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THE COMMAND AND CONTROL STRUCTURE

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1. Magnitude of Problem

Though it may appear to be presumptuous, I shall state from the outset that there exists at present no other problem for the United States comparable in difficulty and importance to that of finding the right "command and control" structure. We are, in this country, confronted with many issues that are more in the public's mind, such as Berlin, Cuba, etc., and there can be no question that they are of vital importance. They range from the over-all military power of the nation to the problem of how to use it politically in order to secure a just and lasting peace throughout the world. Behind it looms, in addition, another, much larger issue which no-one knows how to deal with: how to channel and contain the stormy scientific and technological development so that even greater catastrophes are not brought upon humanity than those we barely dare to contemplate now.

Compared to these problems, the question of what communications system to provide in order to make sure that all military commands can be reached under all conditions by the supreme authority and that complete and unambiguous control over all nuclear weapons exists at all times and that feedbacks from below are provided for, all this seems to be almost trivial. Yet I shall not deviate from my opening remark. The reason is simple: if we do not provide a satisfactory command-control system we have no foundation on which to base our political actions which involve the very existence of the nation and the preservation of peace. The following considerations will give ample proof.

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* The following contains essentially, and with only minor modifications, the text of an invited address to the Ninth Military Operations Research Symposium (MORS), Fort Monroe, Virginia, April 25, 1962.

2. Command under Confusion of Battle

Anyone concerned with the working of communications during hostilities wishing to see how participants in battle maintain or lose contact with other units, fail to secure knowledge (if they had any) of the whole plan of action and how chance intervenes will do well to study military history, no matter of what epoch. But as it sometimes happens, such experience is brilliantly conveyed not by military authors, but by writers of fiction. No-one will fail to see this who reads the opening parts of one of the greatest novels ever written, Standhal's "Charterhouse of Parma", in which the battle of Waterloo is described precisely in these terms. There it is clearly shown how the combattants are forced to act without definite knowledge of what has already happened, and how loosely they fit into the fabric of events they no longer comprehend but to which they should give direction, if not at least participate intelligently.

No matter at what other experiences in military history we look, we will always find that one of the essential features of battle conditions is confusion. The enormous difficulties of getting information to the right place, getting it there in time, interpreting it correctly, getting an order out, seeing that the signal comes back that the orders have been received and understood, and that they have been executed, and then getting the word back as to the result of the operation, means that such communication is almost never achieved. During the last war, for example, even with modern equipment, Allied Forces bombarded the Swiss city of Schaffhausen when they thought they were 50 miles from it, somewhere in Germany. We know that at sea contact is lost time and again, and that great sea battles must be fought when radio silence is ordered. We know that at present there exist no satisfactory technical means to communicate under combat conditions with deeply submerged submarines and to get a quick answer back to an order which might reach them. We know that in ordinary military infantry conflicts the artillery very often

has shot at its own troops. The knowledge of the exact separation and location of our own troops from the enemy's is exceedingly difficult to maintain. These are the real facts. Basic is disorder and chaos and the difficulty is to integrate bits and pieces and still to achieve something of value. One of my ancestors of whom I am rather proud because he had a wonderful idea, was a Professor of Canonical Law in Leipzig and published a book in 1508, of which I have a copy. This book contains sermons in Latin describing what happens to people who misbehave on Earth, and a whole chapter deals with Hell. In that chapter he says that Hell is awful, that it is hot and stinks, and all sorts of other unpleasant things go on, but he states that one of the worst features of Hell is confusion. So you see he had the right idea and I think one of the worst features of battle is confusion also. Now if we multiply past confusion by factors of 1000 and more, we probably approach something of the state of confusion which we must expect in case large-scale nuclear war breaks out.

Recently we had a very minor illustration which had nothing to do with combat, but where confusion reigned supreme: the U-2 incident. It is now known that nobody was prepared. It is well-remembered that totally conflicting statements were made in quick succession by different government offices in Washington trying to interpret what happened when the U-2 went down or was shot down. In short, even in the case of such a very special and relatively minor matter, all of Washington was in a state of, as it was called, "monumental confusion", with very great consequences for the whole world. This gives a foretaste of what might be expected if entirely different things happen which are also likely to happen, which must, in fact, be expected to happen.

Now the command-control situation or problem is really very simple: it is to secure certain physical action in the light of a maximum amount of correctly interpreted data, i.e. information, at a desired spot and at a

desired time, and to get information back as to the results. This is really the problem. The next question is whether one can organize oneself in such a fashion as to make sure that this really can be achieved. First of all, in all my searching for material for a discussion of matters of this kind, there is nothing to be found, as far as I am aware, which gives even a complete enough picture as to how our command-control is set up for the whole country--and I am talking about this, not about any particular branch or any limited part of a branch. We know, for example, that legally the President is the only person who can authorize the use of a nuclear weapon. That is a very nice statement, but what does that mean? It means very little because the President may not exist at the moment when we need this command; so what happens next? We will discuss these questions in a moment. There is, indeed, a very long chain of command and there are many different kinds of nuclear weapons, from the very small tactical to the very large so-called strategic weapons. For all these the command or lack of command has very different meaning and consequences.

The NATO situation is even worse. It is much more complicated because several governments must agree unanimously (!), and if possible simultaneously on whether or not the nuclear weapons are to be used, if the President of the United States has also agreed to it. They must agree separately, namely the members of the NATO council. A map or chart showing the NATO organization and the lines connecting the places where the nuclear weapons are held to the places where authority has to come from, gives an enormously complex picture which most likely cannot be applied where the decision has to be made under conditions when NATO has already been attacked.

Now it is clear that we have to be alerted and we want to have an alarm at the right time. However, an alarm which comes under conditions when we can

do nothing is worthless, just as the recent civilian alarms, for instance: nothing is sillier than to have a civilian alarm installation in the big cities and nowhere for the people to go. This is an insensible, meaningless, alarm in the same sense as the weapon which cannot be armed is worthless and a weapon which cannot be transported to the place where it is to take action is again worthless. Now the NATO picture is very complicated and so is our own command structure; of course the popular belief is that anything that is complicated must have been very well thought out.

3. Nuclear Command without Experience

Now another aspect before we go deeper into the matter is that there is no experience for conditions of nuclear war, and since there is hardly any doubt that nuclear weapons would be used in any large-scale operation, we must say that all our thinking is purely hypothetical. There is no significant empirical, combat background to it, all nuclear explosions having taken place either without opposition, as for the first two actually used, or purely under laboratory conditions. Everything else we say about nuclear war is a construction of our minds, perhaps based on computations, etc., but this is ultimately not reliable. The only thing that is reliable for determining the stability of any physical system is an experiment. A fortiori, the same applies to social systems. You can compute a great deal, but you have to have experiments and here we have none--and we hope we will never get one. On the other hand, we must be prepared, or should be prepared, for the condition when such an "experiment" might be undertaken by one or the other side. So let us ask ourselves, first, what the problem really is and what is new in the problem of command and control, and second, whether one can design a useful and safe

system. What demands must one make on the properties of such a system so that it would really give us the minimum assurance which we would have to expect?

So what is new in the command-control situation? First of all, if there was already so much confusion in every previous war as the historical records show, the essential new features seem to be the following: the scales are totally different by enormously large factors--there is not just a little elongation or projection of the past speeds of reaction. The entire time scale is changing and the speed of reaction which is allowed to us is shrinking continuously toward zero. The extent of potential damage to be done in a given time interval is another one of these factors, which tends toward infinite destruction. In the rather sparse literature on the topic of command and control, one encounters sometimes the idea that the "no Roger" condition is something novel, that is to say, that a signal would go out but there would be no acknowledgement or answer as to whether the signal really had been received and understood. I don't think that this is at all novel. It was common for Naval operations during any of the last wars, in fact, in any Naval war, except at those times when ships were in close line of sight all the time and could operate that way, which has not been the normal thing for a long time. By virtue of its much wider applicability this idea now merely seems to have a novel feature.

A command-control system, that is to say a system where some place gives an order to some other place to do certain things or to pass orders on further, or to specify them so as to make them more detailed, ought to be invulnerable against attack by the enemy. We would normally think that it would be <u>always</u> to the enemy's advantage to destroy our communications and vice versa. Perhaps that is so, but then this is a dangerous thought which we will leave for the moment hanging in the air. Let us first merely state

that in any case we would like to have an invulnerable communications system. Now nothing in the world is totally invulnerable. Invulnerability is always relative to certain efforts to be made. In a command-control system we want information to pass down as well as up. In other words we must certainly demand that there are feedbacks built into the system in order to allow us to change plans in accordance with the changes in the development of the situation. Even our minimum demands already describe a very complex system and therefore our demands for invulnerability are very comprehensive. Obviously it will not be possible to make the system uniformly invulnerable. Therefore certain hierarchies will have to be established on the top of which must unquestionably be the ability of the government to talk to the enemy government and to receive reliable messages from the enemy.

We want next, in particular, as far as nuclear weapons are concerned, guarantees that they will be used when so ordered and we want guarantees that no nuclear weapons should ever be used and can ever be used when it is not ordered. This must be true for peace and war. There is therefore this conflict: we want safety and reliability of the weapons. We want assurance that the weapon will go off when so ordered and we want assurance that it is safe against any specifically unauthorized use: these things are in conflict with each other. This conflict is known and has strong influence even on the design of nuclear weapons, on the number of switches to be built in, their arrangements, etc., things which need not and cannot be discussed here. In summa, we want to make sure that the weapons are made in such a manner as to prevent any accidental or deliberate use or non-use under all conditions.

4. Preparation for Physical Failures

Let us look first at the possibility of an accidental nuclear discharge. That is, of course, a technical matter, but I think it is safe to say the following: the first fact is unquestionably, that in the world there exist now thousands upon thousands of nuclear weapons. I will next state the truism that the world is not deterministic. That is to say, the human mind cannot construct something that is infallible. Applying this to the present situation, we have to conclude that there must some day be an accident with a nuclear weapon, a pure accident, which has nothing whatsoever to do with military or political plans, intentions or operations. Simply some day a nuclear weapon will go off just as sometimes an aeroplane falls down--only they fall down more often than a nuclear accident will happen because it is much more important to concern oneself with the safety of a nuclear weapon. Now what is the implication of this? We ought now to prepare ourselves and the whole world--our side, the Russian side, and the neutrals--for this technical, physical eventuality so that we would know what we should do and not do at that moment. This is not a fanciful idea. I think it is extremely realistic, for when it happens the following can arise. Suppose a city is destroyed by accident or a minor weapon goes off, but one still substantial enough to cause great damage and show that something different has happened than just the explosion of a gas tank or an ordinary ammunition depot. As is well known, ammunition depots have blown up many times all over the world, and they were also well-protected and taken care of, highly guarded, etc. Relative to the damage they could do, one has given them as much protection as one is now giving nuclear weapons relative to the greater damage they can do. The importance for the whole world to prepare itself for these eventualities mounts as the number of nuclear weapons increases, as it does steadily. The

likelihood of being exposed to an accident is obviously greater for the side that has more units on hand and produces and controls them under several authorities, i.e. the Western bloc.

So what will happen? Suppose the accident happens in the United States? First of all, can one be sure it is a real accident, or has it been internal or external sabotage; or was it a smuggled weapon which was set off? By whom was it smuggled in? By the Russians? Smuggled in by some other country which perhaps wants to start something? Perhaps Cuba. Who knows? Nuclear weapons will spread throughout the world. They may even become available in international trade. Even that is not to be excluded. It will not be known with certainty where all existing weapons or other devices are at every moment of time. Each side may not possess absolutely trustworthy information at all times about the weapons it controls. Surely the British and French do not know where the United States weapons are, we may not know where the British weapons are, we are certainly in the dark about the French, yet all three states form the Western bloc, which thus is not fully informed about itself. Yet uniform action by the Alliance is planned!

Many weapons are frequently being transported, and almost anybody can build such devices. In some less developed countries (in the sense of having less experience with these things) one may not use all the safeguards in respect to them which the United States is applying most conscientiously. The danger of an accident of this kind happening somewhere in the world is unquestionably increasing. But there are not even traces of preparations of how to meet this danger.

One question above was "Is it sabotage?" Or was it a true accident? Will the country concerned immediately communicate with each of the other

nuclear powers and say this was an accident, or will we say this was sabotage and accuse the Russians? If it should happen in Russia, will the Russians not immediately accuse us? Or if it happens in Great Britain will this not immediately lead to the demand for the withdrawal of all nuclear weapons from the British Isles which are not controlled by the British, in case it was an American weapon which went off? Perhaps the same demand would be made even if it were a British weapon which went off. In short, we can imagine that it would be very difficult--I believe, in fact impossible--to make a complete list of all possibilities and all the implications and situations which can be expected with some probability, but with an unknown probability. So we have no complete control over the nuclear weapons. The probability is very small, but even very small probabilities occasionally may materialize.

Look again at the U-2 incident, which I mentioned at the beginning. What had one done? A plane had been sent over a foreign country to take photographs. We know that planes fall down, that pilots have black-outs. We know that flame-outs occur in jet engines. We know that every precaution had been taken, that the pilot had been carefully selected and that the engine had been examined backward and forward so that there would be no flame-out. Maybe it was a flame-out which caused it. We knew also that other unauthorized planes had been brought down, that planes can be shot down. If that is not possible for a U-2 at a given moment, the art of bringing down planes advances and therefore a destruction had to be expected. In short, the result was that in spite of all possible precautions that particular plane went down with the respective and rather considerable consequences. Still one was not prepared. Instead, as all Washington analysts know and have now carefully put together, the result was "monumental confusion", and the consequences have not been altogether

digested to this day. But monumental confusion about a U-2 type incident is a very different matter from the possible monumental confusion in the whole world in case of accident with a nuclear weapon. So we should make provisions that no accidents are ever possible. That, I think, cannot be done. We can only make it very improbable, very unlikely, but that will never entirely eliminate that type of accident.

5. System Malfunction

Let us now look at the second point: We want to avoid that the weapon does not function when ordered to go off. Here there can again be technical malfunction. It could happen that the thing does not go off. This must be avoided, too, for strictly physical reasons. To get a large nuclear weapon to a certain spot and then not have it go off is an undesirable event, because of the build-up which is necessary in order to get it there in the first place. Again we must expect that some nuclear weapons will not go off. If there exist very many that can be put on target, this is a minor matter, and I will not discuss this further. It need not be so. In this case a new eventuality arises: in addition to a possible physical malfunctioning preventing the detonation, a signal to detonate a (physically perfect) weapon may not be received or understood. I.e. the weapon may not go off because the information which is telling the weapon to go off (I mean by weapon, of course, the whole installation, the people, etc.) may not get there; for example, we may never reach the command with the signal, word may not get through in time, and as was said before, the time factor collapses almost to zero. Thus this possibility is a much more serious matter than it used to be under other war conditions where the chances of repeating the order and thereby securing the performance were better.

Now the next point where something can go wrong is that the weapon may be used when not ordered. For this there are essentially two reasons: due to a malfunction of the system, a wrong signal may be received which says "go off", and then the consequences are similar to those mentioned earlier about an accident. If the false "go" signal is received during hostilities, this may be disadvantageous, but it is not necessarily a catastrophe. If it is received in peacetime, before the outbreak of hostilities, a disaster has occurred, its nature depending on the size, power and other circumstances of the nuclear explosion. Of course, one will build into a communications system as many safeguards as one can think of to prevent a malfunction of a signal, but I will presently show that it is not quite a simple or perhaps difficult, technical matter; that in fact there is another aspect to which I will come in a little while. So the weapon may be used when not ordered due to a malfunction, and it may be used when not ordered, for example for a reason which I will call "patriotic defection". By this I mean the well-discussed case when a commander, let us say, of a submarine, begins to get nervous and impatient, suffering from many insults having been dealt to the country and perhaps even grave damage having been done to the homeland. Our submarines may still be held back by higher authorities; they are not receiving the order to go. Yet they have the power to go. They are in complete control of all keys and combinations which are necessary in order to activate their nuclear weapons and they may decide on their own to go in and fight after all, if firing rockets can still be called fighting.

This, I would say, would be a defection from the order, or rather from the "not received" order, out of a motive of patriotism, impatience, or combat desire, etc.. That also is a malfunctioning of the system, now of the

entire system of command and control. Finally, and not unimportant, a scarce weapon may be used on a worthless target, where the word "worthless" means that the target has already been destroyed and that the command system has not been built up to such perfection as to allow retargeting. Retargeting, of course, depends on the high command actually receiving information about damage. To receive such information under conditions of nuclear war, to evaluate it and to pass new orders on to the field, would be a very difficult thing, and so weapons may be wasted by firing on worthless targets. That again may be a minor matter, perhaps, if nuclear weapons are plentiful from the point of view of the occasion, and if one is not concerned with physical side effects of their use such as the increasing fallout, etc., nor with political side effects, i.e. doing needless additional damage, for example when hostilities are already abating and the enemy is ready to concede defeat.

Then there exists a whole range of problems aside from the purely technical ones of the safe and reliable design of weapons. There are, for instance, those involving loyalties; that is to say, will people really obey the orders given and not deviate from them? This depends in many cases on the states of information and the interpretation of such information. It is not enough to have data. It is also necessary to understand what the data mean. And as our data increase in diversity of items reported and quantity and speed, this becomes a far greater problem than I think most people imagine.

Again let me stress--at the danger of being tiresome--that we know that the world is not deterministic. Applying this to any conceivable command-control system we must ask ourselves whether that is in our favor or works against us? The same condition applies, of course, for both sides. Since our system cannot be deterministic, there is uncertainty as to its behavior and use.

But this is not necessarily to our disadvantage. On the contrary, it may work for us, because if the enemy is uncertain under what provocations and threat conditions our weapons will go off, he will tend to be careful. But since we are uncertain as to how tight the control of their weapons and their forces is on the other side, this in turn works restrainingly against us. So what is in our favor is also to our disfavor if the same condition applies to the other side, as it necessarily does.

6. Design of Systems

The fundamental question thus is: what kind of command-control system should be designed; what kinds are technically possible and how do we choose among the alternatives? Though all are indeterminate and must remain incomplete, some will appear to be "better" than others. But it may not be easy to order the different systems uniquely so that a choice may become a very difficult matter. Each country naturally will choose a system which it believes to be in its own interest, but that system may also benefit the enemy, as we shall see. In that situation, a new element is introduced into the old command-control problems which is directly associated with the new dimension of speed and extent of damage of which each side is capable.

We raise therefore the problem of the invulnerability of a command-control information system. What can one want from a system designed properly? The fundamental fact is--and that is why I started these remarks as I did--we must not design for peacetime. We must design systems of communication and control for situations where there will be tremendous disturbances and disruptions, utter confusion. Specifically we want a system which will work though it is partly destroyed, which will work under the greatest amount of confusion,

because confusion is certain to arise the moment the very first split-second nuclear action takes place. The system should have the power to repair itself, to grow new links of high capacity fast, to be able to separate in the transmission the chaff from the wheat. The system must take care of the following: in spite of the distances involved (and the new great distances range over thousands of miles and have to reach around the world), we have to realize that mobility is one of the great characteristics of our time. We can therefore very quickly decide that a command-control system has to be based on the recognition of this fact. A system that itself has only a few central, fixed and known command posts is quite unsuited since all fixed points on earth can be brought decisively under attack. It is the principle itself which is faulty: a modern communication-command system should be so organized that it obtains centralization and focus by its structure, the alternative cooperative arrangements of its component parts, rather than the maintenance of fixed centers, no matter how deeply buried in the earth.

The more dispersal and the greater the mobility among our weapons, the greater become the problems of communicating with these moving points, yet the need for dispersal and mobility of weapons is inexorably imposed upon us. It is dictated by the nature of the nuclear weapons as well as by our ability to move them. In the end it is technology which determines what will be done. If you can move powerful weapons to your advantage, you will move them, and any tendency to do anything on the basis of fixed conditions or fixed bases will lose out in the end. Finally, the time interval between the decision to employ weapons and the actual use has already begun to approach zero.

If we think of a system to be built up under such circumstances we must realize that this is a social system, a social affair. There is rapid

and intensive interaction between men and men, over great distances, and between men and machines. It is one of the fundamental facts of the social world, though far from realized, that there can never exist a complete formalization of society. In other words, you cannot prove, and no-one has proved, that it is possible to lay down a completely exhaustive description or blueprint for society. For example, laws cannot be spelled out to take care of every possible, legally relevant future occurrence. It is necessary to give a certain amount of discretion to the judge, and therefore he can either accept or reject evidence, and he can condemn more or less severely or let a man go. There is a certain amount of freedom and elasticity which has to be built into the law. By applying this observation to the organization of a communications and control system, and trying to find out what is really the command structure, we see that the standard organization charts--nice little boxes and lines running from them--cannot be an adequate way of describing an organization. It will become even more apparent, once the above principle is understood, that these charts are totally inadequate for describing what kind of information system is proper for a given type of organization.

7. Mapping of Information System

Let me make this clear from the point of view of human organization--the human body. If you make a map of the human body, you make a chart of the anatomy. We know where the bones are, the heart, the lungs, etc.. This corresponds in some sense to the ordinary organization charts. But what the state of information is in the body about the body--that is totally different. The nervous system projects the body into the brain, but it does not by any means project precisely the anatomical or physical structure into the brain. In the brain

there is nothing corresponding to a one-to-one mapping of the "objective" picture of the body given in terms of anatomical description. In the brain the "organizational" picture is distorted altogether. If you consider the number of nerve endings in the various parts of the body and observe how the body parts are thus represented in the brain, you get a totally different and fearfully "distorted" picture of the human. You will find, for example, that the thumb is enormous and the fingers also are large. But the arms are almost non-existent. The lips are tremendous, the eyes are again enormous, but we have virtually no thighs, no behinds, shortened legs, etc.. In other words our bodies look totally different: the organs of sense are magnified out of all proportion--the eyes, the mouth, the tongue, the thumb, etc., but many other parts, though anatomically large, are mere appendages. This is the way the brain obtains information about the state of the body it controls, and how it passes on orders to those parts of the body which it can use. It is also noteworthy that the brain sometimes expresses preferences, by wanting to be informed in more detail about certain body phenomena at certain occasions. This is achieved by suppressing other--simultaneous--information or signals, in order to avoid confusion due to too many signals at one and the same time.

The description of the mapping into the brain is due to Lord Adrian, the great British neurologist. This has become a very fundamental conception of viewing the neurological properties of the human body, or of any other body, because the same is also true of animals. The picture in the brain is the so-called "homunculus" because it is only similar, not identical to the body itself. The human structure certainly is not invulnerable to begin with, but it is more vulnerable at one spot, less vulnerable at other spots, not all communication being centered in the brain and maximizing invulnerability probably not having been one of its design purposes!

Applying what I have said to the military situation, it means that the commander need not be informed about everything. In fact, it would be foolish for him to try to be informed about everything. The commander and his staff would be drowned in quasi-information. For the commander of an army it is usually enough to know that a certain division actually exists and is combat-worthy, that it is still commanded by General so-and-so, that he is alive and everything is in order. The nearer we go to that division level--or when a critical situation arises--the greater is the amount of specific information which will be needed. The higher up we go in the other direction the less of this kind of information is needed there. However, information of a different kind, relating to activities surrounding the commander is required, information of much greater detail than the information concerning actual happenings in the outlying parts of the battle area. So there is a distortion in the information pattern which is necessary; the pattern need not, and indeed should not, correspond to the "objective" organization structure and to the hierarchies it tries to describe.

Now we can ask what sort of "distortion" is compatible with having nuclear weapons under the command not only of the commander-in-chief, the President, but also distributed from him on down to the last combat field. We have imposed upon the command system and the information system in gradual evolvement extraordinary properties which have never been spelled out and investigated systematically. In addition the system should be invulnerable and here is an added great problem which I shall discuss further below. I don't think that the problem of the optimal construction of such a system has been solved, mostly because it has not even been put properly. The fact is, of course, that no system is invulnerable and certainly not our command-control and communications system.

What happens if our command-communications vulnerability is exploited by the enemy? Is it to his advantage to exploit it by destroying our communications system? Is it to our advantage to destroy the communications system of the enemy? In general one would be inclined to say that nothing could be better. On low levels, i.e. in narrowly defined tactical situations, that may indeed be wonderful. In guerilla warfare situations, it is wonderful if the enemy does not know where he is and you can capture him therefore. But as you go higher up and you destroy the communications, let us say between Khruschev and his top command, you may set things in motion which Khruschev and his commanders (taking them all as a unity) might not have done, as will be shown presently.

To reduce vulnerability we can make use of mobility; we have already fitted a ship as a floating command post, which would cruise on the Atlantic or in the bay outside Washington--provided the President and his staff can reach it in time. It is completely equipped with all the communications devices we can dream of at the present time. On the other hand we have a fixed command post in the Pacific, which is far more vulnerable. Everything that is fixed is quite vulnerable, no matter how deep it might be buried, because if one missile will not destroy it, then two missiles will destroy it, and if 5 megatons don't do it, then 25 will do it. So everything is destructible, and since the location of the Pacific command post is precisely known--and there is no question but that it is perfectly known to the enemy--such fixed command posts are exposed to destruction. They invite immediate attention by the enemy. But, as we shall see, the matter does not rest there. It will be shown that as an alternative to making the system invulnerable, its very vulnerability may be exploited to provide protection, though of a dangerous and tenuous kind.

8. "Efficiency" Aspects

One of the troubles in studying command-control systems is that we look too much at our communications systems from a civilian point of view. We judge its effectiveness by the standards of our essentially money-minded kind of thinking. The military always are in great trouble: on the one hand they are supposed to provide effective defense, yet be "economical"; and on the other hand they should be ready for battle with whatever they have. To give an illustration in logistics operations: it was discovered and it is true (I had something to do with the very idea myself), that instead of shipping supplies from the San Francisco area to the Far East by military sea transport, which goes only sporadically and requires collecting all of the stuff and letting it pile up to wait for shipping, it would be better to send most of it by ordinary parcel post. This is a good idea, it works very well, our supplies get there quickly, they get there reliably, it is cheaper--but it is wrong. The system is wonderful for peacetime, but it is totally useless in wartime. And if you have to make the transition to another kind of operation for wartime, you have to learn again, you have to prepare for entirely different conditions.

And what could be a better communications system than our telephone system! It takes an enormous amount of effort to improve it by a very little part, by even 1%, because it is so efficient; but to take that system as a model and apply it to the military situation is entirely inappropriate. What is needed is a really enormous amount of redundancy, possibly at a lower kind of technology, or at any rate a different kind of technology, in which it would be possible to have pieces and parts torn out and still be able to communicate, though at a lower level of efficiency, with very different alternative mechanisms. Such a system is perhaps in a trivial way "inefficient" compared with the civilian

system, and then the civilians come, particularly in Congress, and say that the military are inefficient: "Look at what a silly system they have and how wasteful it is." To that there is only one answer and that is to say that all military expenditures are wasteful if there is no war. Therefore, this is not a criterion at all. What must be done, even though it may cause difficulty in Congress, is to get away from the habit of viewing a command-control system from the narrow point of view of civilian efficiency which only makes sense when a war never occurs.

I would like to add here a word about a communications system which I think really deserves the greatest attention, and which would be invulnerable. In its invulnerability characteristic I would like to illustrate finally the point made before, namely, do we wish to destroy the strategic communications system of the enemy? The system is based on Project NEEDLES, or West Ford. It is proposed to scatter in space very thin and fine needles, 1-$\frac{1}{2}$ inches long with the thickness of less than a human hair, a very small amount, which would distribute themselves at an altitude of 8000 kilometers in a belt around the earth. This is an artificial way to secure that a meteor scatter type of communication is always available. Now there is no question that it will work--it didn't work when the package with the needles was shot up the first time; the needles did not spread, but that was a purely technical mishap at the first try. The belt does not endanger anybody and it will not interfere with astronomy. Astronauts could fly through it, the distance between one needle and another being more than $\frac{1}{2}$ cubic mile in space, so there is absolutely no danger. The scratches made by meteorites on satellites are much more significant than the scratches that could possibly be made by these needles. All of this has been carefully investigated in public and in the open. There exist many reports by

the National Academy of Sciences, and the President's Scientific Advisory Group has looked into the problem. In short, here is a system which I think ought to be built and will be built even though the astronomers are still somewhat troubled.

The consequence of building this system would be that we would always have available a safe communications system, assuming that transmitters are secure and not very big; the receiving antennas are quite small anyway. The belt itself is indestructable and even if nuclear weapons should almost become free goods, it would be pointless to use them for destroying the belt. So we could always communicate around the world and that we would like to do. But the enemy can use this system too, so if we construct this secure system the enemy also can use it. Perhaps we should even cooperate with the Russians and build the NEEDLES system together. Then we both will have a secure system. We could always communicate with each other. Is it to our advantage or to our disadvantage? Those who have studied the problems of deterrence may recall that one can prove that it is obviously to our interest to have an invulnerable deterrent force, but that in addition it is also to our advantage that the opponent have an invulnerable deterrent force (and vice versa), strange as this may seem at first blush. Only under this condition can we hope to have a stable deterrence, and perhaps, by also controlling the degree of technological progress, to maintain peace.

9. Destruction of Communications

Assume now, however, hostilities. Suppose that we stick to the old idea that it is desirable for one side to destroy the other side's communications system. Suppose we say that the Russians would try at this moment to destroy our vulnerable communications headquarters in the Pacific near Honolulu. What would

happen? Let us make a couple of assumptions. Suppose the fleet, which would now be cut off from a continual stream of messages, finds that these suddenly stop. The fleet has to interpret what the interruption means. Now it could be that the orders for the ships are such that the minute the communications flow stops, the ships are to go in and to attack with everything they have. That is possible. So the enemy, by destroying our communications, thereby causes this attack upon himself to take place. But this goes further. The situation is not good for us either. Suppose this is only a failure, an earthquake, and not an enemy destruction. Does this break in communications set loose the attack--what kind of attack? Plans must be made for the worst possible situation. The worst possible would be that an attack would be mounted also from bases in China against us, but the Chinese might not be involved if the destruction of communications was a Russian attack at all. So we might be attacking China at the same time as we are attacking Russia because this would have to be part of the general plan for the worst possible contingency. And failing reliable news it would be poor strategy to hold forces back, especially when they are vulnerable and might be destroyed before being able to get into action. Now that is altogether a dreadful thing. Then we are in a position even worse than that of the Germans in 1914 when they attacked Belgium, although Belgium didn't fight them, merely because it seemed convenient to go that way into France. This is the kind of problems we have to live with.

We have the same situation with respect to the missiles. The BEMEWs stations, one in Thule and one in Alaska, are continuously reporting, merely to say that they exist and that nothing dangerous is being seen on the radar screen. Suppose one is destroyed. What happens? We have the delimna that even if this is a real destruction, would we retaliate in spite of this being the destruction

of only one station? But would we attack Moscow? Is there time to make the decision, is the arrangement for making decisions adequate? If it was not an attack but just a failure what do we do then? How much time is there for verification of these things? Can we in these critical few minutes talk reliably and effectively with the (supposed) enemy? Can we distinguish bluff from truth? These are the deep problems which are no longer military, which immediately become political, and which give a particular illustration of this intermingling of technical, political, and military problems to which I have pointed before.

10. Invulnerable Systems for Friend and Foe

I think the existence of an invulnerable communications system which under all circumstances is useful to both sides at the same time, is of greatest importance, especially when hostilities should be in progress, in order to be able to communicate to the enemy that one wishes to negotiate, to limit the war, to restrict hostilities to a certain level. In the present situation this is of course, entirely impossible. The time factor is of immense importance and both sides are therefore in very great jeopardy. Several years ago I made the suggestion that one should set up "reserve governments" somewhere in the South Pacific. Each country should have one so that in case the governments are destroyed, these reserve or substitute governments could at least communicate with each other in order to stop the whole business. But that is not very likely to happen. The United Nations is certainly no substitute for this device because in their glass palace in New York they sit in a rather exposed position. So we see that the system we have is completely unstable. It is highly vulnerable, it is not really thought through, the eventualities are not fully explored, and in particular we do not know and do not anticipate what would happen if communication fails.

The system is merely complicated; but in spite of the earlier mentioned common belief this is not a sufficient criterion for intelligent design. We also have many other technical things which will not be mentioned here, like retargeting of ICBM's, etc., things of this sort which would be of particular interest and would become important in this picture if it were to be made more specific.

To sum up: though I hesitate to say this, it has to be said: a little more electronics will not necessarily help. It is not a matter of just a little bit more of some device. This is, however, apparently our principal orientation. Instead we have primarily a question of the design of systems. Technically, we have to find the proper feedback from below and conceptually, we have to solve the problems as to what to do with the communications, not only to increase their volume. In a nuclear war we have no time to learn, while in all previous wars which have had slow build-ups and a protracted course, there was ability and possibility to learn, to adjust and to find out how to stop before destruction went beyond all limits. In the future, there will be nothing of this and there are no other controls which would compensate. Finally, let me remind you that there is no complete formalization of such systems, no complete one has been designed, and none can be given. But it is not impossible to design systems that would improve the present conditions materially.