate ends. We feel that these several efforts need fundamental support in a more unified and basic program of research. The central technical problem is: unwanted signals.

Recommendations

1. We therefore recommend that a basic program of research be undertaken to study the characteristics of clutter returns in ground-based and airborne search and fire-control radars, to understand the phenomena, and to explore the techniques of rejection. Developments from such a program would have impact on all applications of radar.

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Beyond this, we recommend:

2. That the present program of field changes in the FPS-3 radar be prosecuted without further delays for technical elaborations.
3. Installation, as planned, of low-altitude gap-filler radars, continuing review of the problems of assembling data from them, and experimental study as soon as possible of their abilities and limitations in controlling interceptions at low altitude.
4. Firm planning now for a continental radar net to be installed during 1957-1960 which will track small aircraft at altitudes of 100,000 feet, will have at all peripheral sites ranges up to 300 miles on these aircraft, will incorporate the moving target indication (MTI) and clutter-rejection essential to the SAGE system, and will exploit a diversity of frequencies from 100 Mcps to 1200 Mcps.
5. Special consideration of the use of several radars at a single ground site, using widely separated frequencies and scanning simultaneously (re: improved average power, improved rejection of clutter, chaff, and spoofs, and dilution of the enemy's jamming effort).
6. Development of UHF modification kits for present APS-20 airborne search radars, study of the problems of MTI in these radars when used at sea, and study of the problems of controlling interceptions with these lower frequency radars.
7. Enlarging the scope and increasing the intensity of present efforts to develop moving target indication for airborne pulsed fire-control radars.
8. Joint study by the Air Force and Navy of the technical and tactical possibilities of CW radars for air defense interceptors.
9. Further study of CW homing techniques for guided missiles, and of the tactical limitations of CW and infrared guidance of air-to-air missiles.
10. Study of the technical and tactical problems raised by the use of S band frequencies in AI radars.
11. Initiation of the design, development, and planning of a radar system to detect the approach of ballistic missiles and give the maximum practicable warning thereof.
12. Exploration of the feasibility of shore-based low-frequency radars for long-range detection and tracking of sea traffic.
13. Increasing present limited efforts to develop homing missiles, and homing devices in interceptors, for attacking jamming sources.
14. Providing adequate range in future AI radars.
15. A program of development and limited production of components broadly applicable to radars of very high power.

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6. SEA DEFENSES

6. SEA DEFENSES

The Threat from the Sea

Existing Sea Defense Preparations

..... The need for shallow-water auxiliary systems, to tie the ends of the Caesar systems to the shore and to plug any gaps and provide close-in surveillance, has been recognized.

Our sea defenses are based on the traditional three-mile limit, although missile ranges are measured in hundreds of miles. Limited in numbers of officers, men, and ships, and committed to worldwide activities, the Navy is understandably not enthusiastic to commit forces for continuous patrols in fixed offshore areas. The governing philosophy seems to be the freedom of the sea lanes, with an apparent policy of post-Day mobilization of sea defenses.

If intelligence indications are to be accepted, we need more comprehensive sea defenses as soon as they can be established. The entire system should be operative by 1957. To maximize effectiveness and minimize costs, sea defense elements must be coordinated with the continental defense system.

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evaluated, displayed and stored. Project Lamp Light has estimated the volume of information that would be involved; adequate communications and data-processing equipment and techniques are available.

Much information on surface traffic for the above plots can be obtained at small extra cost from existing and future commercial and military activities. In addition, Project Lamp Light proposes shore-based low-frequency (ground-wave) radars that might provide continuous tracking of surface targets out as far as 600 miles. But the technical feasibility of this proposal has yet to be established and experiments and tests are urgently needed, preferably at more than one laboratory to give information for a wider variety of environmental conditions.

Information on submerged submarines is more difficult to obtain. The Caesar systems play a major role. Particular attention must be given to closing any gaps disclosed by operational tests as the installation of the Caesar systems progresses. To augment the Caesar systems, additional fixed installations are needed. These should be designed particularly for submarine detection, tracking, and identification, but they would also have value in monitoring surface traffic.

In terms of a drastically revised concept of territorial waters, defense requires surveillance of any unidentified or suspicious vessels approaching striking range. Surface traffic can be watched from far out, but no technical means are available for midocean detection and surveillance of snorkel-depth and completely submerged submarines.

The detection and surveillance components for harbor defenses must be activated; this is particularly urgent in the period before the Caesar and auxiliary shallow-water systems become operative. Exploitation of postwar developments, e.g., the data analysis and recording techniques as used in Lofar, will increase detection and surveillance capabilities and minimize force requirements.

Arguments have been advanced that peacetime sea defenses would disrupt commercial traffic. Parallel arguments were once advanced against transocean flight controls; these controls have not, in fact, proved onerous. In view of the seriousness of the threat, changes in maritime practices required for adequate sea defenses seem fully justified.

Present harbors and port facilities are unacceptably and dangerously concentrated. Strong and positive measures must be started immediately to reduce our critical dependence on a few harbors. Government installations, which contribute markedly to this

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concentration, should be the first to take cognizance of this danger and to set an example for private industry.

Recommendations

1. We recommend that defenses against attack from or over the sea be—in plan, organization, and operation—an integral and coordinate part of the over-all continental defenses; this can be achieved only if the responsibilities, missions, and means now under the authorities of CONAD, CinCLant, and CinCPac are coordinated for joint action.

2. We recommend that programs for submarine detection and surveillance systems be advanced and modified as follows:

a. That the programmed 1958 date for the Pacific Caesar system be advanced to the 1957 goal for the basic Atlantic system; and that the station for the San Salvador-Hatteras area be likewise advanced.

b. That the Caesar systems be supplemented by surveillance systems in the shallower coastal waters, particularly at the ends of the Caesar systems.

c.

d. That harbor entrance detection and surveillance equipment be installed promptly at all important ports.

3. We recommend that comprehensive programs be instituted to provide effective control of surface and, insofar as possible, subsurface traffic in both oceans from the coast lines to beyond the likely striking range of sea-launched attacks. For proper implementation:

a. International arrangements should be made for the establishment of information reporting procedures and control measures.

b. Studies should be made of appropriate changes in the concept of the "three-mile limit" to permit actions in keeping with the threat of sea-launched missiles and other forms of attack from the sea; for realistic implementation of these policy changes the Coast Guard and Navy missions must be amended and forces increased to equal the tasks of inspection and control.

c. Sea traffic plots should be established utilizing modern techniques for correlating, analyzing, storing and displaying traffic information gathered from both military and civilian sources (e.g., ship schedules and routes, visual and radar sightings by friendly ships and aircraft, the Caesar systems, monitor lines, and

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other surveillance systems). Traffic patterns as well as movements of individual vessels should be carefully watched.

d. Maximum utilization should be made of the surface surveillance capability of the seaward components of the air defense radar system.

e. The feasibility of shore-based low-frequency radar for long-range detection and tracking of surface traffic should be vigorously explored and, if warranted, systems should be installed.

7. DEFENSE AGAINST INTERCONTINENTAL BALLISTIC MISSILES

The increased emphasis on the development of the intercontinental ballistic missile (ICBM) for use by the United States nuclear striking forces has naturally resulted in a growing concern about means of defense against this type of delivery system. This concern is accentuated by the realization that the USSR, without revealing her progress, may be ahead of the U.S. in the race for an ICBM capability.

There follows a consideration of some of the factors involved in attaining "active" means for countering ICBM's. Emphasis in our brief study has been placed on determining the state of knowledge with respect to the basic problems of detection, destruction, and interception. Our findings, while clearly indicating that large technical advances will be needed to make defense possible, are sufficiently encouraging, we believe, to obviate the generally prevailing feeling of hopelessness in the face of the ICBM threat.

Appraisal of the Threat

At this time we can only speculate as to whether the intercontinental ballistic missile will ever become a real threat to the United States. For one thing, the struggle between the USSR and the U.S. may be settled in one way or another before the ICBM becomes an operationally usable weapon system. Although held to be practicable, the development of the ICBM is nonetheless a very difficult undertaking and will take some years to accomplish. Further, because it can carry a larger weapon and can achieve higher accuracy of delivery, the manned bomber will likely remain an important threat long after the ICBM becomes operational.

Moreover, the available intelligence information is insufficient to make possible a reliable assessment of Soviet objectives or progress in the field of guided missiles. Conceivably the Soviets could be developing one or more of several types of long range guided missiles. According to the latest National Intelligence Estimate, the Soviets are believed to favor the ICBM over all other forms of long range missiles and to have concentrated their development effort accordingly. We have no particular reason to quarrel with this estimate. It should be recognized, however, that until much more is known about the Soviet guided missiles program, there is danger of serious miscalculation of the nature and importance of the threat of long range missiles.

The outstanding significance of the ICBM to the aggressor is that it enables the near simultaneous delivery on targets of a considerable number of high yield nuclear

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weapons—of the order of 100 within a period of minutes seems possible. After the missiles are launched, there can at most be about 30 minutes' warning to the areas under attack. That is to say, the ICBM threat could combine to a degree not possible with aircraft delivery systems elements of both surprise and mass attack. Moreover, the ICBM can be made relatively invulnerable to attack at the source by "digging-in" the launching bases or by making them highly mobile and dispersed.

Because of restrictions on weight and size, the nuclear warheads of ICBM's would almost certainly be limited to yields lower than those of the larger bombs delivered by aircraft. However, yields of at least a megaton are considered practicable, even for the earliest missiles, which, at the expected accuracy of delivery (a few miles), would make the ICBM an effective weapon system against cities and against aircraft on airfields. It seems most unlikely that the accuracy would be good enough to enable the user to destroy, at a reasonable expenditure of missiles, well-designed shelters of the sort that could be built to protect people or aircraft.

All things considered, although we cannot justify beyond all doubt a conclusion that the ICBM will become a major threat to the United States, we probably are justified in concluding that this is a distinct possibility. It is our feeling that the ICBM threat, if it does materialize, could be upon us within the 1960-70 time period. We doubt that the evidence from either our own or the Soviet guided missiles programs supports a more precise estimate at this time.

General Considerations of the Defense Problem

Active defense against intercontinental ballistic missiles has, in general, been considered so extremely difficult as to be virtually impossible. Characteristics of the ICBM threat which make defense extremely difficult are:

- a. The very high speed of the missile (about 4 miles per second until re-entry) and the consequent compressed time (minutes) for the entire defense action.
- b. Possible variations in height, re-entry angle, range and direction of approach of flight paths to any likely target area. Although not the theoretical limits, a reasonable set of numbers for these parameters would appear to be: maximum height—300 to 1,000 miles; re-entry angle—15° to 35°; range—3,000 to 6,000 miles (the upper value essentially blanketing the U.S. from all Soviet-controlled territory in Eurasia north of 50° latitude); direction of approach within a 60° sector for most target locations.
- c. Possibility of unpredictable programmed variations in the re-entry flight path which may require that interception take place outside the effective atmosphere.
- d. The small radar target presented by the missile and, in particular, by the re-entry body.
- e. The "built-in" high invulnerability of the re-entry body which probably requires that the nuclear weapon itself be destroyed.

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f. Possibilities open to the offense for employing jamming or decoys against radars used in the defense system.

The implicitly accepted precept of air defense is that the attacking vehicles be destroyed in flight as they approach the target area. It is difficult to see what other precept we could use as the basis for planning a defense against intercontinental ballistic missiles, even though the tremendous speed of the missile allows so little time in which to fight the air battle. Clearly an "active" defense, if it is to be at all effective, requires detection, tracking, and interception components far more advanced than those presently in use or being developed for use against aircraft.

After considering the evidence available from studies made to date and in process, we are at least hopeful that a system of active defense can be devised to counter the most rudimentary ICBM threat. However, whether such a system would have any real value is not at all certain since it would be so sensitive to the sort of assumptions made about the offense missile design. Nor is it possible to predict, with the present state of knowledge, whether or not defense systems can be designed to counter all conceivable forms of ICBM threat, or whether any active defense system would be practicable to implement on a scale sufficient to give the nation a real measure of protection. We are deeply concerned, however, that time, perhaps critical time, is being lost because the necessary theoretical and experimental work on which to base these predictions is not being carried forward as rapidly as we believe it could be. If, after an intensive look at all possible lines of approach, an effective defense does not appear to be feasible, the nation's leaders should be informed as soon as possible in order that our national planning can be sufficient for this eventuality.¹ Some of the important areas where technical work is urgently needed will be discussed briefly in the following section.

Technical and Operational Considerations of Defense Systems

Detection.—Several well-understood radar techniques are applicable to the problems of finding an ICBM in flight and of providing position and velocity information.² It is not our purpose here to discuss the advantages and disadvantages of particular radar system designs but only to point out the various possibilities. These certainly include:

- a. Search-type radars scanning in both azimuth and elevation.
- b. Search-type radars scanning in azimuth and obtaining vertical coverage by two or more separate beams.
- c. Fence-type (multistatic) radars employing one or more separated receivers with each transmitter.
- d. Fixed, fan-beam range-triangulation systems.

¹ Even if a defense system is technically feasible, it may be so complex or so costly that it could be installed in only a few places. In this event, our national leaders would have to make serious decisions as to what targets should be defended.

² Although it cannot be said categorically that only radar has promise of practical use for "finding" ICBM's in midcourse, radar is without doubt the most satisfactory and earliest realizable method of detection with present technology.

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e. Ionospheric (HF) radars able to see below the horizon. (This technique, while offering some chance of detecting an ICBM at take-off, has many practical limitations.)

Broadly speaking, these radars have in common the requirement for large amounts of transmitted energy (order of several hundred kilowatts of average power), large antenna dimensions (half an acre or larger), receiving techniques to enhance the probability of detection and the accuracy of measurement, and methods for eliminating unwanted radar targets, such as meteor trails, aurorae and other atmospheric disturbances. Within each type of radar there are many possible variations in waveform of transmitted energy, method of scanning, signal enhancement techniques, manner of handling the RF power, antenna configuration, and so forth.

There is need for a *large-scale program* for development of components and techniques broadly suitable for these and other types of high power radars applicable for the detection and tracking of ICBM's. The program must not stop with laboratory development but must include environmental testing, manufacturing processes and experience in operation of complete radar systems. The building-up of such a program is technically sound and is clearly a *must*. Such a program will not evolve naturally from present radar work because the requirements are so different.

We are confident that a radar system to provide warning on ICBM's approaching the U.S. can be developed and that, given high priority, it could be installed within five years. The required advances in radar components, although large in extent, are well within the state of the art; the communication requirements could be readily satisfied using present techniques and equipment. With careful selection of sites on this continent, Greenland and Europe, it should be possible to install a radar surveillance system consisting of a very few stations which would cover all probable missile approach paths and provide approximately 15 minutes' warning for targets in the United States. The exact amount of warning would vary somewhat, of course, depending upon the missile flight path, the radar and target locations and the time consumed in generating and passing information. It is expected that the "target" of each approaching missile could be localized to an area approximately 50 miles by 100 miles, the greater dimension falling along the flight path. With continued refinement in techniques of measurement and prediction, these dimensions could probably be reduced considerably.

We consider it most important that work be started immediately on the development of equipment and planning for the installation of this radar warning system for the following reasons:

- a. The amount of warning would be sufficient to preserve much of our nuclear striking force and to permit the launching of a counter-offensive.¹

¹ The subject of "reaction time" of our long-range nuclear striking force is dealt with in Part III. Suffice it to say here that there are proposals within the Department of Defense for increasing and altering the base facilities of Strategic Air Command to permit combat operations with as little as 15 minutes' warning of attack. We believe this capability can be attained so that even the "surprise" of an ICBM attack would not be sufficient to catch all our SAC forces on the ground.

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b. Even 15 minutes' warning, if used effectively by the people in an area under attack, would be sufficient to reduce the number of casualties by a large factor.

c. The warning time and prediction information will be vital to any "active" defense system.

d. It is the one step toward defense against ICBM attack that is definitely within our reach and would give us a major start on this difficult problem.

e. Although not part of the warning system as such, another application of high-powered radars expected to be of much importance is the tracking of our own ICBM's during test firings.

Although we consider that radar detection methods can be most quickly applied to the warning problem, we also urge the study and evaluation of possible alternate methods of detection for whatever application they might have in a defense system, including the very important function of intelligence. Passive as well as active methods of detection should be examined.

Destruction.—As indicated earlier, an ICBM, or more precisely, the re-entry body containing the weapon, is expected to be a very tough object to "kill." Compared to the uncertainties which exist even today with respect to "what it takes" to kill a manned bomber for which configuration and performance characteristics are well known, the uncertainties regarding the vulnerability of an ICBM are orders of magnitude greater. Conceivably, a satisfactory criterion for "kill" might be any one of the following conditions:

A. Detonation of the ICBM warhead at such an altitude and distance from the defended target that the level of damage produced at the target is considered acceptable even if the weapon goes off with full yield.

B. "Pre-initiation" of the warhead to effect so great a reduction in its yield that the level of damage would be inconsequential at whatever altitude and distance from the target the warhead detonates.

C. Deflection of the missile so that it would miss the target by a safe distance when the nuclear weapon detonated.

D. Physical destruction of the re-entry body, the nuclear weapon or both such that the weapon does not detonate at all or detonates with such low efficiency as to be effectively a dud.

The first three conditions all involve the question: how much damage would be considered acceptable? Presumably, any lessening of the destructive effects, whether achieved by somehow reducing the yield of the weapon or by causing it to explode farther from the target, would be worth something. From extrapolated weapon effects data, it seems likely that "kills" by detonation, if possible at all, should take place at more than 50,000 feet altitude, if over the target, in order to satisfy reasonable criteria for "acceptable level of damage" from weapons of yields greater than a megaton.

Condition B, pre-initiation, could be produced only by nuclear radiation energy. It may present very attractive possibilities although the potentialities and practical limitations of pre-initiation are not well understood at this time. Its effectiveness

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will depend a great deal upon the design of the offensive weapon. It could turn out to be the primary means for obtaining a "kill" at any altitude as defined by condition B, above, or it might be just a "bonus" effect of some, never completely predictable, value. Furthermore, the Soviets might employ weapon designs that circumvent this possibility.

Condition C, deflecting the missile off its course a "safe" amount, is conceivable with the use of nuclear defense weapons but is not thought to be promising as a practical criterion of "kill." The same doubt is felt with regard to the practicability of deflecting the missile during its powered flight phase by interfering with the ground-air guidance link. Certainly, however, these possibilities warrant thorough and continuing consideration.

For certainty of kill, one expects that the defense system must be able to produce condition D, i.e., physical destruction such that the nuclear weapon does not detonate at all. Preliminary results from current studies on destruction of ICBM warheads by either nuclear or fragmentation weapons are not very encouraging. On the other hand, they are not altogether discouraging in that there do appear to be promising lethal effects if defense missiles can be made to intercept the ICBM within a few hundred feet.

It should be emphasized, however, that any conclusion one might be led to make at this time concerning the difficulty of the destruction problem must be considered very tentative since many factors have not yet been subjected to detailed calculation or experimentation. Some may not be amenable to calculation unless we are able to obtain positive information on the designs of nuclear weapons and re-entry bodies the Soviets would employ for their ICBM's. For example, self-destruction of the nuclear weapon by aerodynamic heating within the atmosphere after the nose cone was ruptured or torn off might be very effective against certain warhead designs. However, it probably is not a promising means of obtaining a kill if the re-entry body and weapon are an integral, heavily armored structure.

More fundamental data must be obtained on the mechanisms of destruction by high speed fragments, shaped charges, thermal and nuclear energy, blast and other potentially useful effects before recommendations can be made concerning specific types of defense weapons or optimum altitudes of interception. It is considered particularly important and urgent to gain a thorough understanding of the effects of nuclear weapons detonated at high altitudes both with respect to damage to ground targets and to the vulnerability of typical missiles and nuclear warheads. In connection with the latter, the "close-in" effects of nuclear detonations against possible types of re-entry bodies are especially in need of investigation.¹

Interception.—The problem of what type of interceptor vehicle to use is obviously part and parcel of the problem of destruction. It will be influenced by the weapon

¹ The first experimental effort in this direction will occur in the forthcoming Operation TEA-POT. Small spheres composed of various materials will be placed within the fireball radius of one of the bursts in an attempt to determine the effects on the materials from exposure to the fireball temperatures.

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which is to supply the "kill," by the required altitude of interception, by the guidance system employed and by many other factors.

In general, the interception problem divides into two different categories determined by the altitude at which interception is to take place, with the dividing line occurring at roughly 100,000 feet. This altitude marks an approximate upper limit for the practical use of missiles employing aerodynamic forces to maneuver and an approximate lower limit for the "free-flight" path of the ICBM.

Above this altitude the incoming missile would be expected to follow essentially a straight-line, predictable flight path, hence it might be assumed that interception at very high altitude would be easy. This is not necessarily true although it might be if, for instance, the allowable miss distance and time error permit the use of a predicted-fire counter weapon or a missile without terminal homing. However, unless the "kill" radii of weapons considered practicable to build turn out to be very large, it seems likely that some type of homing system will be required to attain the necessary accuracy of interception.

There are several possible approaches to both the interceptor missile design and its homing system. One is to use the more or less "conventional" aerodynamic missile as represented by Nike and Talos. The maneuverability and control problems increase with increasing altitude and speed; weights and sizes become very large for highly maneuverable missiles operating where the air density is low. It represents, however, the type of missile with which we have had most experience, and would likely be the earliest type of interceptor vehicle that could be produced. Against an ICBM re-entry body designed as a high drag device, allowing the defense missile more time to close, an aerodynamic missile of fairly modest performance capabilities, perhaps even an existing missile, might be a practical interceptor vehicle.

Another approach to the interception problem at very high altitude is the "space" missile which depends solely upon rocket thrust to maneuver. Such a missile would be boosted to the interception altitude near the predicted flight path of the incoming ICBM, arriving there at a low velocity, perhaps even zero. It would then be rotated rapidly about its own axes as necessary and accelerated toward the point of interception by rocket thrust. Programming of the timing and direction of flight would be done by some form of homing system with the objective of producing a collision. There are several possible variations of this general principle of an interception system. The method appears to be promising although it presents many new development problems. In any event, difficult or not, it does give some hope of intercepting ICBM's at still higher altitudes where the aerodynamic missile becomes impossible and where, for one reason or another, it may be necessary to make the "kill."

Our feeling with respect to the interception problem is that it is not impossible of solution, even for defensive weapons of quite small "kill" radii. As is the case for the destruction problem, however, there are many parameters of the interception problem which require detailed analysis and experimentation before preferred lines of system development can be selected.

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Research and Development on ICBM Defense Problem

Current work on defense against ballistic missiles is divided broadly into two areas defined by the range of missile, i.e., short range (less than 1,000 miles) and inter-continental range. The work relating to defense against short range missiles is being carried out under Army sponsorship (Project Plato) and is primarily oriented to the problem of defending tactical targets in a military theatre of operations. A second but technically similar problem is defense of coastal targets against ballistic missiles launched from submarines or ships.¹ The work on defense against ICBM's is sponsored by the Air Force. With the exception of a few projects, the work is only now beginning to gain momentum and is expected to be further expanded within the year.

Although we recognize that the time until the ICBM threat could become a reality may be only 5 to 10 years, and hence that work on defense must proceed at top speed if we seriously intend to counter this weapon system by active means, we feel we could not now justify a recommendation for a "crash" program in an effort to develop a defense system along a specific technological line. There simply is not at this time a sufficient body of knowledge upon which to base the design of a defense system in which we could place confidence. As has been brought out in the preceding discussion, only very recently have the fundamental problems in the areas of detection, destruction, and interception begun to receive thorough analytical study. What is needed at this time is expansion and stepping up of the theoretical and experimental work on a broad front. We feel certain that many of the nation's foremost scientists would gladly find time to participate in this work if they were asked. To name just a few of the subjects requiring much more investigation:

- radar techniques for searching for small, extremely fast targets in a very large volume of space;
- effects on radar signals from long propagation paths in varying atmosphere;
- discrimination against signals from meteors, aurorae and man-made false targets (decoys);
- optimization of methods for determining present and future position of ICBM's during any portion of the flight path;
- effects on requirements of interceptor maneuverability, stability and control for various guidance and homing systems;
- stabilization and thrust control of "space"-type interceptors;
- heat transfer and vaporization of material at fireball temperatures;
- transient drag phenomena as relating to destruction of re-entry bodies and nuclear warheads.
- applicability of optical and infrared techniques for detection and tracking.

The building up of an adequate body of technical data upon which to base designs of possible ICBM defense systems will certainly require the cooperative effort of many competent people from many organizations. We believe it is desirable to preserve a maximum freedom of initiative for all participating groups, at least until we begin to see some promising lines of approach. Nevertheless, because of the urgency of the

¹ An earlier study, Project WIZARD, sponsored by the Air Force, was directed to this problem.

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problem, and because of the danger that the total national effort will become too diffuse or that important areas will be neglected, it may be essential to place the over-all direction of the research and development program in the hands of a single organization of high calibre. As studies progress, there must be effective means for exchanging information, for conducting experiments and for initiating equipment developments to permit the program to lead to useful results in a reasonable time. We feel strongly that solution of the ICBM defense problem may well depend upon the way the research and development effort is handled during the next few years.

We know that a special committee has recently been organized under the Scientific Advisory Board of the Air Force to review current work on the ICBM defense problem and to make recommendations to the Air Force concerning further work which should be undertaken. We endorse this step. We are somewhat concerned, however, whether this committee, as we understand its intended manner of operation, will be able completely to explore the many problem areas in sufficient detail and rapidly enough to outline the technical framework for and the means of accomplishing a fully adequate program of study, experimentation and development. A technical group working intensively for a period of several months may be needed to perform these functions.

Conclusions

1. We anticipate that within the 1960-70 time period the USSR could be capable of attacking the United States with intercontinental ballistic missiles carrying high yield atomic weapons. We doubt that evidence from either the Soviet or our own guided missiles programs supports a more precise estimate of the ICBM threat at this time.

2. Considering that weapon yields of at least a megaton would be practicable, even for the earliest missiles, and assuming that the accuracy of delivery would be a few miles (as predicted for our own missiles), our cities and our bomber forces on airfields would be vulnerable to ICBM attack. It seems unlikely, however, that ICBM's would have sufficient accuracy to destroy, with reasonable numbers of missiles, well-designed shelters such as could be built to protect people or aircraft.

3. We are confident that a system of radars which would provide a minimum of about 15 minutes' warning of missiles approaching the United States with reasonably good localization of the target and launching areas could be developed and installed within five years. We consider it very important that such a warning system be built since it could be of great value to our retaliatory striking forces and could mean the saving of many lives even if we had no "active" defense against ICBM attack.

4. Although the technical problems are extremely complex, the attainment of means of countering ICBM's appears sufficiently promising to justify an expanded and accelerated program of research and experimentation on a broad front.

Recommendations

1. Although the technical problems that must be solved in attaining a defense against intercontinental ballistic missiles are extremely complex, there are sufficiently promising leads to justify an expanded and accelerated research effort on a broad

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front. Accordingly, we recommend that there be established a strong, balanced program of theoretical and experimental investigations of the basic problems of detection, interception and destruction. We suggest that the newly established Special Committee of the Air Force Scientific Advisory Board give early consideration to the formation of a full time technical group to carry out a rapid but thorough examination of the entire problem with the objective of laying the framework for the expanded program.

2. One important element of defense against ICBM attack—warning in minutes—is attainable. We recommend the immediate initiation of component development, engineering design and planning for the installation of a radar detection system to provide the maximum practicable amount of warning of the approach of ballistic missiles to the U.S. from likely launching areas. In connection with this program, but not limited to the warning function, we also urge that there be built up a large-scale program of development, limited quantity production and testing of components broadly applicable to very high-powered radars.

8. NON-MILITARY DEFENSES

Introduction

If all measures fail to deter the USSR from launching a surprise attack on the United States, no conceivable amount of active military defenses will provide 100 per cent attrition. Thus one must expect successful delivery of at least a small number of bombs, and these could produce millions of casualties. A vigorous Civil Defense program is essential to reduce these to manageable proportions and to provide this country with sufficient resiliency for survival and recovery. Further, such a program is required to permit freedom of action for a firm peacetime foreign policy.

New Threat

The advent of megaton weapons has radically altered the civil defense picture, for not only can an entire city be destroyed by the explosion of a single bomb, but also thousands of square miles can be covered with dangerous radioactive contamination following a surface burst. Figure IV-II presents an idealized contamination pattern that might result from the surface burst of a 10-megaton bomb. Although this figure indicates an extremely large area of lethal dosage to persons who remain exposed in the open without protective measures, it is important to realize that the area of *many times* lethal dosage is very much smaller. Indeed, at no place outside the area of major blast and fire damage is contamination expected to be much more than 10 times lethal. Thus, relatively easily obtained shielding protection can greatly reduce the area in which radiological fall-out need be harmful. Examples of the type of protection that can be given by different types of structures are shown in Table IV-3.

In order to take the best advantage of radiation protection, it will be necessary to remain in these structures during the entire time at which fallout is occurring and for some time thereafter. The tabulation in Figure IV-II contains a few examples of the time after burst at which one could leave a shelter at a given location and operate unprotected in the open without obtaining a sickness dosage (200 roentgens).

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TABLE IV-3
RADIATION PROTECTION

Type of Building	Protection Factor
Single-story, wood-frame house	2
Cellar of family dwelling	10-20
Commercial building	10-100
Simple shelter—3 feet of earth cover	5000

New Civil Defense Plans

The new threat places a premium on a good civil defense program. Furthermore, plans that were satisfactory for reducing casualties from the other effects of atomic weapons may be quite unsatisfactory in the event of serious radioactive fallout. It is therefore essential that present civil defense policies and plans be re-examined to determine the best protective methods. An early and important step in this re-examination is a comparative analysis of the expected casualties following attacks on a few typical U.S. cities in which fallout did and did not occur, in which evacuation was and was not undertaken, and in which a shelter program was and was not in existence. Such a study should be undertaken immediately by a competent group with access to the needed classified technical data, in order to provide early guidance for the detailed civil defense plans for individual cities. The long-range machine calculations of bomb damage, sponsored by FCDA and ODM, will take too long to satisfy current needs.

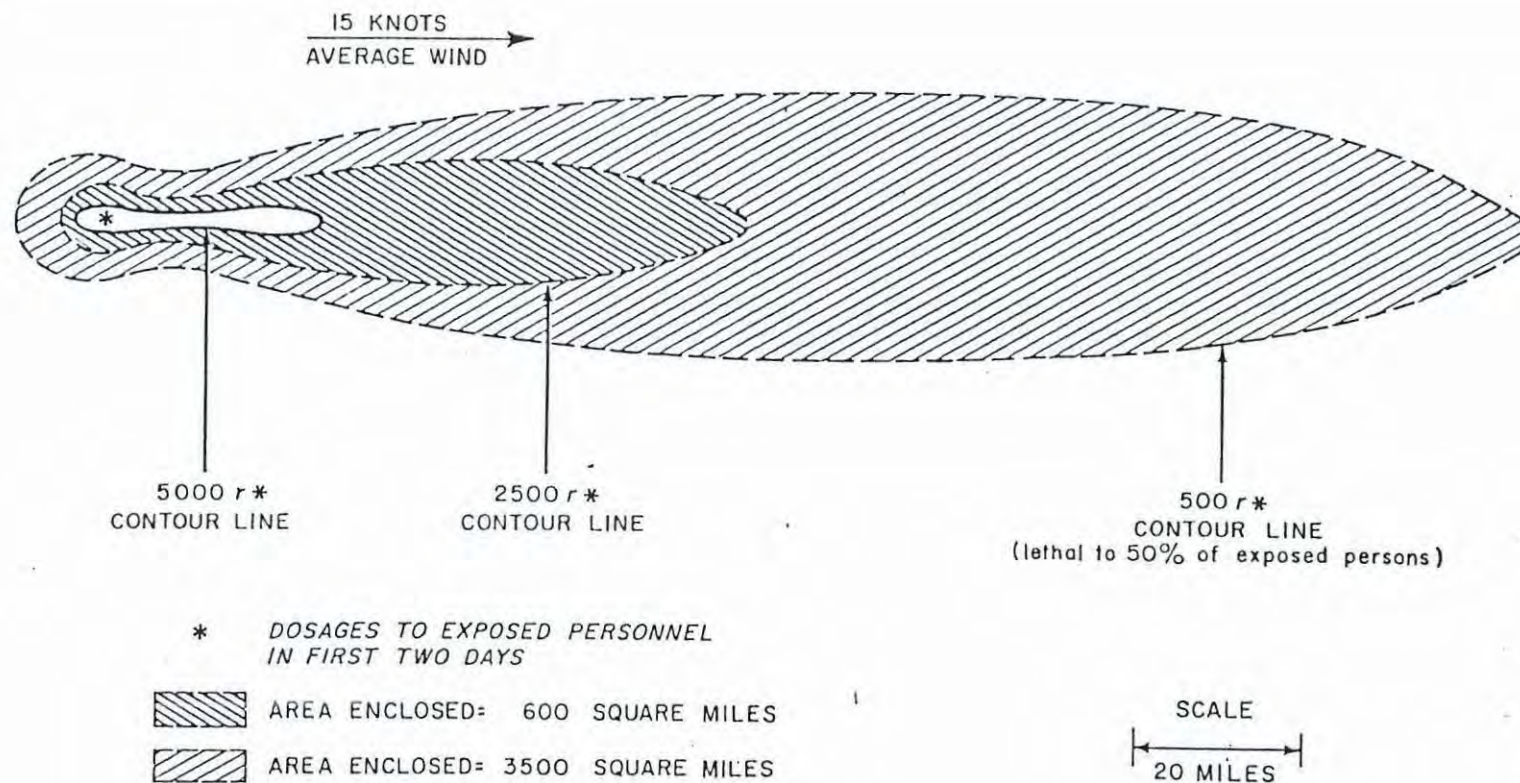
Evacuation and Shelter

Present federal civil defense policy calls for the mass evacuation of many of the urban target complexes. Because of the new hazard of radioactive fallout to people exposed in the open, it will be necessary in the future to place greater reliance on shelters and to keep the number of people evacuated to a minimum consistent with the ability to provide reasonable blast and fire protection. It may prove desirable, therefore, to limit evacuation to the centers of the prime target areas that are particularly liable to an initial attack. (See Figure IV-III.)

Whatever persons cannot be evacuated from the centers of the prime targets should have available strong shelters capable of withstanding a minimum pressure of about 100 psi; this will give protection at about a radius of 3500 feet from a surface burst of a one-megaton weapon. In many cases, this type of shelter can be provided with minor additional cost in the basements of large downtown buildings, underground garages, or subways.

Persons just outside the central evacuation areas should have available moderate blast protection. In many communities, this type of shelter is already present in the cellars of existing industrial and residential structures, and, in other cases, it can be provided at only nominal extra cost. Local codes for new construction might well insist

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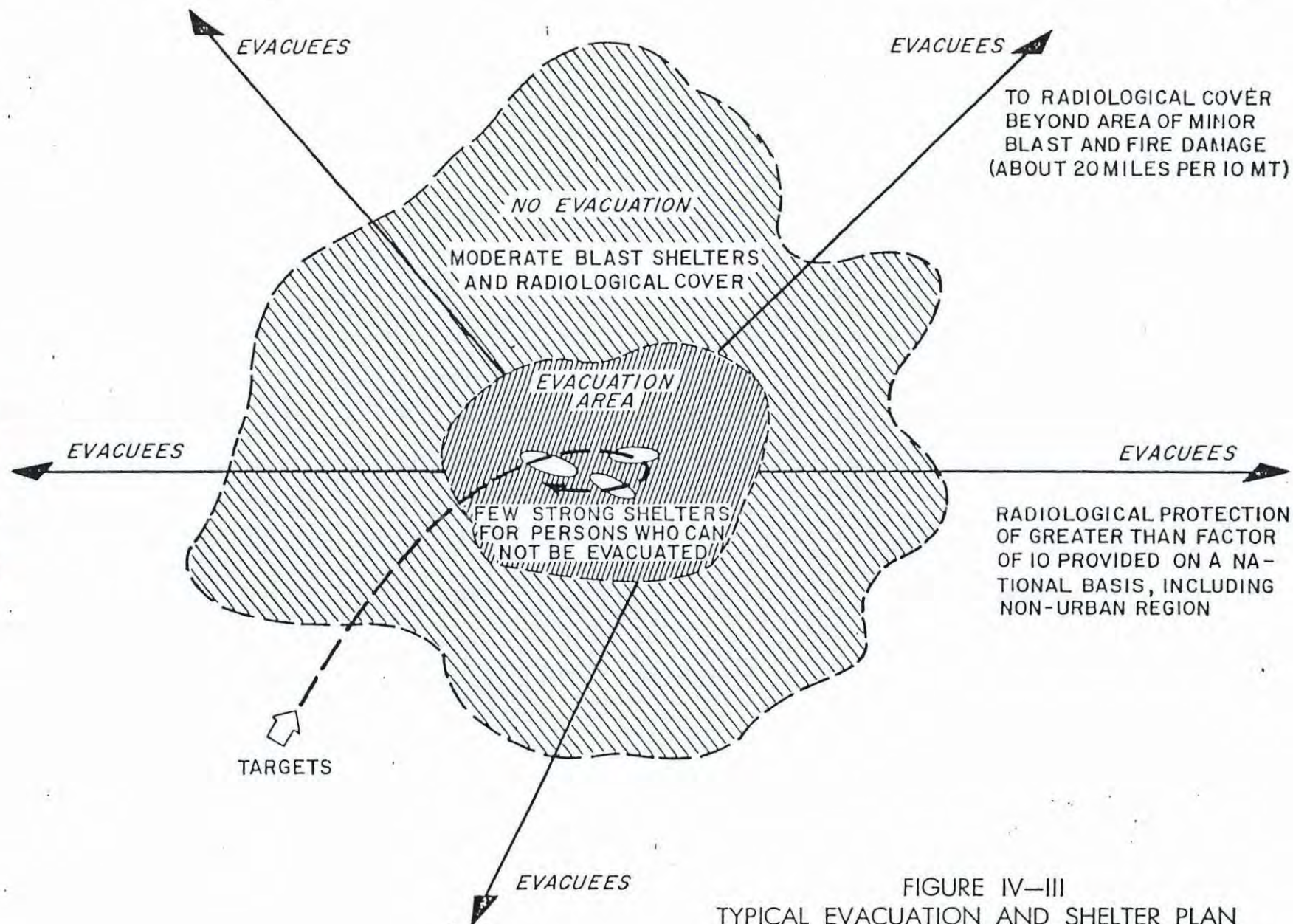


Safe Times for Leaving Shelters

Location	Time of Leaving Shelter	Safe Operating Time in Contaminated Area
500 r contour line	12 hours after explosion	8 hours
	1 day after explosion	1 day
	2 days after explosion	3 days
2500 r contour line	1 day after explosion	4 hours
	2 days after explosion	8 hours
	5 days after explosion	1 day
	10 days after explosion	3 days

FIGURE IV—II
IDEALIZED RADIOLOGICAL FALL-OUT PATTERNS
10 MT SURFACE BURST



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that this type of protection be included. Such policies have already been adopted in the USSR and other European countries.

The exact area within which evacuation should be planned will vary from city to city depending on whether it contains a high-priority target and upon the size of the target area, the anticipated warning time, and the availability of means of rapid egress and of strong shelters. For example, in a city like Washington, all persons within three miles of the central downtown area might be evacuated while, in New York, evacuation might be impractical on any appreciable scale. In a city like Albany, which may not itself contain a high-priority target, no evacuation may be required, since the major hazard might be downwind radioactive fallout from an attack on another target, such as Schenectady or Rochester lying to the west.

Because radioactive fallout can produce serious hazards at distances remote from the target area, nationwide protection against contamination must be provided. Every individual should have available, both at work and at home, a means of obtaining a protection factor of 10 or more (see Table IV-3). Such protection must also be provided evacuees, since it will generally be impractical to guarantee in advance exactly where radioactive fallout will not occur.

When short-range or, eventually, intercontinental ballistic missiles become a major threat, the value of shelters relative to evacuation can be expected to increase since warning will be limited to perhaps 15 minutes. Indeed, in the distant future shelters may provide the only means of protection.

Detection and Evaluation of Radiological Contamination

Since contamination can occur in areas remote from the point of detonation, an alarm system must be available to warn persons when fallout commences so that they can take proper shelter. Radiation instruments can be produced to provide this alarm directly and to determine at what time the actual fallout ceases. Other types of instruments should be available to survey the intensity of the radiation field so that the extent of the hazard can be promptly evaluated. Reliability rather than high accuracy is the prime requisite of such instruments. Prototypes of instruments which should cost between \$25 and \$50, when mass-produced, are available today. Aerial survey can be a very useful method for determining the location of the contaminated areas, while portable instruments will be needed for determining the hazard in local areas. These devices could be distributed to appropriate civil defense officials and made available for sale to the public. Training of monitoring personnel will be required to insure proper evaluation of the radiation levels observed. The public will need indoctrination to accustom themselves to the fact that low levels of radiation can and must be lived with. Radiation must be a phenomenon that is universally accepted and understood.



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Fire Protection

Radioactive contamination has tremendously complicated the problem of dealing with fires. It may no longer be safe for fire fighters to remain in the open for prolonged periods fighting fires. Fortunately, the fires initiated by the thermal flash will start slowly, and prompt individual action, perhaps prior to arrival of fallout could extinguish the largest proportion. However, greater emphasis must be placed on preventive measures—fireproofing of roofs, elimination of debris, shielding of inflammable interiors. The use of smoke screens (TRAC) has been proposed. Under favorable conditions, smoke will cut down the thermal radiation and its use would not be overly expensive; but its effectiveness in the case of a surface burst of a large-yield weapon will be reduced by an unknown amount. Furthermore, it presents a number of operational problems and might interfere with planned evacuation. All these aspects must be thoroughly investigated before any decision is reached on the value of TRAC for civil defense purposes.

Communication

The need for a reliable means of communication to the public is no longer limited to providing warning of an impending attack. The people must be informed of the onset of radioactive fallout, they must be given specific directions as to the proper procedures to follow when the level of the contamination has been determined, and they must be told when it is safe to leave their shelters for limited periods. New techniques of getting information to persons in individual shelters must be investigated. Since power may be nonexistent in the main target areas, reliance cannot be placed on normal communications. The feasibility of supplementing these with simple, cheap radios powered by dry cells or hand generators should be investigated.

Rehabilitation

The effort required in rehabilitation after attack cannot be overemphasized. Extensive urban and residential areas will be demolished. A large portion of the livestock could be dead or dying from radiation, and all exposed objects may be covered with a low level of contamination. The problem of feeding the homeless would be difficult under the best of circumstances, but, under the conditions that may actually exist, the problem could be desperate and may be soluble only by the most strenuous efforts based on realistic preplanning. The assistance of the military, both active and reserve, and of the National Guard will undoubtedly be required. At the present time, the national policy places the responsibility on the FCDA and the local civilian authorities. The military is providing limited assistance only when it is requested by local authorities. Despite this situation, there is considerable public thinking that in an emergency the military will take over and martial law might be declared even on a national scale. It is essential, therefore, that the complex civil-military relationships which may exist should be re-examined and clearly defined in advance so that the civil and military authorities and the public all know where the responsibility lies.

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Dispersion

Dispersion has the primary objective of minimizing the destruction and loss of life resulting from a single attack and the over-all vulnerability of the country. It further forces spreading of the attacking forces, thus reducing the saturation of the defenses. Finally, it forces the enemy to use a large attack, thereby lessening the danger of strategic and tactical surprise.

The Federal Government for a number of years has supported a dispersion program which encouraged critical wartime industries to move more than 10 miles from present industrial and population centers. This minimum distance has recently been increased to 35 miles which, in reality, means dispersion on a regional rather than a metropolitan scale.

Past emphasis has been placed on the contribution of dispersion to our ability to manufacture airplanes, guns, and other weapons after an attack. In the environment of a multimegaton attack, we believe that our effective military countermeasures may rely primarily on means available at the time of the attack. On the other hand the most important element in providing the required national resiliency may be the ability of the people to resume organized activity. Therefore, essential civilian industries must be represented in a dispersion program, not just those that contribute directly to the production of military materials. Accordingly, our dispersion program should be re-examined and a program put into effect that will ensure a maximum recuperative capability of the United States from a nuclear attack.

Funds

At the present time, the FCDA is operating with a small annual budget (\$59,000,000) by comparison to the funds being used for the military defense programs. A large fraction of these funds is being expended for building up stockpiles of medical and other civil defense supplies. In many cases, federal funds can be made available only in the event that they are matched by local funds. Funds for an orderly and continuous research and development program have never been appropriated. All these and other restrictions are indications of the lack of appreciation of the important part civilian defense could play in our national survival.

The civil defense program necessary to meet the new threat posed by thermonuclear weapons will call for the expenditure of additional funds, but should still not cost more than a small fraction (perhaps 2%) of the present total defense budget; yet it might save many millions of people. Many of the defensive measures require almost no federal funds at all, since existing facilities may frequently provide considerable protection. Some blast and fire shelters will have to be built, but in many cases these would have peacetime value as metropolitan garages. These might cost between \$200 and \$500 per person. Smaller sums may be required to strengthen existing structures. Instruments must be procured in quantity, but the total cost of these will not be large. Civil defense must have both the authority and the funds to carry out a research and development program designed to solve its specific problems.

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Policy

No properly designed civil defense program can succeed unless it is reinforced by a clearly stated and widely publicized civil defense policy which recommends reasonable courses of action in the light of the enemy threat. This policy should recognize that the obstacles to be overcome are not technical but primarily political, psychological, and sociological. The policy statement should be forthright, complete, and foresighted so that the necessary detailed planning and implementation can commence at once with reasonable confidence that major changes in policy will not occur within a few years. The reasoning should be made absolutely clear so that the people can understand why they are being asked to support certain courses of action. This policy should have the official support of the President and be endorsed by the National Security Council; the support of Congress must also be enlisted in order to insure adequate appropriations.

Conclusions

1. An effective civil defense will be a major factor in national survival in the event that diplomacy, our striking forces, and all defenses fail to prevent attack on this country; without effective civil defense, freedom of action on the part of the United States to adopt a firm peacetime foreign policy may be dangerously limited. Although the advent of thermonuclear weapons has radically altered the threat to our civil population and the protective measures required, a civil defense that will save millions of lives is technically and economically feasible. The problems that must be solved are political, sociological and psychological. The federal funds required for such a civil defense program are small by comparison with the present total defense budget (perhaps 2 per cent. The present FCDA budget is totally inadequate.

2. In the event of atomic war, one of the most important elements in providing the requisite national resiliency will be the ability of the people to resume organized activity after the initial attack. We are concerned over the concentration of our essential civilian supporting industries in critical target areas and the lack of a positive national program designed to reduce this vulnerability.

Recommendations

We recommend that a positive program to invigorate our non-military defenses be instituted by:

1. Immediate initiation by the FCDA of a study of the expected casualties from typical thermonuclear attacks under various conditions of evacuation and shelter. This study, which should be made by a group with access to all necessary classified data, should point out at an early date the factors influencing the proper balance between shelters and evacuation and provide data for individual community planning.

2. Prompt formulation of a new national civil defense policy designed to cope with the new threat from thermonuclear weapons and the radioactive fallout from surface bursts.

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3. Clear statements of this policy by the President and other high government officials, informing the public of the nature of the threat, the anticipated effects of thermonuclear weapons and the defense measures designed to give all individuals maximum opportunity for survival. These statements should provide the leadership required to give public assurance that, when this policy is implemented, megaton bomb attacks will not produce national collapse.

4. Re-examination and re-statement of the proper relationships that must exist between civil and military authorities in order to cope with the disaster conditions that may follow a large-scale attack.

5. Providing the FCDA with authority and the necessary funds to carry out an orderly and continuous research and development program designed to solve its own particular problems.

6. Further attention to measures to reduce the vulnerability of our essential civilian-supporting industries in addition to those measures now directed toward the dispersion of direct war-supporting industries.



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PART V

INTELLIGENCE: OUR FIRST DEFENSE
AGAINST SURPRISE

*Its performance,
its possibilities,
and its needs.*



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INTELLIGENCE: OUR FIRST DEFENSE AGAINST SURPRISE

1. Probability of Strategic Warning

A classic mission of intelligence is the provision of warning of impending attack. Today and in the immediate future, in the event of a sudden attack, should we count on having useful strategic warning? By *strategic warning*, we mean warning, through intelligence, of an attack while it is in the preparative stage. For an air strike, this means warning before the bombers take off from their staging bases. This warning may be months, weeks, days, or hours before the first blow is felt. By the use here of the phrase *useful, strategic warning*, we mean strategic warning which is clear enough, and well enough used, to deny to the enemy the enormous advantages of surprise attack in modern war. Can we have, and can we depend upon having, useful strategic warning in the event of a sudden attack?

Our military planning is by no means insensitive to the possibility of surprise attack. Effort is currently being directed to development of a radar network that will give distant coverage for tactical warning of a surprise air strike against us. High priority is accorded the protection and readiness of those of our air forces designated for an instant retaliatory strike. At the same time, our intelligence facilities are largely devoted to the problem of strategic warning. The data gathered are constantly studied by capable and devoted groups. (The central one of these groups is just now coming into effective operation.) The highest levels of our governmental security organizations are deeply aware of the existence of danger.

Experience has taught helpful lessons about the subtle nature of strategic indicators. Today's methods include features designed to avoid past errors, at least in the detection and interpretation of suspicious indications.

For all these reasons, we conclude that there is a good possibility that an enemy's preparations for a massive surprise attack on the United States would be detected.

One danger must be recognized: because the need for strategic warning is so very great, in the event of an attack, we have a correspondingly great urge to believe that the warning will be forthcoming. This human factor impairs sober, balanced judgment. Who can be *really* sure that the USSR could not slowly, quietly—over the months—assemble planes and crews for a sudden and possibly desperate attack on our SAC bases? Or what assurance do we have that the enemy may not develop an air force so active that it might, at any time, conduct a "maneuver" which ends with the actual drop of bombs on our cities? How can we know what intrigue or what clandestine attack may be hatching behind that fantastic front, the Iron Curtain?

On the more sober side, it can be said that we have enough information about the Soviet Union to give a probably reliable picture of its levels of military preparedness, industrial development, and technological strength. This picture as it emerges reveals a huge country, with great potential, still backward in many ways by our standards, but going forward rapidly, producing highly competent scientists and technicians in

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many fields, and devoting concentrated effort to the transformation of its brute strength into competence for modern technological war. Yet we must face up to the reality of the actual situation: our estimates of the capabilities of the Soviets have, at their center, only a very limited core of hard facts, and we know even less about their intentions.

Another complication in the strategic-warning problem arises because a surprise attack may involve real surprise in kind as well as in timing. Our intelligence may be thwarted if it is concentrated upon air forces and the first strike should be delivered by sea. The number of such *possibilities* is large, and of those, several might appear as reasonable courses to a potential enemy. We must remember that the advantage of surprise attack has never been so great as now. Moreover, just as we believe that our techniques in the discovery of strategic-warning indicators have improved, so also must we assume that the techniques of denying, confusing, and inverting these indications have advanced. The Soviets are not amateurs in these techniques.

There remains also a question as to the certainty of our putting strategic early warning to effective use. This question assumes larger proportions when considered for the cases of confused warnings, "spoofed" indicator boards, and even of sabotage to vital links in our response mechanisms.

For all these reasons, we conclude that there is a real possibility that a surprise attack might strike us without useful, strategic early warning.

Because we are unable to conclude that the U.S. surely will, or surely will not, have useful, strategic early warning in the event of a surprise attack, and because of the vital importance of adequate and balanced preparation, the first of our recommendations is that our national planning take serious account of both possibilities, and with approximately equal weights.

2. Intelligence and the Scale of the Attack

Our concept of strategic warning leaves to the tactical warning net the detection of bombers after takeoff from their staging bases, of submarines crossing the ocean with atomic weapons, etc. For strategic warning, intelligence must detect and analyze the evolution of the attack which began long before, with the buildup of the striking force, its vehicles, weapons, crews, and bases. Knowledge of that buildup is an essential element in strategic warning but alone does not constitute warning. It does constitute the framework or background against which the final signals have to be discerned and evaluated. Thus we are concerned with both the buildup of the force and its commitment to the attack. The likelihood that intelligence will obtain good strategic warning depends very much on the scale and kind of an enemy's preparations for the attack. This is an inevitable result of the nature of our intelligence system and its targets.

In order to find out what the USSR is planning, we must depend almost entirely on physical manifestations of activity. We deduce enemy decisions only from the actions that ensue, and we read their intentions only out of the *pattern of activity*, in the context of world developments. This is not a perfect intelligence system, but we have no better. It is more powerful than one might suppose, and still can be

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improved substantially. But it will remain, so far as we can foresee, a system that can more reliably detect *things happening*—physical activity and physical change—than secret decisions, intentions, and plans.

This being so, an attack that involves large-scale logistic preparation and numerous attacking forces is less likely to succeed in surprising us than an attack by a smaller force. To prepare for an attack on a larger scale, the enemy must train more crews in long-range missions; he must transport and store more fuel at advanced staging bases, and these bases have to be expanded in facilities or in numbers. If the target system that the enemy plans to strike is widely dispersed within the continental U.S., range limitations of his bombers may force him to stage out from more than one geographical area, making it still harder for him to conceal every indication of the preparatory activity. In brief, if an enemy believes that only a massive assault can accomplish his aim, his prospect of denying us strategic warning is much reduced.

All this has a direct bearing on our own military planning. It implies that our striking power and our defending forces, and their dispositions, affect our ability to obtain strategic warning of surprise attack. (This is not the same as the fact that our offensive and defensive strengths influence the probability that an attack will be made at all.) If the Soviet leaders should decide to attack us, the scale of the operation they would have to mount is to some large degree determined by their estimate of our retaliatory and defensive strength: by our retaliatory force and its disposition because that will determine how many targets over how large a geographical region they must knock out; by our defensive strength because the attrition they expect will influence the size of the initial force they must commit to the operation. Note, in this connection, that the relevant measure of our defensive strength is the enemy's estimate of it, not ours. For this reason, low-confidence measures of defense can play a significant role, leading the enemy to augment his force as a matter of insurance. (An example of such a measure would be the equipment of the Grand Banks fishing fleet with short-range radar.)

As an oversimplified illustration, with hypothetical numbers, suppose our strength, *as viewed by the enemy*, should change in three ways: (1) our striking power increases to such a degree that he has to aim at destroying at least 80 per cent of this force, instead of a figure of 50 per cent which he had previously adopted, to avoid intolerable retaliation; (2) dispersal of SAC is accomplished to such an extent that the number of these critical targets is doubled; (3) improvements in our defenses cause him to revise his expected attrition upward from 20 to 40 per cent. The combined effect of these changes is to increase the size of the needed force by a factor close to 4.¹ The buildup, assembly, and dispatch of such a force is that much harder to conceal from our intelligence.

This is an independent reason, and we think an important one, supporting many of the measures recommended elsewhere in this report, especially for reduction in the vulnerability of our strategic air forces.

¹ A simple calculation, correct in some circumstances is $\frac{80}{50} \times \frac{2}{1} \times \frac{100-20}{100-40} = 4.3$.

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3. The Question of a Major Hoax

While the whole Russian system is engulfed in secrecy, there is little evidence that the Russians have used positive deception. If we distinguish between *spoofing* by deliberately planted misleading evidence on the one hand and *concealment* of valid evidence on the other, then we must conclude either that they are not trying to spoof us or else that they have so completely succeeded in spoofing us that we have not detected their success.

Before examining this latter possibility, let us list a few typical areas in which concealment, as opposed to spoofing, may be operating to confuse us—areas in which we are puzzled by the lack of evidence, or embarrassed because we have such difficulty in obtaining it.

(a) There seems to be no good reason why the Soviets should not be refueling planes in flight:—but we do not know that they are.

(b) There are historical, technological, and military arguments for expecting them to possess effective, and operative, short- and intermediate-range missiles:—but we do not know that they have them.

(c) The pretended Soviet concern about our alleged use of bacterial warfare, and the early German competence in chemical warfare, coupled with elaborate civil defense preparations in Russia for such warfare, indicate that in these domains they could have significant offensive plans:—do they?

(d) Our best efforts and best results in intelligence have been delineating Soviet nuclear activities and potentialities. No tidier work has been done than that in cross-checking knowledge from observations of the product of their explosions with numerous small clues obtained by other techniques of intelligence. On the conclusions of this activity, we base a large part of our national planning for defense. (But because of the iron curtain and the geographic vastness of the Russian heartland, there is a residual uncertainty. Are we sure, in spite of the competence shown in assembling the nuclear jig-saw puzzle, that in all of secret, silent Siberia there are no concealed uranium-235 plants?)

These, then, are examples of how effective simple concealment can be. One can argue that the Russians have been so successful with the straightforward techniques of secrecy that they have had no need for the more intricate techniques of deception and spoofing. Yet, when we consider their talent for brazen manipulation of political propaganda, their expressed devotion to deception as a political tool, and their legendary history of skill in misleading, we must as a matter of duty discuss the possibility that we are involved or about to be involved in a major hoax.

There are two opposite functions for a major hoax: first, to make the USSR appear far stronger than it is; second, to conceal a tremendous strength being readied for prompt conquest. Neither of these presentations would be inconsistent with the Russian character; the first could readily precede the second, with the transition occurring five years ago, or five years hence. And what makes better military and political sense than for a nation to pretend to strength when it is weak, and to hide

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its strength when it is preparing the attack? Could Russia have fooled us broadly? Can she now? If the hoax exists, at what stage is it?

By definition, if we are fooled we cannot know it, either because we do not have the data or because the data have not been assembled in the particular way required to reveal the hoax. We should emphasize that it is a routine undertaking to study new intelligence for deception, so that a large-scale hoax can succeed only because it is large-scale. Within the smaller domains of intelligence in any one period, or in any one field of military activity, there must be actual consistency or the hoax is certain to be apparent to sophisticated observers. But it is uniquely in Russia that such large-scale deception could be planned and carried through—fooling not only the outer world but also her own population.

One point we must stress: if Russia understands all our intelligence techniques, it would be possible for her to feed into our system a factually consistent mass of actually deceptive data.

From such a massive deception there could result two opposite kinds of nightmarish possibilities.

(1) We are wasting resources by arming for a small present danger when we should be making a long-term plan for a necessary defense in a dangerous future.

(2) We are in immediate danger of attack by better weapons, carried by better vehicles, than we believe can exist in the near future.

To meet this difficult problem we should first obtain a National Intelligence Estimate of the extent to which the USSR has discovered and penetrated our intelligence techniques, making sure that the estimators have their attitude oriented toward the grand deception. With this estimate in hand, we shall be in a position to develop new procedures of cross-checking intelligence information from widely separated fields, procedures designed to discover inconsistencies between items in almost unrelated fields rather than between items bearing only on single problems. By applying these procedures, we should try to increase our chance of knowing Russia's true stage of development and to relieve ourselves of the recurrent phobia of a major hoax.



4. The Problem of Surprise in Kind

We have acquired the habit of thinking that a surprise attack, if it comes, will conform to a pattern something like the following:

The main element of the initial assault will be a long-range air strike at our retaliatory force and our control centers. Along with it, or just after it, will come attacks on our industrial targets and population centers. Missiles launched from submarines at coastal targets, and even bombs clandestinely introduced, may supplement the air attack, but are not regarded as the primary threat.

With our attention focused on this prospect, the recurring question is, how many hours' warning will we get, and not what *kind* of attack will we face.

There are compelling reasons for treating this as a very likely pattern for a surprise attack, and we shall recall some of these presently. But one reason—that it would be the natural and logical way for us to carry out a surprise attack on the Soviet Union—

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has perhaps been more compelling than it deserves to be. Timing is not the only element in strategic surprise. Therefore, while we must keep the threat of massive long-range air attack in the forefront of our defensive planning, we must begin to consider seriously the possibility that the attack will develop in a quite different way—a surprise in kind as well as in timing. To guard ourselves against surprise, it is only realistic to be imaginative.

Preoccupation with the air-attack threat has an insidious regenerative effect, through a feedback loop involving intelligence estimates. For example, we accept the exhibition of the T-37 bomber as confirmation of our suspicion that the Soviets are banking on air delivery of a paralyzing blow on the North American continent. If they are, we deduce that they will need a force of some particular strength. Their aircraft plants are thought to be capable of producing at some particular rate. From these deductions follows an estimate of their long-range bomber program with predicted future strengths. This estimate reinforces our assessment of the air strike as the overriding threat and is thus, more or less unconsciously, taken as an indication of Soviet *intention*. The only solid facts were the visible flying machine and some rough plant-area figures. If we should go astray in this estimates process, the danger is not only that we may overestimate the Soviet long-range delivery capability but also that, by misreading their strategic policy, we may fail to recognize a real threat in some other form.

Before trying (as an example only) to exercise our imagination along this line, let us look again at two important reasons why the delivery of atomic bombs on the continental U.S. by Soviet long-range aircraft is widely regarded as the main threat to our security.

Bluntly stated, they are:

- (1) the existence of a Soviet weapons stockpile and long-range bomber force, and
- (2) the conviction that an enemy must expect disastrous retaliation if he does not cripple SAC at its continental bases, which bases can hardly be attacked except by long-range bombers.

These are forceful arguments, doubtless sound, but are they quite conclusive? The Soviet Union today is a military power with almost no practical experience in long-range strategic air warfare, but with a tradition of vigorous tactical air support in ground operations. At the same time the USSR, as an aspiring world power, may well regard a long-range air fleet in being as an indispensable element of its military posture, just as an atomic stockpile in being is surely an indispensable asset in today's power struggle. This is *not* to suggest that the Soviet long-range air armies are a sham or a token force. But it would be compatible with Soviet tradition and aims to have built up such a force *even* while preparing war plans in which this force was not allotted the crucial role that we assign to it in our defensive planning.

As for the second argument—the necessity, from the Soviet point of view, to attack SAC first—we have to remember that this depends on *their* judgment of the threat SAC presents and of the best way to cope with it. There is ample evidence that the Soviets have invested heavily in active air defense and in civil defense as well,

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and that the readiness of their active defenses is maintained at least as vigorously as the readiness of their long-range air force. In a war launched by them, an early-warning problem such as ours does not exist; they even control by the timing of their attack whether the initial air battle at their frontiers is by night or by day. They *may* have a plan to fight off the retaliatory blow, counting on imposing a severe attrition and absorbing the residue. (Again, it is *their estimate* of the attrition they could impose, not SAC's, that is relevant.) If this is their plan for coping with SAC, the possible strategy of their attack on the U.S. is significantly changed—on the assumption that they plan to open a war by surprise attack. Its main purpose then becomes that of cutting off our military support of Western Europe for a time long enough to allow these countries to be seized and the seizure to be consolidated. If they can seal off a temporarily crippled United States for 6 months, the world into which we emerge on recovery becomes one that seems beyond salvation. From the Soviet point of view, this is as good as destroying us, or better. An atomic attack on our seaboard alone might well accomplish the degree of isolation and damage required. For all we know, the USSR is as well equipped at this time to carry out such an attack as it is to launch a successful Bravo mission. It may be better equipped.

The situation may change as we acquire the means for a massive thermonuclear retaliation, probably forcing the Soviets to revise any opinion that they could absorb a sizable fraction of a SAC assault.

If one grants the possibility of a Soviet strategic plan that does *not* depend crucially on the initial neutralization of our retaliatory power by bombs dropped from long-range aircraft on SAC bases, a variety of tactical variations and delivery methods comes to mind. Against some of these we are not well protected (see, Part IV, Sec. 6, which discusses threats from the sea and what needs to be done to cope with them). The possibility of clandestine attacks on key installations and personnel must be weighed very seriously. The physical and human links in the decision-making chain ought to be protected against even the most bizarre assaults. Clandestine tactics of this latter sort are auxiliary to the main attack, which still must involve the delivery of a substantial tonnage of atomic explosive. But, if the enemy thinks he has a reasonable chance to upset our response, he may be willing to gamble on a strategy for the main attack that we would have written off as illogical.

This is only to suggest that more than one *kind* of surprise attack can be imagined which is consistent with the known facts and consistent with the character and aims of the Soviet establishment. We do not propose to substitute the threat of a sea-launched attack for the air threat in our planning. However, according to our interpretation of the best present intelligence, Soviet capability for attack by sea currently could be as great as the capability by air. And at the present time our intelligence is less able to cope with the problem of obtaining strategic warning of the buildup for these kinds of attack other than by air.

We need to improve greatly our intelligence on Soviet weapons and delivery vehicles. For example, we do not know whether their submarines (and surface craft) are equipped for launching atomic missiles. We cannot be absolutely sure that the Russians are not stockpiling modern multimegaton nuclear weapons (without their



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yet having tested one). We know next to nothing about USSR CW and BW programs (Soviet civil defense measures indicate that CW is taken seriously).

In conclusion, we do not know enough now to predict reliably the nature of the surprise attack which we may have to face.

5. The Problem of Total Decision

The advent of a near-total weapon has created a new problem for the military and political executive: the problem of the *total decision*. Although the role of intelligence in strategic warning formally ends when the warning is generated, the decision to action is so grave and so vital that it is a matter for concern to all parties. No executive can undertake the responsibility for altering the face of our world unless he has strategic and tactical information of the highest reliability.

It is only wisdom on our part to believe that a clever enemy will discern the dilemma of the total decision. He can be expected to tailor any surprise attack so as to engender ambiguity in our strategic-warning signals. He may discover and proceed to tantalize our indicator boards. He may disrupt our communications, even probe our radar nets, without making war. He may rattle the sword of conquest and then turn sweetly reasonable, again and again. If he has his way, the total decision will be for our executives an hour of extreme agony.

The total decision must be made almost spontaneously, else it will be too late. Its consequences being total, it cannot be delegated. Because it cannot be delegated, there must be absolute reliability in the pathway by which the question reaches the executive. And there must be by prearrangement alternate arrangements if there arises an insuperable block in the primary pathway.

There must be practice travel over this path. Obviously there should be rehearsals of the communication technique, a testing of the whole variety of wires, machinery, and persons, and of their security from covert disruption or substitution. But beyond this, on a higher plane, there should be the psychological rehearsal—the moral and spiritual preparation for the total decision, in urgency, in conflict, and in confusion. The executive charged with primary responsibility for the decision, and his staff, should conduct experimental exercises, culminating in decision. Rehearsals should be based upon actual and potential strategic-intelligence and tactical-warning situations. The findings should be used especially to sharpen the requirements for adequate strategic-warning signals.

Our military and political executives need not always face the total decision. Besides the black or white decision in response to warning, there are the gray responses, those between purely defensive actions and unmistakably hostile actions. A particular set of warning indications might justify the full arming of SAC, or might justify no more than alerting of radars and ground observers. It is important that responses, as justified, be freely taken. This not only prepares for the immediate development but also gives invaluable exercise to the whole response network. The low-level responses need not, of course, wait upon high-level decisions. Yet enough of the non-trivial alerts should pass through the warning chain to the highest levels, to provide a context for the psychological practice that we recommend.

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6. Early Warning in the Presence of Jamming and Sabotage

The network of Soviet jamming transmitters is very extensive and remarkably well coordinated. It represents a suspiciously heavy investment of material and human resources—heavy, that is, in relation to its ostensible purpose of providing an iron curtain against foreign propaganda. We are compelled to infer that it has an important military function, and that this function probably is the disruption of our long-distance communications in the event of war or at any other juncture when such action appears profitable to the Soviets.

At present, jamming the high-frequency circuits would leave us with extremely limited transatlantic communications. Although the advent of transatlantic telephone cables will improve the situation during the next two or three years, the results of effective jamming will remain very serious. All communications across the Pacific are by radio and can be jammed. (See Part VI.)

For several years the Soviet jamming potential has worried people in the Defense Department and in other agencies. By now a sense of concern may be said to pervade the whole military establishment. Certain positive steps have been taken to provide less vulnerable transatlantic channels of limited capacity, but the situation is still serious and will remain so until much more is done. Elsewhere in this report, the vulnerability of our whole overseas communications system is discussed, and possible remedies are outlined. We shall emphasize here only those aspects of the problem that bear on intelligence and early warning.

Jamming threatens not only military communications at and after the onset of war, but also the lines of communications involved in getting and acting on strategic warning. It is sometimes argued that jamming will not seriously impair early warning because the outbreak of full-scale jamming would be in itself indication of imminent surprise attack. We believe that we should not take comfort from such an argument. In the first place, the scale of the jamming may be stepped up more or less gradually in a tense period, so that there would be no sudden and conspicuous extension of the barrage that could be recognized as significant. Of course, the trend itself would be an indicator, but not a clear one, and not an indicator at all if the enemy had already accustomed us to jamming crescendos which had subsided without further developments. Contrast this with an accepted useful indicator, for example the large-scale movement of troops. If troops could be moved without effort or cost at a moment's notice, the reliability of troop movements as an indicator of surprise attack would be almost nil. An enemy could move his troops widely and often, establishing a pattern of activity which pretty well concealed his intent. The situation in jamming is actually something like that. Once the transmitters exist, as they do, the intensity and scale of the jamming at any moment is simply a matter of the positions of switches and knobs. On such an organ many tunes can be played, and it is reasonable to expect that the program will be laid out with deception in mind.



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The channels over which strategic warning will come can hardly be singled out in advance. In all likelihood, it will not be a single message that conveys the warning, but rather many pieces of information whose full significance is revealed only when they are assembled in the light of other current intelligence. Hence, any contraction of our communication channels may reduce the chance of getting useful strategic warning. The only way to remove this danger is to reduce the vulnerability of our communications systems to the point where a substantial channel capacity over both oceans can survive a determined jamming attack.

While we have emphasized the danger that strategic-warning intelligence may be blocked by jamming, we recognize that full-scale jamming itself can be a useful indicator (just how useful will depend on the enemy's tactics). The current status of all overseas circuits should be available at all times to the National Indications Center and thus to the Watch Committee. By "current," we mean something like hourly; by "status," we mean simply one of three or four conditions, such as operating normally, inoperable for natural reasons, jammed but still operable, or thoroughly jammed. Such information needs anyway to be reported to a communications supervision center if effective use is to be made of the surviving circuits. A more detailed discussion of this matter is to be found in Part VI of this report. The important point here is that this information does not now reach the Indications Center.

7. Automatic Down-Grading of Intelligence

If, as a result of enemy actions, our retaliatory and defensive forces are to be ordered into action, their crews will require our accumulated intelligence on enemy orders-of-battle and capabilities. In peace time, dissemination of this intelligence information is restricted by its very high classification, so that it can be of maximum use in the event of a shooting war. It is important that the barriers of very high classification, which *would* be removed in war time, be removed *soon enough* to aid in the initial actions.

One specific example of the sorts of intelligence involved might be the locations and frequencies of enemy ground-control radar, provided this intelligence needs to be held in a very high security classification during peace. Undoubtedly there are other, more important, examples.

Decisions on down-grading of classification of this kind of material are made by policy boards or committees. Such groups can hardly be expected to move in this matter with alacrity, and this would especially be true in a busy moment of imminent hostility. If the down-grading is to take place in time, the necessary decisions need to be made far in advance; in essence, the down-grading must be automatic. To be automatic, it must be tied by previous, widely understood decision to some non-intelligence action, especially some specific action which will be taken in final preparation for retaliation. An example of such a specific action might be an order to load special weapons into all ready aircraft.

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8. Scientific Techniques in Intelligence

We obtain little significant information from classical covert operations inside Russia. The security zones at the border, the general restrictions in the interior, the security police, and the informers among the populace are brutally effective in limiting the infiltration, exfiltration, and usefulness of agents. The scale of the Soviet security and control activity is enormous. We cannot hope to circumvent these elaborate measures in an easy way. But can we use the ultimate in science and technology to improve our intelligence take.

Intelligence operations already make much use of technological advances—radio, airplane, parachute, balloon, electronic devices for ELINT, audio-surveillance devices, infrared equipment, and polygraphs. Any one of these devices is most useful when applied against an unsuspecting and unprepared opponent. Indeed, the really cute tricks are those so close to the frontier of scientific knowledge that they remain unsuspected for months or even for years. A research program producing a stream of new intelligence tools and techniques would be invaluable.

This is not to say that the intelligence community does no research and development. There are active groups developing code machines, portable radio communication sets, secret-writing inks, etc. These groups are small, are heavily burdened with specific requirements, and usually are charged with the support of field operations. Consequently these are better described as developmental groups. They are not appropriate for broad, fundamental, imaginative research in intelligence techniques. Specialists in outside laboratories now contribute in a limited way as consultants and contractors. The problem is to increase greatly the usefulness of our specialists in all branches of science and technology for this purpose, within the very unusual security restrictions which often are necessary if the end application is to be successful.

One new scientific intelligence technique is the project to use a special high-power radar (Project Draggle) to look from outside at Soviet high-altitude missiles. It is important that this project be made operational at the earliest possible date. There are other possibilities for technical peripheral surveillance of the USSR, most of which are not being fully exploited.

It is too much to expect that all of the nation's scientists should continuously have in mind potential applications of their knowledge and discoveries to intelligence techniques. But we have not made enough use in intelligence of our scientific resources. Some specific proposals will shortly be made to correct our deficiencies in this regard. One of these proposals is for a new laboratory facility where broad, fundamental research in intelligence can be conducted. Scientists and engineers outside the intelligence community will find it easier to give effect to their ideas through this new organization.

9. The Northern Periphery of the USSR

One major area of profitable intelligence activity against the Communist world must always lie on its periphery, wherever that may be. From Alaska south through Japan to the Philippines, east through Pakistan to Turkey and north through NATO

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to Norway and Greenland, we have varying degrees of access to the periphery. (In some regions, political considerations bar certain land areas to us, but the solution to such problems is usually political, not technological.) On the north, from Franz Josef Land through the islands of Novaya Zemlya, Severnaya Zemlya and Wrangell, and along parts of the Russian and Siberian Arctic coast, lies a part of the periphery of the Communist world which we rarely approach. The polar pack ice has been denied to us by geographic factors (weather, travel difficulties, ice-motion dangers) rather than by political ones. Technology should help us to conquer the geographic factors.

In all the world, it is only over, on, and under the polar pack ice that a large, neutral zone separates the Free and Communist worlds. Inevitably, one will be first to fill this vacuum—initially in intelligence and probably later in striking power. The Russians may already have begun this process. It is high time for us to begin now, and our technology seems adequate. Moreover, in case of war, the support of our own transpolar air operations (meteorology, rescue, early warning) will put a premium on the ability to occupy the polar pack ice.

That part of the polar pack ice within about 1,000-mile range of either the northern part of Alaska or the northeastern tip of Greenland is an area where we can easily deliver men, supplies, equipment and prefabricated shelter by single-hop air lift. Either two-hop air lift or air drop can deliver to almost any other part of the pack ice. Enough experience has been obtained in living under arctic conditions to make quite feasible the occupation of a chain of posts, given adequate technological support. Men would have to be carefully selected, and rotated, the posts would have to be located on well chosen ice floes, and evacuations would be planned in advance to avoid emergencies. Those posts near Russian bases would require delivery and supply flights at low altitude to avoid radar detection. With adequate camouflage, stations once on the ice should be almost immune to detection by the Soviets.

The information to be gained from the passive use of such stations would be similar to that obtained from other peripheral locations, by electronic surveillance, visual spotting of air traffic, etc., and possibly by the addition of the passive ends of some flutter links whose transmitters were far to the rear. These peripheral stations would be most valuable, because they should improve our coverage of the air traffic in and out of Russian advance bases, and because the probable routes from Russian staging bases to U.S. targets pass over them.

10. Satellites

A small artificial satellite, weighing 5 to 25 pounds, can be launched into an orbit about the earth by the use of existing rocket components. (The rocket motor of the Redstone missile, which will soon be available in quantity, could be used.) The total cost would be modest. A project of this kind has been proposed in detail to the Department of Defense and may already be under way. Existing designs provide for the small object to travel in an orbit at an altitude of a few hundred miles, circling the world every few hours. After several days or weeks, friction will have destroyed it.

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(With a little more rocket power, the satellite could be put in a higher orbit where it would last for years.)

We want to emphasize that a satellite would constitute no active military offensive threat to any country over which it might pass. A bomb could not be dropped from a satellite on a target below—indeed, anything released from a satellite would simply continue alongside in the orbit.¹ This inability to drop objects from a satellite onto the territory below makes a clear distinction in principle between a satellite orbit and the path of a very-high-flying airplane. Even a huge satellite overhead would constitute almost no direct military offensive threat. Although it might conceivably serve to launch a guided missile at a ground target, it will always be an exceedingly poor choice for the purpose. A missile will more easily be launched from a spot on the ground almost anywhere, even on the opposite side of the world.

We are convinced that small, inexpensive satellites can have several important uses related to intelligence. First, careful observations of the motions of the satellites would give, directly, much information about friction in the extreme upper air, and about fine details of the shape and gravitational field of the earth. This information is wanted for the design and guidance of long-range ballistic missiles and would be useful for the design of large satellites for intelligence purposes. Second, even a lightweight satellite might be constructed to open into an extended structure (resembling a bedspring) which would be an effective reflector for very-high-frequency radio and radar signals. Conceivably this could have applications in communication and in intelligence. Third, the new prestige that the world will accord to the nation first to launch an artificial earth satellite would better go to the U.S. than to the USSR. And although it is clear that a very small satellite cannot serve as a useful carrier for reconnaissance apparatus, cameras, etc., it can serve ideally to explore or establish the principle that space, outside our atmosphere, is open to all. This is a fourth factor pertinent to the value to the U.S. of a small satellite.



No effective doctrine of the freedom of space has been formulated by international convention. Even so, the validity of the principle in some form can hardly be denied. There can be little sensible objection to the presence or activities of non-Russians above Russia at extremely high altitudes (for example, on the moon). It is absurd to imagine the national sovereignty of the USSR extending in an infinite cone from the surface of this planet throughout all the universe, a cone continuously changing with the earth's rotation. At the other extreme, all would admit that control of the air 100 feet over Moscow properly belongs to the Russians. The only significant question is that of the dividing line (actually surface) between these regions. In time, international convention or usage presumably will define the altitude of this dividing surface.

It is obvious that the free space above Russia presents a boundary which can not be closed by barbed wire and police dogs, and indeed, which can hardly be closed at all. Eventually, with proper technological advances, which depend upon the minimum

¹ Even a rifle bullet fired directly downward from the satellite would only assume a new orbit of its own or else be destroyed by friction on entering the atmosphere. In the absence of air friction, a bullet fired directly backwards could reach the ground, but at a point thousands of miles away from the position at the time of firing.

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free-space altitude, the whole of Russia or any other country could be exposed to almost continuous surveillance. It could be to our advantage to take the lead in the development of appropriate international agreements on the freedom of space.

We have assumed here that in time we probably shall conduct extensive reconnaissance by means of large and complex satellites. A complete crash program toward this end would be very expensive in dollars, in manpower, and in priorities. The vehicle at launching would resemble an intercontinental ballistic missile. When the ICBM becomes available it can be modified, with the substitution of a smaller payload of camera or television and communication equipment for the warhead, to produce a true reconnaissance satellite. If we are to get by this means continuous surveillance detailed enough and extended enough to meet our intelligence needs, some extraordinary technical problems will have to be solved. [In particular, the surveillance should be essentially continuous, extensive, and in sufficient detail for the identification of objects (airplanes, trains, buildings) on the ground.] For the large satellites, the important project at present is research and development directed toward the essential components of the information-gathering and reporting system, including its power source.

11. Information Retrieval

Some intelligence comes as simple, straightforward reports, documents or pictures. But much of the intelligence on which we rely must be gained by the selection, combination and interpretation of the valuable bits of information among a vast mass of material. Imagine a tremendous pile of jigsaw-puzzle pieces, a pile containing perhaps 10 per cent of the pieces from each of 50 or 100 important puzzles, mixed with smaller portions of a very great number of other puzzles. The problem is to identify the pieces that belong to the important puzzles, separate them, arrange the pieces of each as best we can, and then deduce the rest of each puzzle. This appears a tremendous task, yet in scale it is far simpler than many intelligence problems where some of the important puzzles have often not been recognized when the pieces are first roughly examined.

The initial steps in handling these masses of data, the first rough sorting out of pieces that seem interesting, the routing of selected pieces to the specialists in the puzzle or puzzles into which they seem to fit, the surveillance of today's new pieces by the specialists and their return for coding and filing, and the retrieval from the file of those pieces that might be of use to a particular specialist studying a special problem are steps analogous in many ways to the filing and retrieval of information in libraries, clipping bureaus and other stores of information. Intelligence agencies clearly face problems of immense size in what is today called information retrieval. We do not know of an information problem of comparable size anywhere else.

Principles and techniques are now developing rapidly in this field, and their speedy adoption and efficient use are of paramount importance in intelligence. Otherwise, the multiplication of manpower in routine intelligence activity can easily become self-defeating because of the limitations on quality of personnel and the difficulties of

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training and communication. The present situation may be dangerously close to injuring the security and limiting the output of the intelligence process.

Any effective program to put the principles and techniques of information retrieval to work in intelligence must be a continuing and extended one. New principles, new techniques, and new machines are appearing at an increasing rate. We need to use each in its place, disdaining to mechanize when a new principle is needed, disdaining to seek a new principle when mechanization is needed.

Libraries often evade their responsibilities while improving the *apparent* quality of their performance by limiting their function. If you know the author, title, publisher, etc. of a book, you can be almost certain to discover from a library card catalogue whether the library has it, and how to locate it. But if you know that a book is 3 inches thick, bound in green, written by a Norwegian, and has one chapter on Labrador, the library card catalogue will do you little good. This is in part because of the way the books are usually coded or indexed.

Some files of intelligence documents contain a half million or so items and grow daily. In some of these files, very modern machine methods of retrieval are in use. But coding systems are at least as important as machines. The familiar library card-catalogue system, with its scheme of coarse and successively finer classifications, is still in use in some intelligence files. Punched-card systems are used in others. These punched cards involve many, but not very many, classifications, and sorting can be done on any combination of classifications. Very promising, and well suited to many intelligence file problems, are newer systems of coding based upon the use of a combination of several punched holes for each of a very large number of classifications. These newer systems offer unusual flexibility with minimal mechanical difficulties, with only the small disadvantage that some unwanted material usually accompanies the retrieved file cards.

It is characteristic of intelligence problems, from the point of view of coding and retrieval, that new classifications and categories frequently need to be added. Each of these additions presents an enormous problem because of the very large number of cards already in the file, each of which may need reprocessing. The size of the files and the frequency with which new classifications should be added are such as to make this problem far exceed that of conventional libraries. Here again, there are quite promising systematic methods by which the file may be reprocessed not quite perfectly but with relatively little human labor. Their basis is that manual reclassification of a random sample of the file will provide material for a machine assessment of those old classification groups which can select from the file the cards most likely to need the new classification marks.

In planning information retrieval for intelligence, we must abandon the idea of being able to get everything of a specified sort in the files, in order to be able to afford enough flexibility in what may be searched for. The implications of this for methods and techniques are extensive and often surprising.

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As a final and special case, let us consider the initial rough sorting of certain large volumes of intelligence information. This initial sorting consists most often of a simple visual examination of the material for the presence of key names and words. This operation now requires a large number of non-specialized employees. Much of this information is or has been transmitted over our teletype circuits. While in electronic or tape form (for the teletypes), the material could easily be searched by machine for key names and words. This mechanization not only would make for savings in personnel but would permit sorting out nearer the source that material deserving immediate transmission, thus saving time and reducing the load on our high-speed communication circuits.

In many kinds of intelligence work, collection and retrieval are the two indispensable functions. We have not been able to attain perfection in either function, but must strive to improve both. Much more effort has been applied to collection than to retrieval, so that today additional effort in retrieval is likely to be valuable.

12. Long-Term Planning for Intelligence

An important requirement of our intelligence community is for long-range directives and plans, looking as much as 20 years ahead. Whereas it is now exceedingly difficult to penetrate into the USSR, there are many countries around the world that are easily penetrated. Most of these are not now of active interest in our foreign affairs and consequently are the object of much less intelligence effort than Russia itself. However, any of these countries may, within a decade or two, become a focal point of world politics. We should today be laying the groundwork for extensive covert operations in *every* country available to our agents, recognizing that without doubt this is an expensive program.

Our agent operations against the USSR are greatly handicapped by the lack of useful, high-level agents. It is shocking to learn the extent to which our operations of this kind have to depend upon agents of wholly inadequate training, education, and experience. (This is not to detract from the courage and devotion of many of these persons.) Operations against Russia today could use, more than anything else, persons of great intelligence, experience, and knowledge, not to mention courage and loyalty, prepared by years of planned activities to have in some degree the confidence of the communists, and able to live or travel legally within the Soviet Union. We need to devote years to the buildup of such activities as Greek shipping firms with capable CIA agents as executives, South American plantations owned and operated by our agents, etc. A man who has appeared for years to be a leftist leader in Mexico or Iran can learn more about Russia, and do it more safely, than one who slips across the border at night and sends out a message or two before being caught by the Soviet security police.

We must have numbers of these high-level agents of great potential effectiveness. We can have them, but not overnight.

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The plans and directives for the CIA probably need to reflect more decision concerning the nature of the role to be played in foreign countries under specified circumstances. Should the covert preparations be only for the gathering and reporting of intelligence, or should they provide also for an active role in the suppression, control, direction, and production of crises and tensions? Should we be prepared there to counter opposing intrigues? All this is not wholly a pleasant business, but had we planned for it ten years ago we might have been able to prevent or reduce such crises as those in Korea and Indo China. This is a matter deserving the most serious consideration. Because it is of marginal direct connection with this report we have merely mentioned it here. We note that among the means that are available for the support of such operations, many can be provided by science and technology.

13. Recommendations

1. Because we are unable to conclude that the United States surely will, or surely will not, have useful strategic warning in the event of a surprise attack, we recommend that our planning take serious account of both possibilities.

2. The fact that the probability of strategic warning increases with the size of the attack gives added support to recommendations (elsewhere in this Report) that our striking forces be further dispersed and that our defenses be strengthened.

3. We *must* find ways to increase the number of hard facts upon which our intelligence estimates are based, in order to provide better strategic warning, to minimize surprise in the kind of attack, and to reduce the danger of gross overestimation or gross underestimation of the threat. To this end, we recommend adoption of a new organizational procedure by which scientific and technological means can be fully exploited.

4. We need to examine intelligence data more broadly, or to invent some new technique, for the discovery of hoaxes. As a first step, we recommend a National Intelligence Estimate, with adequate safeguards, of our success in keeping secret our most useful techniques of intelligence. This Estimate would suggest the extent to which an enemy might be manipulating the information obtained through these sources.

5. There is an urgent need for an examination of all the technical, procedural, and personal links by which early warnings are translated into decisions for responsive actions.

6. Overseas communications systems less vulnerable to jamming and sabotage are urgently needed. Without them messages containing strategic-warning information may not reach our intelligence centers. The National Indications Center should be kept informed of the prevailing status of our overseas circuits with regard to jamming.

7. An automatic procedure to lower the security classification of information about enemy capabilities and order-of-battle, as war starts, is required.

8. There are generally recognized technical and administrative problems in the field of ELINT (electronic noise listening). This situation needs attention. A combination of technical knowledge and adequate authority at a high level is wanted.

9. We should at once take steps to develop the special equipment and specialized personnel needed for intelligence operations in the region of the polar pack ice.



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10. Intelligence applications warrant an immediate program leading to very small artificial satellites in orbits around the earth. Construction of large surveillance satellites must be deferred until adequate solutions are found to some extraordinary technical problems in the information-gathering and reporting system and its power supply; and should wait upon development of the ICBM rocket-propulsion system. The ultimate objective of research and development on the large satellite should be continuous surveillance that is both extensive and selective and that can give fine-scale detail sufficient for the identification of objects (airplanes, trains, buildings) on the ground.

11. The growing principles and technology of information retrieval will advance and may revolutionize the handling of large masses of intelligence data. Their applications should be sought out more actively.

12. A heavy long-term investment should be made in the preparation of covert agents as eventual sources of high-level intelligence.

Note: In order to keep this report out of a more restricted classification, the Panel has prepared for highly restricted circulation, two other reports on intelligence embodying recommendations and conclusions for transmittal directly to appropriate offices of the government.

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PART VI
OVERSEAS MILITARY COMMUNICATIONS

*An examination of how their
reliability may be improved.*



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OVERSEAS MILITARY COMMUNICATIONS

1. Précis

The most important objective of this study is to determine whether the overseas communications facilities for gathering information or giving critical orders would be disrupted in case of a surprise enemy attack.

The answer seems to be that while all parts of the system are vulnerable to jamming and sabotage, a small amount of essential information could probably be passed. The degree of certainty depends on the locations involved. In the case of the European area the chances of satisfactory communication both to and from the United States are the least unfavorable because of the number of alternative circuits including cables. In the case of the Far Eastern areas, there is considerable doubt as to whether the messages would get through without substantial delay.

Improvements should be made both in the technical performance of the communications facilities, and in the organizational arrangements for maximum effectiveness. Technical improvements may take several years to be fully effective, while some organizational improvements could be instituted in a comparatively short time.

2. Communications Facilities

The global communications facilities involved consist chiefly of radioteletype or cable telegraph circuits which form part of the organization of the United States Army Signal Corps, the United States Air Force, the United States Navy, and leased facilities of commercial communications organizations such as AT&T, RCA, Western Union, and Commercial Cable Company.

The combined facilities are extensive and touch all the points that are important from a military standpoint, as well as essentially all the countries of the world. For example, between the United States and the Europe-Africa zone, there are something like 40 teletype channels in more or less continuous military operation. Included in this figure are several all-cable channels. Extensive courier services are also available.

These facilities are employed not only by the military services which operate them, but also handle a good part of the communications for such other government agencies as the State Department, the Central Intelligence Agency, and the National Security Agency. It may be noted that the National Security Agency presently accounts for a major fraction of the traffic involved.

3. Favorable Factors

There are several factors which support the feeling that some essential communications can be carried on in the face of enemy attack. The most important is probably the existence of the comparatively large number of paralleling or alternate routing facilities if all the military and available commercial facilities are pooled. There is diversity in the fact that some of the facilities are radio, subject to jamming, while others are submarine cables, subject to cutting. (There are no trans-Pacific



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cables currently operating under military control.) Of interest is the fact that in the last war no cables in the Atlantic were cut by the enemy.

Related to the matter of the number of available facilities is the fact that in an emergency it is generally agreed and plans have been made by each of the military and other users to limit the amount of traffic over the electrical communications facilities to the bare minimum of essential messages.

In current day-by-day operation the radio circuits are frequently interrupted by natural phenomena and occasionally by inadvertent jamming, so that, in many areas, there is regularly a substantial amount of cooperation between the different military agencies to interchange facilities so that the traffic can be efficiently routed and reach its destination.

There has been a fairly general recognition of the problem of possible enemy jamming of radio links by the military organizations. Research and development programs have been set up by the services to take care of this. Included in the improvement programs are substantially higher powered transmitters, more directive antennas, and new systems of modulation intended to render the teletype circuits less susceptible to jamming. Entirely new routes equipped for "Forward Scatter" transmission are also involved. New cable circuits are planned or under consideration. The adequacy of these programs will be discussed later.

4. Unfavorable Factors

Individually the communication links are very weak at the present time, particularly HF radio links which are potentially subject to jamming. The facilities of the enemy for jamming have been the subject of investigation by CIA and others. His actions in jamming against the Voice of America, Radio Free Europe, British Broadcasting Company, etc., are well known. Studies have indicated that if the enemy used all the transmitters he probably has available and chose optimum locations within enemy-controlled territory, most overseas HF links could be interrupted almost constantly.

The research and development programs previously referred to are intended to improve this situation in the future. However, this improvement program will take at least two years to reach reasonable effectiveness as it involves substantial physical additions to and rearrangements of present plants. The improvement programs of the different services vary. While the Joint Communications/Electronics Committee of the Joint Chiefs of Staff serves to promote interchange of information between the different services, there is no continuously functioning organization to encourage the study of the problem by all of the services and to force action to make specific improvements.

In the main, the present antijamming program applies only to the circuits of the military agencies, and thus far the commercial organizations have not paid especial attention to the possibility of jamming. At present, the commercial radio services appear to be about as vulnerable to jamming as do the military services.

The problem of sabotage has been given some study by the different services. However, it is felt that inadequate attention has been given to this problem. For ex-

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ample, desirable fencing for antenna farms has been omitted in some cases, explained in one case as being due to lack of funds. Also, the various receiving stations, both abroad and in the United States, are particularly vulnerable, for at least a short period, to jamming, if the enemy places small all-wave jammers such as spark coils, very near the stations, even, possibly, within the antenna farm. The surprise element in this case would be important since the necessary direction-finding equipment to locate such a jammer might not always be available.

Commercial services appear to be in a weaker position than the military with regard to sabotage, particularly since in many cases the foreign cooperating terminals are under the control of aliens.

There appear to be no continuous organizational arrangements for carrying on frequent evaluations of system performance under emergency conditions, particularly involving jamming. Some sporadic tests have been made by individual services in the past and a more elaborate test is planned for the immediate future by JCEC.

There is no continuously functioning agency which is at all times in possession of up-to-date information on the status and functioning of the global communications network. The failure to have such an agency makes it difficult to consider the combined facilities of the global networks as an efficient operating unit and to ensure maximum utilization of the entire system, particularly in the case of enemy attack. It would also make it difficult to assess as intelligence data the extent of enemy jamming of these channels. Furthermore, it appears that the military receiving stations have neither trained personnel nor equipment which would enable them to determine the presence and character of jamming signals.

At least one of the agencies, the Air Force, appears to have a status collecting agency for its own facilities. However, at the time of this report, there is no over-all agency combining this information for all military services and the commercial companies.

The commercial facilities presently leased by the Armed Services are an integral part of the military communication system. Plans call for a substantial increase in the use of commercial facilities upon the initiation of hostilities. However, thus far there appears to have been no positive assurances made to the military services that the additional commercial facilities will be released to them *immediately*. Also, some of the services have expressed the doubt that they will be allowed to keep the commercial facilities they now use.

From the standpoint of jamming, an unfavorable technological trend is the growing employment of on-line teletype encrypting devices. Such devices require higher quality circuits for good operation than do ordinary teletype equipments. Also, the use of encrypting devices in the case of telephone transmission, which is increasingly favored by the Air Force, would probably make such circuits more sensitive to jamming.

5. Present Status

The present arrangements to ensure continuity of communications for the different services are probably adequate for peacetime needs. Such arrangements are basically independent for the different Armed Services but there is reasonable coordi-

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nation at theater levels to promote interchange of facilities where circuit conditions and traffic needs require. The physical arrangements are, in the main, aimed to ensure freedom from natural propagation disturbances. There is, as previously noted, no master information center or traffic controller for the combined network of all the services including the commercial leased facilities.

Each service is responsible for evaluation of the functioning of its own links. Checkups are made periodically, once an hour in the case of the Signal Corps. In the case of the Air Force, status information is available from all links on a continuous basis at Andrews Air Force Base in the United States.

Those immediately concerned at the communication terminals have been alerted to look for evidence of concerted enemy jamming and there are understandings that this information will be passed along to higher steps of command in each service. However, as noted previously, there is some doubt that such evidence would always be recognized. Further, there is no assigned responsibility for the collection of such information from all of the services and the commercial communications companies.

There have been some general studies at high levels of vulnerability of the radio circuits to enemy jamming. The Army Signal Corps appears to have made the only relatively complete and quantitative study. This study has been in process for some time. It shows the present Signal Corps overseas network (ACAN) to be highly vulnerable to jamming, assuming, as noted previously, that the enemy is capable of concentrating in favorable locations all of the facilities the best evidence of the CIA indicates he possesses. (Present indications and evaluations credit the Soviet Union with jamming transmitters ranging in number from 350 to 2100. The power radiated has, in at least one case, been estimated to be as high as a megawatt.) For example, the present circuits between Honolulu and Tokyo and between Honolulu and Clark Field, P.I., would be inoperative at all times in the face of a concerted jamming attack. These estimates are based on the ACAN network, but similar estimates apply to the other military and commercial facilities between these points.

As a result of preliminary studies of vulnerability, the need for improvements in the present radio facilities was recognized two or three years ago. Suggestions by the JCS encouraged development and research planning in this connection. The impact of this program on the operating system has not yet been felt.

As part of the study of potential jamming, some of the services have carried out small-scale tests of simulated jamming. These tests verified the seriousness of the situation and also indicated the need for further periodic tests of this kind. A large-scale test involving the different military services is planned by the JCEC for the near future.

The period at the initiation of hostilities is believed to be particularly critical. A wide-spread program of enemy jamming or cable cutting, or both, could be regarded as significant information for intelligence purposes and may, obviously, be directly related to military action. As noted previously, while the military services have alerted their communications personnel to this possibility, it is doubtful that such efforts on the part of the enemy would be discovered in a short time, or that the reports

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would reach the organization responsible for final evaluation and action with sufficient speed.

The ability to pass information at this critical time, both to transmit intelligence from abroad concerning enemy actions or intentions, and to transmit critical orders initiating responsive action on the part of military field forces will depend on the extent to which the enemy is directing efforts to disrupt all communications by jamming, cable cutting, and sabotage of radio and cable equipment.

Since there are, in the case of links between the United States and the most important theater areas, paralleling and diverse facilities, together with alternate multi-link paths in most cases, it is considered unlikely that the enemy could break all circuits at the same moment. This opinion is concurred in by the responsible communications officers of the military services. However, there is no apparent reason why, if the enemy were sufficiently well organized and his planning perfect, he could not ultimately disrupt all of the paths. His potentialities in this respect seem to be adequate.

With the possibility that the enemy could not break all communications circuits at the same moment, a limited amount of information might be passed to and from the United States before the facilities were completely interrupted. The extent to which advantage can be taken of the time elements in this case will be determined by the speed with which the arrangements for setting up alternate routing and interchanging the facilities between different military services, and with commercial organizations, could be accomplished.

The important orders could range from a simple SAC directive to area commands initiating action, to involved situations requiring extensive intercommunications between commands of different services. In the latter case, the problem would be correspondingly more complicated.

Obviously the situation with respect to the availability and reliability of communication facilities for an indefinite period of continued hostilities would depend on similar factors and the extent to which the program for improving technical functioning of the communication facilities were completed. Any estimate must include the possibility that the enemy might be able with time to increase his disruptive facilities.

It is concluded, therefore, that the *present* situation is not particularly promising. The ability to carry on either during the opening period of hostilities or later depends on a somewhat optimistic view of the inability of the enemy to make full use of his potentialities, particularly with respect to high frequency radio jamming and cable cutting. On the other hand, a small amount of traffic could probably be handled provided the organization were modified to enable the systems to work as a unit.

6. The Future

The future situation with respect to vulnerability of communications links will depend on the extent to which the presently scheduled or projected technical and organizational improvements can be embodied in the over-all system. Assuming

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that the various improvements discussed below can be made effective, a communications network of considerably higher reliability than the present looks possible.

7. Technical Improvements

Increased Transmitter Power.—The services now use single side band transmitters with power ratings of from one to four kilowatts. The transmitter power for use with frequency shift keying teletype ranges from fifteen to fifty kilowatts.

The Signal Corps has programmed the installation of higher powered transmitters at all of its important locations. These transmitters will provide up to fifteen kilowatts with single side band operation and fifty kilowatts with frequency shift teletype operation. About 20 percent of these transmitters have been installed and the remainder are to be installed within the next year and a half. It is understood that the Air Force and Navy have also ordered some transmitters of this type. Transmitters in the 300 to 500 kilowatt range are also being developed for the Signal Corps.

Improved Antennas.—The three services and the commercial companies now use rhombic antennas almost exclusively. These antennas have particularly poor side-lobe suppression when operated over a wide band of frequencies. This increases the vulnerability to jamming.

The Signal Corps has studied this situation and has designed and is testing an antenna with considerably better side-lobe characteristics. Unfortunately, this antenna works well only over a narrow band of frequencies and the large-scale application to the links generally may be impractical with respect to space and other limitations. It could, however, be employed to decrease the vulnerability of certain critical circuits. It is possible that further work may reveal broad-band antennas which have desirable lobe suppression characteristics, and which can be used more generally. No plans for antenna improvements appear to have been made by the other services.

If fifty kilowatt transmitters and receiving antennas having characteristics comparable to the antenna under test were substituted for the present equipments, a reduction in the jamming vulnerability would result. For example, it has been estimated by the Signal Corps that a one megawatt jammer could completely disable the Honolulu to San Francisco circuit using present equipment. With the new equipment, operation could be achieved on a twenty-four hour basis. On the other hand, the circuit from Honolulu to Tokyo would be inoperative in the face of a one megawatt jammer with either the present or projected system.

NOMAC.—A high frequency teletype system employing a noise-like carrier and cross-correlation detection (NOMAC) is under development for the Signal Corps. If present difficulties with multipath propagation can be resolved, this system promises to give a reduction in jamming vulnerability equivalent to that obtained with a 20 db increase in transmitter power. This improvement is obtained at the cost of increased channel bandwidth.

Self-checking Code.—There is a teletype system currently being employed to some extent by RCA which uses a six-digit self-checking teletype code. It is so arranged that

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if the receiver fails to record the proper number of digits for a letter group, the information will be returned to the transmitting end by the opposite directional transmitter and call for a repetition of the garbled letter. This does not ensure that the system is any less vulnerable to continuous jamming, but it does mean that if the jamming is interrupted for even a brief instant, the transmittal of useful communication will be resumed at a point where it was stopped and continue again until jammed.

High-speed (Squirt) Transmission.—Systems have been proposed with transmission speeds up to 6000 words per minute. Such systems have unique usefulness where the time interval available for transmission is comparatively short because of jamming or because it is desired not to reveal the position of the transmitter. The Navy is interested in such a high-speed transmission system but currently has no development work going on. A system of Teletype Corporation is presently available which is capable of speeds of from 600 to 1500 words per minute. This system should be given operational tests by the services and the whole problem of increased transmission speeds should be thoroughly investigated.

Multi-frequency Switching.—It has been suggested at various times that one way to acquire an over-all reduction in vulnerability at the expense of considerable frequency allocation space would be to arrange to have a large number of transmitter frequencies and transmit short bursts of message information of several seconds duration, switching in a planned random manner from one frequency to another and with coordinated receiver switching. In this way the enemy would be forced either to jam continuously all frequencies or to follow up switches with sufficient speed to avoid missing parts of the message. Although the enemy is known to have considerable ability to follow frequency changes, it is not believed that he is able to move with sufficient rapidity at present to make such an arrangement unworkable. The proposal, while obviously presenting difficulty to the enemy, also involves considerable equipment to make it effective. At present it is not known that any steps are being taken to develop military equipment of this type. It is understood that some further consideration is being given to the method in some quarters and this should be encouraged.

Facsimile.—The use of properly designed facsimile equipment is one way of reducing the vulnerability of a transmission system to jamming at the expense of rate of transmission. It appears that all the military agencies will make an increasing use of facsimile transmission in the future. If future equipment is designed to take advantage of the increased redundancy, the services should be in a position to take advantage of this characteristic of such systems.

CW Transmission.—It is known that for the low speed transmission of uncoded messages, CW with aural reception has an appreciable advantage over teletype reception from the standpoint of tolerance to jamming. On the other hand, for coded or enciphered text, aural reception, even with most experienced operators, loses most of its effectiveness because of the inability of the operator to fill in parts of common word structure.

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The various military services will probably not be able to take advantage of CW operation to any extent in the future since the number of really experienced operators is growing less with time. The Navy seems to be in the best position in this respect since there are still a fair number of smaller naval craft not equipped for teletype operation and which, therefore, require manual operators. On the whole, however, it seems unlikely that CW operation will offer any large-scale advantages with respect to jamming in the future.

COZI.—Determination of optimum HF transmission frequencies can be facilitated by the use of the Communications Zone Indicator (COZI). This equipment operates by measuring the back-scatter from the ground. This has been proposed as an aid in operations against jamming. It is recommended that operational tests be made of this system under jamming conditions. If the results prove favorable, the equipment should be added to the communications system.

Forward Scatter Transmissions.—The Air Force has one ionospheric scatter circuit in actual operation from the United States to the northern tip of Greenland involving three links. The system has, thus far, exhibited high reliability in an area where HF transmission is subject to serious interruptions due to auroral effects. Plans are under way to extend this circuit by several links, finally terminating in the UK.

It is believed that such a circuit should be less vulnerable to enemy jamming because of the scatter propagation characteristics which limit the area within which the enemy must be located in order to jam. However, it appears that no serious studies have yet been made nor tests conducted to verify this assumption. It is strongly recommended that this be done immediately.

The Signal Corps has a one link ionospheric scatter circuit in trial operation in the Alaskan area and is contemplating the installation of a multi-link circuit from Honolulu to the Far Eastern theater where, as previously noted, the HF circuits seem to be particularly vulnerable. The Air Force is enthusiastic about the future possibilities of this system and is contemplating its employment in other locations.

Although there are situations where geographical conditions do not permit their use, it is believed that the further development and application of these "Forward Scatter" transmission systems should be pushed with considerable vigor.

Meteor Trail Transmissions.—It has been proposed to use high altitude ionization phenomena produced in meteor trails for point-to-point transmission. This system is being studied by Canadian and U.S. laboratories and is believed to be in a fairly early stage of development. The results, including vulnerability to jamming, are not known to the writers of this report. It seems evident that further work and the development of equipment for this purpose should be encouraged.

Artificial Satellite Transmissions.—It has been proposed that by the establishment of a cluster belt of small artificial satellites in the equatorial plane, a transmission path might be established having characteristics similar to that using meteor trails. Because of the equatorial location, such a system should be relatively invulnerable to enemy action. It is suggested that an evaluation be made of this possibility.

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VOA as Point-to-Point Circuits.—The VOA has in operation some global point-to-point circuits using powerful transmitters in day-by-day propaganda operations. These are, ordinarily, one-way circuits emanating from the United States. This system could be made available for two-way transmissions with the addition of certain directive antennas and receiving facilities. It would also be highly desirable to add equipment for conversion from voice to teletype operation.

The merits of this proposal should be studied in detail, and, if the results look promising, immediate steps should be taken for implementation since the transmitter powers available could significantly strengthen presently weak links.

Very Low Frequency Transmissions.—Both the Navy and the Air Force make use of VLF transmissions particularly for one-way broadcasts to mobile points. Such service is understood to have a high degree of reliability. Its vulnerability to jamming has, however, not been thoroughly evaluated, although the Soviets are known to have high-powered transmitters in this frequency range. The Navy has attempted point-to-point communications with the UK with not particularly successful results and further tests are planned. It is also planned to try two-way point-to-point communications with Japan using existing VLF facilities in the near future.

The possibility therefore exists of using such facilities in the case of concerted jamming of the regular HF facilities but, in view of the Soviet potentialities for jamming in this frequency range, the future does not look promising.

Cable.—As has been previously noted, there are a number of telegraph cables crossing the Atlantic. These are, in part, in regular use by the military agencies. They are vulnerable to cutting, particularly in the shallow water locations which, on the United States side, extend for considerable distances from the shore. Correspondingly, of course, repairs can be made fairly rapidly in the shallower areas. In the deep sea locations of 1,000 fathoms or more, the problem of cable location and cutting would be more difficult for the enemy. However, it is also more difficult to pick up and repair such cable. As previously noted, it is a fact that during the last war the North Atlantic cables were not cut by the enemy. The opinion has been expressed, that there is some fair likelihood that these cables may not be cut in the event of hostilities, and that, in any case, it would be difficult for the enemy to keep all cables cut at any one time. However, in view of the size of the Soviet submarine fleet and the status of contemporary mining techniques, it is difficult to understand why the Soviets would not attempt and be able to mount a concerted cable-cutting effort. It is recommended that the problem of cable vulnerability be given thorough study in the light of the present situation including modern technology.

Other cables in the Atlantic area are contemplated. One projected cable would touch the various land masses of military importance in the North Atlantic area, terminating in the United Kingdom. Another cable system having unusually wide band capabilities, essentially for telephone service, is being engineered between the United States and the United Kingdom via Newfoundland. These two cable projects should add to the over-all reliability of the Atlantic communication facilities, although they will not be available before two or three years.

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The Pacific area has no cable facilities devoted to military operation at present except in the coastal waters from the United States to Alaska where there are Signal Corps cables. There is a Canadian cable which runs from Vancouver to Australia via the Fiji Islands. There also exists an unused commercial cable which runs from San Francisco to Hawaii to Guam.

Consideration has been given, within recent years, to the acquisition and rehabilitation of this cable by the military. Thus far, no action has been taken but the matter is currently up for final review. While the facilities afforded would be comparatively low speed, it would seem that having the cable available would add to the reliability of communications with the Far East in case of sudden enemy attack.

Consideration is also currently being given to the provision for a new broad band cable in the Pacific area. This would, of course, take several years to put into operation and the cost would be considerably more than that of acquiring and rehabilitating the old cable.

8. Organizational Improvements

Coordination of Research and Development.—As implied by some previous statements, there is no one organization with full responsibility for studying the reliability of the joint global communication network, planning improvements, and ensuring that the improvements are incorporated in the systems within a reasonable time.

The individual services are doing effective work in some areas. However, it is evident from the preceding discussion of technical improvements that there are many promising ideas on which further study is needed. Also, more definite plans should be made to carry out specific improvements on a unified basis.

The JCEC serves as a common meeting ground to interchange information and ensure that there is no serious overlap in the work carried on by the different services. While it may from time to time give encouragement to certain lines of attack, it is not a directing agency. Neither is there elsewhere in the Department of Defense nor in the ODM an agency with power to perform the functions suggested above.

In view of the great importance of global communications and the weakness of the present situation, it is believed that there is need for an agency having the powers suggested above in order to take full advantage of the research and development resources of this country.

Coordination of Operations.—The value of considering the communications operations from the standpoint of the pooled resources of the various Armed Services and commercial companies seems evident. To some extent this is being done at the present to advantage. A joint services traffic study may further confirm this, particularly if it could be carried out under simulated war conditions.

Since there is no continuous over-all status reporting which includes all the services and commercial companies, the present situation is weak in at least two respects:

a. As has been noted, there is no focal point at which the presence of widespread jamming can be determined and evaluated as possible evidence of enemy intent.

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b. Maximum advantage cannot be taken of the diversity of types of facilities as well as routes and frequencies.

The Air Force, as noted previously, has a status control center for its global communications net and it is known that the commercial companies do this for their facilities. It is strongly urged, therefore, that consideration be given to the establishment of a global military communications office for the continuous collection of current status information and with responsibility for the direction and routing of traffic. Its functions would have to be coordinated with those of the theater communications officers.

There is a joint armed forces courier service which handles a fair amount of day-by-day communications traffic at present. In the event of hostilities, a substantial amount of low-priority traffic could be diverted to couriers, thus making more of the rapid facilities available for high-priority messages. In general, the military services and other government agencies such as NSA have plans for cutting down on the radio transmission of low-priority traffic. The total physical facilities required in the event of hostilities to supplement the present courier service should not amount to a large share of the airborne resources of the military. One user of these services has stated that the present speed of handling courier traffic would be inadequate in time of war. This might require faster planes and more expeditious handling at the terminals.

9. Conclusions

It is concluded that, while all parts of the system are vulnerable to jamming and sabotage, a small amount of essential information could probably be passed. The degree of certainty depends upon the locations involved. In the case of the European area, the chances of satisfactory communications both to and from the United States are the least unfavorable because of the large number of alternative circuits, including cables. In the case of the Far Eastern area there is considerable doubt as to whether the messages would get thru without substantial delay.

The present situation is particularly weak and indicates that the enemy is potentially in a position to jam all radio circuits and to cut all cable facilities.

Improvements should be made both in the technical performance of the communications facilities and in the organizational arrangements for maximum effectiveness.

If the organizational arrangements can be strengthened and certain technical improvements incorporated, the vulnerability, particularly of the radio circuits, can be considerably reduced in the next two or three years.

10. Recommendations

We recommend that:

1. An agency be established, or designated, having responsibility for investigating the reliability of the overseas communications networks, and for planning and promoting technical and other improvements needed to achieve a considerable reduction in the vulnerability of our overseas communications.

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2. A communications office be established, or designated, having responsibility for the continuous collection and evaluation of information on the current performance of all vital links of the overseas communications networks; and that this, or a related office, have responsibility for coordinating the rapid interchange and re-routing of traffic in the event of widespread interference with our communications.

3. The following technical improvements be made:

Sabotage. Immediate steps be taken to insure station and equipment integrity.

Increased Transmitter Power. This program be given all possible encouragement.

Improved Antennas. Further study be carried on very actively.

Self-Checking Code System. Consideration be given to the value of adaptation of such systems for military circuits.

NOMAC. Tests and other work on this system be carried on with highest priority.

High-Speed (Squirt) Transmission. Further studies of feasibility and usefulness be made.

Multi-Frequency Switching. Further study be made to determine whether such military equipment should be developed.

Facsimile. In the design of future equipment, consideration be given to its possible use in the case of jamming.

CW Transmissions. The services be alerted to the possibility of using CW operations in cases where experienced operators can be provided.

Communications Zone Indicator (COZI). Operational tests be made of this system under jamming conditions and, if results prove favorable, that the equipment be added to the communications system.

Jamming Tests. Jamming tests be made at reasonable intervals under conditions that will tax to the limit the ability of those charged with operating the facilities to use evasive techniques, alternate routings, and operational understanding.

"Forward Scatter" Transmissions. Serious studies and tests be made immediately to determine the jamming characteristics of this system. The services are encouraged to install such systems where geographical conditions permit.

Meteor Trail Transmissions. Further work on the development of equipment for this purpose be encouraged.

Artificial Satellite Transmission. Further study and evaluation of this system be made.

Voice of America as Point-to-Point Circuits. That the merits of this proposal be studied in detail and, if the results look promising, immediate steps be taken for implementation of a conversion program.

Cable Vulnerability. The problem of cable vulnerability be given thorough study in the light of the present political situation and modern technology for mining and cable cutting.

Cables. Efforts be made to bring to a conclusion present studies to determine: (a) if an old cable between San Francisco and Guam is worth acquiring and rehabilitating; (b) whether a completely new broad band cable in the Pacific area should be planned.

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PART VII

SKILLED MANPOWER IN THE ARMED FORCES

*A critical link in the readiness
of our complex weapons systems..*



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SKILLED MANPOWER IN THE ARMED FORCES

1. Introduction

Throughout this report we have emphasized the importance of combat readiness to our ability to detect and respond effectively to surprise attack. Combat readiness is a function of a number of factors including the quantity and effectiveness of materiel. Effectiveness of materiel in turn depends on the capability of personnel to maintain materiel and to utilize it to the maximum of its design potential.

In discussions with field commanders on current and prospective weapons systems, we were impressed by the concern they expressed over critical shortages of skilled personnel capable of maintaining complex weapons systems. The Strategic Air Command frankly admitted that its fighting force cannot develop and retain its desired combat effectiveness with only a 25 per cent retention factor over a four-year period. Similar concern was expressed by the Air Defense Command. The situation was also described as serious in the Army and Navy.

On the basis of the judgments of experienced military leaders, present and prospective shortages in skilled maintenance personnel appeared to constitute an intolerable handicap in the achievement of the high degree of readiness required by the threat of surprise attack. We have sought to determine the factors affecting the availability of maintenance personnel and to assess, insofar as possible, the effects of shortages on combat readiness and effectiveness.

2. Requirements for Skilled Manpower

The enormous gains in weapons performance during the past ten years have been achieved at the expense of complexity in our weapons systems. Atomic weapons and the radical extensions of speed, altitude and range of our delivery vehicles have engendered a wealth of innovations in electronic and mechanical equipments. The development of all-weather interceptors and guided missiles to cope with the correspondingly increased offensive capabilities of the USSR has resulted in weapons complexity of a high order in our defensive systems.

The advantages of this improved weapons performance have in many instances been offset by losses in equipment reliability and by increased demands for scarce maintenance personnel. Difficulties of equipment reliability and maintenance may well impose practical limits on future refinements in the performance of weapons systems unless this can be accomplished through designs offering increased reliability and less complexity.

Several of the many examples of the ways in which advances in weapons design have multiplied requirements for maintenance personnel are described subsequently.

At the end of 1945, fewer than 5 per cent of Navy carrier aircraft were configured for all-weather operation. By 1955, 34 per cent of day fighters and 43 per cent of attack aircraft will be all-weather (largely through developments in electronics). Examples

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of the number of electron tubes per 1953 aircraft as compared with the 1945 aircraft which they replaced, and the man-hours required to inspect them are shown in Table VII-1.

TABLE VII-1 ELECTRON TUBES IN NAVY AIRCRAFT					
1945			1953		
Type	No. of Tubes	Inspection Man-Hours	Type	No. of Tubes	Inspection Man-Hours
F6F-5(N)	170	2.8	F3D-2(N)	625	10
FG-1D	77	1.28	F7U-3	449	7.5
TBM-3E	205	3.4	AF-2S	479	8
SB2C	218	3.5	AD-YW	597	10
PBM-5	373	6.2	P5M1	1161	19
PB4Y2	454	7.5	P2V-6	686	12.2

An examination of seven types of Navy aircraft of World War II compared with comparable 1953 aircraft shows that increases in man-hour requirements for electronics maintenance range from 151 to 335 per cent. Similarly, the Navy destroyer of 1940 had 60 electron tubes; the 1955 destroyer has 5400.

Comparison of the Air Force F-86 fighter with its F-51 predecessor (in use two years ago) reveals a threefold increase in maintenance man-hours per flying hour.

A dramatic indication of the effects of new weapons on manpower in the Army may be gleaned from Signal Corps statistics. At the beginning of 1946, there was a total of 2300 enlisted men undergoing training in radio, wire communications, photography and cryptography courses of from 8 to 20 weeks in length. By mid-1954, there were approximately 11,000 men undergoing training at Signal Corps schools in 35 different courses ranging from 8 to 33 weeks in length. During FY 1954, the Signal Corps enrolled over 31,000 men in the various school courses.

Increasing weapons complexity has also lengthened the training times required for maintenance jobs. In the Air Force, a series of critical occupational skills now requires 2 to 3½ years' training, formal and on-the-job (see Table VII-2).

Similarly, a Navy aviation electronics technician spends 28 weeks in "A" school and 40 weeks in "B" school at the completion of 2 years' sea duty—or 3½ years' service and training to qualify.

With 4-year enlistments, and current re-enlistment rates for first-term enlistees of 13 and 5.8 per cent, in the Air Force and Navy, respectively, it is obvious that an excessive number of men must be trained each year in order to satisfy unfilled field requirements at these skill levels.

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TABLE VII-2
TRAINING-TIME REQUIREMENTS IN AIR FORCE

<u>Occupational Skill</u>	<u>Training Time</u>
Jet engine mechanic	2 years
Electronic technician	2 years
Crew-line or hangar chief	3 years
Fire-control system technician	3½ years (involving 3 different schools)

The growing complexity of equipment in the Army, Navy, and Air Force has necessarily changed the functional composition of the Armed Forces. During the past 10 years, there has been a marked increase in the proportion of jobs requiring higher skill levels and training. For the Army, the number of maintenance personnel per thousand enlisted personnel, in five selected specialties, is shown in Figure VII-I.

It is clear that needs for specialized maintenance personnel will continue to increase. This is due to two factors, (a) introduction of new equipment in increasing numbers, and (b) new concepts of strategy required by atomic warfare.

With respect to new equipment, we can now see the expansion of the Strategic Air Command and the phasing in of the B-52 bombers. Although there will be some reduction in the total number of personnel required to maintain the B-52 compared with the B-36 that has been an increase in the required skill levels (see Table VII-3).

TABLE VII-3
SKILLED PERSONNEL REQUIREMENTS AIRCRAFT MAINTENANCE

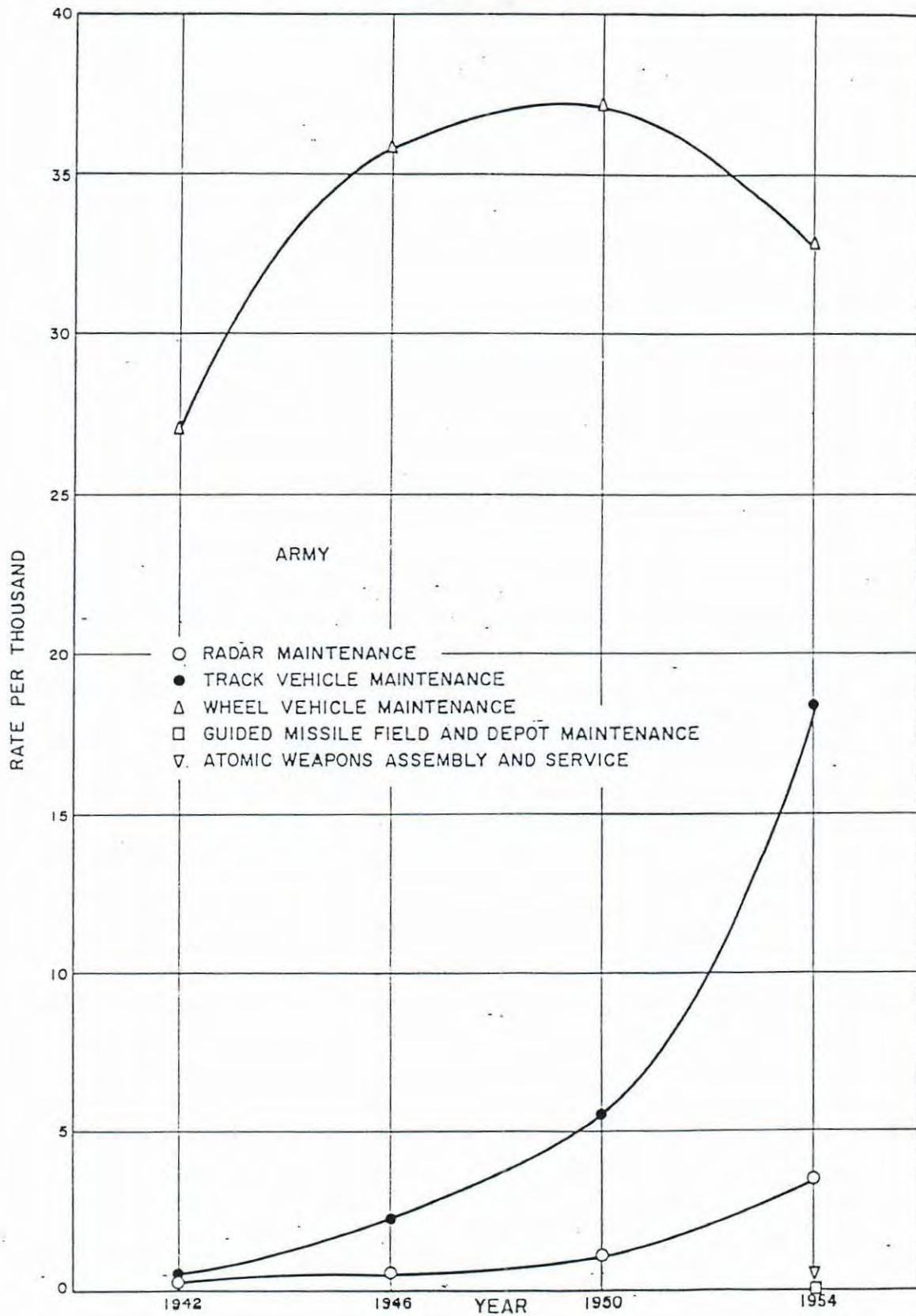
<u>Type</u>	<u>No. of Aircraft (per unit)</u>	<u>Total Maintenance Personnel (per unit)</u>	<u>M/Sgt.</u>	<u>T/Sgt.</u>	<u>S/Sgt.</u>	<u>A/1c</u>	<u>A/2c</u>
B-36	30	1151	110	110	310	400	210
B-52	30	1057	115	120	315	305	200
Increase or Decrease	Same	-94	+5	+10	+5	-95	-10

There will be a substantial increase in the strength of the Air Defense Command over the next 5-year period. The necessary increases in all-weather aircraft, air-to-air guided missiles, radars, computers for the SAGE System, atomic warheads for continental defense functions, and communications to knit the system together—all will require heavy investments in maintenance personnel.

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FIGURE VII-I
SKILLED PERSONNEL INCREASES



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In the Navy, the installation of sea wings contiguous to the continental early-warning line will call for additional numbers of maintenance technicians. Personnel requirements to service radar equipment of airborne early-warning (AEW) aircraft are now being formulated; satisfaction of these needs will undoubtedly require diversion of personnel from other naval tasks. The expanded integration of atomic weapons, guided missiles, and jet aircraft into the Fleet will further tax the Navy's insufficient supply of skilled personnel.

The Army has not yet felt the full impact of its family of guided missiles for air defense and tactical use. Planned installations at critical targets in the U.S. of Nike missiles and their complex control equipment will place an increasing demand on supplies of skilled maintenance personnel. New techniques of radio communication coupled with projected improvements in worldwide communications call for additional technicians. Similarly, the emergence of "battlefield surveillance" with its complex electronic environment will strain maintenance capabilities.

These are some of the principal new developments that will blossom into full field capability in the next several years. There are many others that will place equally competing demands on available maintenance personnel and on skilled personnel training programs.

New concepts of tactics and strategy will also affect requirements for maintenance personnel. Most important is the concept of dispersal—the deconcentration of our striking power. In the Strategic Air Command, it is proposed to increase the number of bases in order to reduce vulnerability and to have a substantial portion of its force on alert status. To achieve the increased number of flying hours per aircraft per month required under dispersed conditions would mean an increase of not less than 25 per cent 5-Level and 7-Level airmen, according to a recent estimate by the SAC staff.

The concept of dispersal finally chosen by SAC, and its timing, will necessarily be influenced by the availability and retainability of maintenance personnel. Increased availability of such personnel would permit greater flexibility of choice and more confidence in the ability of a dispersed force to maintain combat readiness.

In general, dispersal of military aircraft in the Zone of the Interior and overseas, of forces at sea and on the battlefield, will multiply needs for skilled maintenance personnel to support dispersed maintenance facilities. The development of different concepts of maintenance—such as thorough use of central maintenance—may offset additional personnel demands to some extent. On the other hand, seasoned maintenance personnel will be needed to provide on-the-spot maintenance in support of a ready combat capability that is dispersed and alert.

The increasing significance of the Arctic to military operations will tax our maintenance capabilities. Increased numbers of maintenance personnel will be needed for service in the Far North—in the ratio of 4:1 as compared to requirements in the temperate zone. In addition, these personnel should possess the inclination and training essential for living in extreme cold. In preparation for future operations in this area, the establishment of a select Arctic Corps comprising maintenance and other service

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personnel willing to serve extensive periods of time in the Arctic is necessary and seems feasible.

In the light of the foregoing, it is clear that requirements for highly skilled maintenance personnel will continue to increase, probably at an over-all rate greater than that of the past few years. Although it may not be possible to predict with precision the exact types of military equipment and the nature of their deployment for the next 5 to 10 years, it is important for the Services to develop gross long-range requirements for skilled maintenance personnel based on various assumptions as to types, numbers and locations of equipment. This must be done for the entire Department of Defense if future requirements for skilled personnel are to be anticipated as early as possible.

If the forecasts of over-all requirements for personnel with higher skills are considerably larger than the expected input (based on current and past experience), it will be necessary to take long-term corrective steps to bring supply and requirements into alignment. As will be indicated in the following paragraphs, we are already facing a serious imbalance between supply and demand for skilled military manpower. Only in the last year and a half has the problem been recognized in its true proportions. The length of time required for influencing re-enlistment rates and training highly skilled personnel necessitates much longer-range predictions of the expected supply and requirements for such personnel than have hitherto been available.

Useful studies are currently under way in the Manpower Utilization Branch of the Office of the Assistant Secretary of Defense (Manpower) in connection with the identification, classification, and availability of "hard core" personnel. This must precede the development of long-range forecasts. But the development of long-range forecasts represents a considerable extension of the scope of present effort. It will require close collaboration among military planning, operations units, and research and development offices in the three Services and the Office of the Secretary of Defense. The manpower groups in the three Services have made steps in estimating future requirements, but have not projected them beyond the realm of firm military plans. Operations research organizations could play an important role in the preparation of these estimates.

3. Supply of Skilled Manpower

There are adequate numbers of men available to the Armed Forces to satisfy presently foreseeable requirements for maintenance personnel. The problem is one of quality—not numbers. It is the problem of retaining in the Service the best men in whose training this country has made a large investment.

Since fully qualified maintenance personnel require from 2 to 4 or more years of training, career enlistees should provide the backbone of the maintenance corps. But the number of qualified career enlistees is quite small, and the bulk of the maintenance jobs is performed by first term enlistees or draftees under supervision of the scarce careerists. Hence, many of the maintenance jobs requiring highly skilled personnel are actually being performed by apprentices under the direction of thinly spread

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careerists whose talents are being diverted from the more difficult maintenance problems to the training of personnel. Build-up of the required enlisted skill and experience levels cannot be achieved without increases in the reenlistment rates for highly trained personnel.

The quality-quantity paradox is clearly reflected in the composition of the force maintaining the key bombing-navigation system (K-System) of the Strategic Air Force, as follows:

K-SYSTEM MAINTENANCE PERSONNEL
(Jan. 1955)

<i>Skill Level</i>	<i>Required</i>	<i>Assigned</i>
Supervisors (7 Level)	1230 (38%)	387 (12%)
Skilled Mechanics (5 Level)	1816 (57%)	625 (19%)
Apprentices (3 Level)	151 (5%)	2223 (69%)
	3197 (100%)	3235 (100%)

There are obvious reasons for the serious disparity between the skill levels required and those actually assigned. Despite the huge training programs in the Army, Navy and Air Force, the number of trained first termers who reenlist is grossly inadequate to provide the requisite number of experienced personnel. As of July 1954, three-fourths of the enlisted personnel in the Armed Forces had less than 4 years' service. There is a marked contrast between the reenlistment rates for first termers and the rates for those who have reenlisted at once. (Table VII-4)

TABLE VII-4 REENLISTMENT RATES		
	First Term (per cent)	Others (per cent)
Army	5 (draftees) 10.9 (3-year enlistees)	51
Navy	5.8	85
Air Force	13	65



This suggests that considerable effort should be directed toward influencing in favor of the first reenlistment—a factor which has already been recognized in the recently enacted reenlistment bonus. More powerful (and all-embrasive) incentives are in order. We shall revert to this later.

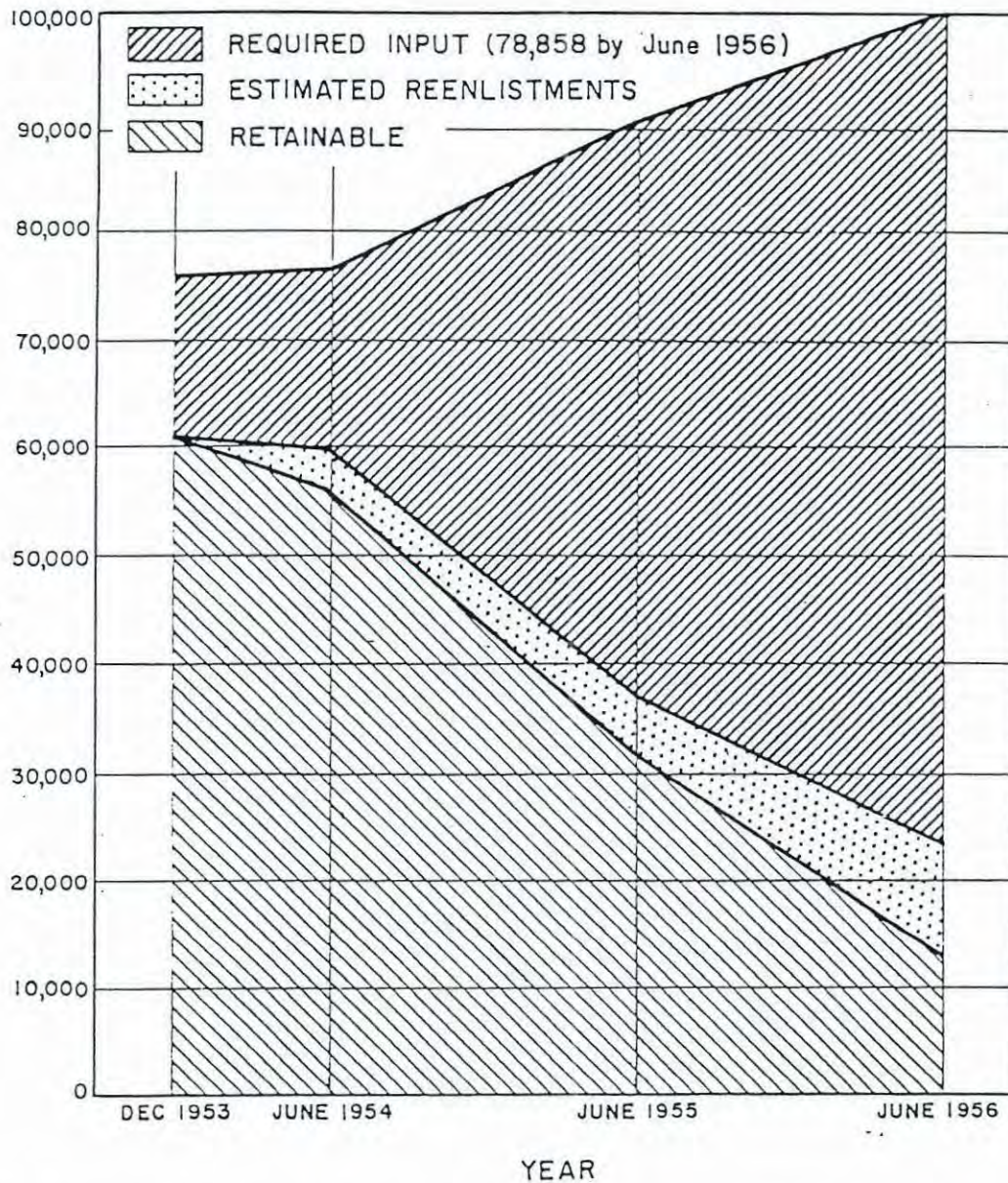
There are indications of small improvements in the reenlistment picture (possibly due in part to the reenlistment bonus approved by the Congress in 1954). Nevertheless, the gap between personnel required and numbers assigned continues to increase

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for upper skill levels. This is shown in the accompanying Figure illustrating the trend in availability of SAC airmen at Skill Level 5 (skilled mechanics). (Figure VII-II)

FIGURE VII-II
SAC AIRMEN RETAINABILITY AND REQUIRED INPUT



On the basis of past experience and recent polls of reenlistment intentions, it can be expected that the reenlistment rates for "hard core" skilled maintenance personnel will be considerably lower than reenlistment rates for "soft core" personnel.

A similar trend was noted in the greater loss rate of the more highly educated enlisted personnel. This is shown in a sample survey of first-term airmen conducted in August 1954 (see Table VII-6).

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TABLE VII-5
ARMY REENLISTMENT RATES IN SELECTED OCCUPATIONAL FIELDS
(JULY 1954)

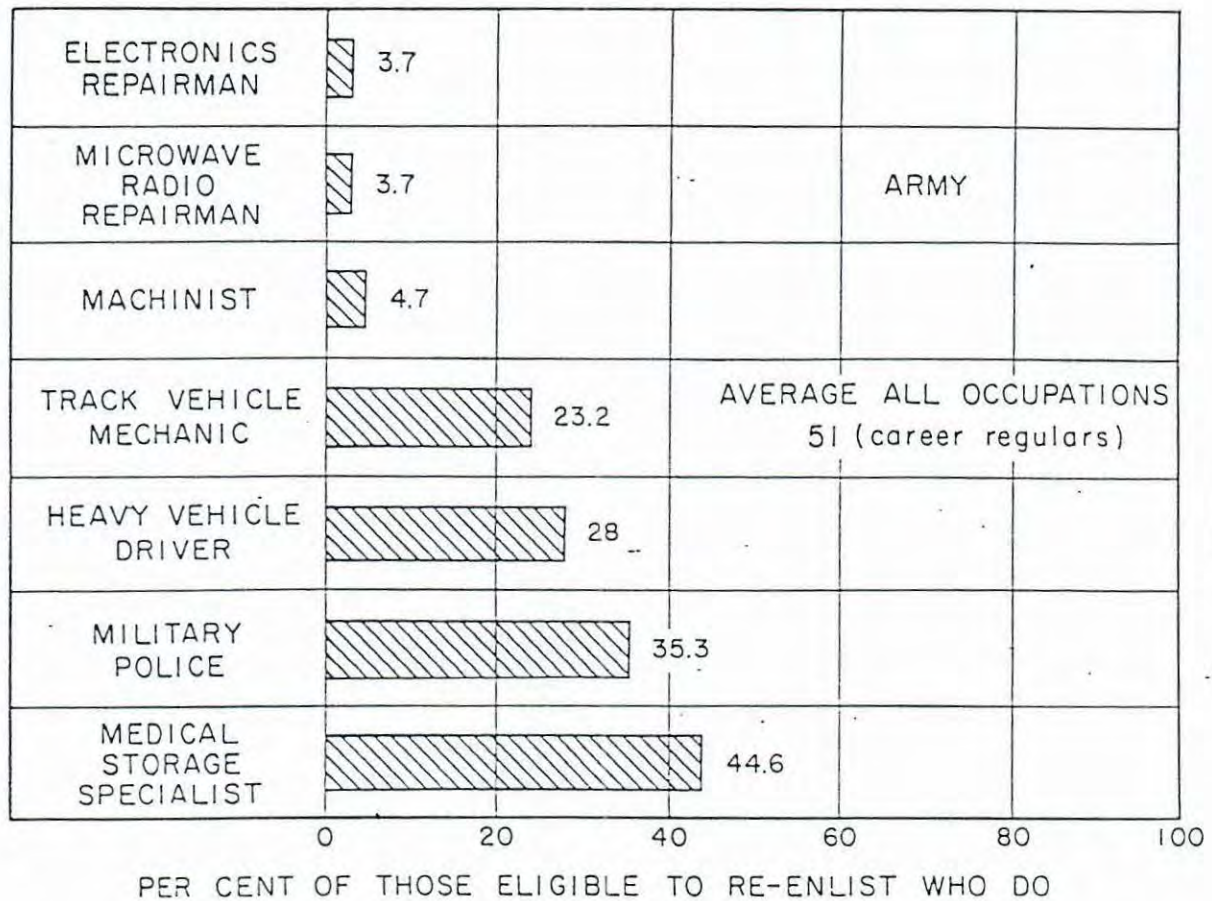


TABLE VII-6
REENLISTMENT INTENTIONS

Education	% Favorable to Reenlistment	
	Attended but Non-Graduate (per cent)	Graduate (per cent)
Grammar School	26	19
High School	20	12
College	11	7

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The net effect of these trends is a continuous sapping of the strength of the Armed Forces in the selective loss of the more highly trained and educated personnel. When considered in the light of increasing military complexity and specialization, these trends have dangerous implications for the future of our armed strength. They will leave their imprint on our combat readiness and capability. They also add heavily to the cost of the defense effort.

4. The Price of Low Reenlistment Rates

It is difficult to assess the price we pay for low reenlistment rates in terms of loss of combat capability. Elsewhere in this report we have called attention to the paramount importance of early warning in getting our defenses in motion, and in launching the retaliatory strike with operationally ready aircraft within the available warning time. This calls for a higher degree of materiel readiness than ever before in military history. We share the general concern of military commanders that this readiness is seriously handicapped by the excessive turnover of maintenance personnel.

For SAC missions, the total probability of destroying an assigned target with one bomber is a function of the probability that the bomber will be maintained within specified limits and ready for takeoff within a specified time. As a recent study by the Office of the Assistant Secretary of Defense (R&D)¹ points out, the unreliability and unreadiness of existing bombing and navigation systems represent one of the most important limitations in the total striking capability of the strategic forces. Further, this limitation will become much more significant if readiness times are reduced and if the aircraft are dispersed in smaller groups.

For the K-Systems in the B-47, for a 10-hour readiness time in undispersed locations, a 6-hour mission time to target at high altitude for a good crew, against average defenses, with a CEP of about 2500 feet, and with a megaton bomb against an average target, the following average values are probably representative for combat ready wings:

$$\begin{array}{cccccc} P_{\text{total}} = & P_m & \times & P_r & \times & P_g & \times & P_b & \times & P_s \\ & 0.45 & & 0.75 & & 0.75 & & 0.95 & & 0.95 & & 0.90 \end{array}$$

where:

P_{total} = total probability of destroying an assigned target with one bomber

P_m = the probability of the bombers being maintained to within specified limits and ready for takeoff

P_r = the probability of reliable operation of the bombing and navigation system

P_g = the probability of proper gross navigation from the takeoff point to the target area and correct identification of the assigned target or associated offset point

P_b = the probability of destroying the target when the bomb is released, given a level of performance within the limits specified in P_r .

P_s = the probability that the bomber will survive in the face of enemy defenses.

If the readiness time were reduced to 2 to 3 hours and the aircraft were dispersed in smaller groups at more bases, P_m might drop to from 0.75 to 0.50 or less. This may

¹ "Bombing and Navigation Systems for Manned Aircraft," October 1954 (RD275/1).

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well place the limit on dispersion. The values of P_s , P_a , and P_b would not be very greatly affected.

With a reasonable increase in the probability of maintenance—from 0.75 to 0.85—other factors remaining constant, the expected fraction of targets destroyed would increase from 0.45 to 0.51. It is impossible to fix, in terms of dollars and trained crews, the over-all worth of 6 per cent more targets destroyed, let alone the importance of those extra targets in a military campaign involving the thermonuclear weapons.

Although the example above is drawn from the Air Force, the situation is common to the three Services. The seriousness of the Navy's problem is illustrated by a recent report from Commander Service Forces Atlantic Fleet, summarizing the field-inspection reports of engineers inspecting the fire control radars of Navy vessels (Table VII-7).

TABLE VII-7 TYPICAL FIELD INSPECTION REPORT NAVY RADARS		
Radar	Number Inspected	Unsatisfactory* (per cent)
Mk 25	78	57
Mk 31	108	85
Mk 39	11	63
Mk 26	10	30
Mk 13	20	45
Mk 27	18	61
* "Unsatisfactory" meant either the radar or its associated system was inoperative to the extent that acquisition and tracking of targets could not be accomplished at the time of the inspection.		



The report asserted that "the principal reason for this unsatisfactory state of affairs to be a critical lack of skilled, experienced personnel. Also, no relief from this condition is foreseeable."¹

Despite shortages in the higher skill levels, there appears to be considerable variation in the performance of different maintenance crews within a single command; there is reason to believe that management plays an important part in this. The causes of varying over-all performance of maintenance teams should therefore be more intensively studied with a view to taking such steps as will raise the over-all quality of maintenance.

¹ "Naval Ordnance Problems and Difficulties Encountered in its Operation and Maintenance," Bureau of Ordnance, August 1954.

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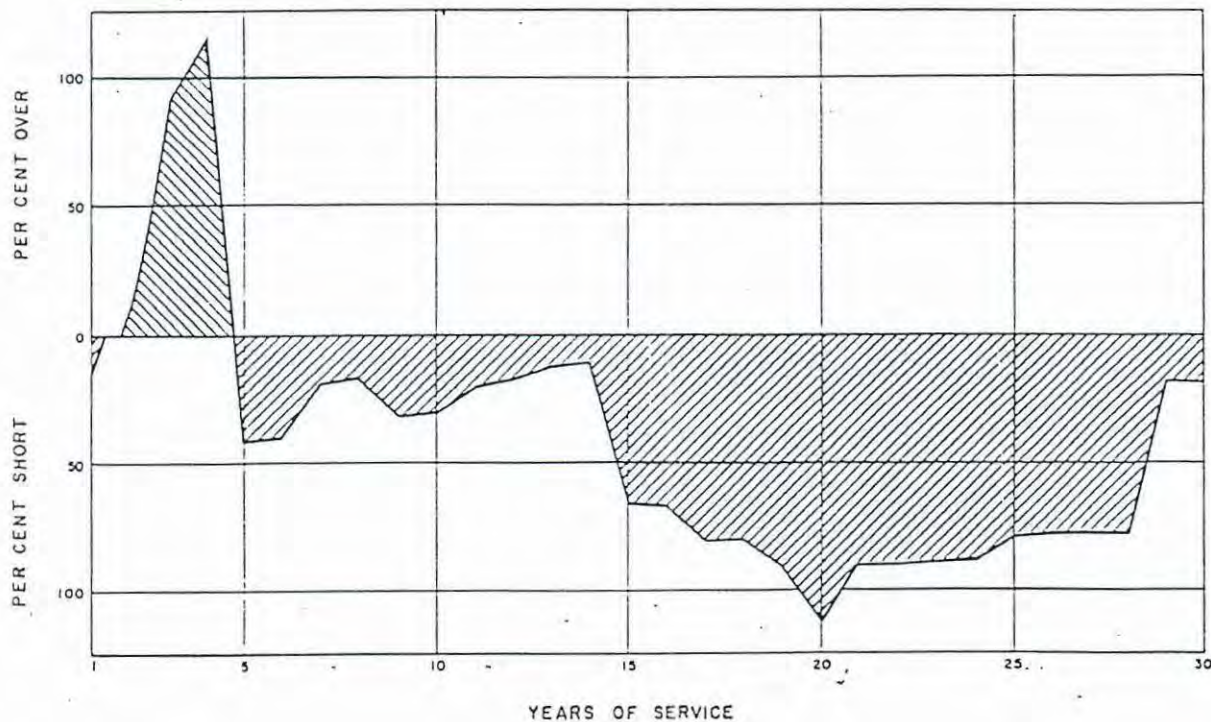
In addition to its visible effects on current military capabilities, we are concerned about the long-term effects of low reenlistment rates on the introduction of new weapons systems over the next 5 years. Shortages of the more skilled maintenance personnel may seriously affect their availability in the field. Equally important, the shortages could affect the extent to which desirable concepts of tactics and strategy are implemented—e.g., the geographical dispersal of our striking power.

The existence of a "hard core" of highly trained maintenance personnel is essential to the rapid expansion of the Armed Forces in an emergency. The long training times involved—longer than most production lead times—require that the career maintenance personnel serve as the nuclei of new maintenance crews. In order to expedite emergency expansion, Reserve training programs should be developed to give maintenance experience and training with latest-model weapons to the "Immediately Callable" Reserve.

The cost of this shortage of career maintenance personnel can be measured in dollars as well as in performance. As previously mentioned, three-fourths of enlisted personnel have less than 4 years' service. Out of this large reservoir comes a mere trickle of reenlistees. The rest are lost at the end of their first enlistment; and, to a considerable extent, the dollars invested in their training, housing and feeding are likewise lost. The basic training investment alone in 100,000 men amounts to \$320 millions.

If the reenlistment rate could be substantially increased, a considerable reduction in the training base could be achieved. This is illustrated in Figure VII-III.

FIGURE VII-III
SHORTAGES IN MORE EXPERIENCED AIRMEN



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5. Remedies for Low Reenlistment Rates

Although the maintenance problems that currently beset the Armed Forces stem in part from the rapid technological advances of the last decade, we cannot look with assurance to technology for short-term relief.

The study by the Office of the Assistant Secretary of Defense (R&D), previously cited, concluded that new systems, as presently planned, appear to be predictably less maintainable in their probable future environment than are existing systems in today's environment. Nonetheless, in new weapons design, it is essential that maintenance requirements be in the forefront, and that simplicity, reliability and maintainability be stressed. Additional weapons systems analyses need to be undertaken with a view to trading complexity for better reliability and maintainability wherever it can be accomplished without serious degradation of the combat performance of the over-all system.

The Services are aware of the importance of simplicity and reliability in weapons design. There is in some areas encouraging progress in the equipment design that will remove some of the burden from field maintenance crews. This is more than offset by increasing needs for the higher level skills; but design improvements must be emphasized to keep future maintenance needs within manageable limits.

It follows that ways and means must be found to substantially increase the rate of reenlistments among maintenance personnel, and as rapidly as possible. We are not qualified to make recommendations on those non-technical measures that should be taken in the circumstances. There is ample evidence that the problem is receiving serious attention by the Administration and the Congress. It has been the subject of a special Presidential message to the Congress. The reenlistment bonus and the proposed revisions in Service pay favoring skilled personnel should help to alleviate this serious situation. We can only reiterate that the measures adopted be commensurate with the gravity of the situation. To this end we advocate that careful and continuing study be given to the effects of the recently enacted reenlistment bonus, and, if enacted, of the proposals contained in the President's recent message to Congress in order to determine whether stronger incentives are required to correct the precarious lack of highly trained maintenance personnel.

The composition of today's military force differs from previous peacetime forces in two important respects: it is much larger; and its personnel is necessarily much more specialized. Over half the total authorized enlisted spaces require skill levels of the journeyman-technical supervisor types, and 85 per cent of the shortages occur in this skill area. It is essential that the Services have a professional maintenance force; but it is impractical to attempt to build a professional maintenance force on the basis of draft, and enlistments encouraged by draft, without a career concept and long-term opportunity for promotions and rewards comparable to opportunities in private industry.

The disparity between the pay of skilled enlisted personnel and comparable civilian positions is shown in Table VII-8.

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TABLE VII-8
PAY OF SELECTED ENLISTED SPECIALISTS COMPARED TO CIVILIAN POSITIONS*

<u>Enlisted Title</u>	<u>Military Grade and Salary (E-7)</u>	<u>Comparable Monthly Civilian Salary (Wash. - Balt. Area)</u>
Wire electronics repairman	\$ 287-333	\$ 402-517
Microwave radio repairman	287-333	402-464
Radar repairman	287-333	402-464
Telephone & teletypewriter repairman	287-333	299-400
Single side-band radio repairman	287-333	402-464
Light antiaircraft fire-control repairman	228-273	309-357

*From Signal Corps staff study on "Retention and Control of Long Term School Trained Enlisted Specialists," 16 February 1953 (SIGMP-4).

Whereas pay and fringe benefits strongly influence the reenlistment rate, we believe there are other important considerations in the case of skilled personnel. Efforts should be made to develop a career concept for such personnel, permitting them to continue in technical assignments in an environment that identifies the technical specialists as a group, permits some freedom of assignment within that group, and is conducive to a high esprit de corps. Some means must be devised to provide additional inducements, such as greater promotional opportunities, to serve as attractive long-range goals for first-term enlistees.

Although increased compensation is but one of several steps that need to be taken to establish an attractive career for maintenance personnel, there are strong indications that it is a *controlling* factor influencing reenlistment. In a 1953 survey by the Air Force, of those airmen not intending to reenlist, 62 per cent gave pay as the most important factor for not choosing an Air Force career. A recent poll of all SAC airmen indicated that the over-all enlistment rate for skilled maintenance personnel might be doubled if there were 25 per cent increase in pay.

Even if everything possible is done, there will still be a deficit of skilled maintenance personnel for many years. This shortage can be partially corrected through more extensive use of industrial contractors. The Services have used industrial contract maintenance with considerable success in a limited number of situations. Industrial maintenance, although it seems especially well suited to jobs in the ZI (particularly in the Air Defense Command and, to some extent, in SAC), is not without difficulties. The need to train personnel in the United States to permit rotation of overseas maintenance personnel restricts the widespread use by the Services of civilian maintenance in the U.S. The objection has also been voiced that labor difficulties, or diversion of civilian personnel to other tasks in the event of war, does not permit reliance on such personnel in the event of emergency. Also, there could be serious morale problems

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incident to mixing of higher-paid civilians and enlisted personnel with similar jobs unless military pay scales are adjusted.

It is our belief that contractor-maintenance has sufficient merit to justify more widespread use, particularly in the short term in the light of prospective shortages of skilled personnel.

A broad study of the use of industrial contractors to provide services to the Department of Defense is now under way. In this study, special attention should be given to the possibilities of industrial maintenance of military equipment including field maintenance for operational units. It is necessary to examine past experiences with this type maintenance in the Services and define the technical areas, locations and conditions best suited to the use of industrial maintenance. A comparison of costs and efficiency would be an important element. Finally, such study should include the legal and other problems involved in assuring the continued performance of civilian personnel in a national emergency.

6. Conclusions

1. A professional "hard core" military maintenance force should be developed of sufficient stability to satisfy future requirements for maintenance personnel. A "hard core" of highly trained maintenance personnel is also essential to the rapid expansion of the Armed Forces in an emergency.

2. The increased complexity of weapons and weapons systems since World War II has multiplied military needs for technical maintenance personnel in the higher skill experience levels. Future introduction of new weapons such as guided missiles, atomic warheads, and weapons for continental defense will magnify further the need for such personnel, as will dispersal tactics and strategy required by the atomic threat.

3. Present and prospective reenlistment rates for technical maintenance personnel in all branches of the Military Service are insufficient to achieve the numbers of highly skilled and experienced personnel required for effective maintenance.

4. Shortages of highly skilled maintenance personnel are seriously impairing the combat readiness and operational capability of our Armed Forces. This situation will worsen unless ways and means are found to substantially increase the reenlistment rate of skilled maintenance personnel.

5. The proposals contained in the President's recent message to the Congress on military manpower fully recognize the importance of retaining in the Military Services highly trained technical personnel. It is hoped it will do much to create the incentives and national climate needed to accomplish this objective.

7. Recommendations

1. A professional "hard core" military maintenance force for each service be developed of sufficient stability to satisfy future military needs for maintenance personnel.

2. Careful and continuing study be given to the effects of the recently enacted re-enlistment bonus, and, if enacted, of the proposals contained in the President's

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recent message to Congress to determine whether stronger incentives are required to correct the precarious lack of highly trained maintenance personnel.

3. Greater efforts be made to develop a career motivation for skilled maintenance personnel by providing an organizational environment that recognizes the skill attainments of such personnel and that permits a greater range of promotional opportunities.

4. More attention and emphasis be given to long-range personnel planning in the highly skilled technical manpower areas, and to the impact that planned new weapons systems will have on future requirements for technical maintenance personnel.

5. The specific use of industrial contractors for the maintenance of weapons systems in the ZI and overseas be given more extensive study by the Department of Defense. This requires investigation of the kinds of military operations that can be served through industrial maintenance contracts and of ways in which civilian maintenance can be adapted to the military system, particularly under conditions of emergency.

6. Consideration be given by each service to the organization of a select corps of maintenance personnel willing to serve extensive periods of time in the Arctic area, in anticipation of expanded military operations in that area.

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APPENDIX

HISTORY AND ORGANIZATION OF TECHNOLOGICAL CAPABILITIES PANEL

On 27 March 1954, the Science Advisory Committee of the Office of Defense Mobilization met with the President to report on its activities and to receive instructions for future work. During the course of this meeting the President expressed concern over the vulnerability of the United States to surprise attack and suggested that the committee consider, from the point of view of science and technology, the steps that could be taken to reduce this danger.

On 9 July 1954, Mr. Arthur S. Flemming, Director of the Office of Defense Mobilization, forwarded to the President a memorandum from Dr. Lee A. DuBridge, chairman of the Science Advisory Committee, outlining a proposed program for study of the threat of surprise attack. Mr. Flemming, in his accompanying memorandum to the President, recommended that the study be approved. This recommendation bore the concurrence of the Secretary of Defense, the Director of the Central Intelligence Agency, and the Chairman of the Atomic Energy Commission.

On 26 July 1954, the President asked Dr. James R. Killian, Jr., President of the Massachusetts Institute of Technology, "to direct a study of the country's technological capabilities to meet some of its current problems." On 9 August 1954, Dr. Killian wrote the President his acceptance of the assignment.

The Science Advisory Committee formed the Technological Capabilities Panel, recruited membership and set up an organization to carry out the study program (see accompanying chart). Project 1 of the Panel studied the problem from the standpoint of our over-all offensive capabilities; Project 2 concerned itself with continental defense; and Project 3 covered the area of intelligence.

The Steering Committee of the TCP held its first meeting on 13 September 1954. Between 13 September 1954 and 1 February 1955 the members of Panel held numerous meetings and conferences, internally and externally, with governmental and civilian representatives and agencies.

Field trips were made to Headquarters, Strategic Air Command; Headquarters, Tactical Air Command; Headquarters, Air Defense Command; the Air Research and Development Command; and to Project Lamp Light briefings in Cambridge, Baltimore and Norfolk. In Washington the Panel met with representatives from the White House, the Office of Defense Mobilization, the Department of State, the military services, SHAPE, the Central Intelligence Agency, the Atomic Energy Commission, the National Advisory Committee for Aeronautics, and the Federal Civil Defense Administration.

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The following figures are given as typical of the number of briefings, field trips, meetings, conferences, visits, etc., in which the members participated:

Steering Committee:	132
Project 1:	86
Project 2:	50
Project 3:	39
TOTAL	<u>307</u>

The Panel wishes to acknowledge the invaluable contributions made by all concerned—those who either appeared before it, or who contributed in any way of their time and experience to the study. No relevant information was unavailable to the Panel.

The departments of Government gave the Panel every possible assistance. The Office of Defense Mobilization, the Office of the Secretary of Defense (R&D), the military services, the Atomic Energy Commission, and the Central Intelligence Agency were particularly cooperative in making available administrative and staff personnel as required.

The Panel gratefully acknowledges the assistance rendered by the Military Advisory Committee and the Military Consultant Group, Lt. Gen. L. L. Lemnitzer, USA, Maj. Gen. Harry McK. Roper, USA, Rear Adm. H. D. Felt, USN, and Brig. Gen. Bruce K. Holloway, USAF. As the designated official points of contact in their respective Departments, these officers rendered an invaluable service in arranging for briefings and inspections, in making available classified material, and generally in paving the way for a close working relationship between the Armed Services and the Technological Capabilities Panel.

Responsibility for housing and servicing the Panel was undertaken by the Office of Defense Mobilization. Special acknowledgment is extended to the staff of ODM who assisted in the handling of security, personnel and fiscal problems and whose efficiency contributed greatly to the success of the operation. We also wish to acknowledge the exceptional cooperation and competence of the employees of the GPO-State Service Office.

The contribution made by the members of the security guard detail of the Air Force deserves special mention. Their faithful fulfillment of an important responsibility reflects great credit upon them and upon the military service they represent.

Grateful acknowledgement is extended to the personnel of our administrative staff for their loyal and untiring efforts during the approximately five months period of the study. Working long hours, often under extreme pressure, they made a major contribution to the preparation of this report. Our assignment could not have been completed without their help.

We record with special affection and gratitude the exceptional services rendered the Panel by Mr. David Z. Beckler and Lt. Col. Vincent T. Ford, USAF. Through their patience, support, and experience, they made a contribution to this study that went beyond any normal call to duty.

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TECHNOLOGICAL CAPABILITIES PANEL

STEERING COMMITTEE

James R. Killian, Jr.	(Director of TCP)	Massachusetts Institute of Technology
James B. Fisk	(Deputy Director)	Bell Telephone Laboratories
Marshall G. Holloway	(Director of Project 1)	Los Alamos Scientific Laboratory
Leland J. Haworth	(Director of Project 2)	Brookhaven National Laboratory
Edwin H. Land	(Director of Project 3)	Polaroid Corporation
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James H. Doolittle	Member-at-Large	Shell Oil Company
James P. Baxter	Member-at-Large	Williams College
Robert C. Sprague	Consultant	Sprague Electric Company

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Burke Horton	Office of Defense Mobilization
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Julian M. West	Bell Telephone Laboratories
Carroll Zimmerman	Strategic Air Command



PROJECT 2

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Daniel Dustin	Lincoln Laboratories
Richard Emberson	Associated Universities, Inc.
Robert Gilruth	National Advisory Committee for Aeronautics
Albert G. Hill (part time)	Lincoln Laboratories
Brockway McMillan	Bell Telephone Laboratories
J. L. Morton	Commander, U.S.N.
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Lt. Gen. L. L. Lemnitzer
*Rear Adm. H. D. Felt
*Brig. Gen. B. K. Holloway

U.S. Army
U.S. Navy
U.S. Air Force

*With Maj. Gen. H. McK. Roper,
U.S. Army, constitute military
consultant group.

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Lt. Col. Vincent T. Ford

Office of Defense Mobilization
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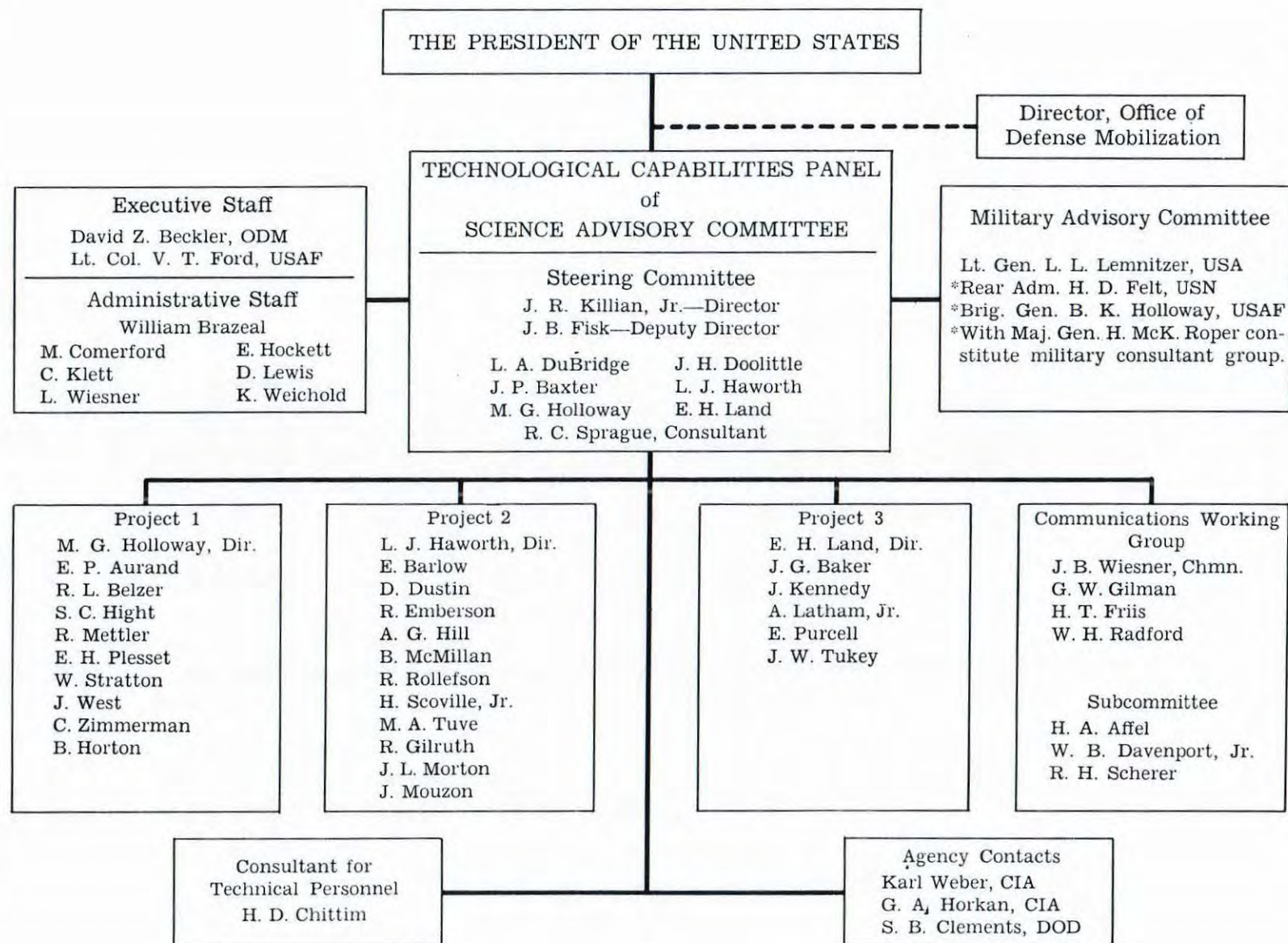
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