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FINAL REPORT
15 SEPTEMBER 1960

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PREFACE

This report is the final report of the Winter Study Group. It includes the overall conclusions and recommendations of the Winter Study Group as well as a recapitulation of the studies made by the Specialty Panels. Other reports of the Winter Study Group are as follows:

- WSR-1 thru -4 Winter Study Group Status Reports
- WSR-5 NORAD COC Study Final Report
- WSR-6 List of Winter Study Reports (out of print)
- WSR-7 Winter Study Group Final Report
- WSR-8 System Panel Final Report
- WSR-9 Special Studies Panel Final Report
- WSR-10 Data Processing Panel Final Report
- WSR-11 Sensing Equipment Panel Final Report
- WSR-12 Threat Panel Final Report
- WSR-13 People Panel Final Report
- WSR-14 Display Panel Final Report
- WSR-15 Communications Panel Final Report
- WSR-16 Cost Panel Final Report
- WSR-17 Vulnerability Panel Final Report
- WSR-18 Design Methodology Panel Final Report
- WSR-19 Ad Hoc Studies Final Report

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SUMMARY

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1. INTRODUCTION AND BACKGROUND

The composition of the Winter Study Group, present and planned USAF command, control, and sensor systems, and the approach taken by the group are described in the following sections.

1.1 Composition of Winter Study Group

On 13 October 1959, Lt. Gen. Schriever of ARDC met with Maj. Gen. McCormack (Ret.) of M.I.T., Maj. Gen. Bergquist of AFCCDD, Dr. Overhage of Lincoln Laboratory, and Mr. Halligan of the Mitre Corporation at Mitchell Field to discuss the planning which the USAF had been doing on command and control systems. Gen. Schriever proposed that further studies were needed as a result of (1) the proposed ARDC reorganization which was designed to streamline the management of the ARDC, stressing the concept of concurrency, and (2) the need to place the USAF L-systems in a realistic time-frame in view of the present and future state of the art and the need to evaluate these systems on an inter- and intra-system basis.

At subsequent meetings on 5 and 12 November between representatives of USAF, ARDC, AFCCDD, Mitre, Lincoln, and SDC, it was decided to have the Mitre Corporation host, under the auspices of AFCCDD, a technical group composed of individuals from these and other scientific and military organizations.* This group would be called the Winter Study Group. Its primary emphasis would be to resolve the problems discussed in (2) above.

On 30 November 1959, another meeting was held with the representative organizations. At this meeting the basic organization of the Winter Study Group was established. An operations staff was organized which consisted of the senior representatives of each of the participating organizations. This staff was intended to guide the detailed operation of the Winter Study Group and to act as the contact point for each of these organizations. On 22 December 1959, the operations staff met at Hq. ARDC. The final agreements for the Winter Study Group were established and nominations for membership on the various panels of it were started.

At the same time, discussions were being held between Hq. ARDC and Hq. USAF on the need for and a designation of a senior scientific guidance group which would represent the Secretary of

* The final composition of the Winter Study Group included individuals from the following organizations: ARDC, AMC, ADC, SAC, Intelligence Community, TAC, Lincoln, RAND, SDC, STL, Mitre, IBM, Itek, Stromberg-Carlson, General Atronics, IT&T, AT&T, and BTL.

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the Air Force in giving the necessary technical guidance to the Winter Study Group. Dr. A. G. Hill, M.I.T., was requested by the Secretary of the Air Force to act as Chairman of this Scientific Guidance Group, the charter for which, as expressed by the Secretary of the Air Force, reads as follows: "I would like the Committee to guide the work of a full-time study group which has been organized to examine critically and objectively from a technical point of view, the entire complex of existing and planned Air Force command and control systems. This includes an examination for technical realism of the needs and objectives of the individual Air Force elements as well as a study of the problems associated with integrating the various systems." At its initial meeting the Scientific Guidance Group recognized that the Winter Study would need the help of certain people from industrial organizations who could make unique contributions because of their background and directed that invitations be extended to these people.

The Winter Study Group had its first meeting during the week of 11 January 1960. On 18 January 1960, members of all of the panels met with the heads of their panels. On 5 February 1960, the first meeting between the Winter Study Group members and the Scientific Guidance Group was held. During this first meeting, the Winter Study Group proposed its method of operation, organization, activities, and schedule. Subsequently, Mr. Gordon N. Thayer, Vice President of AT&T, was requested to become Director of the Winter Study Group. Mr. Thayer has since devoted full time to directing the activities of the Winter Study Group, which met at Mitre's Bedford, Massachusetts, facilities from January to July 1960. This report is the final report of the group to the USAF.

The chart on the next page shows the organization and manning of the Winter Study Group.

1.2 The USAF Planned L-Systems

Revolutionary advances in the destructive power and in the speed and range of delivery of weapons have greatly changed the concept of general war. No longer is it possible to generate plans and to build up and exercise forces over a period of months or even days after the start of hostilities. The force for countering the enemy strength must be in being, fully exercised and ready to go in minutes, but under rigid control to avoid the possibility of accident. The requirement for rigid control and high speed has resulted in military commanders' requesting centralized command, control, and sensor systems that can collect, process, and display information faster than people can function.

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Proposals and plans have thus been made for a number of command, control, and sensor systems, the numbered L-systems in the USAF, calling for the most advanced technology in computers, displays, data processing, communications, and sensors. In general, these proposed systems have been planned to fill functional jobs, such as intelligence, warning, operations, and logistics, that exist in a given command. However, when the total command and control job is studied, with the ties and overlaps between functional jobs, the planning appears deficient, but the need for some of the systems and facilities within systems can be determined. In particular, it appears that the approach to planning taken heretofore has led to proposals and designs that, if implemented, (1) might create barriers between parts of a command and between commands, (2) will not balance requirements and cost, and (3) may not tie together for a command and between commands.

The Winter Study Group, as a point of departure for its studies and as background information, reviewed the proposals and plans for eighteen of the L-systems now under consideration in the USAF. Descriptions of each of these L-systems are presented in Addendum A. to this report and in WSR-18, and the appendixes to this report. These eighteen systems have been divided into the following categories for study purposes:

Command

465L, SAC Control System
473L, Hq. USAF Command System
425L, NORAD Combat Operations Center System

Intelligence

438L, Intelligence Data-Handling System
466L, ELINT-COMINT (ELCO) System
117L, SAMOS, satellite system for gathering photographic and electromagnetic intelligence data

Warning

117L, MIDAS, satellite system for detecting infra-red emanations from the exhaust of launched missiles and for giving alarm of such launchings
474L, Ballistic Missile Early-Warning System (BMEWS)
496L, Space Track System for detecting and cataloging space vehicles
413L, Distant Early-Warning (DEW) Line

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Control

- 416L, Continental Aircraft Control and Warning System, including the SAGE System
- 412L, Theater Air-Weapon Control System
- 413L, Traffic Control and Landing Project (TRACALS)

Support

- 480L, USAF Global Communications Management Project
- 433L, Weather Data-Gathering and Forecasting System
- 470L, Communication Satellite System
- 423L, Communications Logistics Net (COMLOGNET) for AMC

The following are not designated as L-systems but were reviewed to some extent by the Sensor and Communications Panels.

- OSR-62, Atomic Strike Recording System (ASTREC)
- OSR-290, Bomb Alarm System

The costs of the above systems have been analyzed by the Cost Panel in order to forecast their effect on the USAF budget. The system configurations which were costed were formulated by the Cost Panel after discussions with ESSPO's, using commands, and Hq. USAF. These configurations do not necessarily reflect official plans. In summary, if the present plans for the above systems are implemented on schedule, the USAF will require an additional obligational authority of about \$12 billion from FY 1961 through FY 1965 for research and development, test and engineering, initial capital investment, and annual recurring costs, including personnel pay and allowances in addition to that currently required for command and control functions. Assuming a static configuration for these systems after FY 1965, an increment of about \$8 billion will be required from FY 1966 through FY 1970 for annual recurring costs, including maintenance. It is important to note that these cost figures include only the money to be spent and do not include what has already been spent on these systems. The incremental method of costing used results in costs which must be added to the current USAF budget for technical facilities, personnel, and operations in the command and control area. Any savings accrued by replacing existing facilities and personnel with the above systems have been taken into account in the cost analysis. This cost analysis is for present plans only; it does not include additions or major modifications to present plans; it does not include local control systems which are an integral part of weapon systems such as for the Minuteman; it does not include the 117L MIDAS and SAMOS vehicles; and it does not include anything for future systems other than those listed above.

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An analysis of the FY 1961 situation has indicated that not all of the present plans for the above systems can be met within budgetary ceilings. About an additional \$560 million is needed: \$185 million in P-600 (research, development, test, and evaluation) funds, \$325 million in P-800 (other procurement), and \$50 million in P-200 (missile procurement) would be required in FY 1961 before current planning schedules can be said to be realistic from a funding standpoint.

1.3 The Approach of the Winter Study Group

In developing an approach to the command and control problem, the Winter Study Group focused on the time from 1960 to 1970. The chief effort and subsequent output of the group has been in the development of a way of thinking about the command and control function as a whole, which would lead to the formulation of broad guiding principles for the subsequent design, development, and implementation of systems. Little effort has been expended in defining and clarifying operational missions or in engineering specific systems; emphasis has been placed on methods, design and implementation concepts, and state-of-the-art capabilities and limitations, rather than on engineering recommendations. The relation of military strategies and force structures and of military technology and organization to requirements for command and control design and implementation has been stressed. In a limited way, the group has applied its concepts to some of the presently planned L-systems, leading to the comments on the specific L-systems given in Section 4 of this summary.

The formulation of a context in which to study the command and control problem requires an understanding of the spectrum of conditions and situations in which these systems will have to operate. Two broad frameworks should be considered. First, a functional framework consisting of: (a) the intelligence function performed by a community of agencies including the three services, NSA, CIA, and others, but not including the warning function; (b) the force-establishment function performed by the three services and including long-range planning, budgeting, research and development, procurement, and installation; and (c) the operations and combat intelligence functions performed by JCS, the service headquarters, some service commands (e.g., TAC), and the unified and specified commands and their component service commands. Second, a strategic framework consisting of a wide spectrum of conditions from peace to all-out war: peace, cold war, show of force, limited war, general war, arms control and inspection, and space operations.

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The Winter Study Group's effort has been concentrated primarily on the operations function and on the relation of strategies and force structure to command and control requirements for general war. Consideration has been given to the peacetime control problem, the response and execution functions, survivability, and the role of combat intelligence and warning. The group has not considered the operational relation of limited war, show of force, arms control and inspection, and military use of space to command and control requirements.

Almost all of the planned USAF L-systems are oriented toward the general war problem. Very little up to now has been done in planning for command and control of weapons in limited war situations. Also, much has yet to be done in formulating operational concepts and plans for the intelligence community, for support and logistics, for arms control and inspection, for military use of space, for air defense, and for higher command.

The Winter Study Group believes that automated command and control systems can contribute in a major way to the effectiveness of the military. To avoid the pitfalls of a compartmentalized approach, the group believes that a central agency, technically skilled and operationally oriented, should be established to aid the USAF in the planning, design, and implementation of these systems on a continuing basis. This group must be guided by USAF command and staff people and must have day-to-day access to the operations they seek to improve. The Winter Study Group believes that only in this way can a sound comprehensive plan for the L-systems be formulated. The Winter Study Group's output has contributed to such an effort in the following areas:

- (a) The development of concepts:
 - (1) Concepts and plans for operations in a general, or strategic, war situation; the control of the force, the role of intelligence and warning. Some aspects of the limited war problem have been considered;
 - (2) Design and implementation concepts relating to command and control problems in general;
 - (3) Design and implementation concepts relating to control and sensor systems in general;
- (b) Management concepts needed for the design, development, and implementation of command and control systems;
- (c) Conclusions on the operational and technical design of the presently planned L-systems.

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Sections 2 and 3 below summarize the Winter Study Group's concepts and management recommendations as they apply to the command and control problem. The conclusions and recommendations of the Winter Study Group as they apply to the specific L-systems are summarized in Section 4. The section is arranged so that for each L-system area (command, intelligence and warning, control, and communications) the general concepts which apply to the area and their effect on command requirements are discussed and are followed by specific comments on the systems presently being planned to fill the needs.

Chapters I through VI comprise the main body of the report. Chapters I, II, and III present the Winter Study Group concepts. Chapter IV summarizes the research and development areas which are indicated by Specialty Panel work to require additional emphasis, either by reason of foreseen deficiencies or hope of high payoff at an early date. Chapter V provides a recapitulation of the Specialty Panel reports. The current plans for L-systems are described in some detail in Addendum A to this report.

The appendixes to this report contain the reports of the System Design Panels, the Specialty Panels, and the work of various ad hoc groups formed within the Winter Study Group to study specific problems. These reports in many cases present conflicting views and divergent opinions. Because of the broad area of investigation with which the Winter Study Group was confronted and the diversified approach of the various panels, it was not desirable to insist that the comments of the various panels be in consonance with the central concepts or be consistent with each other. The work as reported in the appendixes, therefore, does not necessarily represent a coordinated position of the Winter Study Group but does represent the results of considerable investigation and analysis of the command and control problem in the context of the various panel areas.

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2. CONCEPTS

The concepts developed by the Winter Study Group for operations, command systems, and control and sensor systems are described in the following sections.

2.1 Operations

The function of command and control systems (including sensor systems) is to help the military organization control the force. Specifically, it is to facilitate the flow of information into the organization, within the organization, and from the organization to the weapons. Command and control is an old art; the urgency of the present problem comes from the need for automation, which appears to be necessary to meet the requirements imposed by the recent and continuing revolution in military technology. The complexity, variety, destructiveness, and range of weapons has increased drastically, while the useful lives of weapons and the decision times required for their operation has decreased. To solve the problem of command and control, to evaluate proposed systems, and to formulate realistic requirements, it is necessary to view the problem in a context broader than just the applications of automatic communications and data processing. Besides the technology of communications, computers, displays, etc., we must look at the nature of the organization that will use command and control systems, the structure of the force to be controlled and the strategies which the force is to serve. Our purpose here is not to discuss these subjects as such or with any completeness, but to look at their relation to the command and control problem.

It is convenient to consider command, control, and sensor systems in a spectrum extending from sensor systems (e.g., 117L) at one extreme to command systems (e.g., 425L) at the other. What we have to say about such systems will vary with the part of the spectrum being discussed. In fact, contrasting the ends of the spectrum helps to understand the whole command and control problem. For example, sensor systems are in many ways similar to weapon systems. They are closely related to the physical environment and are developed, produced, and delivered to the command essentially complete. A command system, on the other hand, is deeply imbedded in the structure of the command. It should grow and develop within the command and in a way that is determined by the experience of the command in working with it.

The command-control-sensor spectrum is discussed further in Sections 2.2 and 2.3 and in Chapter II, especially in relation to the military organization and to technology. This section will discuss the bearing of force structure and strategy on the command and

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control problem. We shall present general concepts relating to operational command, make some specific recommendations, and point out some major problem areas. Strategic questions bear most directly on plans for actually using the force in war. Our attention will be focused primarily on the general war problem and on operational command, as contrasted, for example, with support and long-term intelligence. It should be recognized, however, that operational command is largely a peacetime function involving the continuous planning, training, and exercising of the force. Problems of peacetime operation are covered in Section 2.2 and more fully in Chapter II. The subject of the present section is discussed at greater lengths in Chapter I.

2.1.1 Relation of Command and Control to Force and Strategy

Control and sensor systems are necessarily closely coupled to the weapons with which they interact. For example, changes in enemy weapons (even relatively minor changes) may make obsolete a sensor system designed to detect those weapons. Command systems, on the other hand, should be closely coupled to the military organization, and only loosely coupled to the rapidly changing weapon systems. The military organization needs continuity and stability, a chance to build up tradition and to evolve at a rate compatible with the response time of human institutions. Insofar as is possible, command systems should cushion the shocks involved in the adjustment of the organization to a volatile military technology.

Our purpose in the Winter Study Group has not been to make a comprehensive study of military strategy, national policy or war plans, nor to suggest what our strategy will be or should be during the next decade. Rather, we have considered how strategic choices affect the requirements on command and control systems. To what strategic factors are these requirements sensitive? Of what are they relatively independent? What follows will discuss these questions and will point out how, if care is not taken, command and control systems could unnecessarily restrict strategic flexibility.

It is necessary to distinguish between long-term strategic choices (such as deciding on the kind of force we build) and short-term choices having to do with how an existing force is used under various contingencies. The long-term choices affect the requirements for command and control systems. One desirable requirement is that the command and control systems not restrict strategic flexibility in the short term, or at least restrict it no more than it is already restricted by the weapons themselves. For example, there would be little point in having a hardened, survivable

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control system for a force which could not survive a surprise attack. In short, the command and control system should try to maximize the number of ways in which the force can be used.

There are two cases, however, where the command and control system could restrict strategic flexibility more than it is restricted by the nature of the weapons:

(a) Some ways of using the weapons may require command and control or sensor systems which are so elaborate and expensive that they compete with the weapons for defense funds, technical manpower, or other limiting resources. This will hardly apply to command systems, which are inexpensive compared to weapons. It could apply, however, to sensors. For example, the use of our missile force to knock out the opposing missiles would require expensive sensor systems for surveillance, especially if the opposing missiles were hardened, dispersed, concealed, or mobile.

(b) Some ways of using weapons might be deliberately rejected as being too dangerous in reality or appearance or both, or they might be rejected for political reasons. For example, continuous surveillance of the opposing missile force might be rejected as part of a formal or tacit arms-control agreement to reduce the fear of surprise attack.

Let us now apply these general principles to some specific problems, beginning with the so-called compression of time in modern strategic war.

2.1.2 Quick Reaction and Survivability

The most severe requirements on command and control systems come from the high rate at which data is required to flow (that is, be gathered, processed, and then retrieved, displayed or transmitted). The required rate, of course, depends on the volume of data that must flow and on the time during which the flow is required to take place. To solve the command and control problem, we should not depend entirely, or even primarily, on elaborate electronic equipment designed to give high rates of data flow. We should also look for those procedures which reduce the required volume, or increase the available time, or both. Sections 2.2 and 2.3 and Chapter II will discuss ways in which the volume of data can be reduced by developing languages involving various degrees of detail or abstraction which are appropriate to various levels of command. This section will consider the so-called compression of time which is one of the most important consequences of the revolution in weapons.

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In modern strategic war, it is necessary to distinguish between (1) a first strike, or strike launched by an undamaged force, probably with the hope of achieving tactical surprise, and (2) a second strike launched with a force damaged by the opponent's first strike. There is a great difference between a first-strike capability, which depends mostly on firepower and accuracy, and a second-strike capability, which depends on the ability either to react to warning or to survive a surprise attack.

For some time the security of SAC has depended on the ability to detect a threatening attack and respond by putting bombers on alert or launching them under positive control. The response time of the force (that is, the time to prepare and deliver an attack or counterattack) has been decreasing as we go from piston engine airplanes to jets to missiles and especially to solid-fueled missiles. Missiles make an ideal first-strike weapon because of their quick response and the relatively inconspicuous preparations required to launch an attack. A second-strike capability based on the short response time of missiles would require an equally short response time for the command and control system. This is the meaning of the compression of time.

However, a second-strike capability could also be based on another feature of missiles, namely their ability to survive a surprise attack. Unlike aircraft, which can be protected only at great expense (e.g., airborne alerts), ballistic missiles can be protected by mobility or by a combination of hardness and dispersal. The choice between a second-strike capability based on quick reaction and one based on survivability has a profound effect on requirements for command and control and especially for sensor systems. A soft, quick-reacting force requires a highly reliable, high-data-rate system to gather data on the enemy attack, process, transmit and display the data to a decision-maker, arrive at a decision and transmit it to the force. The system, however, can be relatively soft. There is no point in having a survivable system to control a non-survivable force. However, a strategy of relying entirely on quick response to warning is dangerous and, we believe, should be rejected. The chances of either failing to get warning or "retaliating" on a false alarm are too great. Thus we favor a survivable system. However, only a fraction of the normal peacetime functions of the command and control system would need to survive or should be expected to survive. The data rate of the surviving system could be quite low.

There is a danger that planned command and control systems will be neither reliable enough to launch a quick retaliation on warning nor survivable enough to control a force which survived a first strike.

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In summary, the best solution to the problem of compressed time is not elaborate electronic data-processing facilities designed to make quick reactions safe, but a survivable and perhaps quite simple system designed to make quick reactions and snap judgments unnecessary, at least where thermonuclear war is the issue.

2.1.3 Sensor Systems for Warning and Surveillance

There is, of course, a difference between depending on quick reaction and having a capability to get and act on tactical warning. For example, objections to launching missiles on warning do not apply to aircraft, which can be launched under positive control. As long as our deterrent depends to any degree on manned bombers, tactical warning will be valuable. How much money it is worth spending on sensor systems to give tactical warning of a missile attack will depend on the confidence we have in them and on what could be done with the same resources to give us a second-strike capability independent of warning. The cost of proposed warning systems is comparable, for example, to the cost of an airborne alert or to some missile programs. This is an example of the principle mentioned earlier where the ability to use certain strategies competes for funds with measures to increase the size or performance of the force.

Even in the case of ballistic missiles, there is an argument for being able to fire on tactical warning and for making the enemy think that we might do so, especially if we received strategic warning. This would complicate his strategy in launching a first strike. However, since the hair-trigger readiness required to fire on warning is dangerous, we might deliberately reject such a strategy in order to reduce the chances and fears of accidental war, or as part of an arms-control agreement. This is an example of the other principle mentioned earlier where certain strategic options might be deliberately foreclosed as being or appearing to be dangerous. It also illustrates how requirements for command, control, and sensor systems are affected by questions of national strategy.

Finally, consider sensor systems for surveillance. The priority of these systems will be affected by strategic choices, particularly by whether or not we try to have a credible first-strike capability in addition to a second-strike capability. Should we accept the strategic nuclear stalemate and concentrate on stabilizing it by building a purely second-strike force, or should we try to break the strategic stalemate and have a first-strike capability to offset the superiority of the Communist Block in ground forces? This strategic question is crucial both to our national policy and

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to the requirements for sensor systems. A first-strike capability would require sensor systems to locate fixed missile sites and to keep mobile missiles under surveillance.

Operational experience with sensor systems for both warning and surveillance also has a legacy value. It would leave us freedom to change our strategy or to respond to unforeseen technological developments. As long as we are in an arms race based on a volatile technology we should foreclose no more alternatives than we have to because of limitations on resources. There may be uses for tactical warning and counterforce surveillance which are not now recognized.

The major part of the cost of the proposed L-systems lies in sensor systems for warning and surveillance. These systems compete for funds with major weapon systems. It is not the function of Winter Study Group to recommend how much of the defense budget should be devoted to sensor systems. Instead we have tried to give the decision-makers useful data and concepts. The report of the Sensor Panel in Winter Study Report No. 11 gives technical analyses of proposed systems. Section 3 of Chapter I presents arguments for and against several different strategies involving different roles for tactical warning.

2.1.4 Survivability

Command and control systems cannot be made invulnerable. What we do in protecting them is to increase the effort that the enemy would have to make to degrade the system. The degradation can take the form of a loss of functions or passage of functions to a lower level of command. Our problem is to find criteria for the size of attack needed for particular degradations. We suggest two such criteria, a quantitative one and qualitative one. An example of the quantitative one would be to protect the local control centers for our missiles so that an attack on the centers would cause the same degradation in our counterattack as would be caused by concentrating the whole attack on our missiles themselves. The qualitative criterion involves setting a threshold of attack for which a particular degradation of command and control would be tolerable. An example is the passage of a command function from a higher to a lower level of command. Such passage would be considered tolerable under sufficiently drastic conditions of attack. Protecting the higher command is a way of defining what level of attack would be sufficiently drastic. A specific example is the problem of the trigger and safety catch for our retaliatory force. We want to insure that the force could be triggered in time of war but that it will never be set off by mistake. The command and control system should be designed so that an attack on it weakens the safety catch, and

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the system should be well enough protected so that any attack which would weaken the safety catch would have to be so heavy and deliberate that the weakening would be tolerable, that is, the attack would shift our fears from the security of the safety catch to the survival of the trigger. Another example of this is the passage of control from a fixed local control center to a mobile backup when the former is knocked out. Another is the degradation of the higher command function to the point where it can do no more than give the word for all-out retaliation in case of a deliberate attack on the command itself. Which criterion is relevant depends on the context.

The requirements for the survivability of a command system depends on what functions the surviving command is expected to perform. Hence they involve strategic questions. We feel that, even under a massive attack on our retaliatory force, we should preserve the ability to control our reaction, to evaluate the feasibility of a counterforce retaliation, to retarget our surviving weapons and to communicate with the enemy and terminate the war before both sides have exhausted their ability to damage one another or before an initially counterforce exchange has degenerated into unrestricted city busting. It is doubtful whether any image of a nuclear war can be realistic enough to serve as the basis of a single, preplanned automatic response.

More study should be given to the question of how a military organization should transform under an attack which knocks out a large fraction of the command centers and communication links. We have suggested that to control our reactions to a massive attack we require a single, central level of military command above the level of local control, and that it should be possible to perform the function of military central command at any one of several hardened and dispersed command centers which are also involved in normal peacetime operation. Thus there should be a hardened JCS center. If it is knocked out, central command would pass, for example, to a hardened SAC center, then to a NORAD center and so on. There should also be a mobile backup, such as an airborne command post, which would take over if all of the fixed hardened centers were knocked out.

We expect that many and perhaps most of the normal peacetime command functions will disappear under attack. However, no centers or functions should expect to be suddenly activated. The surviving centers and functions should be part of the continuing operational command structure. Both wartime functions and the take-over of central command by successive centers should be practiced in peacetime exercises.

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2.1.5 General Conclusions

In the light of these reflections on the overall problem of operational command, we can make some general comments on the whole L-system program. The conclusion is that far too little emphasis has been placed on a realistic approach to surviving an attack and controlling our reaction. Planned L-systems are addressed almost entirely to a pre-strike mode of operation with the expectation that this mode will be available in a post-strike situation. Most of the expected cost goes to sensor systems for tactical warning, the role of which in the missile age depends on controversial questions of strategy.

2.2 Command Systems

We next consider the problem of operational command and the role of command systems, such as 425L NORAD and 465L SAC, in this function. We are distinguishing here the operational function from the other functions of support and of long-range intelligence also performed by the services. Operational command consists of planning for and directing forces-in-being; the line of command includes the Joint Chiefs, the Unified or Specified Commands, and the component commands. Also, by considering command systems, rather than control and sensor systems discussed below, we are primarily addressing the headquarters functions of operational command.

There is considerable agreement within the USAF that we are facing a crisis in operational command. Although the United States is developing an up-to-date arsenal of mixed weapons and electronic systems, there is concern whether commanders have the tools to realize and evaluate the performance of these systems, to prepare adequate war plans, to maintain a ready posture, and to direct forces when action is required.

The crisis in operational command capability is the result of a technological revolution in weaponry. The planner and commander are confronted with both conventional and nuclear weapons; many forms of delivery; and extremely complex control, sensor and weapon systems whose potential capabilities can only be gradually realized. But these capabilities have short useful lives before a new wave of systems comes into the field. Similarly, the enemy threat changes as his weaponry improves. The available decision cycle for war planning and force employment becomes shorter and shorter but the consequence of these decisions is greater and greater. Finally, our military is undergoing a major reorganization so that lines of authority and responsibility are changing and not always clear.

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The mushrooming requirements for command systems and more automation are a symptom of a crisis in operational command capability. In order to evaluate the presently proposed command L-systems and to consider whether some areas of need have been overlooked, Winter Study has had to consider the problem and needs of operational command in a context broader than "how can automatic communication and data processing help?" Independent then of the use of automation, seven factors must be recognized if operational command is to be strengthened:

(a) The military is responsible for exercising command - this function should not be delegated inadvertently to machines or engineers.

(b) Operational command is a single, continuing management problem. Whereas forces and functions phase in and out year by year, the command function must grow continuously under direction of the command.

(c) Within a command, there is a severe need for effective communicating between intelligence, operations, materiel, and plans functions as they relate to the total operational command role.

(d) Operational command must be adaptable to uncertainties in threat, policy and technology. It must respond to major contingencies caused by these uncertainties in weeks and months, not years.

(e) Commands must develop a stronger linguistic framework as an aid to rapid, succinct consideration of their problems and capability for coordinating them with higher and adjacent commands.

(f) The need for improved communication and information handling to strengthen operational command is predominantly for pre-combat capability. This is the essence of the forces-in-being concept - peacetime operational command generates and exercises the simpler plans and procedures that are required for combat.

(g) Communications and coordination between commands and with JCS command must be expanded to include more joint planning and exercising during the pre-combat phase.

" In order to strengthen operational command, three approaches must be pursued together:

(a) An increasing use of automated communications, data processing and display can help. This capability is required primarily in peacetime; it should be provided early and in gradual steps. " Present plans for command L-systems are often too long-range and too ambitious.

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" (b) The commands require much more on-going technical assistance not only to aid them with appropriate automation but equally to strengthen the analysis, planning, exercising and evaluation which are needed as more complex systems become part of the force structure.

" (c) Finally, the lines of operational command must be clarified and strengthened, a stronger service-independent JCS command center must be evolved, and guiding operational concepts and standards for all command centers must be developed.

" The following principles should be observed in applying automation to command headquarters:

" (a) Each command should apply automated communications and data processing in modest, successive phases so that capability and understanding can be built on previous command experience. Initial use of automated capability in any phase should leave considerable spare capacity for growth and change.

" (b) During all phases of adding automation, a commander's or "capping" system is required which acts as a "staff" cutting across the organizational lines of operations, intelligence, materiel and plans wherever these functions support operational command. This planned growth of automation in a command should be directed toward the building up of a data-base or command model. The data base would be stored in the command's computing machines and would represent all the data and procedures and plans and experience pertinent to the operational command function.

" (c) The command organization should participate in the design of automated procedures and models as part of their command job. Many steps could be taken today with available techniques to increase this participation; "requirements for command L-systems have not included this capability.

" (d) Design of command systems should include capabilities for the discussion and evaluation of performance and the development of a command language. " Presently planned L-systems usually include a greatly improved capability for performing known tasks, not a capability for considering how important tasks are and how well they are being performed.

" (e) One of the major factors which caused delay of the L-system program and then the establishment of the Winter Study Group was a stated need for more "integration" between the L-systems. " It is important to distinguish between functional and technical integration. In the latter, one emphasizes such needs as use of standard equipments and programming languages, or sharing of a

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single facility for several tasks (such as common communication systems for several users). In the case of functional integration, one emphasizes clear and effective and realistic allocation of roles to commands, close coordination within commands and between commands in planning and support, and effective higher command of subordinate commands.

"Adequate functional integration at this time is much more important than technical integration. A strong requirement for early technical integration is technically both infeasible and undesirable; undue emphasis on technical integration threatens early needed strengthening of operational command capability at individual commands. Stronger functional integration will gradually result only as individual commands and JCS command are strengthened under the broad guidance of overall functional and technical plans."

Next, let us consider the need for stronger, continuing technical assistance to the commands. The Weapons System Project Office Manager procedure which has been used by the USAF for developing major weapons and electronics systems does not provide adequate technical support to the operational command problem. It does not insure continuing assistance; it does not provide the proper impact of command requirements on weapons, control, and sensor system design; it does not provide enough continuing iteration between command needs and technical feasibility. The establishment of the Hanscom complex with a strong continuing technical support for AFCCDD can do much to remedy these shortcomings, if:

- (a) Hq. USAF, DOD and the using commands recognize, support and use this capability at a high enough level;
- (b) Adequate financial support and priority are given to building appropriate technical and managerial capability within the complex.

The relationship between AFCCDD and the using commands for command systems should be two-fold: consultant and developer. In its consultant role, the relationship must be much closer than that required for weapons and electronic systems: in effect, AFCCDD is participating in the planning and organization of the user command and the user command is participating in the development and design functions of AFCCDD. AFCCDD should be like a management consultant or technical staff to the using command. Unless this relationship exists, AFCCDD will be incapable of providing fully effective, continuing technical assistance required by the commands; it will be unable to propose or support the continuing GOR's required for command improvement.

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In its development role, AFCCDD should manage a development program which produces a family of "on-the-shelf" (or at least "in-the-catalog") command system components which are useful for several commands. In this role, the relationship between AFCCDD and the individual user commands is not as close. The development of computers, displays, communications, and computer programming tools should not aim at the particular requirements of one using command---it should reflect the anticipated overall requirements of many commands.

A most important factor to be appreciated here is that our capability to build hardware components is well beyond our knowledge to build systems out of these components. We have learned a great deal of how computers can be programmed and how to build display devices and automatic communications, but we require a much larger understanding of basic information processing in order to learn how to handle interactions between these elements and how to compose these elements into an effective system.

The major development requirement in the equipment area is in developing standards for tying these components together and modularities of design so that processing capabilities in command centers can be expanded and improved without disrupting operations.

Another element of a command system research and development program is conducting operational experiments in an operational environment (e.g., the 438L experiment at SAC). Such experiments should not be viewed merely as the development of a prototype system for a particular command; more important they should attempt to develop and improve automatic techniques which might be used in a different fashion by many commands, including the development of a common language for the use of the command and control systems.

Also, we need basic development programs in command center technology: how command centers operate; the proper role for men and machines; how operational personnel can direct properly the automated portions of a system.

" In summary, we have stressed that operational command capability must grow within a using command and be designed primarily by that command; that a development agency such as ARDC is more a technical consultant to a using command rather than an independent designer for the command. The USAF is responsible for supporting the command system requirements of many headquarters, some of which exercise operational command over other service commands, some of which receive operational command from unified commands whose command system requirements are supported by other services. Service support of operational command systems will be workable but the

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USAF should press for the early development of a clear JCS command system operational concept and the early strengthening of a service-independent JCS command center.

2.3 Control and Sensor Systems

In the previous section we considered the problem of operational command and the role of command systems in this function. We indicated that the distinction between command or headquarters systems and control and sensor systems is both meaningful and necessary.

Both control and sensor systems are imbedded deeply in the physical environment of forces, resources, and technical facilities, whereas command systems are imbedded in the military organization and its command personnel. The properties of control and sensor systems are affected chiefly by the design parameters imposed on them and by the physical environment in which they will operate rather than by the command structure which will use them. Control and sensor systems are loosely coupled to the military organization in that a change in a system is not necessarily reflected in a change in the command organization.

Both control and sensor systems have elements of command, control, and sensing facilities within them although any single control or sensor system is oriented toward one objective, i.e., control and maintenance of the forces of a command or collecting data on the enemy for a command. Sensor systems collect data for many commands and agencies and so they may be concerned not only with the operational command function but also with the support and intelligence functions. Control systems usually control the forces of only one command. Within a command, filtered operational information flows from its control systems and sensor systems to the highest command level where command is exercised over its forces and resources in being. Control systems such as 416L, 412L, and sensor systems such as 466L, 117L, 474L, and the proposed 496L are representative of these classes of systems.

It is useful first to distinguish a number of general properties of control and sensor systems before formulating a set of design and implementation concepts:

(a) The cost, complexity, and time availability of these systems are highly sensitive to the strategic and tactical doctrines under which they will be used and the operational parameters (e.g., survivability, response time, mobility, etc.) which are imposed on their design. For example, the cost of a space surveillance system can vary from about \$500 million to \$3 billion depending on whether new satellites must be detected in a maximum of 4 hours or 10 minutes, respectively, after launch.

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(b) The cost, complexity, and time availability of these systems are also highly sensitive to their vehicle or sensing element characteristics (e.g., reliability) and to the degree of control and coverage the system must exercise as an operational requirement. For example, with respect to reliability, the five-year cost of a satellite intelligence-data-gathering system (117L-MIDAS and SAMOS) can vary from \$1.2 billion to \$2.5 billion depending on whether the useful lifetime of a satellite is 50 weeks or 12 weeks, respectively. These costs apply to a system where 26 satellites (18 for SAMOS and 8 for MIDAS) must be maintained in orbit continuously.

(c) Most of these systems are characterized by high cost with respect to command systems. For 16 of the planned L-systems, about \$7.5 billion are needed for the sensor systems through 1965, about \$2.5 billion for the control systems, and only about \$600 million for the command systems.

(d) Control and sensor systems are much more dependent on the technical state of the art than command systems. For example, the BMEWS can be rendered ineffective by improvements in missile technology (lower radar cross-sections, higher or lower re-entry angles, ECCM, etc.), whereas it is relatively unimportant whether the SAC war plan is generated by a command system using transistorized computers or vacuum-tube computers. This dependence on the state of the art tends to result in uncertainties in the configuration of a control or sensor system, thereby continually compromising operational objectives and budgetary allocations. These uncertainties can result in inadequate operational planning because the planning is put off until a definite system can be configured. The importance of operational planning for the use of control and sensor systems must proceed simultaneously with their design and development and must take into account the continual changes in technology.

(e) Because of their unique operational objectives, these systems have not usually been implemented in a planned-growth manner, but rather in their entirety at a time oriented toward specific objectives. Here, an excellent example is the BMEWS. For optimum effectiveness the system should be implemented in its entirety toward the specific objective of providing 15-minute warning for the quick-reaction capability of our forces. If the strategic situation or our objectives change while the system is being implemented so that this warning would no longer have as high a value, little use may be made of the system.

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These factors, therefore, tend to result in control and sensor systems having long lead times, little post-operational growth, and more susceptibility to obsolescence relative to command systems.

Five broad concepts should be pursued in the design and implementation of these systems. Application of these concepts to the planned L-systems has been reflected in our comments in Sections 3 and 4 of this Summary:

(a) System analysis based on a foundation of broader mission and command analysis must be performed to bridge the gap between broad goals and detailed design and implementation. This system analysis must include adequate time/cost/effectiveness studies and must be a part of on-going technical assistance by AFCCDD to using commands in planning, exercising, and evaluation. We discuss in Chapter III an example of the type of system analysis and cost analysis needed by analyzing some requirements in the area of space surveillance. This type of analysis will give insight into the tradeoffs that may be achieved in cost and time versus strategic objectives and operational parameters.

(b) Research and development programs with long-range goals which are tied to a broad base of strategic objectives are needed. These programs should have as an objective the development of component subsystems applicable to a mobilization base which can be used to assemble systems in accordance with the strategic objectives of the time. This approach offers the only hope in reducing lead time and obsolescence of systems needed for changing strategic situations. Alternative approaches must not be ruled out on the basis that they do not fit today's strategic objectives.

For example, the following techniques and items should receive development support: common-user communication systems; hardened, message-switching, communication centers; hardened, low-bandwidth, backbone communications systems; mobile and hardened control centers; shock-resistant computing and display equipment; hardened, phased-array radars; mobile computing, communications, and sensing equipment; etc. Control and sensor system components must be developed which are adaptable to the changing strategic situation.

(c) Directed assignment of a control or sensor system to a single operational command should be made as soon as possible for any system which is necessary to the operational command function and which will be used by more than one command. Examples are 496L and a common-user ZI communications system. Assignment to one operational command insures that the necessary planning,

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exercising, and evaluation with respect to command missions will begin and that the maintenance and operations doctrines will be developed. Technical people should not function as independent designers and operators of such systems.

(d) On-going, operationally oriented studies must be performed to formulate and determine: 1) strategic and tactical doctrines and situations under which these classes of systems will be used; 2) realistic reliability and survivability requirements which distinguish the difference between peacetime and wartime needs and allow for the peacetime exercising of these systems under both of these conditions. AFCCDD and others must provide the using commands assistance in both these areas.

(e) Adequate functional integration of control and sensor systems within a command and between commands must be emphasized rather than technical integration. This emphasis must be placed in three areas:

(1) Development of a communication language of increasing abstraction from the sensing elements themselves back to the command is necessary in order that data from many systems can be processed and correlated at the command. This has not been done up to now, most strikingly in the intelligence area, so that it is almost impossible to apply automatic data-processing techniques for filing, retrieving, and correlating data from many sources because no precise and common language exists within a system or between systems.

(2) Communications from a command to its sensing elements must be provided which are able to implement a method to dynamically control the operation of the sensors from the command in accordance with the existing operational situation. Resources must be able to be committed rapidly to test hypotheses and to obtain more information on a particular situation seen at the command headquarters. This is especially true in the intelligence area.

(3) The design and implementation of the sensing vehicles themselves such as satellites and ground-based gata gatherers, and their associated communication systems must be done in a context which considers the functional integration of these elements with the data processing facilities and procedures of a command which is to use the data from these systems.

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Engineering design of the communications and data-gatherers of a control or sensor system should not be done, therefore, until the functional design of the associated command system or systems has been formulated and the command's data processing needs determined in a context which considers the communications and sensor inputs. The need for a 5-megacycle link, for example, from satellite-to-ground in the SAMOS system should not be based on the amount of data that the satellite can collect but on what data is needed, when it is needed, and how it is going to be used by the command.

For the above reasons, AFCCDD should be given responsibility for providing technical assistance to the operational commands in working out functional and technical integration of sensing systems such as 117L BMEWS and should also guide the design of command data-processing portions of these systems in conjunction with the using commands.

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3. RECOMMENDATIONS FOR COMMAND AND CONTROL SYSTEM MANAGEMENT

The Winter Study Group was asked to examine the proposed and planned L-systems to determine whether they were realistic and technically sound. In the course of this examination and in their reports, the panels commented on various aspects of the management of the current L-systems and made suggestions about what should or could be done in the future to improve the process of generating and managing command and control systems. In the main, the panels found that the L-systems were being managed separately and that taken together, there did not appear to be a consistent set of operational objectives, agreed upon strategic and tactical plans, or a set of standards and general plans for the orderly introduction of command and control systems into command. The following, then, is a management concept consistent with these observations which appear throughout the Winter Study Report:

(a) Concentrate the responsibility and authority for making command and control system engineering decisions at the Hanscom complex.* Staff the Hanscom complex with the appropriate mix, quality, and number of operations, cost, equipment, systems, production, and installations experts.

(1) Those parts of the operational commands' headquarters staff at the Hanscom complex (SAC, TAC, NORAD, ADC, Hq. USAF, theater commands) that are concerned with design of the future command and control systems for the commands should have the confidence of and be attached to the highest level of the commands.

(2) Hq. USAF should use the information generated by the organization at the Hanscom complex to supplement its own work on command and control matters.

(3) The concentration of this authority and responsibility should be gradual, geared to the build-up of capability of the complex.

(4) The command and control decision-making process should be focused around the decision to buy operational systems for the

* The Hanscom complex consists of the USAF organizations now or to be located at L. G. Hanscom Field, Bedford, Mass., (AFCCDD, ESC, and the using command detachments) plus the AFCCDD system engineering support contractor, the Mitre Corporation, and other organizations responsible to or in support of members of the complex, whether or not physically located at Hanscom. For example, the Rome Air Development Center located at Griffiss AFB, Rome, N. Y. is a part of AFCCDD and is therefore considered part of the complex.

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commands. Decisions to try techniques, experiments etc., should be properly related to this decision to buy.

(5) The level of competence at the Hanscom complex should be great enough to maintain the confidence and respect of this military, industrial, and scientific community.

(6) All command and control systems, including those closely associated with weapon or sensor systems, should be the responsibility of the Hanscom complex for concept, configuration, and program control to minimize duplication and to insure a single, compatible, aerospace control environment.

(b) Establish at the Hanscom complex a central planning activity that will treat the whole command and control problem in its operational, equipment, time, and cost context and develop the concepts that will guide the decision-makers.

(1) The planning activity must cover the objectives, expected performance schedules, and costs of the total force structure, or at least the USAF force structure, and develop a methodology for estimating performance, schedules, and costs of proposed systems.

(2) It must develop methods for integrating weapon systems and command and control systems.

(3) It must understand the objectives of the individual commands and develop measures of the effectiveness and cost of the systems the commands need.

(4) It must establish the general principles (policies and standards) concerned with the development of command and control system components (people, displays, computer programs, communications, etc.).

(5) It must develop the concepts which guide the design, development, and implementation of command and control facilities.

(c) Establish at the Hanscom complex a development activity for command and control systems that will be a focus for the development of command and control operational techniques, equipment standards, maintenance procedures, etc.

(1) Enough of the actual operational experiments, component tests, etc., should be done at this activity to maintain the competence of its personnel and to establish it as the leader in the field.

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(2) Operational experiments performed at places other than the Hanscom complex must receive their technical direction from the complex when the technical competence eventually exists. Operational experiments that are incremental changes to present operational command capability should be distinguished from those that result from major changes in command force, or sensor structure, or command organizational changes. Incremental changes should be guided by the operating elements of the command which needs it, acting through the Hanscom complex. Major changes should be guided by the planning elements of the command or Hq. USAF operating through the Hanscom complex.

(3) The development people should be competent in the fields of specialty required in the command and control system area--operations, human factors, computers, and computer programming, communications, displays, and sensor equipment. This competence should be great enough to command the respect of industrial technical personnel.

(4) The development activity should be responsible for guiding the development of a generally useful line of components, i.e., computers, communications, sensors, programming techniques, etc., for command and control systems. This development should not all be directly related to particular L-systems. A substantial portion of this work should be funded separately from system contracts.

(d) The operating command (or Hq. USAF) is a customer for command and control systems. It is also one of the principal system designers. The operational commander is responsible for the design of command and control systems in the same sense that he is responsible for the design of his organization. The Hanscom complex should provide to the operating command consultant help on the cost/time/effectiveness of alternative systems, in estimating and stating requirements, and in performing operational experiments, etc.

(1) The system which a commander uses to command and control his force is an organization of people, computer files, communication gear, rules of information flow, etc. The L-systems are pieces of this system and should not be considered outside its framework by the managers or technical directors of the program. Thus the equipment should not be thought of as separate from the command organization.

(2) The operational commander must consider the design of the command and control systems he uses four or five years in the future in its proper environment, as determined by the command organization, the weapons available, and the threat.

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He should not confuse today's problems with tomorrow's. He should separate these things both in his thinking and in the way he organizes his staff.

(3) Predictions of requirements for command and control systems will be continually modified due to changes in threat, force structure, organization, etc. The management organization for the L-systems must treat this as the norm rather than as an exception to the norm.

(4) The commands should receive consulting help from a competent sustaining staff provided by the Hanscom complex on current operational systems as well as future systems. This help should consider the operations/technical/time/cost problems of the command, and the phasing between the present system and the future systems should be coordinated within the Hanscom complex. Mission evaluation and test criteria should be started early to act as guidelines for the system design.

(5) Exercising and training requirements should be planned along with the system.

(e) Plans that cover the need, objective, general system design, and employment of a command and control system and that are based on the proper cost/time/effectiveness studies and experiments should be produced before contracts are let and should be used as the basis of the work statements for the contractors.

(1) The preparation of these plans requires a system design based on the proper level of functional analysis; a schedule estimate based upon requirements; and an analysis and determination of the system's cost. An appropriate methodology must be established for performing all these tasks within the Hanscom complex.

(2) The preparation of these plans may require various study contracts, experimental investigations, etc.

(3) These plans should reflect whatever standards and general policies are established by the Hanscom complex.

(4) The preparation of these plans should include the proper participation of the operational, logistics, and development personnel.

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4. OPERATIONAL PLANNING AND SYSTEM RECOMMENDATIONS

Our comments below are divided into two general areas: first, a summary of recommendations and problem areas pertaining to broad operational planning in each of the indicated operational areas of command and control (higher command, intelligence and warning, strategic offensive and defensive forces, tactical war operations); second, specific recommendations pertaining to some of the planned L-systems.

4.1 Higher Command

The USAF should press that a JCS concept for all command systems be developed and maintained (i.e., changed). This concept should be sufficiently broad to recognize different approaches by the services and different requirements by the commands. It must distinguish the proper relation of strategic and limited war facilities and the relation of the operations, intelligence, planning, and support and logistics functions. Application of this concept by a properly manned staff should aid communication and cooperation between commands and therefore growing functional integration and operational command effectiveness.

The USAF should also press that a much stronger, independent JCS command center start to be evolved immediately, including plans for the growth of the center to an advanced, automated capability. This center is needed so that subordinate commands can receive appropriate higher command direction and provide adequate feedback to higher command. It is recognized that service headquarters command centers realistically will play a strong role in a JCS command center. However, the more that these centers are strengthened in the absence of greater strengthening of the JCS command center, the more operational command will tend to be weakened and become inflexible.

For general war, the majority of the command activity is primarily a peacetime function; only a small portion of the command system is likely to survive. The survivable portion must be highly integrated and centralized and must be extensively exercised during peacetime by the peacetime system, but probably not colocated. Some ways to achieve this survivability are discussed below.

Interlocking of hardened, primary, command centers (such as JCS, SAC, NORAD) and their links to weapons, warning and intelligence sources, and logistics support in order to achieve a tolerable threshold of general war survivability for higher command

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is a desirable possibility which requires further investigation. Such interlocking will initially require utmost simplicity in war-time modes and functions, revision in current military succession plans and peacetime exercising programs, much higher military organizational integration than has been achieved or proposed up to now, and technical designs and developments which have not yet been undertaken. The technical feasibility, design, and level of protection and concealment of hardened control centers and communications needs to be investigated in much more detail, as well as the possibility of active defense of these centers. It should be recognized that such interlocking of hardened centers cannot result in absolute survivability; however, it will complicate enemy first-strike strategy and offensive tactics.

An additional possibility to be investigated for an interlocking system is a single-level, mobile (airborne, sea-borne, or landbased) command system for poststrike operations of higher command. The Winter Study Group has made some preliminary investigations in this area with respect to an airborne system which is discussed in several sections in Chapter I of this report.

For tactical or limited war operations, survivability of the peacetime command function is both more essential and easier to achieve. Some backup may be required to allow for natural disasters.

4.1.1 473L Hq. USAF Control System

To accomplish its assigned tasks more effectively, Hq. USAF may find it appropriate to begin to evolve an increasingly automated, integrated command system designed to accept, index, correlate, store, retrieve, manipulate, and display the types of data specifically associated with its present responsibilities. It is the opinion of the Winter Study Group that the current proposal for 473L is not uniformly addressed to the various functional areas associated with the present responsibilities of the headquarters. The "capping" nature of a command system is not recognized; too much emphasis is being placed on real-time control of forces and on war gaming; insufficient attention is being given to the requirements of intelligence and of force establishment and support. Further, the nature of the relation between the 473L system and the future automated command systems, if any, of JCS, SAC, NORAD, AMC, ARDC, TAC, MATS, etc., is nebulous.

Accordingly, with respect to the 473L system, the Winter Study Group recommends:

(a) That a continuing technical consulting team be organized from within the Hanscom complex to (1) assist Hq. USAF

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in performing appropriate headquarters mission analyses and command analyses, (2) improve the present headquarter's manual command system, (3) conduct appropriate operational experiments, and (4) effect a gradual transition from the manual system to a more automatic system based on the analyses and operational experiments.

(b) Until the system needs are properly defined by this team, a highly automated command system for Hq. USAF should be deferred and action not be taken to implement the 473L system as presently planned.

4.2 Intelligence and Warning

(a) Intelligence: The need for a single, functionally integrated, intelligence system is stressed. This system would be separated functionally into two channels: first, a fast-response channel for handling intelligence data critical to the operational command function (e.g., warning and damage assessment data); second, a slow-response channel to handle intelligence data concerned with enemy long-term capabilities and objectives. The fast-response channel might include inputs from such sensors as BMEWS, MIDAS, acoustic and seismic detectors, bomb-alarm systems, critical ELINT and COMINT data, and real-time television photography. The slow-response channel might include inputs from such sensors as photography, normal ELINT and COMINT data, collateral and open-source data.

A precise language for describing and transmitting the data from each source must be formulated such that a common data base for filing, indexing, correlating, and displaying the data at command centers can be designed and implemented. Each command and using agency would have access to the data pertinent to its needs. Operational commands (SAC, NORAD, JCS, etc.) primarily would process data from the fast-response channel; agencies such as AFCIN and ATIC primarily would reduce and process data from the slow-response channel, set up a library and an intelligence base, and make this data available to the using commands to include in their data base where necessary. The system should be structured so that: 1) the operational commands can exercise some real-time control over the fast-response sensors, and 2) the intelligence data can be integrated functionally with operations and support data at each command to provide an effective warning function for that command.

(b) Warning: In order to use effectively any strategic or tactical warning that we may get, the desirability and feasibility of a single, automated warning center should be investigated. The role and purpose of such a center would be to

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provide the national decision-making mechanism (JCS, President) with a continuous warning indication that could also be communicated rapidly to all levels of command, including theater CINC's and forces. This center might be duplicated at several locations (e.g., JCS, SAC, NORAD) for survivability and reliability purposes, with the Washington center serving as the primary location. The redundant locations at SAC and NORAD, for example, would serve as backup to Washington as well as functioning as the normal warning centers for these commands. The center in Washington could serve as one element of the JCS command center discussed above. We believe that this center is needed to provide complete, rapid, and decisive correlation and dissemination of pertinent operations, intelligence, and warning data.

Inputs to this warning center could consist of summary status of our forces and resources and the data from the fast-response channel discussed above. Speed and considerable data processing would be required in order to correlate the multiple inputs in real time and to rapidly pass the warning output to affected CINC's and to local control centers. It is important to note that by a single center, we mean that there would be a single correlation process, (periodically revised to meet the changing situation), which would be duplicated at whatever places the center was located. Automation of this single correlation process forces us to consider it more objectively, to develop techniques which can be consistently exercised and evaluated, and to suffer less when operational personnel will be rotated in and out of the warning center.

It is also important in formulating this single correlation process and the warning output that a warning language be developed jointly by many commands and that reactions on the basis of this language be well understood throughout the commands. This warning language must be a precise way of describing: 1) the immediate readiness of warning elements; 2) how much warning are we getting and how good is the warning (i.e., what are the warning levels), and 3) the agreed upon response to the warning. We feel that the present warning language used, viz., the five DEFCON statuses, does not adequately meet the needs of these three factors.

4.2.1 466L ELINT-COMINT (ELCO), 438L Intelligence Data-Handling System, and 117L SAMOS and MIDAS System

At present, instead of a single, integrated intelligence system, the USAF is planning three separate systems, 466L ELINT-COMINT, 438L Intelligence Data-Handling and 117L SAMOS-MIDAS, with independent facilities. Implementation of the 466L system is currently confined to a small study contract, but the

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plan is to install major elements of this system in the Alaskan, European, and Pacific theaters to collect intelligence data from ground sensors, process this data, and retransmit it to the users. The proposed 438L system, which is now limited to an experiment at SAC to determine if automation will really help in the warning function, is scheduled to have twelve facilities with each facility providing the operational personnel in a particular command with all of the intelligence information that is to be made available to the command in which the facility is located. The proposed 117L system contains: a) SAMOS, consisting of ten photographic and eight electromagnetic ("ferret") satellites and five ground stations; and b) MIDAS, consisting of eight satellites with sensors for detecting infra-red emanations of launched missiles and three ground stations. Joint use of a satellite operations center and a data processing and transmitting facility is planned for SAMOS and MIDAS.

In connection with the 466L, 438L, and 117L systems, the Winter Study Group now recommends that:

(a) Since intelligence systems invariably must be closely related to command systems, USAF authorize the organization of a continuing technical team from within the Hanscom complex to study all aspects of USAF intelligence information collection, processing, and dissemination, including planning, programming, and financing.

(b) This technical team be given the task of re-orienting the presently planned 466L, 438L, and 117L systems in such a manner that the data processing aspects of these systems are compatible with the concept of a single, integrated intelligence - data processing system; currently scheduled initial operational dates for 117L should not, however, be set back by such a re-orientation.

(c) Pending completion of the first phases of the work of this technical team, those activities in the 117L and 466L systems having to do with raw data collection and initial filtering be continued as presently planned, since the principle of the single, intelligence data-processing system is more directly related to the full exploitation of intelligence data than to the devices used for its collection; for example, in the plan for the 117L system only the data processing functions would need to be modified to fit the concept of the single, intelligence data-processing system.

(d) The 438L experiment at SAC headquarters be continued beyond its presently scheduled termination date, since it is believed that the development of new data processing techniques directly in the operational climate of a command is most desirable and necessary.

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4.2.2 413L Distant Early Warning System

Although the level of the Soviet long-range bomber threat to the continental United States probably will decrease markedly by 1963, the Winter Study Group is of the opinion that the 413L system will be needed until 1965 or later, but with equipment and operational characteristics modified somewhat so that this system will be more 1) easily maintainable and reliable, 2) able to provide high-altitude capability to 100,000 feet and low-altitude coverage sufficient to make successful sneaking between stations improbable, 3) insensitive to false-alarm conditions.

Although the manned-bomber threat in the 1960 to 1965 period will lessen, the present 413L system is not entirely suitable to meet this threat because of certain deficiencies: 1) the AN/FPS-23 (fluttar) radars have high false-alarm rates and are often deactivated because of them, 2) the low-altitude coverage of the AN/FPS-23 radars is deficient, 3) no low-altitude coverage is planned either for DEW east or DEW west, 4) the main DEW east stations are not on the air at all since their radars are still in production, and 5) appreciable traffic near the DEW Line requires increased operating personnel since the automatic function of the line is destroyed by such traffic.

With respect to the 413L system, the Winter Study Group recommends specifically that:

(a) Installation of equipment in the eastern extension of the DEW Line be expedited to complete the early-warning coverage that is necessary against the present manned-bomber and reconnaissance threat.

(b) Techniques be studied in an effort to obtain for use in 413L: 1) some means for automatically generating valid alarms in a relatively dense traffic situation, and 2) an inexpensive low-altitude aircraft detection capability that can be made operational within the next few years.

4.2.3 OSR 290 Bomb Alarm System

The President, the JCS, SAC, NORAD, and other military and civilian agencies require immediate and highly reliable knowledge of nuclear detonations within the United States. USAF's bomb-alarm system (OSR 290) presently is planned to fulfill this need by establishing a network of sensors, communications, and displays specifically designed to identify, for yields from 1/2 to 20 megatons at altitudes below 12,000 feet, the characteristic pulse shape of the thermal radiation from nuclear explosions.

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Concerning the bomb-alarm system (OSR-290), it is the opinion of the Winter Study Group that the design of the apparatus currently being proposed for use in the system is appropriate to the need for nuclear bomb alarm and that implementation should proceed without delay. It is to be emphasized, however, that no additional operational function beyond the simple detection of a nuclear explosion should be added to the system at this time. For example, NORAD has indicated a requirement to measure the magnitude and direction of the nuclear blast; to incorporate these features into the proposed bomb-alarm system would result in considerable delay, greatly increased cost, and most important, unacceptable reduction in detection reliability.

4.3 Offensive Forces

It is virtually impossible to lay down detailed plans for the command function several years into the future. Year by year there are unpredictable changes in threat, international climate, strategy, force performance, budgets and organizational policy. The operational command function must be adaptable to these changes; it must be capable of developing rapid, adequate response to these changes; this capability is much more crucial than developing optimum capability for presently known functions. For example, present plans and designs for a SAC Control System have concentrated primarily on improving present bomber-tanker capabilities. By the time the system is first operational (mid-1963), an airborne alert may be in operation, some U.S. ICBM's will be operational and a retargeting capability may exist. Intelligence estimates of Soviet air and missile active defense may be radically different, a joint strategic strike command may be partly implemented (for present SAC forces, Polaris, Pershing, etc.), and some arms inspection may be underway. Also, we will need more peacetime training for and coordination between the three services which have widely deployed offensive forces. Since proper response to contingencies will be more important to guaranteeing SAC capability than optimum use of the bomber-tanker force, a SAC Control System (and all other command systems) must assist, rather than impede, this needed adaptability.

Goals for system reliability during peacetime operation must not be too ambitious; absolutely continuous operation is neither essential nor economically feasible. For example, one 15-minute downtime per week might be a more reasonable goal for a SAC Control System than one requiring no more than one 5-minute downtime per year, and would make the system less complicated and would provide an achievable goal of reliability.

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Obviously, natural disasters must be anticipated in providing backup facilities at alternate locations.

The distinction between peacetime needs and war-time needs for command and control is also important. A danger is to pay lip service to the distinction so that "some" backup or survivability is provided, but since the elegant peacetime function "may" survive and it seems to possess much more satisfying capabilities, the complex function is overly exercised and provision for a simpler, austere backup is almost totally ignored.

4.3.1 Retargeting

With respect to the retargeting function, missiles may be a much more flexible weapon than manned bombers. Retargeting bombers, for example, is restricted by the number of targets the crews have been trained to handle and also because a bomber attack is a highly-coordinated operation involving bomber-tanker mating and the coordination of penetrations and times over target. By contrast, a missile using radio guidance, for example, can be quickly and easily retargeted. Furthermore, missiles can operate independently. Hence, the retargeting is a much simpler problem, and once a target list has been accepted, is mainly an exercise in elementary bookkeeping, much of which can be preplanned even for completely centralized retargeting.

The Winter Study Group undertook a study of the weapon allocation and retargeting function to determine if any value existed in providing a missile retargeting capability in the command and control system. Four classes of targets and five methods of using and retargeting weapons were considered, ranging from a completely centralized retargeting to local-center retargeting. Retargeting was based on data on our survivable forces only. This study is reported in detail in Winter Study Report No. 19, Ad Hoc Studies.

The optimum allocation of weapons (the numbers of weapons assigned to each target) was determined in each case and the mean value of destruction on the enemy computed. The effectiveness of retargeting also was computed in terms of an equivalent augmentation of the weapon force to determine the relation between the value of retargeting and the cost of weapons. The increase in mean enemy value destroyed in a retargeted force ranged between 20 and 80 per cent in typical cases, and the equivalent augmentation factor of the weapon force ranged between 1.7 and 3. The costs of increasing the utility of a force (measured by the mean value it can destroy) by (a) increasing weapon production, and (b) making provisions for retargeting, could then be compared.

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Because of the effectiveness and the substantial savings obtained by retargeting as demonstrated by these studies, we strongly recommend that the engineering feasibility (communications, data processing, missile control equipment) of providing a retargeting capability in our missile force and its associated command and control facilities be investigated.

4.3.2 465L SAC Control System

For the more effective operational command of the manned-bomber force, SAC needs now: 1) faster, more reliable communication of operational command information throughout the entire command and control organization---communication that minimizes human delay and human error; 2) more uniform application of automated data-processing to the operational command aspects of operations, planning, intelligence, and materiel; 3) additional off-line data-processing capacity and substantially improved computer programs for the generation of both operational and longer-range plans; 4) some on-line data-processing capability and associated computer programs for assessing the status of the force; 5) increased insurance against loss of the central control function in peacetime from accident or natural disaster; 6) greater emphasis on operation of the force without the central control function (but not without the central command function), since the facilities necessary for central control are not likely to be available during and after an enemy ICBM attack; and 7) improved ability to exercise and evaluate the capabilities of both the force and the various command posts under a spectrum of realistically simulated conditions.

The 465L system is addressed to the above areas of need at SAC headquarters and presently has scheduled dates of: a) 1 January 1962 for installation of a military computer at SAC headquarters, b) 1 April 1963 for initial operational capability of the system, and c) 30 June 1965 for complete operational capability. The Winter Study Group is of the opinion that these scheduled dates are late in light of the rapidly changing threat and composition of the SAC force. Further, it appears that present planning for improvement in SAC's operational command ability, as evidenced by the 465L program, tends to neglect certain important matters, as follows: 1) in 465L, new hardware, new computer programs, new operational procedures are to be introduced relatively abruptly, a situation that could result in a decrease rather than an increase, in the operational command capability of SAC for an appreciable period; however, efforts which SAC is making to train and familiarize its staff and its plans for parallel operation will help somewhat in this regard. 2) There is a continuing need for data-processing experiments in the operational

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environment at SAC headquarters; 3) staff and line personnel of the headquarters should participate more directly in the designing, filling, changing, using, and policing of 465L's evolving data base as part of their everyday job; 4) in 465L, attention is being concentrated on the activities of the Director of Operations; to be effective a command system must be designed to achieve a uniform integration of the operational command functions of intelligence, planning, materiel, and operations; 5) the value of the 4-headquarters equipment configuration for survivability and reliability purposes is questionable; rather it is important to stress the mission of the overall system in peacetime as one of preparing for war and, as such, it should emphasize the generation and exercising of an austere backup system which one should really expect to use during crisis and general war; 6) the appropriate role of the SAC command system in a future force that will include large numbers of fixed-targeted missiles requires increased emphasis and resolution.

No well thought out alternative now exists to continuing the initial portion of the 465L system, with the exception of the remote communications complex (RCC), since SAC's need for improvement of its operational command ability cannot risk being delayed further. The Winter Study Group believes, however, that action can and should be taken in the immediate future to change the present 465L program both to provide SAC with an increased command system capability at an earlier date and to reduce any deleterious effect that the introduction of highly automated equipment and procedures into the existing SAC organization is likely to cause.

Accordingly, in regard to the 465L system, the Winter Study Group recommends that the USAF establish a continuing technical consultant team from within the Hanscom complex to (a) assist SAC headquarters with the accomplishment of mission and command analyses, (b) help SAC personnel achieve better operational command capability at an earlier date with SAC's present command system (c) undertake detailed planning to ease the phaseover problem from the introduction of the initial 465L equipment configuration into the SAC organization, and (d) determine an integrated command-system command plan for SAC.

We believe that the USAF, through the help of the Hanscom consulting team, should look into the following proposals:

(a) Obtain the immediate assignment of a number of operational design and computer programming personnel to SAC headquarters in Omaha to help SAC personnel with an extensive effort to improve the SAC command system by adding more operationally useful programs on a continuing basis to existing and future computers.

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(b) As soon as a military computer can be installed at SAC headquarters (earlier than 1 January 1962 should be possible) then: 1) expedite the conversion of existing programs to the new computer, 2) design and write other computer programs that can evolve toward the more automatic SAC command system, and 3) arrange to use SAC personnel extensively in this latter aspect of the work.

(c) Speed development activity on the traffic control centers (TCC), local control complexes (LCC), data modems, crypto devices, and military computer, but incorporate into the design of the TCC the ability to accept teletype inputs as well as high-speed, digital-data inputs.

(d) Defer production on the remote communications complex (RCC) and the data-presentation subsystem pending a study to determine if less expensive and less elaborate equipment can meet realistic system needs.

(e) Define an equipment list for the next step toward a more automatic system for the SAC command after the initial operational capability as determined by the above study.

4.4 Defensive Forces

The Winter Study group, like many other groups, does not foresee any effective AICBM system at least until the late 1960's. For this reason, our review of command and control of strategic defensive forces did not include AICBM system considerations.

Winter Study also did not seriously consider the need for space surveillance and satellite interception capabilities. The basic questions to be answered here are who needs space surveillance and satellite interception capability (i.e., what commands and agencies), why do they need it (e.g., arms control and inspection, active defense), what do they need, and who is responsible for it? Although Winter Study has not considered these questions, we have made a technical and cost analysis of the space surveillance problem which is reported on in Chapter III and in Winter Study Report No. 11, Sensing Panel.

4.4.1 416L Continental Aircraft Control and Warning System

The weapon control aspect of continental U.S. air defense is currently provided by the 416L system. When 416L is operating in either Mode I or Mode II (i.e., using SAGE), it appears to have sufficient control capability to cope with the anticipated

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manned-bomber threat in the period 1960-1965, unless the enemy adopts low-altitude penetration tactics. However, 416L and its associated weapons are quite vulnerable and could not survive even a moderate missile attack directed at the SAC force. Yet, current capability for Mode III operation in 416L (without SAGE) is inadequate for meeting the anticipated threat in the period 1960-1965 from Soviet manned bombers in a follow-on attack to an initial missile strike against SAC bases.

With respect to the 416L system, the Winter Study Group recommends specifically that:

(a) Either adequate facilities be provided at the long-range radar sites in 416L to provide a broader base for Mode III operation or some other method be implemented to provide suitable air defense control capability following an initial counterforce ICBM attack by an enemy.

(b) Operation of the SAGE portion be brought up to as high a level of efficiency as possible, but no further equipment be added beyond that provided by currently committed funds, except as necessary to accomplish the recommendation in (a) above.

(c) Studies be expedited and a decision reached on the suitability of a modified SAGE for both civilian and military air traffic control and continental air defense weapon control.

Some clarification and qualification to the above recommendations are necessary:

(1) The Mode III or post-strike system mentioned should assume no SAGE Mode I or II capability to be available. However, with respect to this post-strike phase, we need more common agreement (after proper study) on the role of the Soviet manned bomber after 1962. Maybe this role is so insignificant or impossible to cope with when there is no AICBM system that we should forget post-strike air defense.

(2) With the demise of the super combat center program, all high-level planning and study on joint DOD-FAA control facilities has decreased. The USAF should press that this high-level co-operation be recreated before proper studies and planning can be undertaken with respect to the role of SAGE as a national surveillance network and its use in enroute air traffic control as well as peacetime air defense.

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4.4.2 425L NORAD Combat Operations Center System

Various studies by the JCS, USAF, NORAD, and ADC have resulted in a broad expansion of NORAD's mission from air to aerospace defense. Further studies are in progress to define in more detail the assignment of specific tasks over and above those recently assigned such as BMEWS and MIDAS. It is reasonable to expect that these studies will result in the assignment of additional tasks such as space surveillance and ballistic and satellite defense within the framework of the broad mission of aerospace defense. Therefore, in regard to the 425L system, the Winter Study Group now recommends that:

(a) A continuing technical consultant team from within the Hanscom complex be organized immediately to: 1) See that NORAD has the necessary interim help to improve significantly its present capability for command of existing forces, 2) examine the functions that NORAD should perform in aerospace defense responsibilities, 3) examine the functions that NORAD should perform in support of and as an alternate headquarters for JCS and SAC, 4) assist NORAD in a detailed command analysis leading to an evolutionary system command plan in accordance with the approved recommendations resulting from the studies referred to above and those currently in progress.

(b) Upon completion of the studies currently in progress, requirements for an automated, hardened, NORAD command system be determined and steps taken to implement the system indicated by the study.

4.5 Theater Operations

" The requirements for post-1963 limited war operations and the USAF role in those operations are not clear. Consequently, the selection of the force composition and the associated command and control facilities are difficult to define. This is exemplified by the very few L-systems planned to date that are directed toward this purpose. Two basic questions must be answered with respect to theater operations: a) The role of theater forces in general war and in limited war operations, and b) the operation of Composite Air Strike Forces (CASF) in limited war operations where plans must be fluid because of the unknown areas of operations and the unknown and changing target situation.

Three areas should be strengthened: a) The communication between higher command the theater CINC's and forces to achieve warning (both ways) and strike authorization in general war (bomb-

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alarm systems in the theaters would aid in achieving the warning), b) fixed command and control facilities in the theater for the direction of air defense and strike weapons, and c) mobile command and control facilities for deployment and use of CASF in limited war operations.

Enroute, main base, and forward base communications to meet the above needs must also be improved and augmented. Also, computer assistance in the ZI for rapid updating of CASF contingency plans (employment and deployment) can be profitably used. The Theater Operations Section of Winter Study Report No. 8, System Panel, further suggests some specific and detailed areas that should be studied, although the recommendations in WSR-8 are not co-ordinated Winter Study Group recommendations.

4.5.1 412L Theater Air-Weapon Control System

For tactical air-weapon control, the equipment of 412L is too large, complex, and cumbersome to be used in a fluid tactical situation. Accordingly, in regard to the 412L system, the Winter Study Group recommends that:

(a) A continuing analysis team be established immediately from within the Hanscom complex to work with TAC and the theater commands and determine the requirements of an air-trans-portable or airborne, integrated control system that can provide uniform assistance to the theater commanders in all aspects of their weapon-control functions.

(b) Except for those 412L systems that are scheduled for fixed installation overseas or for associated training activity in the U.S., further procurement of 412L system equipment be deferred pending determination of the proper need and configuration of an integrated command and control system for theater operations.

4.6 Communications*

To increase both the efficiency of peacetime communications and to reduce the vulnerability of communications under harrassment and in wartime, the USAF needs, as soon as possible:

* The Winter Study Group did not consider the responsibilities or position of the Defense Communication Agency.

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- (a) A world-wide pre-hostility, integrated communication network that can be shared with respect to both switching and transmission facilities by all points requiring communications; and
- (b) A separate, highly survivable, backbone communication network to maintain at least a portion of the basic operational command functions during and after an enemy attack.

The Winter Study Group is of the opinion that, to date, sufficient steps to develop and implement these necessary communication networks have not been taken by USAF, since activity under the 480L project has been limited to the writing of communication standards and the offering of advice on communication problems to the other L-systems. Accordingly, the Winter Study Group now recommends that:

(a) The 480L project be broadened in scope and given authority and responsibility for implementing, without further delay, a world-wide, common-user network as well as the hard-core communications necessary to maintain some basic command functions during and after an attack.

(b) Work that is already well under way on the separate communication facilities for the various L-systems be continued only as necessary for not delaying the scheduled operational dates of these systems and, in each case, a capability for tying into and using the common-user and hard-core communication networks at a later date be provided.

(c) Both the traffic control center (TCC) in the 465L system and the message-switching equipment in the 423L system (Comlognet) be evaluated as possible prototype apparatus for the common-user communication networks.

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CHAPTER I. CONCEPTS OF OPERATION

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CHAPTER I CONCEPTS OF OPERATION

The command and control problem must be put in context and the things to which it is related examined. The function of command and control systems is to help the military organization control the force. Specifically, it is to facilitate the flow of information into the organization, within the organization, and from the organization to the weapons. Sensor systems gather and process data about the enemy force; control systems involve direct control of our own force; and command systems facilitate the flow of information needed to make decisions and to coordinate the activities of different commands. Thus, a command and control system is related to the organization which will use it and to the force it controls. The force is controlled for purposes (to support a plan or strategy) that should also be considered in designing command and control systems and in setting realistic operational requirements for them. Finally, the design of command and control systems will be affected by the prevailing technology. We, therefore, have studied the command and control problem in a context which, for convenience, can be broken down into the following four related but distinguishable parts.

Military Organization: It is customary to think of an organization in terms of an organization chart showing the lines along which authority flows. A complete description of the organization would show all lines of flow of data, or information, of which authority (or commands) are one kind. We shall think of the military organization as a group of people plus a set of rules for the flow of information between them.

Force: By this we mean the numbers, kind, and performance of weapons, both our own and the enemy's. The recent and continuing revolution in military technology causes rapid and drastic changes in the force structure. The command and control problem, like most current military problems, arises to a large extent from the rapidity of these changes and the difficulty people and organizations have in adjusting to them. The problem considered by the Winter Study Group is how electronic data processing can be used to help a rapidly evolving organization control an even more rapidly changing force under conditions where failure of control becomes increasingly dangerous.

Strategy: We use this term in a general sense to mean national military policy, war plans, and tactics, in fact all those plans for deterring deliberate war, stabilizing the international situation against war by mishap, and conducting war and terminating it on the best possible terms should deterrence fail.

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Command and Control Technology: This includes the technology of computers, communications, displays, and sensors and the various methods of protecting such equipment against attack.

These four subjects are not discussed for themselves, but rather for their effects on the design of command and control systems. The use of automation in command and control is a newly recognized problem. At present there is no group of people whose experience and competence lie directly in the area of command and control systems in the same sense that there are people who have experience in the related areas, such as weapon systems or communications. Thus, the approach to the problem necessarily involves getting people from these surrounding fields to extend their sphere of understanding into the field of command and control systems. Progress in command and control will therefore tend to be greatest where the command and control problem borders most closely on related areas. This chapter, for example, will deal primarily with the relation to force structure and strategy. The following two chapters will emphasize the relation of command and control systems to the military organization and to technology. However, before turning specifically to questions of strategy and force structure, it will be desirable to say a few words about all four of the related subjects and to indicate briefly how they influence the design of command and control systems and also how requirements for command and control systems may influence developments in these related fields.

As will be discussed fully in Chapters II and III, it is convenient to consider command, control, and sensor systems in a spectrum extending from command systems at one end to sensor systems at the other. What we have to say about systems will depend on what part of the spectrum is being discussed. Sensor systems are, in many ways, similar to weapon systems. They are closely related to the physical environment and are developed, produced in quantity, and delivered to the command essentially complete. A command system, on the other hand, is deeply embedded in the structure of the command. It should grow and develop within the command and in a way that is determined by the experience of the command in working with it.

Just as the command should determine the evolving character of a command system, so an overall plan for distributing command systems within the military organization can influence the way in which the military organization evolves. We are here referring to the actual operating organization (the lines along which information, including orders, actually does flow) which is never completely defined by paper organization charts. Today the military organization is evolving in the direction of strengthening the role of the unified and specified commands. An overall plan for command systems

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could either encourage this development, or it could retard it and strengthen the role of the services. The Winter Study Group does not feel qualified to say how the military organization should evolve. We do, however, point out that here is a possible means of influencing such evolution and that this means could be exploited to force the organization to develop in a desired direction. Indeed such influence will probably be exerted in any case. If it is not exerted consciously and deliberately to support a high-level decision, the influence of command systems on organization will fall by default to the sub-policy level and be exerted by people who may have little qualification to determine military organization, who may have no desire to do so and perhaps may not even be aware of the influence they are exerting.

The coupling of a command system to the force should be as flexible as possible in the sense that rapid changes in the force should have as little effect as possible on the usefulness of the system. A military organization requires continuity and stability and a chance to build up tradition and to evolve at a rate compatible with the response time of human institutions. One of the present difficulties of the military organization is that the revolutionary changes in weapons have tended to upset the traditional organization lines. New functional patterns of organization are superimposed on the remains of traditional patterns, thus creating confused lines of authority. Because command systems are intimately tied to the military organization, they should be relatively flexible in their relation to weapon systems. Command systems should, as far as possible, cushion the shocks involved in the adjustment of the organization to a volatile military technology.

Next consider the relation of our problem to command and control technology. Certainly the development of technology will determine and limit the design of command and control systems. However, the influence can and should go also in the reverse direction. The needs of command and control systems should stimulate general, long-range research and development in command and control technology. To date, command and control systems have had to use available equipment designed and developed mainly for other purposes; or else equipment has had to be developed for a particular system. What command and control technology needs is the same kind of basic research and development programs that have given weapon systems and commercial applications a rich background on which to draw. Just as fundamental studies in propulsion and guidance are undertaken to support missile systems, so similar studies in computers, communications, displays and other fields should be undertaken specifically to support the command and control program. Stronger guidance and stimulation for such studies is urgently needed. This point is discussed more fully in Chapter II: Chapter III, which covers the roles of command and control, and Chapter IV, which covers technology.

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Finally, consider the interaction with strategy, which is the main subject of this chapter. Our purpose here is not to give a comprehensive discussion of strategy, nor to suggest what our national strategy will be or should be in the next decade. Rather we shall consider how strategic choices affect the requirements on command and control systems. To what strategic factors are these requirements sensitive? Of what are they relatively independent? We shall point out ways in which, if care is not taken, command and control systems could unnecessarily restrict strategic flexibility; that is, strategies could (perhaps unconsciously) be built in to the command and control system.

It is necessary to distinguish between long-term strategic choices (such as determining the kind of force we build) and short-term choices having to do with how an existing force is used under various contingencies. The long-term choices affect the requirements for command and control systems. One desirable requirement for such systems is that they not restrict strategic flexibility in the short term, or at least that they eliminate no more strategies than are already ruled out by the nature of the force. In other words, command, control, and sensor systems should try to maximize the number of ways in which the force can be used. There are two cases, however, where command and control systems may independently limit strategic flexibility.

(a) Some ways of using the force may require systems which are so elaborate and expensive that they compete with the force itself for money, technical manpower, or other limiting resources. This will scarcely be so for command systems which are inexpensive compared with weapon systems. It could, however, apply to sensors. For example, if we want to be in a position to knock out enemy missiles with our own missiles, we would need expensive sensor systems for surveillance, especially if the opposing missiles were hardened, dispersed, and concealed, and even more so if they were mobile, since that would require almost continuous surveillance.

(b) Some possible ways of using our force might be rejected deliberately as being too dangerous, or appearing to be too dangerous, or because of political reasons. For example, continuous surveillance of opposing missiles might be rejected as part of a formal or tacit arms control agreement to reduce the fear of surprise attack.

What follows will apply these general ideas to specific problems.

While reflecting on the overall problem of operational command, a few general comments on current and planned L-systems are suggested. The main conclusion is that far too little attention

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has been given to the survivability of command and the ability to control our reaction after we are hit. Planned systems are designed almost entirely for peacetime or pre-strike operation. In terms of the distribution of dollars, the emphasis of the L-system planning seems to be on tactical warning of missile attack. Whether such emphasis is sound depends on the controversial strategic question of what role tactical warning would play in the missile age.

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1. THE FLOW OF INFORMATION

The function of a command and control system, as mentioned earlier, is to facilitate the flow of the information required to enable the military organization to control the force. The rate of flow of information depends on the volume of information that must flow (that is, be gathered, processed, transmitted, stored, retrieved or displayed) and on the time during which the flow is required to take place. Thus:

$$\text{rate (of information flow)} = \frac{\text{volume}}{\text{time}}$$

The volume of information is becoming increasingly large. With the development of faster and quicker-reacting weapons, the time is decreasing so rapidly as to give an almost explosively rapid increase in the required rate of information flow, thus creating requirements which present systems are not able to handle. However, increasing the rate by building more elaborate and automated systems is not the only approach to the problem. For example, we can also look for procedures which reduce the required volume of data.

To find realistic operational requirements for the design of new systems, we must look at a wide spectrum of conditions of peace, cold war, limited war, and general war. Systems should be designed not to facilitate a single response (such as all-out retaliation) nor to deal with a single contingency (such as a surprise attack) but to permit a variety of responses to a variety of contingencies, including diplomatic crises, extremely provocative acts, limited strategic attacks and counterattacks, possible technological breakthroughs and even political breakthroughs, such as limited arms-control agreements.

However, certain of the conditions under which systems may have to operate may be dominant in the sense that, if the system can perform satisfactorily under them, it will also perform well under other, less stringent conditions. In particular, we should look at situations where the volume of data is large or the time is short or both.

The large volume of data to be handled is a dominant factor in peacetime operations such as intelligence processing, generating and evaluating plans, and war gaming. These activities will be discussed in Chapter II, which will also cover the special problem of SAC where the present system is strained because of the need to pass a large volume of data up to the higher command so as to maintain a tight centralized control. There is a similar need for tight and relatively centralized control in tactical operations, but the

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requirements on the command and control system come more from the need for rapid communications rather than large volumes of data.

In tactical or theater operations in limited wars, and especially when the operation involves our intervention in an internal upheaval, there is a need for a tight centralized control which will permit the dominant political constraints to be imposed on the military operations. It is the essence of limited wars that they are limited by political rather than military considerations. If the basic political purposes are to be realized there must be an ability to coordinate military operations and political objectives at several levels of command. This requires rapid communications which can be rapidly established even in remote places, since the success of limited operations depends to a large extent on their timeliness.

The section on theater operations in Winter Study Report No. 8, System Panel, discusses in detail some of the command and control problems of TAC and theater operations, and shows how much could be done now with off-the-shelf equipment if relatively modest funds were available. The rapid planning necessary to launch a successful limited war operation can be greatly facilitated by a computer, since the success of the operation depends to a great extent on the ability to move forces and their support quickly. If the necessary support elements and the interactions between elements of the force and their support have been represented in the computer program, possible sources of trouble and conflict may be uncovered and straightened out before the operation is well under way. A force which has reduced its own internal sources of trouble by careful planning will surely be better able to cope with external difficulties and uncertainties. A computer can aid in making such plans, especially in a crisis when a response has to be improvised quickly.

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2. THE CRUCIAL CHOICE

The severe requirements on command and control systems imposed by the compression of time arise from the speed and quick reaction of modern weapons and the nature of modern strategic war. It may be useful to digress briefly to take a general look at the revolution in strategic war. We have traditionally viewed war as the use of force to protect value. By value is meant people, their homes and institutions (such as freedom), land, food supplies, natural resources, industry and so on. The recent technological revolution has upset the classical relation between force and value. The change may be summarized by saying that countervalue attacks have become much easier, while counterforce warfare has become more difficult and has come to depend increasingly on the ability to achieve tactical surprise to get in the first blow.

In the past a military force, such as an army, could play a protective role by interposing itself between the value it is defending and the opposing force. The enemy could not threaten the value without first dealing with the force. Now, however, the value is more exposed than the force. In fact, because of fallout, the enemy cannot attack our force without also damaging some of our value (how much depends on our civil defense).

In the past any weapon, such as a gun, tank, or battleship, was expected to fire many shots during a war. Consequently, it made sense to shoot and keep shooting at opposing weapons and try to knock them out before they could do a decisive amount of damage, no matter who happened to fire the first shot. Now, however, we are moving into the era of ballistic missiles, which fire only once; so there is no point in shooting at them unless one can fire the first shot. Thus, success in modern strategic warfare depends on destroying the opposing force in a sudden and coordinated first strike, thus eliminating the opponent's ability to threaten one's exposed value. Deterrence of a counterforce first strike depends on the ability to strike second, that is, to retaliate against an enemy who has struck first.

We shall define the response time of the force as the time from the decision to attack until the force arrives over target. Thus, the response time includes both preparation and flight time. The response time of the weapons has been steadily decreasing as we go from piston-engine planes to jets to missiles and especially to solid-fuel missiles with short countdowns.

At present the security of our bomber force depends on our ability to detect a threatening attack, or preparations for attack, and to respond by putting our bomber force on a higher degree of alert or even getting it into the air. As the enemy goes

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through the cycle of preparation from maintenance to ground alert to take-off to flight, we plan to go through a similar cycle with a delay determined by the response time of our command and control system. The response time of our command and control system is the time required to gather data on enemy moves, to process, evaluate and transmit the data, display it to a decision-maker, reach a decision and transmit the decision to our force. As the response time of weapons decreases, the response time of the command and control system must also decrease. Too long a delay between enemy action and our reaction could be fatal. Our force could be taken by surprise and knocked out on the ground.

Ballistic missiles (in particular solid-fuel missiles) drastically decrease the reaction time of the force. Extrapolating present trends into the future, one can imagine a command post where data from sensor systems is displayed on a large screen showing the trajectories of enemy missiles coming toward the U.S. from distant points. Decisions to counter-attack are made in a few minutes and transmitted to our missiles. Perhaps the buttons that fire our counterattack are located in the command post itself. The commander then conducts the war looking at the display showing enemy moves and pushing buttons to make the desired countermoves. Many of the currently planned systems seem to be pointed, at least implicitly, toward this image of strategic war in the missile age. Some such image usually lies behind references to the compression of time.

The ballistic missile is an ideal first-strike weapon because of its short response time. This is the feature of ballistic missiles which the side striking first would exploit. The defender, or the side striking second, could also exploit the quick reaction of missiles to prevent his force from being caught on the ground. This would require that his command, control, and sensor systems also be fast reacting. However, there is another feature of ballistic missiles which the defender can exploit, namely their survivability. Unlike aircraft, which are vulnerable and can be protected only at great expense, ballistic missiles can be protected by some combination of hardness, dispersal, and mobility. A second-strike capability for missiles need not depend on quick reaction to avoid surprise. It can depend on the ability to survive a surprise attack. The choice between exploiting the quick reaction of missiles or exploiting their survivability is a crucial one for national foreign and military policy as well as for setting operational requirements for command and control systems. A soft, vulnerable, quick-reacting force requires a highly reliable system with a very high data rate. The system, however, can be soft since it must do its job before being hit. One does not need a survivable system to control a non-survivable force. On the other hand, if we decide to depend on a survivable force that could accept a

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surprise attack and remain able to strike back, we need a command and control system which can survive with the force and control it. The data rate of the surviving system, however, may be relatively low.

A soft, quick-reacting force is relatively inexpensive. The size of force required for a specified level of retaliation is much lower if the whole force, or most of it, can be launched than if much of it must expect to be destroyed. Furthermore, the force need not be hardened, dispersed or made mobile, all of which cost money. The money saved by having a relatively small, soft, quick-reacting force could more than pay for the elaborate sensing and warning equipment required by a fast reacting command and control system. However, against this coice and in favor of survivability and a slower response are the following powerful arguments:

(a) The preparations required for a missile attack are much less lengthy, elaborate, and evident than those for a bomber attack. Consequently, there is much less chance of getting reliable strategic warning. It seems inconceivable that our strategic warning would even appear conclusive enough to convince the President to order a pre-emptive attack, that is, an attack launched after the enemy had decided irrevocably to attack but before his attack had actually been launched. Thus, a quick response would have to depend on the detection of an attack which had been launched but had not yet arrived.

(b) It may be possible to develop reliable means of foiling the sensors designed to detect ballistic missiles in flight. Systems such as MIDAS and BMEWS react to relatively weak signals that the enemy may find ways to mask.

(c) The sensors are also vulnerable. Reconnaissance satellites could be shot down. BMEWS is soft and could be knocked out. Although an attack on our warning system would itself be a warning, it would scarcely be a warning which would justify launching an all-out attack. Destroying BMEWS for example, although an unfriendly act, would not provoke massive retaliation, especially if the destruction were accomplished by high-explosive bombs or by sabotage.

(d) The sensors are liable to give false alarms, which probability could be reduced by having a number of sensor systems, each with a low false-alarm rate and by depending only on correlated signals from several independent systems. However, it is not certain that we could have even one really reliable sensor system, let alone a number of independent ones.

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(e) The high state of readiness required for quick response is itself dangerous and increases the chance of war by mishap.

(f) Even if such a hair-trigger state of readiness were not dangerous, it looks dangerous, frightens people, and leads to popular pressure on the government to conclude hasty, ill-considered disarmament agreements without adequate safeguards. Furthermore, any brief decline in our state of alertness would tempt even a non-aggressive enemy to eliminate our quick-reacting force simply to rid the world of what he would regard as an accident-prone menace. To be sure, warning systems are a display of a second-strike, or retaliatory, strategy. But there are other ways to display a second-strike strategy without appearing or being accident prone. Examples are airborne-alerted aircraft and hardened, dispersed, and mobile missiles.

(g) Electronics may make it possible for machines to do accurate calculations in one thousandth of the time previously required, but no electronic data processing and displays, however elaborate, can effect a comparable compression in the time required for the human mind to reach sound decisions. Ultimately, the compression of time runs up against the constant human factor and forces us to choose between surrendering our power of choice to a machine or stopping the compression of time by depending on survivable, rather than fast-reacting, weapon and command and control systems.

The best solution to the problem of compressed time is not elaborate electronic data-processing systems designed to make quick reactions safe, but a simple survivable system which makes quick reactions and snap judgments unnecessary, at least where thermo-nuclear war is the issue.

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3. SENSOR SYSTEMS

The objections to launching missiles on warning do not apply to aircraft, which can be launched under positive control. However, the expense of ground alert plus the sensor systems required to detect missiles in flight should be compared with the expense of other measures which do not depend on tactical warning. Such measures include airborne alert for the near future and hardened, dispersed, and mobile missiles later. We have had more experience in keeping airplanes in the air than in detecting ballistic missiles. The success of an airborne alert is less dependent on the unpredictable progress of technology. Bombers in the air will certainly not be destroyed on the ground, but even the most elaborate sensor systems may fail to give warning. Both airborne alert and protected missiles provide a continuous capability independent of enemy moves. On the other hand, launching aircraft on warning which turns out to be false causes a temporary drop in capability.

The cost of currently planned warning systems is comparable to that of airborne alert and major weapon systems and comprises the greater part of the funds for all of the L-systems. Because of this expense and because these systems will have operational lives extending well into the missile age, it is desirable to have the clearest possible understanding of the value of tactical warning for ballistic missiles. Rejecting a strategy which depends on tactical warning does not necessarily imply that we should reject the capability to get tactical warning. The question is rather how much of our limited defense funds should be spent on sensor systems for detecting missiles? It is not the function of Winter Study to answer this question. Rather we have tried to give the decision-makers useful data and concepts. The report of the Sensing Panel in Winter Study Report No. 11 gives technical analyses of proposed systems. This section will attempt to clarify the strategic problem by listing several possible roles for tactical warning and giving arguments pro and con without making any definite recommendation. The suggested possibilities are as follows:

(a) We could build both a warning system and a force of solid-fuel missiles well enough protected to survive a massive surprise attack. They would, of course, also be able to react quickly to warning if it were received. In fact, it can be argued that protecting the force and making it quick reacting are complementary measures. The better protected the force, the larger the attack which would be required to knock it out and hence the greater the chance that the attack would be detected. Also a thousand signals recorded by a sensor system would be less likely to be a false alarm than ten or a hundred. However, some care should be exercised in calculating the probability of one thousand simultaneous false

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alarms from the probability of a single false alarm. Undoubtedly, the chance of a thousand independent signals occurring at once would be so small as to give a comfortable feeling of safety. However, there may be some unanticipated phenomena of such character that they produce many simultaneous signals which are not statistically independent. It is difficult to predict the probability of such phenomena. Indeed all calculations showing the false-alarm rate to be vanishingly small are subject to some uncertainty as to the probability that the calculation has ignored relevant factors. This probability may be several orders of magnitude higher than the calculated probability of false alarm.

Furthermore, if we build a survivable force which can accept a surprise attack and remain able to strike back, there would be less pressure to spend the considerable sums of money needed for highly reliable and redundant sensor systems. There would also be less willingness to retaliate on warning or even to assume the dangerous hair-trigger posture required by a strategy of quick reaction.

There is also the question of what targets to hit in an attack launched on tactical warning. A force designed to survive a massive attack by most of the enemy force could easily afford to take a light attack. But, if the enemy launched most of his force, a counterforce retaliation would be futile, unless our sensor systems could tell us immediately and precisely just which enemy missiles has been launched and we knew the location of the remaining ones. On the other hand, a retaliation against cities is so desperate and hopeless a gesture, it is difficult to imagine a U.S. President ordering it while there remained the slightest hope that the warning was a mistake. Perhaps the only reasonable targets would be airfields from which bombers had not yet taken off.

(b) We could give the enemy the impression that we were prepared to shoot on warning while actually having no intention of doing so. Thus, we could increase the retaliation the enemy would have to fear without putting ourselves in an accident-prone posture. The argument against such a facade is that it might frighten friends and allies more than it did the enemy.

(c) We could have the capability to get tactical warning and react quickly but not normally assume the alert, hair-trigger posture necessary to exploit such capability. The threat to go on alert could then be used as a deterrent to provocative action or as a response to strategic warning. The fear of putting us on alert would complicate the enemy's problem in preparing a first strike since he would have to be careful not to give strategic warning. This might reduce the number of missiles he would dare to launch in the surprise blow.

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There is a deterrent value in being able to increase at will the strength of the counterblow we could deliver. However, a strategy of going on and off a dangerous alert might be more of a provocation than a deterrent. It would give the enemy an incentive to hit us as soon as we returned to our normal posture. Once having gone on a hair-trigger alert we might find ourselves fearing an accident if we kept it up and an enemy attack if we did not. It would be dangerous to relax such a posture unless we were sure of our normal deterrent, in which case there would have been no need to go on a risky alert in the first place.

To be sure, we could threaten to assume such an alert only in the event that the enemy evacuated his cities (a clearly threatening and deliberate act) and to return to our normal posture as soon as he did. Thus, we would increase the potential force of our attack as he increased his ability to absorb an attack. The current state of our civil defense, however, suggests that we do not take seriously the idea that the Soviets would be prepared to push the threat of nuclear war to the point of evacuating their cities.

(d) Even if we reject any intention of firing on warning, there is still some value in having it. In addition to launching aircraft under positive control, we would have some time to alert the decision-making function and perhaps to get some people to safe places. Lower levels of command could be alerted and authorized to fire in case the attack knocked out the higher command. Some appraisal could be made of the size of the attack and the feasibility of counterforce retaliation. If many nations acquire nuclear weapons and missiles, a detection system would enable us to tell who was attacking us (unless the missiles were launched from ships at sea).

Also some operational experience with warning systems has a legacy value. It would be valuable to be able to acquire a capability for tactical warning in a relatively short time---say three months rather than three years---in case we decided to change our strategy in response to a technological breakthrough such as a surveillance system which enabled the enemy to keep track of our mobile missiles. This argument applies especially to satellite systems where an initial capability could be augmented by putting up more satellites.

(e) Finally we could decide that tactical warning was unnecessary for ballistic missiles and evaluate current systems, such as BMEWS, solely as a means of prolonging the useful life of bombers (and especially of the B-47's which are less suitable for airborne alert). The money saved on sensor systems could then be used for airborne alert or for measures to make our missiles survivable. This proposal might be defended as the best way to live within a

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limited budget. It has the advantages of unequivocally rejecting measures which might increase the dangers of accidental war and of concentrating on survivability under conditions where even that may not be easy to achieve. However, it sacrifices strategic flexibility in both the long and short run and would leave us less able to respond to technological changes which might indicate that warning is more reliable than we now think or that other measures for protecting our retaliatory force (such as mobility) are less reliable.

Let us next consider sensor systems that are designed for surveillance rather than tactical warning. Reconnaissance satellites, for instance, could be used for counterforce intelligence, to locate hardened missile sites, and to keep mobile missiles under surveillance. The need for such surveillance will depend on a strategic choice, namely on whether we should try to maintain (or as some would say, regain) a credible first-strike capability in addition to a second-strike retaliatory capability. Should we accept the nuclear stalemate and concentrate on stabilizing it by building a purely second-strike, or retaliatory force, or should we try to break the stalemate and establish a strategic superiority based on a force suitable for launching a first strike against the enemy force so as to reduce the damage done by his counterblow? Could we in this way acquire a strategic superiority great enough to offset the strength of the Communist Bloc in conventional forces and by the threat to strike the first strategic, or intercontinental, blow deter provocations other than a direct attack on the U.S.? This controversy is crucial to our national, foreign, and military policy. The decision will have an important bearing on how much of our resources should be devoted to sensor systems for counterforce intelligence.

Surveillance systems have also been advocated for arms control, as part of an open skies plan to guard against surprise attack. However, the preparations for a missile attack could be concealed from such inspection, especially if the missiles were in underground silos or if they used solid or storable liquid fuels. In fact, surveillance of the enemy force would be likely to defeat any plan for arms control by providing knowledge of the location of enemy missiles and thus make a first strike feasible. Arms control might better be based on enough periodic inspection to let each side know approximately the strength of the opposing force but not its location. Surely the minimum requirement for arms control would be for each side to allow the other an invulnerable retaliatory force. (For a fuller discussion of this point, see the article by H. Kissinger in Foreign Affairs, July 1960.)

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4. SURVIVABILITY

As discussed earlier, the most general requirement on command and control systems is that they be able to maintain a rate of information flow determined by the volume of information and the allowed time. Thus:

$$\text{rate} = \frac{\text{Volume}}{\text{Time}}$$

The system may be strained because the volume is large (the main problem in peacetime operation) or because the time is short (as in a crisis or just before an attack) or because the system has been so damaged and degraded that it cannot maintain even a low rate (the problem of survivability). If we reject a deterrent based on quick response to warning, and depend upon a survivable retaliatory force, we must have a command and control system that is also survivable. There is a real danger that the L-systems will neither give sufficiently reliable warning to permit the force to react before being hit, nor survive to control the reaction after being hit.

Of course, not all of the functions of command and control systems need to survive an attack; probably only a small fraction needs to. It should also be recognized that nothing can be made invulnerable. What we do in protecting our force or our command and control is to make the enemy work harder to knock it out or to bring about a particular degradation. The degradation of command and control will take the form of a loss of functions or passage of a function to a lower level of command or to an alternate center.

The vulnerability of any element of the command and control structure can be represented by a plot showing the probability that it will be knocked out as a function of the number of enemy weapons (say ICBM's) committed against it. Usually it is convenient to express its vulnerability by a single number representing the number of enemy weapons (with a particular yield and CEP) required to give a certain confidence (say 90 per cent) of knocking it out. We shall refer to this as the price of what we are protecting. Since the price cannot be made infinite we have the problem of finding criteria for setting the price required for any particular degradation of command and control. What follows will present two such criteria, a quantitative one and a qualitative one. Which one is relevant will vary with the context.

The quantitative criterion may be illustrated as follows: Consider a number of squadrons of dispersed and hardened missiles, each squadron having also several dispersed and hardened control

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centers. The enemy has the choice of concentrating his initial missile salvo on our missiles, or of dividing the attack between our missiles and our control centers. The purpose of hitting the control centers would, of course, be to prevent the missiles from being fired, or at least to delay their firing long enough for them to be taken out by a follow-up bomber raid. What criterion should we adopt for setting a price on the local control centers? One natural criterion would be to make knocking out the control centers just as difficult as knocking out the missiles themselves. The opposing offense is then offered two equally attractive (or, hopefully, two equally unattractive) options.

However, as CEP's decrease, this criterion may require either intolerably expensive hardening for the control centers or the provision of one control center for each missile. Consequently, we might prefer to depend for survivability on a mobile backup system. Suppose the backup system can do no more than send a firing order by radio to the missiles, in contrast to the fixed local control centers which, let us say, can also retarget missiles so as to make best use of the missiles surviving an attack. It might well be, for example, that the attack had knocked out the missiles targeted for the highest priority targets and the surviving missiles were targeted for targets of relatively low priority. The effectiveness of our counterattack could then be increased by re-targeting. Again we can present the opposing offense with two alternatives. He can knock out the fixed local control centers (we assume that shooting at the mobile backup is clearly less attractive than attacking the missile force itself) or he can concentrate all of his attackers on our missiles. In one case he faces a counterattack with a larger, but less efficiently targeted force, and in the other a smaller, but better coordinated attack. The fixed centers should be numerous and hard enough to make the two options equally unattractive.

In many cases it will be impossible to find an exact quantitative measure for what price should be put on a particular function or on the ability to have it performed at the desired level of command. It is rather a matter of protecting the command and control enough to establish some tolerable threshold for degradation. The price is simply a quantitative expression of what is intuitively felt to be tolerable. There are certain functions one would like to preserve but would be prepared to lose under sufficiently drastic conditions. Protecting the command and control is simply a way of defining what is sufficiently drastic. This may best be illustrated by the trigger and safety catch problem for the retaliatory force.

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5. TRIGGER AND SAFETY CATCH

We want to make sure that (1) our strategic offensive force could be triggered in time of war, since otherwise it would be useless as a deterrent, and that (2) it will never be set off by mistake during peace. Thus, the trigger must be able to operate after an attack while the safety catch must remain absolutely secure during peace. The command and control must be survivable enough so that even a deliberate attack on it could not destroy the triggering function. On the other hand, a weakening of the safety catch under a deliberate attack is more tolerable. The same attack that weakens the safety catch reduces the need for it. As the intensity of attack increases, our concern shifts from the security of the safety catch to the survival of the trigger, suggesting a qualitative criterion for protecting our command and control. We design the command and control so that an attack on it weakens the safety catch and we provide enough protection so that only a heavy and deliberate attack would weaken the safety catch, as illustrated in the following example.

Local Control Centers: Consider a squadron of fixed missiles with two fixed control centers. Both centers can send each missile a firing order. The logic of the control system is arranged so that, if both control centers are surviving, the missiles will fire only when both centers send the firing order. Thus each control center acts as a safety catch on the other. However, the logic also insures that, if either control center is knocked out, then the remaining center can fire. Thus an attack which knocks out one control center removes the safety catch and leaves the other an uninhibited trigger. The control centers should be hardened so that an attack which would take out a center would be drastic enough to justify removal of the safety catch. This is a simple illustration of the principle. It could be generalized to a missile complex having more than two control centers.

Mobile Backup: Again consider the case of a mobile backup capable of sending the firing order to the missiles by radio. The mobile backup is a man operating a truck with radio. Certainly one would not want a truck running around the countryside with the ability to set off a part of our retaliatory force. Such a system would be much too dangerous and too far removed from the normal line of command and control. However, under sufficiently drastic conditions of attack, we would tolerate such an arrangement and, in the extreme case, even be glad to have it. Thus the normal fixed set of local control centers should be numerous enough and dispersed enough and hard enough so that they could be knocked out only by an attack considered drastic enough to justify passage of control to the mobile

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backup. Multiplying, dispersing, and hardening the fixed centers is a way of defining precisely the threshold (measured, say, in enemy ICBM's on target) required to shift our fears from the security of the safety catch to the survival of the trigger.

This problem comes up also at higher levels of command. It is difficult to design a single command and control system which, under attack, degrades gracefully from its normal peacetime capability to the low-data-rate, last-ditch capability required to maintain an ability to strike back after a heavy attack. Those protective measures which cause the least disruption of normal operations are the least effective for insuring survival. Thus, a natural tactic is to have two command and control systems, a fixed, preferred, primary system which is convenient to operate and is hardened and dispersed just enough to create a tolerable threshold for passage of control to a mobile backup which is unsuitable for normal operations but is highly survivable. This problem will be discussed more fully later in connection with the transformation of the operating military organization under an attack which destroys pieces of it and its communications.

Higher Command: A command above the level of local control should make the decision to fire missiles and perhaps should even have a physical veto over the firings. However, since a small number of higher command posts could be knocked out, it is also necessary to allow the local centers to take over if the higher command is knocked out. The multiplication, dispersal, and hardening of the higher command centers then establishes the threshold for passage of control to the lower level.

It would be desirable to place bomb alarm systems with the sensors at higher command centers and readouts at the local control centers. Then, if the local control centers find they cannot communicate with higher headquarters, they have additional assurance that the higher headquarters have been attacked. This assurance is in addition to that provided by the fact that the protection of the higher headquarters has been designed so that only a deliberate attack on the headquarters would knock them out. It is desirable, as will be discussed later, for command centers to be located far enough from air and missile bases so that the command is not knocked out as a byproduct of an attack on the force. Should a number of nations acquire the ability to launch missiles with nuclear warheads, the problem will become much more complex. Bomb alarms can tell the local control centers that we are under attack, but not who is attacking.

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Another reason for protecting the higher command centers is to prevent them from being knocked out by a sneak attack that might go undetected. If the command centers are sufficiently numerous and well protected that any attack which would knock them out could, with a high probability, be detected, then there would be time to issue warnings to the local centers. Although it is questionable, as discussed earlier, whether we would ever fire on warning, it would be desirable to warn the local control centers of an attack. This warning, followed by loss of contact with all of the higher command centers, plus signals from all of the bomb alarms, would constitute as reliable evidence of attack as it is possible to expect, especially if the local centers had both wire and radio communications with headquarters so that loss of contact with the higher centers would not occur as a consequence of the failure of a single form of communication.

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6. CONTROLLED REACTION

Let us next consider the survivability of the highest level of command, the function of deciding the issue of war or peace, of committing us to war, and of terminating the war. We have assumed that this function in some form should be well enough protected to survive an attack and at least be able to give the order to retaliate. Otherwise, our deterrent is a mere facade. There are various views about what, if any, additional functions the surviving command should be able to perform. Probably the most widely held view in the West is that the whole purpose of our military planning is deterrence, that the failure of deterrence would be so catastrophic that there is no point in making the painful effort to think beyond it, and that therefore the surviving higher command has no function but to order indiscriminate uncontrolled retaliation, and that even this makes sense only because the threat of it is the basis of deterrence. Thus, the function of higher command is to decide on a threshold for retaliation (presumably high enough to exclude accidents), to survive long enough to verify that the threshold has been exceeded, and to give an authenticated order for all-out retaliation. This has been called the spasm theory of general war.

At the opposite extreme from the view of strategic war as an uncontrolled spasm marking the end of civilization is the so-called broken-back theory according to which the nuclear exchange, although perhaps destructive beyond precedent, is only the curtain raiser of a prolonged struggle which will be decided by ground forces occupying territory. This is the accepted Soviet image of future all-out war. The alleged superiority of the Soviet social system is cited as the factor which will maintain the resolve and discipline necessary to carry the struggle through to a successful conclusion.

Another position between the extreme of the official Soviet view and the spasm, or last-gasp-of-civilization, theory has argued that, although all outcomes of nuclear war are horribly tragic, some are nevertheless much less horrible and tragic than others and that achieving the least catastrophic outcome depends both upon preparations for civil defense and recuperation and also upon being able to control our reactions during the nuclear exchange and to terminate the war by negotiated agreement before both sides have exhausted their capability to wreak destruction on one another.

It is not necessary to go so far as to accept the idea of a fight-and-win-the-war capability (let alone accept the concept of broken-back war) in order to see serious defects in the spasm view. One objection concerns the definition of a threshold at which our uncontrolled reaction should occur. This should be high enough to exclude accidents. But suppose a bigger accident than we had

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anticipated occurred. In modern strategic weapons we are dealing with phenomena far removed from any human experience. We cannot foresee all the possibilities for mishaps.

There is also the possibility of a sincerley mistaken attack. The Soviets are committed, at least in the published writings of senior military figures, to a pre-emptive strategy (a strategy, that is, of "retaliating" on strategic warning). Suppose that they have reluctantly and in desperation launched a pre-emptive attack based on mistaken intelligence. Or they may have cold-bloodedly calculated that they could knock our force out in a surprise attack with little damage to our population but their attack has gone wrong and they have suffered a military disaster--not to say a political disaster in exposing themselves as initiators of an unprovoked nuclear aggression. In all these cases, and in others which we may not be able to imagine, both sides would have an incentive to terminate the war on terms which we would find far preferable to allowing an initially counterforce war to reach the stage of mutual, unrestricted city busting. Thus we need a surviving high command which can both control our own response and maintain contact with the enemy, negotiate the termination of the war and set at least the initial terms of an armed truce.

It may be objected that such a view of a nuclear war is not realistic. But this is not the question. The question is whether any view of nuclear war can be realistic enough to form the basis of a single automatic, pre-planned response. It may be that people would not behave at all rationally under the extreme and unprecedented conditions of a nuclear exchange, but this is not the question we face now. The question now is whether, in the calm of peacetime, we want (deliberately or by default) to design a command and control system which would deprive us of the opportunity to act rationally in case a general war broke out in spite of our best efforts to prevent it. If at some juncture both sides still had much to lose and desperately wanted to stop the exchange, it would be tragic and inexcusable not to have provided the means to do so.

Quite apart from the question of negotiating with the enemy, there is the question of choosing a counterforce or a countervalue retaliation or some mixture. By all odds, the counterforce retaliation is preferable because it reduces the damage the enemy remains able to do to us. However, a counterforce retaliation may be futile. Whether it is or not depends on how much of our offensive force is surviving, how much of the enemy force has been expended (there is no point in knocking out empty missile sites) and how well, if at all, we know the location of the enemy's remaining weapons. For the latter, rapid, surviving, counterforce intelligence would be useful although some estimate of the feasibility of a counterforce

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attack could be based on an assessment of our own damage, which would indicate both our remaining strength and the fraction of the enemy missile force that had been committed in his initial salvo.

If, unhappily, nuclear weapons and long-range delivery systems are allowed to spread to a large number of nations including some with unstable irresponsible governments, then we will have the additional problem in a sudden attack of deciding who attacked us.

Another objection to the automatic all-out response is that retaliating with everything we have would leave us at the mercy of an enemy who had withheld some of his force from his initial counter-force attack--as a calculating aggressor surely would. With this he could threaten our cities while we would have no counterthreat. However, if we have retained something, then we have a bargaining and negotiating position which we could exploit to end the war on satisfactory terms. This would be especially important if the war had arisen out of some major provocation, such as a Soviet threat to occupy a NATO country. Our present obligations require us to go to war over such an issue. Surely it would be foolish to go to war over an issue in which we expected to lose interest once the war began. Again the question is not whether we would react so foolishly in war, but whether in peace we should deprive ourselves of the possibility of a more rational reaction.

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7. PROTECTING THE HIGHER COMMAND

Let us now translate the discussion of strategy in the preceding section into possible requirements for command and control systems. In terms of the discussion so far, we can distinguish three levels of survivability for command and control: (1) No survivability at all under attack; complete dependence on warning and quick response. (2) The ability to give the go order for a spasm retaliation when a threshold of attack is exceeded. (3) The ability to maintain control of the force and communication with the enemy. We have ruled (1) out. Let us look at the conditions which could cause us to degrade from (3) to (2), that is, to fall from a controlled response to the spasm reaction.

We can distinguish three classes of contingencies that tend to degrade our command and control. One is our own accidents, enemy sabotage or a light enemy attack such as he might launch by accident. The second class is a massive attack directed at our offensive force. The third is a massive attack directed at our command and control as well as our own force and in particular at our higher command function. Certainly we want our command to be well enough protected that we do not lose control by accident. Thus, we have the following three policies from which to choose. The choice will depend both on strategic preference and on technical feasibility.

(a) The higher command could be so survivable that it could maintain control of the force and communicate with the enemy under any conditions including a deliberate and massive effort on the part of the enemy to knock out the higher command function. Such a command may not be technically feasible. In any case, one can question whether there is much point in being able to negotiate with an enemy who is determined to destroy the higher command with which he would negotiate.

(b) We could maintain the higher command function under a massive attack on our force, but accept degradation to the automatic "go" if the command itself were directly attacked. In this case we should tell the enemy beforehand that his making the substantial and deliberate effort to knock out our higher command would leave us no choice but to launch a blind retaliation, the fire order being transmitted, say, by a bomb alarm system with readouts at the local control centers as discussed earlier. This would mean, at the minimum, insuring that the higher headquarters and their communications to the local centers were well enough protected not to be knocked out as a bonus incidental to an attack on our missile and air bases.

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(c) Finally, we could make the higher command function hard enough so that it could be knocked out only by a deliberate attack, but try to insure that it would be knocked out by any massive attack, even one directed at our offensive force. This would mean committing ourselves to the spasm theory by virtue of the design of our command and control.

The preceding section presented arguments against taking (c) above as the requirement for survivability. Although the argument in favor of (c) is unconvincing to us, in fairness it should be discussed in order to clarify fully the impact of strategy on the choice of operational requirements for command and control systems. The argument has to do with protecting ourselves against what is called post-attack blackmail. This can be illustrated by the following sequence of three attacks:

- (a) An enemy attack on our force.
- (b) Our retaliation against his value.
- (c) His counter-retaliation against our value with the part of his force withheld from (a).

The threat of (b) is supposed to deter (a), but the threat of (c) can be used to deter (b), and so remove the deterrent to (a). This is one of a number of situations where it is rational to make a threat which it would be irrational to carry out if the threat failed to deter. (An example from everyday life is the threat to incur \$100 in legal expenses to punish and recover a \$50 loss.) Thus, it can be argued that our retaliation (b) must be made automatic to insure deterrence. In the degree that we maintain control and communicate with the enemy we expose ourselves to threats. This is an example of how strategic problems, which may not be widely recognized, are implicitly involved in the design of command and control systems and of how strategic flexibility could be restricted by technical decisions.

It should be pointed out in conclusion that the threat of post-attack blackmail is proportional to the vulnerability of our offensive force to a first strike against it. An initial counterforce attack may be deterred by either or both of two effects: (1) The attack is militarily disadvantageous; the enemy would expend his offensive force faster than he would destroy ours. (2) The attack would provoke a punishing retaliation; the better we protect our own force, the less deterrence has to rest on the threat of retaliation.

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As a hypothetical example, consider a retaliatory force made up of submarines able to fire ICBM's. They could then be stationed in the Great Lakes or Hudson's Bay. (This avoids the controversy over slow attrition of a submarine force operating in a public place like the ocean.) If the enemy did not know where the submarines were located, the threat of punishing retaliation would not be necessary to deter an attack on them. The ideal deterrent is one in which an enemy attack is deterred not only by our ability to punish him but by the assurance that he would be punishing himself. This is another example where protection of our own force makes the command and control problem easier.

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8. POST-ATTACK ORGANIZATION

Let us think of the military organization as a group of command centers connected by communication links along which information is supposed to flow. We could also sketch in the lines on which information can flow. These would connect nearly every center in the ZI with every other, since each center presumably has a telephone. After an attack, whether or not the command and control were prime targets, the organization will be fragmented. Both centers and links (official and unofficial) will be missing. The problem is to find some simple concept for indicating how the surviving pieces of the original organization should transform into a structure able to exercise command. There are two general possibilities here. One involves passage to a secondary, or backup, system which is especially designed for survivability. The airborne command post is an example. The other is to have a set of rules whereby the normal operating command centers pass their functions to other such centers upon being knocked out.

The objection to alternate command posts is that command should be continuous through the transformation from peace to war. One cannot expect to suddenly activate command centers and command functions. Some functions and centers may disappear under attack but no unexercised ones should be expected to suddenly begin operating. There should be a continuity of command activities from planning through exercising, warning, alerting, and on to maintaining control during attack and until the war is terminated.

One suggested rule of transformation for continuity of command is to divide the functions of the commands (or at least of the unified and specified commands) into two: a global, or strategic, function; and a tactical function. The rule would be that, if the command is knocked out, its global function would pass either up to the JCS or, if the JCS command post is out, it passes over to another command post on the same level. The tactical function, however, would pass down to the next lowest level within the command. For example, if both JCS and SAC headquarters were knocked out, the global job of CINCSAC would pass to CINCNORAD, while the tactical function would pass to a numbered Air Force. According to this doctrine each unified and specified command would have to be able to perform its own global function, plus the distinct but related global functions of all of the other commands. The rationale for this is that CINCSAC, for example, has much in common with CINCNORAD in familiarity with high-level policy and strategy and that CINCNORAD would therefore be better qualified to do rapid global planning for the use of SAC than would the command of a numbered Air Force.

There are several objections to this concept. For example, it is difficult to draw a sharp line between the global and tactical functions of a CINC. The Winter Study Group has tended to favor

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another concept (discussed further in the following chapter) which postulates a single higher-command, general-war function which could be performed either at the JCS command post or at a unified and specified command. This function would, in fact, be included as part of the peacetime function of each command and each would exercise it on a rotational basis in peacetime exercises. If JCS were knocked out, this function (of central military command) would pass to SAC, then to NORAD and so on through several such centers. The number of centers and their hardness would determine the size of attack required to knock the function out. This could be increased by going deep underground or perhaps by a combination of hardening and active defense (which would also have to be hard).

However, as mentioned earlier, those measures which seem most likely to insure survival are the least compatible with the normal operating procedures of a command. An airborne command post, for example, is highly survivable but also highly inconvenient except as a backup. Perhaps a satisfactory solution would be a mobile backup, such as an airborne command post, manned on a rotational basis by officers who also take turns at the regular fixed command post and who, therefore, do not become detached from the day-to-day operations of the command but acquire the experience necessary to take over smoothly in a crisis. Such takeover, in fact, should be regularly included in exercises.

The regular fixed centers could be numerous and hard enough to establish a tolerable threshold for passage of command to the mobile backup (as in the case discussed earlier of a mobile backup for local control centers). An illustrative example for a mobile backup system for higher command and the associated communication links to missile and air bases is presented in the addendum to this chapter.

The next question is how many levels of command should have mobile backups. For example, to consider the offense, should there be one for JCS, one for SAC, and one for each numbered Air Force? To answer this let us look at the flow of information required in the case of an attack that damages the normal fixed command structure. The usual concept of an organization is represented by a pyramid. This also applies to the flow of information in the form of decisions. A small number of general, or highly aggregated, decisions are made at the top. Details are filled in by decisions at the next level and so the total amount of information grows as we proceed from the apex down toward the base of the pyramid.

It is questionable, however, whether this is an accurate image for the post-strike function in general war. Certainly, if the higher command could do no more than give the go order, and perhaps also choose a particular emergency war plan, the pyramid would become a straight column; a single decision made at the top is passed down to the force. However, even if the command remained able to

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completely retarget the missile force, there would be only a small deviation from pure centralized control. At the top would be the choice of the targets in order of priority. The next level of detail would involve assigning targets to missile squadrons. The assignment of missiles to targets could be done at the local squadron control centers. Both the choice of a target list and the assignment of targets to squadrons could be done at a single level of command and perhaps by one person, who would need to know only the number of surviving missiles at each squadron. In fact, if this information were relayed to the squadrons, together with the choice of a target system, the squadrons could make their own assignments on the basis of a preplanned procedure for taking over one another's targets. Thus, for the offensive force, a single level of surviving command above the local control level may be sufficient, simply because of the highly centralized control required. Intermediate centers would have little function except to transmit orders.

While the command function for the offense becomes highly centralized, for the defense it becomes highly decentralized because each local defensive battery or control center must react reflexively to the local threat. A single mobile backup for the higher command could, therefore, serve both the offense and the defense. The offense because control is completely centralized and the defense because control is so decentralized that there is little for a higher command to do once the war starts.

The subject of retargeting the missile force is discussed in Winter Study Report No. 19, Ad Hoc Studies. Contrary to popular impression, missiles may be a more flexible weapon than manned bombers. Retargeting bombers is restricted by the number of targets the crews have been trained to handle and because a bomber attack is highly coordinated operation involving bomber-tanker mating and the coordination of penetrations and times over target. By contrast, a missile using radio guidance can be quickly and easily retargeted. Furthermore, missiles can operate independently. Hence, the retargeting is a much simpler problem, and once a target list has been accepted, is mainly an exercise in elementary bookkeeping, much of which can be preplanned even for completely centralized retargeting.

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ADDENDUM TO CHAPTER I

Olympus - A Skeleton Command System

The purpose of this addendum is to sketch out a sample survivable backbone communication system that is specifically addressed to some of the problems dealt with in Chapter I. There has been great concern about the extent to which vulnerabilities of just the communication links jeopardize the nation's abilities to quickly evaluate the nature of a nuclear event or series of events, to insure appropriate retaliation without excessive likelihood of accident, and to perform post-attack recovery. One would like to have a communication system to carry out these functions and for the system to have two attributes, survivability and directness.

The "Olympus" scheme proposed here consists of a small group of aircraft acting as airborne relays, with one or more of them also being airborne command posts. These aircraft are the nodes of a very simple network linking together in a direct manner the top six to ten command people of the country and as many weapons as are within communication range. Sufficient geographical flexibility should be possible to permit these commanders to connect into the network without intermediate relays or switching centers even when these people are temporarily away from home base (for example on vacation), but within line-of-sight range of one of the airborne relays.

Functions of the System

Fig. 1 shows the geographical deployment of five relay aircraft and one combination relay and command post aircraft, which interconnect the top eight command locations and a majority of our ZI strategic bases. There are three main functions that such an interconnecting communication system could perform:

(1) Provide a high command party line facility on which the nation's top command personalities could hold a caucus to work out such questions as "Have we been hit?" "Where and how badly?" "Could it have been an accident of ours or theirs" "How much of a counter attack shall we make?" "Against whom?" "What weapons do we have left?" and most important "Which one of us is the senior survivor?" A communications capability that would allow such a caucus to take place no matter what sort of attack was incident would go a long way toward alleviating the necessity for an "automatic pre-planned response," if, and only if, the conference capability was supplemented with a second function:

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(2) A direct channel from this caucus to the weapon--not all the weapons, but a fraction large enough so that the enemy loses confidence that he can isolate enough of our weapons from the firing command to satisfy his conditions for war. With airborne communication relays transmitting, the receivers would be located at all our strategic weapons that are within range. It is envisioned that this second function would not be a party line arrangement, but would be a predominantly one-way flow of communication, the weapons responding only to report their continued existence and to acknowledge commands. The nature of the message sent could range all the way from a broadcast "go" command to a weapon-by-weapon firing command including retargeting information.

These two are the main functions of the Olympus scheme, which, because of vulnerability of the aircraft to other aircraft and homing devices, would probably not live through a prolonged attack that included aircraft. There is, however, a post-attack period of at least several hours or perhaps days between the time that enemy missile impact or enemy aircraft cross the warning line and the time that the Olympus aircraft are either sought out and destroyed or can no longer be refueled. During this period, a third purpose could be served:

(3) Command and communication facilities for post-strike civil and military recuperation and (if necessary) communication with the enemy. The high speed and mobility to be obtained with aircraft means that if at least one aircraft had a fair-sized complement of communication gear aboard operating over much of the rf spectrum, and also had aboard a senior surviving officer, this officer could size up the situation and improvise rapidly (and in many different parts of the country) both restrike functions and coordination of civilian recovery, for as long as he had places to land and refuel. If the plane did not have the senior surviving person aboard, it is conceivable that it could land and pick up this person.

The link for NORAD would be particularly important to maintain in the immediate post-strike period.

Intelligence inputs to the airborne commander would come to him in abstracted form from the normal 466L - 438L complex during the prehostilities period. After that (presuming that this function is lost because of its lack of survivability) he would have to improvise his own inputs.

During the pre-strike period, tactical warning systems (BMEWS, 496L, 117L, DEW Line) would normally feed their large-volume inputs into the ground bases as presently planned, but with semi-automatic arrangements for passing on to the airborne commander the most significant information.

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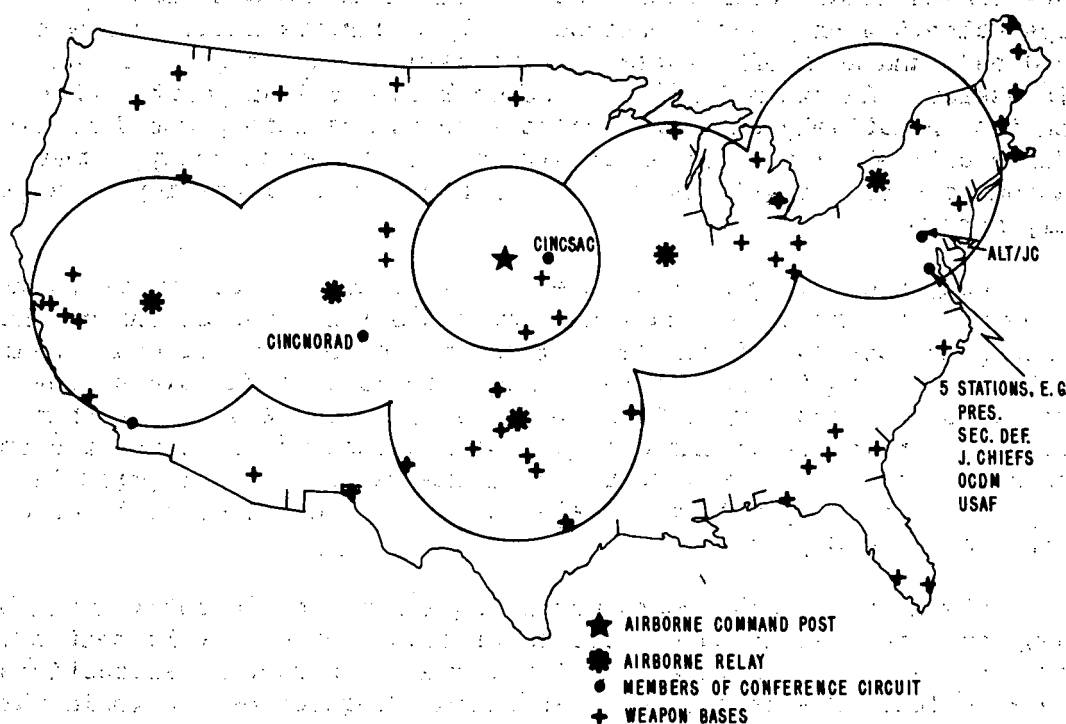


FIG. 1 OLYMPUS-A SKELETON COMMAND SYSTEM

Description of the System

In constructing this sample hard-core system, we have endeavored to suggest procedures that could be implemented within a year or two. The reasons for using airborne relays rather than ground relay points of various kinds (tropo, cable, microwave link or others) are principally that airborne relays simplify matters by reducing greatly the number of intermediate relays required and provide the geographical flexibility needed for the post-strike function. They also rely on equipment that is available with little further development needed. Satellite relays would be undesirable for the communication functions since the large horizon distance would make jamming or listening possible at excessive distances, and since the satellite would be much more vulnerable to covert destruction. The exception to the latter difficulty is the "Needles" passive satellite scheme which would provide one-hop propagation between any two points in the Olympus network at a low data rate. As discussed in Section III of Winter Study Report No. 15, Communications Panel, the use of 10-foot dishes at all the ground points, mobile or fixed, and in the airborne command post (or posts) would provide information bandwidths of 80 cps for reasonable Needles belt densities (ten times the payload weight of the proposed test shot). However, implementation could begin sooner and wider information bandwidths would be assured using

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more conventional techniques, such as UHF or microwave airborne relays (albeit with greater expense and less survivability than with Needles), and so a UHF system will be assumed in the rest of this discussion. An extension of the network to overseas points, which would be relatively easy if Needles were in operation, would involve a prohibitively large number of aircraft if airborne relay communication is used; therefore, we shall restrict the discussion to a ZI-only system.

Only those weapons that are in an operational ready status will be members of the communication circuit providing the second of the three functions just described. That is, the Olympus aircraft would talk only to missile launchers having weapons counted down to several tens of minutes till firing, and only to those aircraft that were airborne or on ground alert. Instructions to all other weapons would come through normal means until the weapon carrier (missile or aircraft) was brought to the ready status, whereupon control would be turned over to Olympus.

UHF airborne and ground mobile equipment is presently available that could be used in such a system without further development effort were it desired to implement it immediately. Frequency allocations would be less of a problem at even higher frequencies, as would the likelihood of jamming or interference from beyond the horizon. If it is desired to use directive antennas on the aircraft or on the ground, for decreased vulnerability to homing missiles, these antennas could be smaller the higher the operating frequency.

Fig. 1 shows only one of many possible configurations of the system. In the example, only one aircraft (KC-135) serves as both communication relay and command post and five others (U-2) act as relays only. Clearly other combinations and geographical dispositions are possible.

Line-of-sight range to the radio horizon from a KC-135 aircraft at 35,000 feet is 260 miles; from a U-2 at 70,000 feet it is 360 miles. The figure shows circles of these radii about each aircraft. At these short line-of-sight ranges there is no particular premium on transmitter power (even with isotropic antennas) except to overcome jamming. Jamming from a satellite is conceivable, but the satellite would be at an enormous disadvantage in range and in weight-carrying and power-developing capability. Much more of a problem would be intruder aircraft or missiles, or off-shore vessels in the case of planes covering the east and west ends of the line. For the latter reason, these particular aircraft should stay fairly far inland. The jamming problem, and also the homing missile problem make it advisable to make frequent shifts in operating frequency and to use short-duration transmissions.

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For the conference circuit involved with the first of the three functions defined earlier, encrypted voice would be the most suitable mode of operation, since, compared to any form of record communication, it would be much easier and quicker to use in carrying out the necessary discussions. For the weapon command function, voice or data circuits using the appropriate authentication would be suitable. For the third function, post-attack improvisation by the command post aircraft, there would be a premium on using communication equipment compatible with the most common civilian and military frequencies and forms of modulation.

Costs

Any system using aircraft flying on station is expensive, since the number required in service for one on station is something like five. For six stations, as shown in the figure, and assuming one KC-135 and five U-2 airplanes, it is estimated, with this 5:1 support ratio, that the total cost of the airborne units would amount to \$63 million for the initial investment and \$13.5 million annual operating costs. Initial costs: \$38 million for the 5 KC-135's with communication gear, \$1 million for each of 25 U-2's each carrying two AN/ARC-34's. Operation costs: \$8.5 million for the KC-135, \$1 million for each relay station.

A system using entirely KC-135 aircraft at 35,000 ft would require seven relay aircraft instead of the five U-2's at 70,000 ft shown in the figure. The initial cost would then be about \$300 million. This enormous initial investment cost could be lessened by using B-47 aircraft which are now beginning to be phased out of SAC.

Summary

A system such as proposed here would have the effect of tying together, in a communication network of limited capacity, the President, JCS, CINCSAC, CINCNORAD, Head of OCDM, the airborne SAC alternate commander and some of the weapons. It would thus transcend some of the functions of some of the L-systems, particularly 425L, NORAD COC and the 465L SAC Control System. It is doubtful that these two L-systems would survive a sizable attack, because of vulnerabilities of both the center and the communications and their complexity and large communication volumes. Rather, they are to be regarded as systems to prepare the offensive and defensive forces, the actual trigger being placed in the hand of the country's senior surviving command person or in the airborne commander.

The present discussion was intended to be suggestive of the kind of approach that might be used to give the most vital hard core of command and control functions the two desirable characteristics of survivability and directness. With respect to survivability the

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scheme suggested is only a partial solution: whatever survivability it has results from the assumption that attack by homing devices deep with the ZI would be an act of war.

With respect to directness, it is pertinent to point out that the recent U-2 incident showed what can happen when communication between semiautonomous organizations is left to chance and has to take place through many intervening relays. No technical inadequacies such as circuit reliability or capacity were involved; the problem was organizational.

Several limited-capacity backbone systems have been proposed (NSCS, bomb alarm), but suffer from the disadvantage of not connecting enough functionally different organizations together.

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CHAPTER II: CONCEPTS FOR COMMAND SYSTEMS

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CHAPTER II: CONCEPTS FOR COMMAND SYSTEMS

We next consider the problem of operational command and the role of command systems, such as 425L NORAD and 465L SAC in this function. We are distinguishing here the operational function from the other functions of support and of long-range intelligence also performed by the services. Operational command consists of planning for and directing forces-in-being; the line of command includes the Joint Chiefs, the Unified or Specified Commands, and the component commands. Also, by considering command systems, (rather than control and sensor systems discussed below) we are primarily addressing the headquarters functions of operational command.

There is considerable agreement within the USAF that we are facing a crisis in operational command. Although the United States is developing an up-to-date arsenal of mixed weapons and electronic systems, there is concern whether commanders have the tools to realize and evaluate the performance of these systems, to prepare adequate war plans, to maintain a ready posture, and to direct forces when action is required.

The crisis in operational command capability is the result of a technological revolution in weaponry. The planner and commander are confronted with both conventional and nuclear weapons; many forms of delivery; and extremely complex control, sensor and weapon systems whose potential capabilities can only be gradually realized. But these capabilities have short useful lives before a new wave of systems comes into the field. Similarly, the enemy threat changes as his weaponry improves. The available decision cycle for war planning and force employment becomes shorter and shorter but the consequences of these decisions are greater and greater. Finally, our military is undergoing a major reorganization so that lines of authority and responsibility are changing and not always clear.

The mushrooming requirements for command systems and more automation are a symptom of a crisis in operational command capability. In order to evaluate the presently proposed command L-systems and to consider whether some areas of need have been overlooked, Winter Study has had to consider the problem and needs of operational command in a context broader than "how can automatic communication and data processing help?". Independent then of the use of automation, seven factors must be recognized if operational command is to be strengthened:

- (a) The military is responsible for exercising command--this function should not be delegated inadvertently to machines or engineers.

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(b) Operational command is a single, continuing management problem. Whereas forces and functions phase in and out year by year, the command function must grow continuously under direction of the command.

(c) Within a command, there is a severe need for effective communicating between intelligence, operations, materiel, and plans functions as they relate to the total operational command role.

(d) Operational command must be adaptable to uncertainties in threat, policy and technology. It must respond to major contingencies caused by these uncertainties in weeks and months, not years.

(e) Commands must develop a stronger linguistic framework as an aid to rapid, succinct consideration of their problems and capability and coordination of these with higher and adjacent commands.

(f) The need for improved communication and information handling to strengthen operational command is predominantly for pre-combat capability. This is the essence of the forces-in-being concept --- peacetime operational command generates and exercises the simpler plans and procedures that are required for combat.

(g) Communications and coordination between commands and with JCS command must be expanded to include more joint planning and exercising during the pre-combat phase.

In order to strengthen operational command, three approaches must be pursued together:

(1) An increasing use of automated communications, data processing and display can help. This capability is required primarily in peacetime; it should be provided early and in gradual steps. Present plans for command I-systems are often too long-range and too ambitious.

(2) The commands require much more on-going technical assistance not only to aid them with appropriate automation but equally to strengthen the analysis, planning, exercising, and evaluation which are needed as more complex systems become part of the force structure.

(3) Finally, the lines of operational command must be clarified and strengthened, a stronger service-independent JCS command center must be evolved, and guiding operational concepts and standards for all command centers must be developed.

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The following principles should be observed in applying automation to command headquarters:

(a) Each command should apply automated communications and data processing in modest, successive phases so that capability and understanding can be built on previous command experience. Initial use of automated capability in any phase should leave considerable spare capacity for growth and change.

(b) During all phases of adding automation, a commander's or "capping" system is required which acts as a "staff" cutting across the organizational lines of operations, intelligence, material and plans wherever these functions support operational command. This planned growth of automation in a command should be directed toward the building up of a data-base or command model. The data base would be stored in the command's computing machines and would represent all the data and procedures and plans and experience pertinent to the operational command function.

(c) The command organization should participate in the design of automated procedures and models as part of their command job. Many steps could be taken today with available techniques to increase this participation; requirements for command L-systems have not included this capability.

(d) Design of command systems should include capabilities for the discussion and evaluation of performance and the development of a command language. Presently planned L-systems usually include a greatly improved capability for performing known tasks, not a capability for considering how important tasks are and how well they are being performed.

(e) One of the major factors which caused delay of the L-system program and establishment of the Winter Study Group was a stated need for more "integration" between the L-systems. It is important to distinguish between functional and technical integration. In the latter, one emphasizes such needs as use of standard equipment and programming languages; or sharing of a single facility for several tasks (such as common communication systems for several users). In the case of functional integration, one emphasizes clear and effective and realistic allocation of roles to commands, close coordination within commands and between commands in planning and support, and effective higher command of subordinate commands.

Adequate functional integration at this time is much more important than technical integration. A strong requirement for early technical integration is technically both infeasible and undesirable; undue emphasis on technical integration threatens early needed strengthening of operational command capability at individual commands. Stronger functional integration will gradually result only

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as individual commands and JCS command are strengthened under the broad guidance of overall functional and technical plans.

Next, let us consider the need for stronger, continuing technical assistance to the commands. The Weapons System Project Office Manager procedure which has been used by the USAF for developing major weapons and electronics systems does not provide adequate technical support to the operational command problem. It does not insure continuing assistance; it does not provide the proper impact of command requirements on weapon, control, and sensor system design; it does not provide enough continuing iteration between command needs and technical feasibility. The establishment of the Hanscom complex with a strong continuing technical support for AFCCDD can do much to remedy these shortcomings, if:

- (a) Air Force Headquarters, DOD and the using commands recognize, support and use this capability at a high enough level.
- (b) Adequate financial support and priority are given to building appropriate technical and managerial capability within the complex.

The relationship between AFCCDD and the using commands for command systems should be two-fold: consultant and developer. In its consultant role, the relationship must be much closer than that required for weapons and electronic systems. In effect AFCCDD is participating in the planning and organization of the using command and the using command is participating in the development and design functions of AFCCDD. AFCCDD should be like a management consultant or technical staff to the using command. Unless this relationship exists, AFCCDD will be incapable of providing fully effective, continuing technical assistance required by the commands; it will be unable to propose or support the continuing GOR's required for command improvement.

In its development role, AFCCDD should manage a development program which produces a family of "on-the-shelf" (or at least "in-the-catalog") command system components which are useful for several commands. In this role, the relationship between AFCCDD and the individual using commands is not as close. The development of computers, displays, communications, and computer programming tools should not aim at the particular requirements of one using command--it should reflect the anticipated overall requirements of many commands.

A most important factor to be appreciated here is that our capability to build hardware components is well beyond our knowledge to build systems out of these components. We have learned a great deal of how computers can be programmed and how to build display devices and automatic communications, but we require a

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much larger understanding of basic information processing in order to learn how to handle interactions between these elements and how to compose these elements into an effective system.

The major development requirement in the equipment area is in developing standards for tying these components together and modularities of design so that processing capabilities in command centers can be expanded and improved without disrupting operations.

Another element of a command system research and development program is conducting operational experiments in an operational environment (e.g., the 438L experiment at SAC). Such experiments should not be viewed merely as the development of a prototype system for a particular command; more important they should attempt to develop and improve automatic techniques which might be used in a different fashion by many commands, including the development of a common language for the use of the command and control systems.

Also, we need basic development programs in command center technology: how command centers operate; the proper role for men and machines; how operational personnel can direct properly the automated portions of a system.

In summary, we have stressed that operational command capability must grow within a using command and be designed primarily by that command; that a development agency such as ARDC is more a technical consultant to a using command rather than an independent designer for the command. The USAF is responsible for supporting the command system requirements of many headquarters, some of which exercise operational command over other services commands, some of which receive operational command from unified commands whose command system requirements are supported by other services. Service support of operational command systems will be workable but the USAF should press for the early development of a clear JCS command system operational concept and the early strengthening of a service-independent JCS command center.

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1. THE PROBLEM OF OPERATIONAL COMMAND

We start by defining the problem of operational command. Each of the services is concerned with three major areas: support, intelligence, and operations. The support function is internal to each service and includes long-range force planning, budgeting, research, development of new systems, procurement, testing, installation, training and maintenance. The intelligence function (excluding warning) is performed by a community of agencies including the three services, CIA, NSA, and others; as defined here, this function includes long-range technical and capability intelligence. The operational function is performed by the Joint Chiefs of Staff, the three service headquarters, some service commands (e.g., MATS and TAC), the unified and specified commands, and by component commands under the unified and specified commands. The operational command function includes warning, operational direction of forces in being, generation of war plans, and (increasingly) some responsibilities for exercising and evaluation.

" The Winter Study Group has found it useful to distinguish between command, control, and sensor-weapon systems as follows: The sensor-weapon systems (such as BMEWS and Minuteman) are at the bottom of an organizational and informational pyramid or hierarchy. They are the "front-line" systems with which we sense and combat the enemy's forces. Control systems such as SAGE are "half-way up" the pyramid---they control weapons and sensor systems in order to perform specific operations such as air defense. Command systems are at the apex of the organizational pyramid---these are the headquarters systems which the commander and his staff use for their war planning, warning, force direction, and evaluation functions. "

Clearly, there are gray areas between these definitions---in fact, we are dealing with a spectrum of systems extending from command systems on the one hand to weapon systems on the other from the headquarters to the field. If we understand the various properties of this spectrum, we are in a much better position to understand the design and implementation processes required for the different systems on the spectrum. For example, at the sensor-weapon end, we are fighting a state-of-the-art battle with the enemy; BMEWS eventually can be evaded, electronic countermeasures can threaten air defense. The state-of-the-art problem is not nearly so important at the command end of the spectrum---whether a plan for SAC emergency war operations is generated by punched card equipment or transistorized computers is less important than whether the plan is realistic and adaptable. (In this example, we are not implying that technological improvements cannot significantly improve the headquarter's function, but rather that the use of improved technology is not as critical to the headquarters as it is to the field, that the use of improved technology should be subservient to other critical headquarters functions such as definition of workable organization or investigation of a wide variety of threats and the command's role in countering them).

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We have distinguished the operational role from the support and long-range intelligence roles; and command or headquarters systems from control, sensor, and weapon systems. In this light we address the problem of how command-control technology can assist the headquarters in performing their operational command function. We will be concerned with headquarters at several levels: JCS, service, unified or specified command, service command and component command. Although many of these headquarters perform in all three areas of support, long-range intelligence, and operations, we shall primarily consider the problem of operational command.

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2. CRISIS IN OPERATIONAL COMMAND

While the Winter Study Group discussed the command-control problem with many agencies--operational commands, supporting commands, Hq. USAF, DOD, scientists, and industry--there was a surprising consensus that present U.S. operational command capability is seriously, if not critically, deficient. According to this view, the U.S. has developed or is developing a large and mixed arsenal of up-to-date weapons and sensors and the present concern is whether our command capabilities will allow us to use these tools effectively. There is also surprising agreement on the manifestations of this crisis in operational command:

(a) There is often a lack of appropriate knowledge at different levels of a command of the performance of the command's forces under realistic conditions. By appropriate we mean, for example, that CINCNORAD's understanding of the defense capabilities of a Bomarc squadron must be much more general or global but no less realistic than the understanding of the Bomarc squadron commander. There is not only the problem of detailed or low-level knowledge of force performance but also the problem of appropriately communicating this knowledge up through the command, i.e., correctly abstracting the know-how.

(b) There is a lack of confidence within many commands that forces can be successfully directed according to present war plans. Is continuing assessment of force posture correct or up-to-date enough for a realistic option to be chosen? Will commands be communicated to forces in time?

(c) There is a lack of adequate communications and coordination between commands where command missions are mutually supporting and even overlapping. An outstanding, but hardly sole, example is the strategic, or general war, strike mission where at least four unified or specified commands include Soviet targets in their detailed war plans. These individual war plans depend on detailed targeting, priority, and time-over-target factors, but they are only very generally, and often inaccurately, coordinated in overall war plans.

(d) There is relatively little investigation of a broad spectrum of alternative strategies and tactics before retaining a workable number of alternative plans. Equally important, there is little anticipation of a wide spectrum of threat situations and preparation to counter with appropriate plans.

Basically, the crisis in operational command stems from the revolution in military technology which has taken place over the past twenty years and which is becoming fully operational in the 1960's.

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It is important to recognize the most salient features of this revolution for each places a stringent requirement on operational command:

(a) We are faced with an ever-increasing spectrum of weapon lethality and delivery techniques and of sensor sensitivity. As a result, there are many more situations and possibilities faced by the planner and operator.

(b) As both the U.S. and U.S.S.R. develop greater kill potential, we become increasingly concerned with the consequences of each operational decision. We must limit wars but be prepared to exchange cities.

(c) For most situations, we depend on a concept of forces-in-being. Except for prolonged limited wars (such as Korea), each engagement, be it a show of force or a general war, depends on operational forces in being. There is no time to develop or procure new forces; there may not even be time for slight modifications to war plans and doctrines.

(d) Closely allied to the above and often overemphasized is the "compression of decision time." To be sure, increase in weapon delivery speed and decrease in warning capability have reduced the time available for making decisions, even in non-general war situations where prompt action could force the enemy to back down. On the other hand, as pointed out in Chapter I, one may wish to accept somewhat slower decision times in return for more positive control and increased certainty of achieving a decision.

(e) Our sensor and weapon systems are becoming larger and more complex so that the task of generating operational plans for using these systems is more difficult. At best, potential capabilities of the weapon or sensor system are only gradually realized after many iterations of exercising, replanning, and evaluation. Throughout this growth period, the operational climate is gradually changing because of new enemy threats, new technological developments, and new U.S. strategies and alliances. And finally, the realistic operational life of the weapon or sensor system may be very short because we develop a radically better replacement or the enemy develops capabilities which obsolete the weapon. SAGE, which is not yet fully operational, is a classic past example of this problem. But consider how little time remains to develop and test operational plans for using BMEWS, MIDAS, manned bombers (with or without ALBM's), fixed missiles and Polaris in coordinated pre-emptive or retaliatory strikes.

(f) Finally, our military establishment is undergoing a major reorganization whereby responsibility for operational command is being transferred from the services to unified and specified

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commands and to a single Joint Chief of Staff. Although the major outlines of this reorganization may be complete, considerable experience is still required within these outlines before pressing questions of authority and responsibility can be resolved.

In summary, operational commands are gradually gaining command over their present forces only to face, in the coming five years, the introduction of many more complex systems in order to cope with many new threats, many of which cannot be anticipated now. Also during this period, the lines of operational command and the relationship of support and intelligence functions will be changing as they are clarified.

What can be done or is being done to restore operational command? Unfortunately there is no panacea, not even the introduction of "integrated electronic data-processing systems at command headquarters to process high volumes of data in shorter times." On the contrary, the Winter Study Group can see instances where pursuit of this solution has hidden the real problem and feasible improvements and threatened to consolidate the present command situation. In conducting our study of the present and required command L-systems, we have come to believe that three broad lines must be pursued:

(a) Appropriate, increasing use of automation in communications, data processing, and display, particularly in peacetime, can help. We discuss below instances where present command L-system plans along these lines are sometimes inappropriate, inadequate, and overly ambitious.

(b) The present command headquarters greatly require more on-going technical assistance, not only to aid them with appropriate automation but also to assist in the analysis, planning, exercising, and evaluation that are needed as complex systems become part of the force structure. It is interesting to reflect on how much technical manpower from government, non-profit corporations, and industry has been applied to the problems of system development and force composition and how little has been concerned with the command of forces. Consider the effort by many agencies to develop a BMEWS system and the insufficient planning on when and how and who should use BMEWS, or how to react if BMEWS is sabotaged or jammed. This technical assistance is not only homework for more automation--it may indicate a need for less.

(c) Finally, the lines of operational command must be clarified and strengthened, a stronger service-independent JCS command facility must be evolved, and guiding operational concepts and technical standards for all command centers must be developed. Winter Study has not considered itself qualified or responsible to make specific recommendations in this area. On the other hand,

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the first two goals of appropriate automation and increased technical assistance cannot be fully effective if these steps are not taken.

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3. FACTORS IN IMPROVING OPERATIONAL COMMAND

Before considering the promises and pitfalls of automation, we indicate the most important needs which must be satisfied by any command organization in order to improve operational command. These needs are independent of the degree of automation, although some become more apparent when automation is considered, and some can probably be fully achieved only through the increasing use of automation. These factors are:

- (1) The role of the military (versus automation)
- (2) Continuity and growth of command
- (3) Intracommand communicating
- (4) Uncertainty and adaptability
- (5) The development of language
- (6) Predominant peacetime need
- (7) Intercommand communicating.

3.1 The Role of the Military

Clearly, the role of the military in a command headquarters is to command. If automatic data processing and communications are introduced in a headquarters, their role is to assist command. We must be careful though that we do not build strategy and command into our automated elements and thereby make the military organization simply monitors of the command system action. In this sense, a command system, which consists of people and automation, is very different from a weapon system. An interceptor does not help a pilot to be a pilot---the combination of pilot and interceptor are a useful system to conduct interceptions. (For some uses, we dispense with the pilot and use Bomarc or Nike.)

This concern that command systems may assume a significant part of the command role is not academic. In several of the proposed command L-systems, considerable command performance is designed into the system (most noticeably into computer programs). To be sure, the command and his staff can turn off the system or ignore it, but this hardly contributes to effective command.

3.2 Continuity and Growth of Command

A command uses mixed weapon systems which phase in and out, year by year. The command itself is a single organization which continuously develops procedures, traditions, doctrines, and plans for controlling its weapon and sensor systems. The command often critically needs assistance before a long-lead time L-system can be installed. If a long-lead time command system is planned, then the

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introduction of this system must strengthen, not disrupt, on-going operations--the system should include on its operational date all of the most recent command procedures and know-how. Finally, the system must continue to strengthen operational command after it is installed.

3.3 Intracommand Communicating

Within a command headquarters, effective operational command depends upon developing throughout the command a common understanding of:

- (1) The range of performance capabilities of weapon, sensor, and control systems,
- (2) The role and capability of different parts of the organization, and
- (3) The total mission of the command.

The command is generally organized functionally into intelligence, operations, plans, and materiel areas. The total mission of the command (the commander's concern) cuts across all these areas; the mission includes:

(a) Warning which predicts both imminence of activity and threat to the command mission (the command should be warned not only by positive intelligence on enemy actions and capabilities but also by absence of intelligence or absence of support).

(b) Force control which assesses, evaluates, predicts and redirects force and sensor status.

(c) Operations analysis and evaluation which depend on unit, force, and battle-staff exercising; war gaming; threat analysis; and intelligence evaluation.

(d) Replanning on the basis of new forces and evaluation to produce new war plans for warning and force direction.

(e) Operation coordination with adjacent and higher commands and with intelligence and support.

Stronger operational command depends on increased communicating (not communications) across the command line organization.

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3.4 Uncertainty and Adaptability

It is virtually impossible to lay down detailed plans for the command function several years into the future. Year by year there are unpredictable changes in threat, international climate, strategy, force performance, budgets, and organizational policy. The operational command function must be adaptable to these changes; it must be capable of developing rapid, adequate response to these changes which is much more crucial than developing optimum capability for presently known command functions. For example, present plans and designs for the SAC Control System have concentrated primarily on improving present bomber-tanker capabilities. By the time the system is first operational in mid-1963, an airborne alert may be in operation, some U.S. ICBM's will be operational, intelligence estimates of Soviet air and missile active defense may be radically different, a joint strategic strike command may be partly implemented and some arms inspection may be underway. Since proper response to these changes will be more important to guaranteeing SAC capability than optimum use of the bomber-tanker force, the SACCS system must assist rather than impede adaptability.

3.5 The Development of Language

A crucial requirement in improving operational command is developing a conceptual and linguistic framework for planning and operations and keeping this language up to date; often a command's most serious problem is not being able to talk intelligently and succinctly about its threats and resources. Commands must be prepared to generalize--to develop shorthand and labels. The labels will often be too vague or too detailed or misleading; but it is important to start with some terms, to use them (exercising) and to be ready to change them. Such languages are needed at all levels of the command; they must grow and relate to each other. They are even more needed between commands and between all commands and JCS.

If such languages are not developed, there is a tendency to require volumes of detail (i.e., the same information) at all levels of the command even though the ability to comprehend and effectively use the information decreases with higher and higher levels of command because of the broader responsibilities of the fewer people seeing the information. Where considerable data processing is used by a command, the computer programs and displays will represent an important fraction of the command language. Since the military is responsible for command, it is important that the linguistic and doctrinal aspects of the data-processing system be governed by the command organization and subject to ready change and innovation.

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3.6 Predominant Peacetime Need

Most of the factors which we have discussed above are required only in "peacetime" as preparations for combat. That is, the greatest part of the operational command function, the people and the procedures and the equipment, need not survive a general war and should not be employed during the crisis periods of a cold-war. This is the essence of the forces-in-being concept--operational command generates and exercises much simpler plans and procedures than are required for combat, an important distinction which is often overlooked: One fallacy is to assume that no distinction exists, that both the peacetime "honing" function and the wartime capability must and will survive. Another danger is to pay lip service to the distinction so that some back-up is provided; but since the elegant peacetime function "may" survive and it seems to possess much more satisfying capabilities, the complex function is overly exercised and the simpler back-up is almost totally ignored. The relationship between Mode I and Mode II air defense, or between 465L and the airborne command post could be examples of this danger.

3.7 Intercommand Communicating

One of the greatest needs is for greater communicating (not merely communications) between commands, particularly in the peacetime operational command functions of generating war plans and estimating mutual support. We have already mentioned one example in the number of commands involved in strategic strike missions. Another is the extensive mutual support between CINCSAC and CINCNORAD. NORAD defends SAC bases, a SAC counterforce strike aims at NORAD's threat. In all these cases, communicating must be more than an uncoordinated after-the-fact transmission of status--it should start with planning and analysis.

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4. THE PROMISE OF AUTOMATION IN OPERATIONAL COMMAND-SYSTEM DESIGN CONCEPTS

Now we consider the role of automatic data processing and automatic communications in helping operational command. We will start by considering some design concepts, or ideals, for an extremely automatic command center. Then, we will consider how these concepts can be applied today.

First, let us consider the capabilities of computers for handling information. It is well known that computers store and process information at extremely high speeds under the control of computer programs stored in the computer. How can this capability be applied to the command function? First, the computer can act as an industrious, if unintelligent, file clerk. In this role, it can remember large quantities of status, performance, and intelligence data, and make this information available as required in reports and displays, in a way similar to the use of computers in business for controlling inventory or handling sales transactions. The important feature of the computer here is not the economy with which it stores information (manual records are much cheaper) but rather its ability to rapidly search and summarize and present information if given proper procedures and terms.

Next, the computer can perform many detailed calculations and procedures (such as detailing war plans) which require considerable time and manpower if performed manually. This is similar to the use of computers that assist in engineering design. In this application, computers are much faster so that detailed procedures can be rerun when unpredicted situations arise.

Next, the computer can simulate complex situations and therefore perform or participate in war games and exercising. One stores performance models in the machine by inserting many of the detailed elements of a situation to be modeled; then, by operating the model, overall performance under different conditions can be measured. These models can include uncertainty so that performance includes uncertainty and is measured statistically rather than precisely (these are called Monte Carlo models). For any given situation, different levels of detail or abstraction can be incorporated in the model; a computer model which does not include much detail is said to be aggregated. In general, the more a model is aggregated, the faster it can be operated. Consequently, a highly aggregated model can be exercised more often under different conditions than a detailed model. There is a tendency to believe that aggregation and accuracy are incompatible; that accuracy depends on considerable detail in a model. There is no inherent reason for this to be true, since the realism of the model depends on the accuracy of the elements built into the model. Often a highly detailed model is overly

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and incorrectly refined so that it is both misleading and wasteful of data processing capacity. Models can represent enemy threats, enemy defenses, weapon and sensor system performance, overall force performance, command performance, support performance, etc. In other words, models can be built up out of submodels. War gaming is no more than exercising a model which includes two submodels---one for each side.

Finally, through a combination of the file-clerk and the calculation and simulation capabilities of the machine, a computer can be an aide to decision-making. It can suggest alternative courses of action and evaluate them according to given criteria. Many techniques have been developed for commercial and military application such as dynamic programming which can, if properly applied, aid the decision maker.

All of the above capabilities are feasible today; they have been tested and used to great advantage in many problems. In the next five years, continuing improvement in computer and computer techniques for using computers should yield:

- (a) Larger, cheaper memories for much more extensive files;
- (b) Much faster machines (by a factor of 10 or 100) so that today's techniques can be run more quickly or more complicated techniques can be used;
- (c) Improvement in computer languages should make it eventually possible for humans to speak their language to the machine in directing its operation or requesting information;
- (d) Development of adaptive program techniques should make it possible for the human to state the problem or the goals to the machine (rather than the solution or the means) and the computer will then program itself to give some solution.

If, to build a command center, we had available today the machines and the techniques for using them that will probably be developed during the next five or ten years, how would we design a command center? First, we would store in the machine a data base or command model which represented all the information and procedures and plans and experience pertinent to the operational command function. At a command headquarters, the data base would replace files, manuals, regulations, backs of envelopes, routine manual processing capabilities, organization charts, distribution lists, etc. As such, the data base would be a model of the command's organization, resources, performance and strategies and, when pertinent to the command mission, the enemy's resources and performance. It would contain status data, war plans, and models of force performance under different conditions of alert and threat damage.

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Actually, the data base would consist of sub-bases for each different organizational area such as intelligence, operations, materiel, and plans and for each organizational level such as CINC, deputy, director, and branch. For example, at the CINC level there would be a sub-base of appropriate status data, command procedures, war plans, force performance, and threats. Also, there would be sub-bases for past, current, and planned activities. Clearly, there would be extensive duplication or overlapping between these sub-bases whenever interactions existed between organizational areas and levels.

Finally, the data base would include rules for communication, access, and transfer of information within the data base. It would indicate authority for change and access, source and destination of information, requirements for frequency of up-dating information, etc. In other words, all information in the data base would not be accessible to all personnel in the command.

The data base would always contain some errors of the following types:

(a) Factual Errors: That is, discrepancies between the data base and reality. For example, the data base may indicate communication delays which could be expected within the command when certain priority procedures are in force under certain alert conditions; in fact, subsequent experience may indicate that the communication delays are quite different.

(b) Inconsistencies: That is, discrepancies between the same piece of information in two overlapping sub-bases. For example, the CINC's estimate of communication delays and the branch level estimate (where the latter is obviously much more detailed) may not agree.

(c) Omissions: That is, the data base indicates that certain information should be available and it is not. For example, a war plan or a performance estimate may depend on an estimate of communication delays and no estimate or at least no up-to-date estimate may be available in the data base.

In other words, the data base is in many ways inadequate, wrong, and subjective. It is the command's view of the command. This is a crucially important quality of the data base: if the command's estimate of a situation is inaccurate, then the inaccuracy is reflected in the data base. If elements of the command are not communicating, then this lack of communication is apparent in the data base. We cannot increase communications without discovering absence of communication; we cannot improve accuracy without pinpointing sources of inaccuracies.

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Policing routines included in the data base would help discover these various errors and bring them to the attention of appropriate command personnel. For example, the results of exercises could be compared with models. More detailed models at lower levels could be operated and summary results compared with the detailed elements of higher level models. The common portions of overlapping models could be compared; what enemy defenses are predicted by intelligence versus what enemy defenses are assumed by operational plans.

The role of hardware in the command center is best described in the terms of the data base: Computers store and process the data base. Display and input devices transmit portions of the data between command personnel and the computer. Automatic communication links transmit portions of data bases between the command and adjacent command centers.

A major role of the military personnel in the command is command of the data base: Staff and line personnel should design, fill, change, use, and police the evolving data base as part of their command job. The command center cannot be a command post designed by engineers and programmers and used only by command personnel in crisis situations. When we stress that military personnel design the data base we do not imply that military programmers use machine language to do the job. Rather, we envision the development of operational languages and procedures which are familiar to all personnel in the command and are used by them to evolve the data base. For example, the military personnel can write simple plans and procedures and insert them into the data base; they can create new vocabularies and insert them in the data base or abstract from existing vocabularies in the data base and create new terms and procedures.

The tools by which the military would create the data base are operational translators. Operational translators are programming systems which convert from a language usable by the military to a language useful to the machine hardware. Whereas in the present L-systems the computer programs delivered with the system are the operational programs for command function, in the advance command center, machines would be delivered with operational translators with which command personnel would prepare and change the operational programs (i.e., data base).

One of the most attractive features of this advance computer center would be the ability of the automated portion of the system to act as a staff which cuts across organizational lines of intelligence operations, materiel, and planning and so help the commander to integrate the operational command functions of these deputies. In other words, the command center becomes an integrated combat operations center, combat intelligence center, combat planning center, and combat materiel center.

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Over the life of a command, the command center must continuously grow and adapt in order to improve the headquarters operational command capability. The data base evolves; it grows in size through design of the military. It becomes more accurate through policing by the military. As weapon and sensor systems are phased in and out, its models, plans, and procedures are changed by the military. The data base reflects a growing linguistic framework within the command organization; it helps the organization to test new vocabularies and doctrines, and to evolve an efficient linguistic framework. As the data base grows, the commands' capabilities to use, design, and police the data base grows; the data base can only get larger (that is, require more computers, storage, display, and communication capabilities) if the capability of the command organization to command the data base grows proportionately.

The hardware which is used to process the data base (computers, display, input devices, and communications) grows as required by the data base. Components are modularized so that capabilities can be increased as required. Interconnections between components are standardized so that portions of the system can be replaced without obsoleting the entire system. All equipment is off-the-shelf so that lead times for improvements are short, costs are known, and installation problems such as system integration and testing are minimal.

During evolution of the data base, the command must be careful not to use its increased processing capabilities merely to increase centralization. To be sure, the addition of automatic communications and greater data processing at a headquarters makes it possible for the headquarters to receive more data in greater detail; similarly, within the headquarters, increased data processing and improved displays make it possible to give the highest level of the organization more detailed information. On the other hand, such tight centralization will probably not pay off as much in strengthening operational command as the development of procedures of aggregation and delegation, i.e., the development of levels of language and doctrine. We have indicated above the importance of such a linguistic framework to the capability for investigating alternative strategies and tactics and anticipating and planning for the widest possible range of enemy threats.

The problem of communication between commands becomes a problem of developing common language and exchanging data bases accordingly. In other words, a part of the data base at one headquarters will be received from other headquarters (or command center), i.e., portions of the data base of each headquarters will be transmitted to others. In this way, commands will not merely exchange after-the-fact

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status data; they will exchange plans, estimates of performance, and procedures. For example, NORAD should send to SAC its current and planned models of air defense effectiveness in cases where these models involve defense (or impossibility of defense) of SAC capability.

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5. DESIGN OF PRESENT COMMAND SYSTEMS

Let us start by summarizing the probable design features of a highly automated command center:

(a) The role of automation is exemplified by a data base or command model which is a memory or store of the command's view of its status, procedures, plans, performance, role (with respect to other command centers) and the enemy threat (to the command). The data base is subjective in that it is the command's view of the situation; it is objective in that information common to the command is stored in a medium where communicating of the information can be less dependent on transient individual attention.

(b) A major role of the command personnel is to design, change and police the data base so that it becomes more effective and realistic; they do this using operational translators which convert between command language and hardware language.

(c) The data base acts as a staff cutting across intracommand organizational lines.

(d) The data base improves (i.e., grows, adapts, becomes more accurate) as the command organization develops capability to command (i.e., design, change, use, and police) the data base.

(e) The command need not always use automation to centralize; it should use the data base to develop higher-level language and doctrine and to consider alternative strategies and threats; the data base may lead to delegation and decentralization.

(f) Commands and JCS communicate between themselves primarily by exchanging appropriate portions of their data bases.

(g) Off-the-shelf, modularized hardware components with standardized interconnections are applied as necessary to handle the growing data base.

Such a command center is beyond today's technology. We are just beginning to develop and gain experience with the languages required for operational compilers (most current activity is in the fields of scientific and business computing where the requirements are markedly different from those in command centers). Similarly techniques for creating and manipulating a data base which is under the control of many people are in an early stage. In this regard, size of the data base is not the paramount problem--many computerized files used in business today are considerably larger (i.e., contain more information) than those which would be useful to military commanders in the foreseeable future. The real problem is one of giving many

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people access to overlapping sub-bases without causing chaos and attendant lack of communication. In the area of hardware which handles the data base, the need for modularization (which allows easier integration and interchangeability of components) is only beginning to be realized. Finally, the long-range goal can be achieved only after extensive experience throughout the military on the proper use of automation as an assist to command.

But even if a complete realization of the ideal is impossible at this time, the ideal does highlight many of the shortcomings of presently planned command L-systems; it also suggests steps which could be taken immediately, within present technology, to correct these problems. Basically, the present command L-systems depend too much on long lead-time procurement of hardware; they do not consider sufficiently the growth of a data base under command of the military. Often the evaluation of these systems by agencies responsible for approval and funding is similarly biased. For example, in many reviews of the 465L SAC System, it has often been stated that the system does not take missiles into account and may not be even needed for the missile force. Such statements often do not distinguish between:

- (1) Provision of adequate communication between missile bases on the various SAC headquarters and
- (2) Adequate continuing consideration at SAC headquarters on how and when missiles can be used as part of a mixed-weapon strike system, many elements of which are not SAC's responsibility.

The second question should be answered first. It is a very difficult question whose answer will change from year to year. Evaluation of the need for the system after 1963 should ask whether the system will help SAC, USAF, and JCS to answer this question; not ask what the answer is.

Let us consider now some of the specific shortcomings of the present program for command L-systems. In a typical, admittedly worst-case situation, the plans for the L-systems include the sudden and simultaneous introduction of all new hardware (computers, display, communication, etc.) a new data base (fully grown) and new facilities (offices and a hole in the ground) after a lead time of three or more years. The operational computer programs which make up a good part of the data base are prepared by contractor programmers under the occasional guidance of the military at the headquarters. (The military can't be blamed; they have problems and jobs today and the promised breakthrough is many years off.) Even though the system will not be fully operational for four or five years, the design of the operational computer programs probably reflects a command model only one or two years in the future. Also,

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the computer programs mechanize presently understood manual solutions or problems; they do not aim to help the command discuss its problems and try out completely new procedures and plans. Finally, since the command has few ideas regarding L-system plans at adjacent commands and JCS, there is little emphasis in the system design process on organizing and preparing the data base so that it can assist intercommand communication in the future.

As a result, the "worst case" command L-system does little to help operational command capability before the operational date of the L-system; the cutover problem from manual to L-system operation is so slighted that command operational capability may actually degrade during the transition; the new system will often be so complex that the command will spend years learning the new system (which may be out of date), rather than learning how and where to change a more modest system.

The following design principles can be applied today to improve operational command through automation:

First, each command should apply automated communications and data processing through successive phases so that capability and understanding can be built on previous command experience. Initially, the command relies on teletype and voice communications, manually plotted displays and paper records. Then, the command may start to use computers and programs for such functions as plan generation and evaluation, force assessment, and direction, exercising and war gaming. Also the command may add automatic display devices, possibly driven by computers, or digital communications within the command or to and from adjacent commands. During the early phase of introducing automation, all hardware items are off-the-shelf at the time of procurement and may have a planned useful life of only one or two years (many are leased). As the command gains experience in the use of automation, hardware components and standards are planned for a longer and longer useful life so that capabilities for communications, display, and data processing can be individually expanded, or replaced with more up-to-date off-the-shelf equipment, without disrupting operations. Each of the phases acts as a foundation or starting point for the next phase. The cutover problem of adding or replacing hardware is carefully considered in order to insure continuous growth rather than disruption. The rate at which automation is introduced will vary between commands as a function of the nature and importance of the command function and the growth in capability achieved by the command with its present automation. A command need not necessarily reach an advanced stage of automation, but if it does this advanced capability should be based on some earlier experience with data processing assistance. For example, if a hardened computerized center is planned for NORAD in three years, then transitional experience with automatic data processing should be

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scheduled much earlier. (Even if the long lead-time center is not included in today's plans, the transitional phase might be desirable.)

Whenever hardware that does not have readily expandable capabilities is scheduled for a command, then initial plans for using the hardware should leave ample spare capacity; only 20% to 50% of the available capacity should be used at first. Unfortunately, procurement and budgeting often require justification that all the capacity is critically required. Therefore, the designer includes a proposal requiring all the capacity initially, and functions included in the proposal soon become requirements. In the case of command data-processing there should be a requirement that a very minimum of 50% spare capacity be reserved for immediate growth.

It is often felt that a single, integrated, computing system should be used throughout a command for all its operational command functions, i.e., that standard communication facilities, displays, and communication and programming languages should be optimally combined in a single system. In most cases, this goal seems far off at this time; the technology for building such a system and also satisfying other requirements such as adaptability and early availability is not sufficiently developed; also, some commands have already established mixed systems of computers and communication which represent sizable investments. On the other hand, it is important that all phases of adding automation provide for a "capping" or commander's system which acts as a staff cutting across the organizational lines of operations, intelligence, materiel, and plans wherever these functions support operational command. The depth of the capping system must be limited by available technology but also be such that highly detailed processing is not incorporated in the command's capping data base. For example, one should be cautious about including satellite cataloging or processing of raw MIDAS data in the NORAD commander's system. Also, it must be made clear to designers whether they are working on a commander's system or a deputy's system. Is 465L a system for the Deputy of Operations or a CINC system; if the latter, then intelligence, materiel, and plans functions must be integrated in the data base.

Although it is impossible at this time to satisfy fully the requirement that the military should design and police the data base, there are many steps which can be taken with available techniques to insure a much heavier participation by the command itself in data base design. The most important has been implied already; the early, increasing use of automation by the command in a capping system. As successive phases of automation are introduced, the command staff and the command organization grow with the system and their experience determines its growth. Another important step is the development of operational translators which are within the state of

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the art and the early use of them by command personnel in a command situation. Since a requirement for these tools has never been stressed in L-system design, the little progress to date has depended on the initiative of the system programmers. An example of an area where such tools could be most profitably used is storage design, inputting of data, and generation of reports and displays. Instead of giving the command fixed format displays selected by number, part of the command function (in peacetime) would be the design of proper displays during or after exercising. Another step is more participation of the command personnel in the design process. As suggested above, it is questionable whether adequate participation of appropriate command personnel can be achieved unless the material being designed will go operational in much less than three to five years. A final step is the early development of tools and procedures for simplifying design changes and shortening the design change lead-time. Since the value of a command system depends heavily on the adaptability of the system, we must be ready to invest enough to insure that the system (particularly the computer programs) can be readily and quickly modified.

Finally, design of command systems should include capability for the discussion and evaluation of performance and the development of command language. Many of the needs we have mentioned above will contribute to this requirement; early, gradual use of automation, provision of a capping system, and military command of the data base. In addition, the inclusion of models, gaming, and other exercising tools as parts of the system is essential. Too often, models and games are considered the province of the non-military system developer or evaluator rather than a possible part of the command process. A model can be most valuable only when its prediction of results can be compared with live or semi-live operations and exercises. If there is a discrepancy, the model should be fixed; where there is agreement, confidence in the model is higher so that it can then be used to investigate performance under many other conditions and threats, to suggest alternative procedures which would improve performance, or as part of a bigger model. This is particularly significant when we consider that models can represent not only the command's force structure but also the enemy capabilities (as viewed by intelligence or operations or plans), the command organization's capabilities for commanding, and its interaction with adjacent commands or higher command. Many such overlapping models can be developed in a command, and then compared within the command or with another command. These models should be sufficiently aggregated that they can be operated often under a wide range of conditions or in concert with other models. Unless the natural tendency to include every detail in a model can be curbed, a giant model which can never be verified or used will result.

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6. INTEGRATION OF SYSTEMS

One of the major problems given the Winter Study Group was the possible reconfiguration of L-systems to achieve greater integration. For command or headquarters systems, integration can have at least three distinct meanings:

First, by technical integration we mean emphasis on the use of a common communication system; and at each command on use of similar computers, displays, communication switching equipment and programming languages. For example, a SAGE-like system could be designed where each headquarters would have a center adapted to its individual needs. (An extreme form of technical integration would use common computing and display facilities for several commands.)

Next by functional integration we mean emphasis on insuring that all operating command functions are clearly and appropriately assigned to the commands, that the commands coordinate their plans and communicate actions with one another as required for mutual support and overall effectiveness, and that a strong higher command provide overall direction of forces and management of change.

Finally, by integration for survivability we mean interlocking of primary command centers so that any single surviving center in a network of several command centers could perform all the post-strike functions of the several commands.

Any one of these integration aims is compatible with the others. On the other hand, it is important to distinguish these aims since each presents its own requirements and they are not all equally feasible or desirable at this time.

Technical integration can be desirable because of economy and because it may facilitate functional integration by easing communication and simplifying future realignment of roles. On the other hand, the Winter Study Group does not believe it is desirable at this time to formulate a definite design for a "single command system" because:

(a) There is a wide variation between commands in investment in automation, understanding of automation and need for automation.

(b) Overall operational and technical needs are not sufficiently defined. All the services and all the commands would be involved in defining these needs if they could be defined with present experience.

(c) Premature application of technical integration would delay early realistic growth of operational effectiveness at individual commands.

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Although technical integration is neither feasible nor desirable in the immediate plans for strengthening individual commands, it is important that DOD, USAF, and the other services start as soon as possible to establish long-range goals and coordinated development plans that will make it more possible in the future.

Fortunately, the absence of technical integration at this time is not at all critical. The use of different computers, different communication standards and different programming languages can be easily accounted for at fairly small costs. If the attendant problems are recognized early in design, steps can be taken to connect systems where necessary.

The Winter Study Group feels that functional integration presents a much more critical problem. Functional integration is almost wholly absent between presently planned command L-systems and between these L-systems and those command headquarters which are supported by other services. Functional integration is clearly an evolving process, but significant improvements are possible.

First, greater functional integration depends on strengthening operational command at individual commands. As soon as possible, both early assistance and longer range command system programs should be planned for all commands as appropriate to their individual needs and progress. These plans must stress a capability for each command to express its plans and estimated performance to adjacent and higher commands. Initially, the individual command plans can be only broadly coordinated by JCS, service headquarters, and development agencies such as ARDC.

Next, the JCS command center must be greatly strengthened in successive phases so that it can give appropriate direction to subordinate commands based on feedback it receives from these commands. A stronger JCS command center is a vital element in insuring inter-command communication and coordination of war planning and force direction.

Finally, it is recognized that service headquarters command centers will probably play a significant role in a JCS command center. On the other hand, the more that service headquarters command centers are strengthened in the absence of greater strengthening of a central, service-independent, JCS command center, the more we will continue to weaken operational command.

Let us take an example which illustrates all three of these points. Hq. USAF has expressed a requirement for a two-sided, two-way model of a general war, that is, a model which includes U.S. offense and defense and Soviet Union offense and defense and all interactions. (Needless to say such a model can have many outcomes

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depending on initiative, strategy employed, degree of strategic and tactical warning achieved, etc. All these variables must be incorporated in the model.) For such a model to be valuable in force planning, war planning, exercising, and force direction, it should be sufficiently aggregated to be operated often under a wide variety of situations and time periods, and its users must recognize its limitations. Equally important, the value of the model will depend on how much it helps JCS and the individual commands to understand their own capabilities and to communicate with each other.

The model must include warning, U.S. offense, U.S. defense, U.S.S.R. offense, U.S.S.R. defense, U.S. strategy and decision procedures, etc. That is, it must include: Strategic warning and BMEWS, DEW, MIDAS; SAC and other manned aircraft, Atlas, Titan, Polaris, Minuteman and overseas IREM's; air defense and missile defense (or the absence of them). Almost all the unified or specified commands and many other intelligence and support agencies must supply submodels of the model; the overall model is clearly a JCS responsibility. Inevitably, the submodels will overlap and sometimes be inconsistent; one of the purposes of the model is to find gross inconsistencies. The model will need continuous policing; exercise will demonstrate that portions of it are not realistic; new forces and new plans will require modifications.

The complete incremental costs of preparing and maintaining such a model for general war operations should be in the vicinity of \$2 million to \$20 million per year, a cost above and beyond what individual commands, service headquarters, and JCS already do in this regard. In other words, the total costs over five years should be significantly less than the cost of any individual command system or a single SAGE center.

One can have very genuine doubts as to how effective such a model will be---one can find out only by investing a little money and trying it out. On the other hand, this investment is certain to be wasted if one has too high hopes (the model is an aide, not an arbiter), if responsible commanders are not involved or do not support and use the model, or if the model is so detailed that it cannot be operated often.

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7. PLANNING AND MANAGING SYSTEM DEVELOPMENT

Up to now, we have considered the problem of operational command and the role of automatic communications and data processing in assisting the headquarters command function. We have concluded that operational command is a continuing management problem, that the command personnel must take the initiative in designing the plans and procedures of operational command, and that automation can be of some assistance if appropriately and gradually applied under command of the headquarters. What is the role then of development agencies such as ARDC and AFCCDD in implementation of command systems?

The project-office/prime-contractor procedure which has been used by the USAF for the development and procurement of major weapons and electronic systems is not sufficient for command systems because:

(a) It provides technical assistance to the operational commands during the phase of major hardware installation only. Actually, this assistance is usually required on a continuing basis; first when modest data processing assistance and analysis can provide the most benefit, then when requirements for major hardware improvements are being formulated (before a contractor can be selected), and finally long after the installation of the major hardware improvement (when the command is growing its data base).

(b) The contractor who provides technical assistance for the headquarters command system cannot fully consider or appropriately influence the impact which operational command must have on the design and deployment of those weapons, control, and sensor systems which feed into the command system. Project offices for these other systems are on an equal footing with the Command System Project Office.

(c) Since the contractor support is limited to a specific hardware configuration for a limited period of time and has not been involved in earlier work with the command system, there is not enough feedback between the requirements expressed by the command and the designs proposed by the contractor; the flow from requirement to design is almost unilateral. In the worst case, approving agencies such as DOD and USAF are faced with a very general statement of requirements, the GOR, and a parts list, the design. It is difficult to feel confident that the GOR and the design will match.

The establishment of the Hanscom complex with strong, continuing technical support for AFCCDD can do much to remedy these shortcomings.

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Before considering the nature of the roles of development agencies in more detail, let us consider the development context in which AFCCDD and the using commands will operate. Many agencies are involved in supporting the command system needs of JCS, the unified and specified commands and the component commands: Department of Defense, JCS, the services, and the using commands. In the foreseeable future, the services will be responsible for development, procurement, installation, and maintenance of the hardware portions of command systems even though the unified and specified user commands may have equal representation from two or three services. For example, the USAF is supporting the NORAD Command Center at present; the Navy is supporting CINCPAC. This arrangement is workable, but:

(a) The need for on-going technical support to the operational commands must be clearly recognized and the responsibility for supporting individual commands must be assigned to one of the services.

(b) The using command must accept and start to use the technical support on an on-going basis well before the situation calls for a long-range super-system.

(c) A stronger, service-independent JCS command center must be established with its own technical support so that it can act as an on-going focal point for functional integration.

(d) A JCS plan for integration of all operational command systems must be gradually established and maintained. The plan must be sufficiently broad to recognize different approaches by the services and different requirements by the commands. It must be sufficiently specific to generate useful guidance to development agencies and using commands on integration and interface problems. Generation of such a plan will require participation of the service headquarters and development agencies under the aegis of a JCS staff.

Such steps cannot be accomplished overnight, nor by ad hoc committees. They require continuous effort by properly manned, recognized agencies.

Within this context, let us consider AFCCDD's consultant role to the using command. In order to perform this role, AFCCDD must continuously analyze the command mission and the attendant operational command problem. Mission analysis considers the projected mission and force structure of the using command and results in a family of performance models for successive time periods and different contingencies. The major input to AFCCDD mission analysis will come from Hq. USAF, WSEG, using commands, other development divisions in ARDC, other service development agencies, RAND, and others. Command analysis considers the organization, information processing and command systems needed to realize the performance

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models for mission analysis. Needless to say, this should not be a unidirectional process from force to mission to command; the results of command analysis should feed back to weapon system design and force composition. For example, the design and deployment of a tactical warning system such as BMEWS is heavily dependent on who will use the data and how he will use it.

System analysis in support of the present L-systems has generally not been based on a foundation of broader mission and command analysis. As a result, it is often only a tool to detailing design rather than a bridge between broad goals and implementation. Using a continuing command analysis as a basis, AFCCDD and the using command could periodically and jointly prepare a command system plan for the headquarters function. This plan should cover a period from the present up to ten years in the future; it should discuss, where possible, capability criteria and designs for successive phases of data processing assistance; costs and time schedules; interface problems with other commands, including those for which the USAF is not the responsible support agency; and plans for operational experiments at the commands. If such joint planning had been performed in the past, then AFCCDD would be able to assist the using commands in preparing realistic and meaningful GOR's for command system hardware.

It is crucial that such command plans be jointly prepared for all commands which the USAF supports. It is not sufficient to wait until a need is felt for the super command system. The collection of all command plans, which cannot properly be called a master plan, serves many purposes: It should assist JCS and Hq. USAF with functional integration and master planning; it should suggest budgets and schedules for command system hardware; it should guide, and be guided by, a development program for future command system components--computers, communications, displays, and programming tools.

AFCCDD's consultant role to the user command should not consist of analysis and planning only. When the time comes to apply automation, AFCCDD should guide the procurement of equipment and computer programming tools and it should help the command to install and use them. Experience in these implementing roles is a major input to AFCCDD's continuing help to the command, to other commands, and to the development process.

In its development role for command systems, AFCCDD should plan and manage a development program which results in on-the-shelf components for command systems: Displays, computers, communications, input-output devices and programming techniques. Development planning for these components should indicate needs and standards for families of components which will satisfy the overlapping requirements of individual commands. AFCCDD's most unique responsibility

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is to see that development planning and command planning support each other. Success of such a development program will depend on close cooperation between AFCCDD and the other services and with non-military users since USAF requirements do not in themselves provide a broad enough base for developing a catalog of on-the-shelf equipment.

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8. RESEARCH AND DEVELOPMENT FOR COMMAND SYSTEMS

Finally, we consider some of the elements of the research and development program that must be undertaken to improve future command systems.

Perhaps the most important factor to be recognized in this regard is that our present capabilities to build hardware components for use in systems is well beyond our knowledge of how to assemble these components into efficient systems. While over the past few years we have learned something about computers, displays, and automatic communications as separate devices, we must obtain an increased understanding of basic information processing before we can either handle the interactions between these elements or compose these elements into fully effective command systems.

For example, in the design of a command system there is a critical, but largely unexploited, tradeoff between computer capability at central locations and computer communication capabilities between locations. Similarly, tradeoffs exist between machine hardware and computer programming, and between the role of men and the role of automation. This lack of knowledge with respect to information processing exists because the field is extremely new, cuts across classical engineering specialties, and has not developed top-level experienced specialists. Consequently, the first essential element in a research and development program for command systems is basic work to develop the theoretical foundations of information processing.

The second major requirement in a research and development program in connection with command systems is in the equipment area. Increased sophistication in components (communications, displays, computers) is not the urgent need; what is required is the development of standards for tying such components together, and modularity in design so that the capabilities in command systems can be expanded and improved without disrupting operations. This latter development should then result in families of expandable computers, display devices, input devices, and communication devices such that the information processing centers of future command systems can be designed by using individual items of equipment from these families which can be easily integrated into a system.

The third important element in a research and development program for command systems is the conducting of operational experiments in an operational environment. Such experiments should seek methods of using automatic information processing to solve specific operational problems, but these experiments should not be directed merely to the development of prototype systems for particular commands. More important, in every case these experiments should attempt to develop and improve automatic techniques that can be used

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in various fashions by many commands. For example, one capability particularly needed for some command systems is the development of a strategic attack language so that detailed war plans can be generated by computer programs that are given only very general inputs on the nature of enemy defenses, possible attack strategies, and the tactics to be used by both sides. With such a comprehensive language, it would then be possible to generate and evaluate many alternative strategies within a short time. An experiment to develop such a language (which could be used by the military) might be undertaken at SAC, but any such language would be extremely useful to JCS, Hq. USAF, and other unified commands which have a strategic attack mission.

The fourth element that should be sought in research and development programs related to command systems is the development of a command center technology. How do command centers operate? What is the proper role for men and machines? How can operational personnel properly direct automatic portions of the system? How do command centers grow in a command environment? How can large data bases be created and manipulated so that the data base can be controlled and exercised by many operational personnel?

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CHAPTER III: CONCEPTS FOR CONTROL AND SENSOR SYSTEMS

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CHAPTER III: CONCEPTS FOR CONTROL AND SENSOR SYSTEMS

In the previous section, we indicated that the distinction between command or headquarters systems and control and sensor systems is both meaningful and necessary. It is useful to note that both control and sensor systems are imbedded deeply in the physical environment of forces, resources, and technical facilities, whereas command systems are imbedded in the military organization and its command personnel. In this sense then, the properties of control and sensor systems are affected chiefly by the design parameters imposed on them and by the physical environment in which they will operate, rather than by the command structure which will use them. Control and sensor systems are loosely coupled to the military organization in that a change in the system is not necessarily reflected in a change in the command organization. In this light we will address the problem of the design and implementation of control and sensor systems without reference to the organizational structure which will use them.

The role that control and sensor systems have in the total command and control spectrum is shown in Fig. 2. As a matter of definition, we distinguish a number of points in the areas which

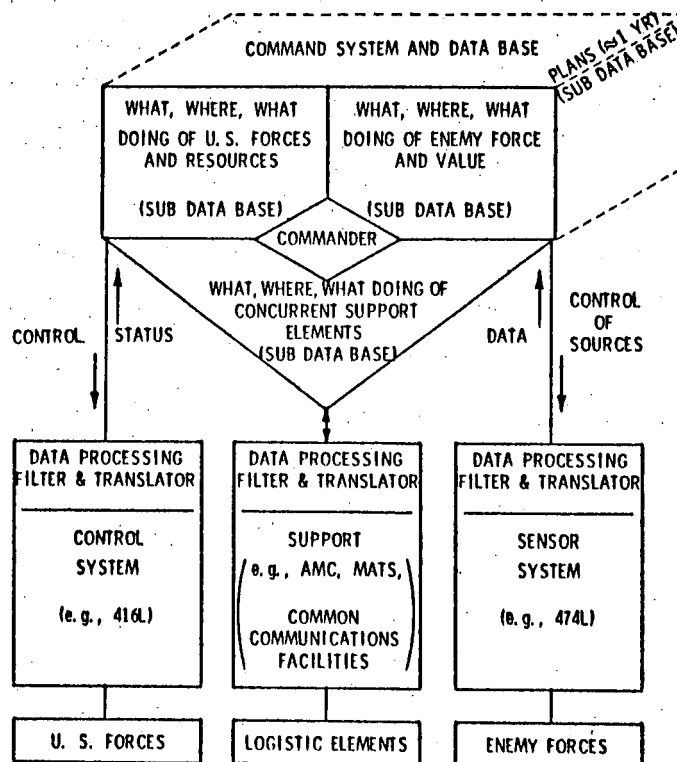


FIG. 2 THE ROLE OF CONTROL AND SENSOR SYSTEMS

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control and sensor systems cover and the manner in which they are used. Both control systems and sensor systems have elements of command, control, and sensing facilities within them, although any single control or sensor system is oriented toward one end objective, that is, control of the forces of a command or collecting data on the enemy for a command. In most cases, a sensor system will collect data for many commands and agencies, and so will have multiple outputs. In these cases, sensor systems may be concerned not only with operational command, but also with the support and intelligence functions. In most cases, a control system will control the forces of only one command and so will be responsive to only that command. Within a command, filtered operational information flows from its control systems and sensor systems to the highest command level where command is exercised over its forces and resources in being. Control systems, such as 416L SAGE and 412L Theater Air-Weapon Control, and sensor systems, such as 466L ELINT-COMINT, 117L SAMOS-MIDAS, 474L BMEWS, and the proposed 496L Space Track, are representative of these types of systems.

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1. PROPERTIES OF CONTROL AND SENSOR SYSTEMS

In developing a set of design and implementation concepts for control and sensor systems, it is useful to distinguish a number of general properties of these systems which are common to both types and which differentiate them from command systems, realizing that these distinctions and properties cannot be true in all cases.

(a) The cost, complexity, and time availability of control and sensor systems are highly sensitive to the operational requirements and parameters which are imposed on their design. For example, the cost of a space surveillance system can vary from about \$500 million to \$3 billion depending on the initial detection time for new satellites that is imposed as a requirement on the system. In this example, the detection times are 240 minutes and 10 minutes, respectively, after launch.

(b) The cost, complexity, and time availability of these systems are also highly sensitive to their vehicle or sensing element characteristics (e.g., reliability, coverage, accuracy, resolution) and to the degree of control and coverage the system must exercise as an operational requirement. For example, with respect to reliability, the cost of a satellite intelligence-data-gathering system can vary from about \$1.2 billion to \$2.5 billion, depending on the useful lifetime of a satellite which varies from 50 weeks to 12 weeks, respectively, before it must be replaced. These numbers apply to a system where 26 satellites (18 for SAMOS and 8 for MIDAS) must be maintained continuously in orbit to meet operational requirements for coverage. Fig. 3 illustrates the cost sensitivity of the system as a function of satellite reliability and the probability of successfully orbiting a satellite.

(c) Strategic and tactical doctrines impose a first-order effect on the technical configuration of these types of systems. The degree of survivability, response times, level of control, mobility or transportability, etc., that are specified for a system can affect the cost, complexity, and time availability by an order of magnitude. For this reason, the strategic and technical doctrines under which these systems will operate must be well understood before a useful configuration can be formulated. (Ref. Chapter I.)

(d) Most of these types of systems are characterized by high costs, that is, a fixed amount of money, usually large, must be spent before any operational usefulness is derived from the system. Of the total money required for the presently planned 16 L-systems through 1965, about \$7.5 billion is required for the sensor systems, about \$2.5 billion for the control systems, and only about \$600 million for the command systems. In the sensor system area, e.g., in

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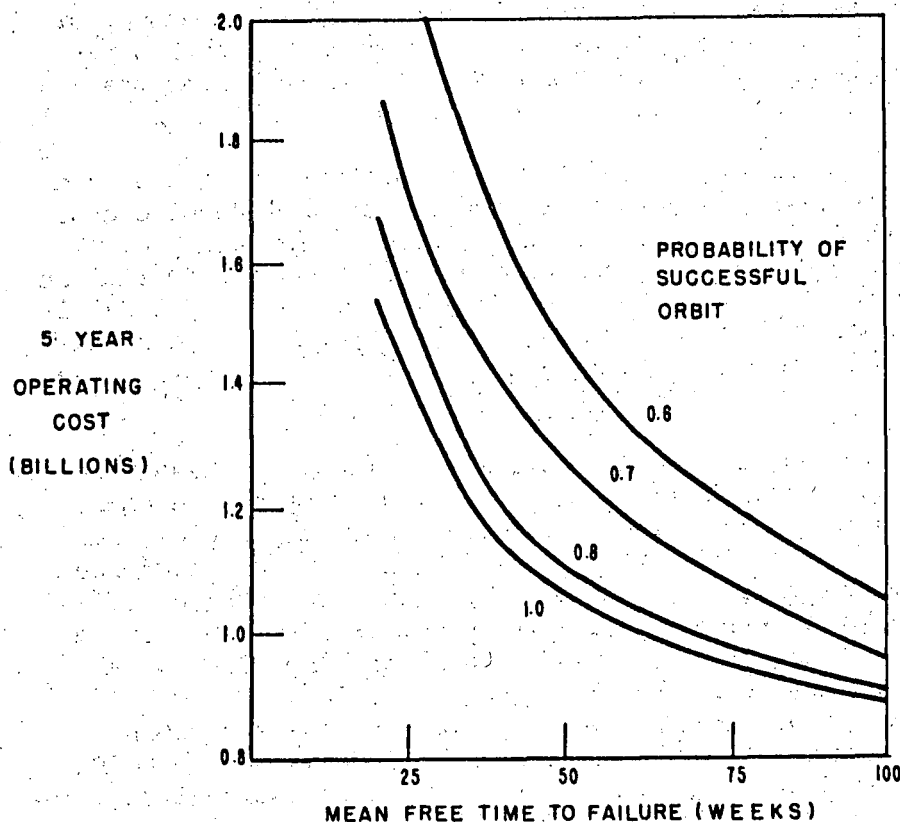


FIG. 3 COST SENSITIVITY ANALYSIS, MIDAS, SAMOS

496L and 117L, only about 10% of the cost and 25% of the military manpower will be used for the command data-processing function and the remainder for the equipment and its maintenance and operation.

(e) Because of their unique operational objectives, control and sensor systems are not usually implemented in an evolutionary manner (i.e., with planned growth) but are implemented in their entirety at a time which is oriented toward specific objectives, such as control of a particular weapon system or collection of warning data on a particular threat. For this reason, these types of systems usually have long lead times, little post-operational growth,

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and more susceptibility to obsolescence compared to command systems. Facilities provided in these systems for expandability usually result in longer lead times and obsolescent systems, if treated as a free commodity for improvement in the operation of the system in its current objectives, rather than being held in reserve for future requirements.

(f) Control and sensor systems are much more dependent on the technical state of the art than command systems. This factor tends to result in uncertainties in the technical configuration of the system, thereby continually compromising operational objectives and parameters and budgetary allocations.

(g) Control and sensor systems are usually functionally oriented, rather than command oriented. That is, they usually perform functions oriented directly toward operations or intelligence or logistics, rather than toward the integrated command task. For this reason, the aggregate language with which these systems converse with command systems must be compatible with the overall command language or data base as specified by the command, which implies that the functional relation of a control or sensor system to the overall command mission must be well understood before the tasks which the control or sensor system must perform can be formulated.

(h) The overall operation of a force designed for a particular mission must be studied before the desirability of a particular configuration of a control or sensor system for that force is designed and developed. The 412L system for TAC is an example of a system where this factor was not considered adequately. The use of the 412L system in Combined Air Strike Force Operations would require more than 60% of the transport capability available to TAC for a particular mission. Such limitations tend to obviate the universal use of a system such as 412L for both fixed installations and mobile or air-transportable applications. In addition, even after being transported, the 412L system might have to operate in an area where logistics support (fuel, etc.) would not be available to the aircraft 412L was designed to control and defend. Thus, logistics and tactical factors outside the scope of 412L tend to make it superfluous in some cases.

(i) Lastly, the complexity of these types of systems and their dependence on the state of the art usually result in a need for an extensive research and development program and a test bed before the operational configuration can be formulated. This factor usually delays the integration studies and experiments that must be performed with respect to the use of such a system in a command. The uncertainties in the technical configuration of a system result in operational plans for its use which are changing

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continually and which fail to realize the potential capabilities of the system before it becomes obsolete. An example is the current lack of time to develop tested plans for the integrated use of BMEWS, MIDAS, intelligence data, bombers, and missiles in various strategic situations. More emphasis, then, is needed on how commands will use the data from these systems to balance the emphasis placed on the design of their technical configurations.

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2. DESIGN AND IMPLEMENTATION CONCEPTS

In conducting our study of the planned control and sensor L-systems, we have formulated five broad lines that should be pursued in their design and implementation. The applicability of these concepts to the planned L-systems has been reflected in the comments presented in Sections 3 and 4 of the summary of this report and Chapter IV.

(a) System analysis based on a foundation of broader mission and command analysis must be performed to bridge the gap between broad goals and detailed design and implementation. This system analysis must include adequate cost/time/effectiveness studies and must be part of an effort of on-going technical assistance to operational commands in planning, exercising, and evaluation. We discuss in Section 3 of this chapter an example of the type of system analysis that is needed as a part of operational planning by analyzing some requirements in the area of space surveillance.

With respect to cost analysis, we believe strongly that an appropriate means of accomplishing effective military system planning is to measure the trade-off possibilities of three important variables: (1) the relative effectiveness of alternative system configurations; (2) the relative time required to achieve the mission objective under each alternative; and (3) the relative cost consequences of each alternative in terms of available resources. It is important that each of these items be treated as a variable.

Three specific types of cost analysis are required to accomplish the above: (1) total force-structure costing; (2) group L-system costing; (3) individual L-system costing, including the cost sensitivity of a system to changes in the system's parameters, e.g., satellite reliability. This cost-analysis methodology is treated in detail in Winter Study Report No. 16, the Cost Panel Appendix to this report, and in summary in Chapter V, and some examples are given below. Such a cost analysis activity must become an integral part of AFCCDD's work in command and control systems and in its support of the planning done by the using commands.

(b) Research and development programs with long-range goals that are tied to a broad base of strategic objectives are needed. These programs would support component subsystems applicable to a mobilization base which can be used to assemble systems in accordance with the strategic objectives of the time. This approach offers the only hope for the reductions needed for changing strategic situations in lead times and obsolescence of systems. Research and development of components and techniques should not be tied to a particular system being implemented for a particular strategic objective, but alternative developments should be pursued on items and techniques which may be required for a variety of future

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strategic situations. For example, although a mobile control-center system may not be needed as an integral part of our strategic facilities today, the fact that we may, with medium confidence, need it five years from now should result in a development program which would allow us to mobilize such a system in relatively little time. Alternative approaches should not be ruled out on the basis that they do not fit into today's strategic objectives.

Many examples in the control and sensor area can be given of items and techniques that should be developed because they may be needed in the future, e.g., hardened phased-array radars; common-user communication systems; message-switching communication centers; hardened, low-bandwidth, backbone communication systems; mobile and hardened control centers; shock-resistant computing and display equipment; computing, sensing, and communication equipment applicable to mobile use; special types of intelligence data gatherers, etc. Such a development base would allow systems to evolve in a planned-growth manner and would reduce the technical uncertainties in operational planning. Also, general research and development in technology by the USAF should be guided and stimulated by the needs of control and sensor systems as it now is by the needs of weapon systems.

(c) Directed assignment of a system to a single operational command should be made as soon as possible for any system which is necessary to the operational command function and which will be used by more than one command. The increasing complexity of these systems and the problem of maintenance that this complexity implies tend to allow these systems to pose as much of a threat to the command mission if they become inoperative as the threat that enemy forces pose. One way to alleviate this situation is to allow the principal using command to operate and maintain a system which other commands also need and to direct this principal user to make available those facilities and data required by the other using commands.

Examples where this principle could apply are 496L Space Track and a common-user ZI communication system that might evolve from 480L. Since both of these systems are essential to the operational command function, they should be assigned to an operational command as soon as possible so that the necessary planning, exercising, and evaluation with respect to command missions can begin and the maintenance and operations doctrines can be developed. Technical people should not function as independent designers and operators of such systems.

(d) On-going, operationally oriented studies must be performed to formulate and determine: (1) the strategic and tactical doctrines and situations under which these systems will be used; (2) the relation of the control and sensor system requirements to other

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requirements (e.g., logistics) concerned with the overall operation of a force in particular situations; (3) the manner in which data from control and sensor systems will be used by the command and what alternative actions can be taken in the event of system failures; and (4) realistic reliability and survivability requirements which strike a balance between peacetime and wartime needs and allow for the exercising of these systems under both of these conditions. (Ref. Chapter 1.) Because the control and sensor system area offers much more challenging problems in the technical state of the art than the command system area, the emphasis has been much too strong in concentrating on the technical configuration of systems without reference to the operational context in which the systems are to be used. Assistance to the using commands from government agencies and industry has therefore been strong in the technical area only; AFCCDD and others must provide assistance to the using commands in all of the above areas.

As an example, much of the current work on control and sensor systems is implicitly pointed in the direction of instant reaction to warning of attack, resulting in an emphasis on elaborate and redundant sensor systems, high-capacity data-processing systems and highly reliable, high-data-rate communications and displays. Some effort should be placed on more austere and survivable systems that can work with a survivable force and that are exercised during peacetime as a part of the normal operation of a command.

(e) Adequate functional integration of control and sensor systems within a command and between commands must be emphasized, rather than technical integration. This emphasis is required in three areas:

- (1) The data processing hierarchy from the sensing elements themselves back to the command system must reflect a communication language of increasing abstraction which can culminate in a common correlation of data at the command from many systems. In many instances, most strikingly in the intelligence area, great effort and costs have gone into collecting large amounts of information and relatively little effort and money has been spent on integrated data-processing techniques and facilities to process and use the data. Also, little functional integration has been achieved between intelligence data and operations data. Because of the nature of the intelligence problem, much data must be collected since little can be done in the way of selecting the data that is to be saved and correlated. However, because different types of intelligence systems are implemented separately, little effort has been placed in planning a common data base or in planning for the common correlation of data at a command. In fact, because no precise or common language exists within an intelligence area or between

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different intelligence areas, it is almost impossible to apply automatic data-processing techniques for filing, retrieving, and correlating data from many sources in a reiterative manner. The Winter Study Group's Special Studies Panel has proposed that a first step in alleviating this problem would be to provide a single, integrated, intelligence-data-processing system containing two channels. The first channel would have a fast response and would handle all data that is critical to the operations function (e.g., warning data, damage assessment data) and which must be made available at once. The second channel would handle data concerned with long-term capabilities of the enemy and by its nature would have a slow response. The next step would be to formulate an organization of data processing facilities that would extend from the sensors to the users and which would contain a precise communication language of increasing abstraction and provide a common data base throughout the system.

(2) A means for communication from the command to its sensing elements must be provided which can implement a method of dynamically controlling the operation of the sensors from the command in accordance with the existing operational situation. No sensing mechanism or system which has much inertia in adjusting the commitment of resources is adequate for warning or intelligence. Resources must be able to be committed rapidly to obtain more information on a particular situation seen at the command headquarters. Data from intelligence systems (e.g., from the fast-response channel mentioned above) should be observed and compared with a data base that would include operations data, and then a model or hypothesis suggested by the data should be formed. In principle, the correlation process should not look for missing data, but rather suggest a test that would support the hypothesis or model of what the missing data consisted. This principle, then, would require some method of dynamically controlling sensor operation.

(3) The design and implementation of the sensing vehicles themselves, such as satellites and ground-based gatherers, and the communication systems must be done in a context which considers the functional integration of these elements with the data-processing facilities and the procedures of a command. In many cases, a proper match is not made between the ground-based data-processing functions and the communications and sensors. Profitable tradeoffs may be realized if response times and bandwidth and reliability requirements of communications are determined in a context which considers the data-processing function of the system. Here, switching methods present the most pressing technical problems. The real cost of high-bandwidth communications is the amount of people and data-processing equipment

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and programming needed to process and evaluate the data, not the cost of the communications themselves. The traffic control center (TCC) of the 465L System is the first example, however unsophisticated, in any of the L-systems where an integrated and functional approach was attempted in considering sensor, communications, and data-processing requirements of the system.

One of the ways of facilitating functional integration of the above elements is the use of common-user communication systems. Here, priority schemes can be built into the system which prevent everything from being assigned an urgent priority under overload conditions. Also, reliability can be achieved through use of alternate routing and different kinds of links.

Lastly, unless communications can be assured all the way back from the sensors to the command, operating doctrines must be changed to account for unscheduled breakdowns. Possible delays in the system must be planned for in the design of the decision-making process and doctrines. For example, it is not enough to say that a system must perform with a certain response time. If this response time cannot be reliably achieved technically, then the doctrine must be changed.

Consideration of the above from a management point of view results in the conclusion that AFCCDD should assume responsibility for the functional and subsequently the technical integration of sensing systems such as 117L and should guide the design of the command data processing portions of these systems in conjunction with the using commands.

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3. SYSTEM ANALYSIS EXAMPLE: SPACE SURVEILLANCE SYSTEM

In order to illustrate the concept of the cost/time/effectiveness study in the analysis of operational requirements and technical system configurations the area of space surveillance has been selected as being representative of sensor systems. The analysis as presented below treats only the sensitivity of time availability, cost, and effectiveness to changes in operational parameters for space surveillance. It is intended for illustrative purposes and is not a Winter Study Group recommendation.

A system is postulated for performing the functions of ICBM warning and space surveillance with maximum time to initial detection of 4 hours for new satellites and an ICBM warning capability of 15 minutes. The system is to have the capability to track space objects at altitudes to 2500 miles. Due to the predicted growth of the satellite population and the development lead time for surveillance system components, consideration of requirements is divided into the 1960-1968 and 1968-1975 periods. The system as postulated is for the 1960-1968 period. It uses existing components and is evolutionary with respect to the number of satellites it must catalog, the range of ICBM's it must detect, and component improvements.

3.1 Conclusions and Recommendations

Conclusions and recommendations resulting from the analysis of space surveillance system requirements are:

(a) Satellite surveillance and warning against ICBM attacks could be provided by a combined system. Care must be exercised in setting operational parameters since cost and time availability factors are highly sensitive to changes in these parameters.

(b) The cost of a system for satellite surveillance only is significantly less than that for the combined system, although the cost of a combined system is less than that for separate systems to do each task.

(c) The high cost of a combined ICBM warning and satellite surveillance system (about \$2.5 billion) using a surface radar network should stimulate studies in two areas: 1) new approaches other than surface radar systems to perform the same task, and 2) broad strategic studies as discussed in Chapter I to determine the value of such warning to our strategic posture and the tradeoff that might be achieved by buying more survivable forces.

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3.2 System Description

In the 1968-1970 period the system would consist of:

- (a) The three northern BMEWS sites currently under construction,
- (b) Five additional sites to be used for ICBM warning against missiles launched from any direction and for satellite surveillance with a maximum initial detection time of four hours,
- (c) A satellite tracking site in southern Texas to obtain precise orbit parameters, and
- (d) An operational center in the U.S., possibly at NORAD, with data-processing capability.

The radar sites would surround the continental United States in a manner which provides for 15-minute warning of a ballistic missile attack. The operational center would exercise operational control over the system, receive warning of ballistic missile attack from the radar sites, and transmit the warning to appropriate agencies and commands.

The system's satellite-detection function would operate as follows: Crude calculations would be made at any of the radar sites upon detection of a satellite to see if it is contained in the current satellite catalog. For old satellites, acknowledgment of the sighting would be made to the operational center. For new satellites, the orbital parameters would be reported to the operational center where they would be entered into the satellite catalog. Whenever a satellite passed over the Texas site an accurate orbital parameter would be computed and transmitted to the operational center to be included in the satellite catalog. Periodically, the updated satellite catalog would be transmitted to each of the radar sites.

(a) Radar Sites

The locations of the radar sites would be as follows:

	<u>Approximate Locations</u>	
Thule, Greenland	BMEWS northern sites currently under construction	
Clear, Alaska		
Fylingdsdale, United Kingdom		
Site 1 - Trinidad	60°W	10°N
Site 2 - Galapagos Islands	90°W	0°N
Site 3 - Marquesas Islands	140°W	10°S
Site 4 - Azores	30°W	40°N
Site 5 - Hawaiian Islands	155°W	20°N

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The present BMEWS system seems reasonably adequate for the threat against which it is designed. The setting of a raid threshold criterion is still a subject of study. However, since false alarms due to natural causes will soon be evaluated, and false alarms due to unfiltered satellites will be negligible until a considerably larger satellite population is present, the problem is not urgent, particularly since the solution will most probably lie in computer program modifications rather than in new heavy equipment.

At each of the five new sites there would be three AN/FPS-49 radars, two of which would provide 2-fan coverage for the detection of space objects while the third would scan 180° vertically from horizon-to-horizon, east to west, then 360° in azimuth looking near the horizon. The cycle would be repeated at a rate of 10° per second. This scan mode would be interrupted from time to time to track individual targets for approximately 15 to 30 seconds each in order to calculate orbital parameters.

Based on the characteristics of the AN/FPS-49, the overall probabilities of target detection per pass using one radar are shown below. Calculations are for polar circular orbits. Inclined orbits should result in better detection, because of longer time in coverage with non-transverse crossing of the fan.

Over-All Detection Probability

<u>Orbital Altitude</u>	<u>Per Pass</u>
Fan 2000 nm	80 per cent
Detection 1000 nm	60 per cent
Disc 650 nm	96 per cent
Detection 100 nm	86 per cent

In addition to the three AN/FPS-49 radars, each of the five additional sites would contain data-processing equipment roughly equivalent in speed and capacity to that now being installed in the northern BMEWS sites. Monitoring displays would also be necessary.

With these eight sites in operation it should be possible to obtain at least 15 minutes warning of an ICBM attack against continental United States, together with an 80% probability that any satellite would be detected within a maximum of four hours after launch. In Fig. 4, we present a curve showing the number of sites required as a function of this detection time. The lower curve applies to the case where satellite surveillance only is to be performed, while the upper curve is for both satellite surveillance and ICBM warning.

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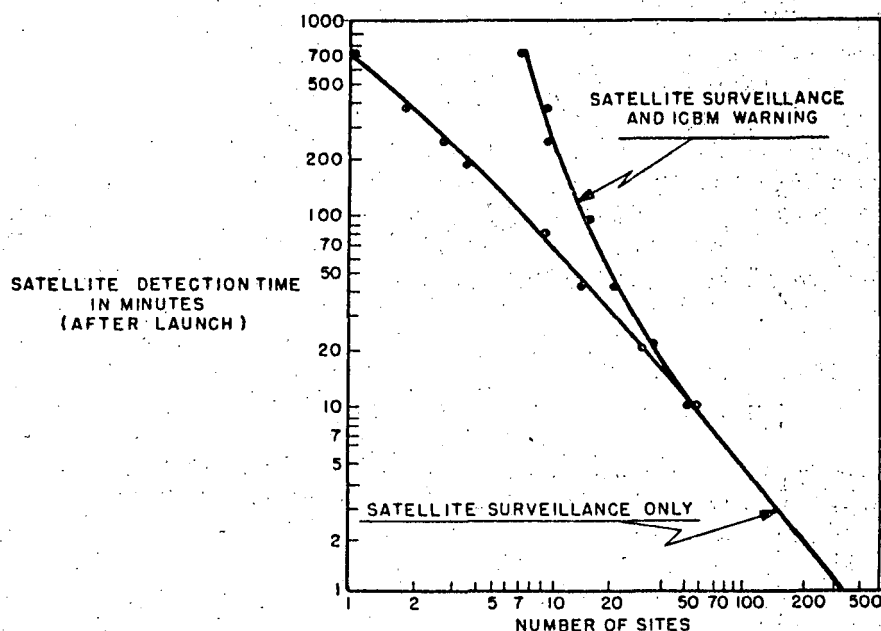


FIG. 4 NUMBER OF SITES REQUIRED FOR GIVEN SATELLITE DETECTION TIME

(b) Satellite Tracking Site

The satellite tracking site in southern Texas would be used for more precise determination of orbital parameters and for periodic updating of these parameters. Initially, one FPS-49 at this site would be sufficient to handle the satellite traffic. More radars could be added at future dates as the number of satellites increased. Since these radars are to be used only for tracking known satellites, no scanning is required. When a satellite passed through radar coverage, a track of from one to five minutes would be obtained, enabling precise determination of the orbital parameters.

In addition to the radars, this site would require a substantial amount of data-processing equipment (probably something equivalent to a duplexed 7090) and numerous display facilities.

(c) The Central Facility

The major pieces of equipment required at the central facility would be large-scale, data-processing equipment and

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numerous displays. Appropriate voice bandwidth communication facilities to all other sites would also be required. Communications must also be maintained to all other agencies and commands interested in satellite surveillance and ICBM warning information.

3.3 Cost Analysis

Fig. 5 is a schedule for site implementation showing the buildup of system capabilities as a function of time. We note that after early 1965, the system would be complete except for "system improvements." The screen against ICBM's approaching from the south would be completed and high-power radars to give us warning against ICBM's with greater apogees would be needed. ICBM's from the south are not considered a threat before this time, not because boosters will not be available earlier, but because the necessary accuracy will probably not be attained.

The cost of the system excluding BMEWS is about \$2.5 billion. The dotted curve in Fig. 6 indicates the cost if both requirements were implemented separately.

Figs. 7 and 8 illustrate the cost sensitivity as a function of the detection probability and altitude coverage requirements which are set on a system to do satellite surveillance only. In each case, the costs would double at the 240-minute detection point if the requirements were increased from 0.8 to 0.95 probability of detection and from 2000 miles to 2300 miles altitude coverage. This is because the radar system used in the analysis is operating at its peak performance on the lower curves and new and more radars would be required to achieve the higher performance figures.

Fig. 9 illustrates the cost sensitivity as a function of maximum detection time for new satellites for a system which does satellite surveillance only. The costs shown on this chart, as well as on subsequent charts, include site installation and investment costs, annual operating costs for five years including personnel pay and allowances, and communications and data-processing systems. The point on the curve for a detection time of 240 minutes shows a cost something less than \$500 million for a system with three sites in addition to BMEWS, each with only one radar since the coverage requirements are much less stringent than if the site were to function as an ICBM warning site also.

Fig. 6 repeats the same curve as Fig. 9 at the bottom of the chart and adds the cost sensitivity curve at the top of the chart for the combined ICBM warning-satellite surveillance system described above. In the latter system there would be five sites, each with three radars, in addition to BMEWS to provide full ICBM coverage as well as 240-minute detection of new satellites.

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DATE	SITE IMPLEMENTATION	PHASE	SYSTEM CAPABILITIES				
			Coverage of Continental U.S. Against ICBMs Arriving From:			Satellites	
			North	South	Any Direction	Detection Time (from Launch)	Accuracy of Orbit Estimation
Jan. 1960							
Jan. 1961	← ZI Site (BMEWS) ← Thule (BMEWS)	1				12 hours	Poor
Jan. 1962	← Clear (BMEWS) ← Trinidad Central Facility ← Galapagos Is.	2	2/3	1/3		10 hours	Poor
Jan. 1963	← Fylingdale (BMEWS) ← Southern Texas	3	2/3	2/3		7 hours	Good
Jan. 1964	← Marquessa Is.		Complete	Complete		4 hours	Good
Jan. 1965	← Hawaiian Is.		Complete	Complete	Complete		
Jan. 1966	System						
Jan. 1967	Improvements						
Jan. 1968							

FIG. 5 TIME PHASING AND SYSTEM PERFORMANCE OF PROPOSED ICBM WARNING AND SATELLITE SURVEILLANCE SYSTEM

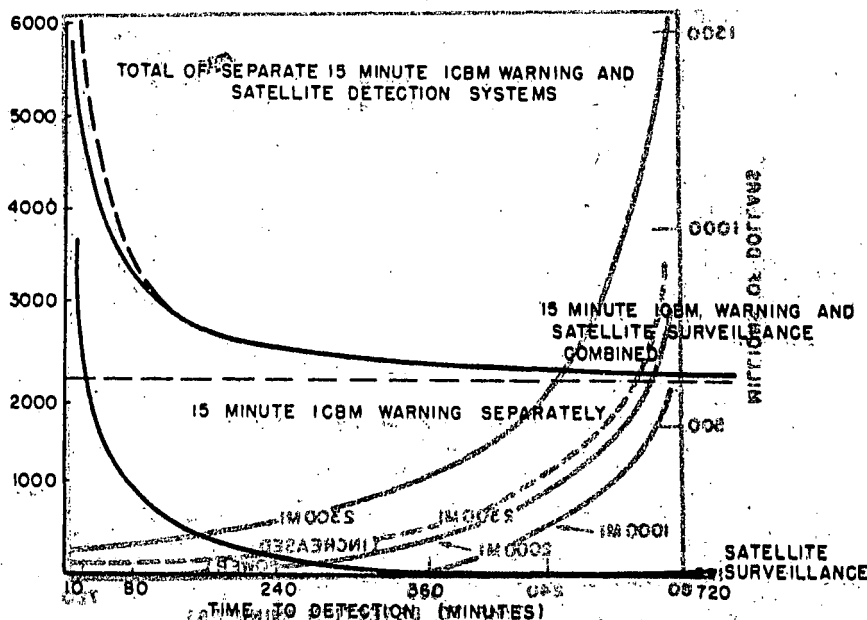


FIG. 6 SATELLITE SURVEILLANCE & 15 MINUTE ICBM WARNING SYSTEMS (0.8 PROBABILITY OF DETECTION - CIRCULAR ORBIT)

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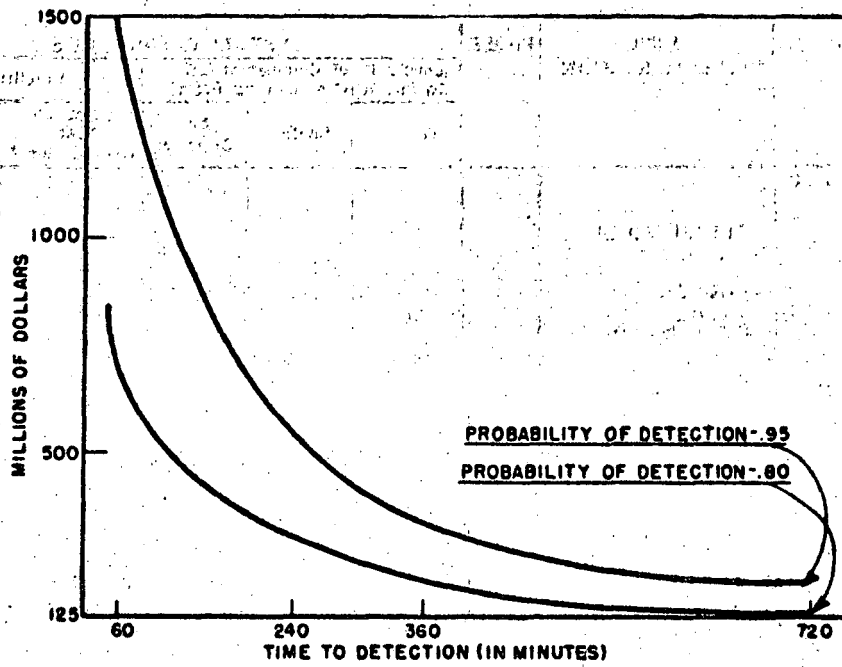


FIG. 7 SATELLITE SURVEILLANCE SYSTEM
(CIRCULAR ORBIT)

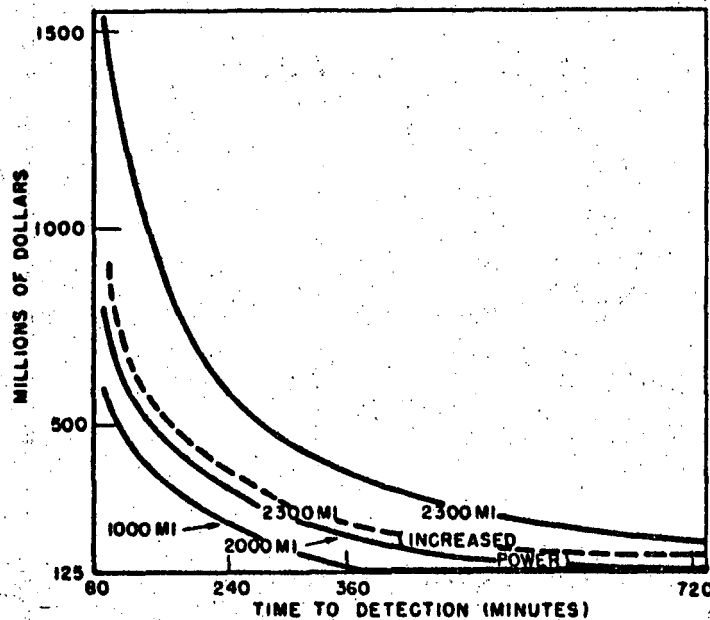


FIG. 8 SATELLITE SURVEILLANCE SYSTEM
(0.8 PROBABILITY OF DETECTION - CIRCULAR ORBIT)
BASED ON NUMBERS OF RADARS

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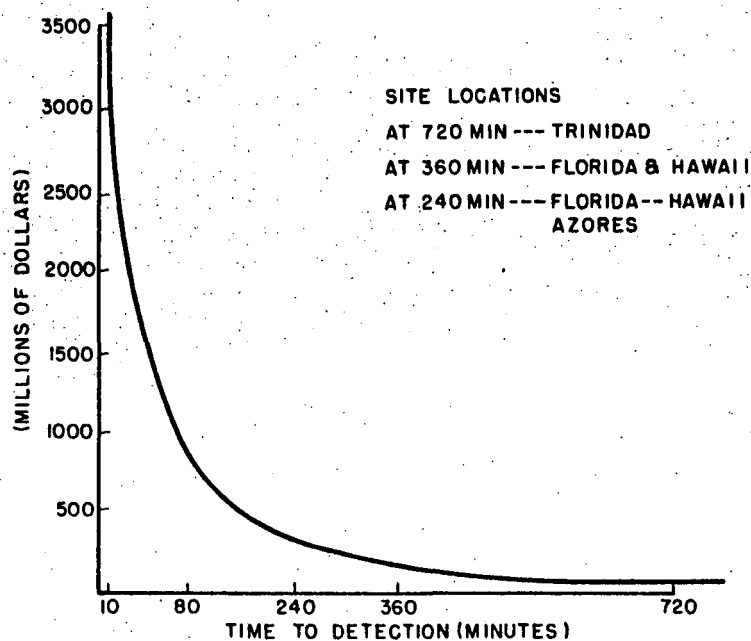


FIG. 9 SATELLITE SURVEILLANCE SYSTEM
(0.8 PROBABILITY OF DETECTION - CIRCULAR ORBIT)

CHAPTER IV: RESEARCH AND DEVELOPMENT RECOMMENDATIONS

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CHAPTER IV: RESEARCH AND DEVELOPMENT RECOMMENDATIONS

The recommendations summarized in this section for research and development activity related to the L-systems are focused on achieving those new capabilities that are considered to be both reasonably achievable in the foreseeable future and especially necessary to increase the performance and economy of command, control, and sensor systems. These recommendations result from the work of the Specialty Panels and do not necessarily include all areas of future research and development required in connection with command and control systems. Many of the improvements suggested herein probably can come into existence from some redirection of research and development programs already under way or from more or less normal advances in the state of the art in particular fields. Other needed techniques and components, such as cost analysis methodology, data-processing procedures, and human performance in highly automated systems are related to technical areas so new and unexplored that, unless special emphasis is given to their development now, it is likely that many of the realistic operational requirements of L-systems will remain unsatisfied. Additional details concerning the research and development programs described in this section, as well as specific recommendations for improvement to the components of particular L-systems, are to be found in Section 4 of the Summary, in Chapter V, and in the Specialty Panel Reports that form the appendixes to this report.

1. COMMUNICATIONS

Considerable research and development work in the field of communications for L-systems is already in process. The Winter Study Group considers, however, that some additional effort should be expended to obtain as soon as possible:

- (a) devices for reducing existing "non-electrical" communication times, e.g., the delays in the flow of a message from human originator to electrical transmitter, electrical receiver to electrical transmitter when humans are involved in message relaying, and electrical receiver to intended human user of the message;
- (b) survivable facilities for low-volume supplementary communication between command posts (fixed, mobile, and airborne) and between command posts and weapon facilities that are reasonably invulnerable to intensive harassment during a cold war and to nuclear attack;

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- (c) flexible, economical circuit and message-switching apparatus that can handle a high volume of digital and analog data, operate with a variety of message formats, and recognize transmission errors;
- (d) non-time-consuming methods to obtain message security, even with switching errors, in a common-user communication network that carries both high-security and unclassified traffic;
- (e) techniques to permit effective policing and control, by appropriate authority, of communication priority;
- (f) standards for communication apparatus that will allow the implementation of a common-user network, but at the same time not inhibit the application of advances in the state of the art to that network.

2. COST ANALYSIS

Proper military planning constantly involves the selection, within the resources and schedule constraints of particular courses of action, that will maximize the effectiveness of the total force. Cost analysis is a technique for determining the implications of resources on the possible courses of action and vice versa. With respect to the L-systems, however, no adequate methodology exists now for determining the total initial and recurring costs of these systems or for analyzing the variables in these costs in relation to

- (a) measures of system effectiveness, and
- (b) time needed to achieve various degrees of improvement in operational capability.

Fully effective management of the L-systems cannot be achieved until a methodology for system costing is developed and intensively used in making decisions, both within a given system and between the family of systems. Accordingly, a program is recommended specifically directed toward achieving techniques for analyzing the costs of L-systems that will lead to the establishment of an adequate methodology.

3. DATA PROCESSING

The equipment now available or planned for the near future in the field of data processing is numerous and well advanced. Over the next five years, normal improvements in the state of the art for computers will probably result in machines 100 times faster than those available today. Consequently, the Winter Study Group is of the opinion that additional emphasis in the area of computer equipment is required to develop only:

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- (a) modularity and the flexible interconnecting devices to allow the necessary addition of computing capacity to L-systems without reducing the usefulness of previously devised computer programs and operating procedures,
- (b) specific machine organizations to permit the use of processes that search for patterns to determine the existence of complex relationships in the data, and
- (c) a theory to relate machine characteristics to data-processing requirements to facilitate the selection of command and control system equipment.

The associated area of processing procedures, unlike computing equipment, is virtually unexplored. To meet the minimum needs for command, control, and sensor systems during the next ten years, a great amount of research and development effort must be started immediately and continued in:

- (a) higher-order programming languages,
- (b) utility support programs,
- (c) tools for program testing,
- (d) methods of understanding and communicating program organization,
- (e) procedures for automatic indexing, file interrogation, and information correlation,
- (f) operational translator programs,
- (g) techniques for modeling and simulation of subsystems and complete systems,
- (h) application of modeling and simulation to design analysis, program testing, and system testing and evaluation,
- (i) use of linear programming, dynamic programming, game theory, general decision theory, and Monte Carlo methods for war gaming, allocation of resources, etc.,
- (j) role and relationships between men and computer program complex, and
- (k) the effect of a highly automated data-processing environment on human organization and decision-making.

4. HUMAN FACTORS AND DISPLAY

Present research and development programs appear to give little emphasis to the increasing need for basic information on the performance of humans in teams within large, highly automated command, control, and sensor systems as opposed to the performance of an operator of a piece of equipment. Accordingly, it is the opinion of the Winter Study Group that a considerable effort should be applied to the following human factor areas without delay.

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(a) Effect of Change on Total Performance: The sudden introduction of large quantities of equipment, highly automated procedures, etc., (i.e., the introduction of a new data-processing system) is known to reduce operating effectiveness of an existing organization for an appreciable time. On the other hand, it is also contended that a continuing series of much smaller changes to equipment and procedures may cause as great or greater deterioration in total performance than a single large change. Some experimental literature is now available concerning the effects of large and small changes in industrial organizations; much further work is needed in this general area to determine the consequence of various kinds of change on command, control, and sensor systems and to develop the training and other techniques necessary to reduce the deleterious effects of changing these military systems.

(b) Human Communication in Networks: Experimental and pragmatic observations of humans in communication networks show that the effectiveness of communication between humans is greatly affected by the configuration of the network. Much more experimental work must be undertaken, however, before this effect of network configuration on human communication can be properly related to the design of large command, control, and sensor systems.

(c) Human Intervention: Human operators handle messages before electrical transmission and following electrical reception. Human operators establish the priority rules for message transmission and then violate these rules. Very little is known now but much systematic knowledge is needed of why and how human operators in large command, control, and sensor systems influence the flow of communications and of what can be done to retain the desirable characteristics of these human operators without having them seriously degrade the planned communication function.

(d) Level of Data Abstraction: Too high a level of abstraction of data may cause a human in a system to misunderstand or doubt the validity of the information being presented. An example is when a human reacts negatively to a conclusion simply because he does not feel he knows the evidence upon which the conclusion was based. On the other hand, too low a level of abstraction of data leaves to the human in a system the often impossible task of analyzing, classifying, and filtering the data to extract the required information. Research and development programs leading to principles governing the proper level of abstraction and to techniques for filtering, coding, and classifying data are urgently needed.

(e) User Participation in the Design and Implementation of Automatic Data-Processing Procedures: There is a continuum of ways for users to participate in the design and implementation of the data-processing aspects of command systems. At one extreme, user

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personnel might be selected and trained to undertake the entire task. For example, some personnel would be selected so that they will be trainable as computer programmers, and then trained so they are computer programmers. This course of action would require research into how to select and how to train computer programmers. At the other end of the spectrum computers and utility programs might be designed so that a system operator could talk to a computer in English and thereby instruct the computer to perform the required work. In between, intermediate languages could be developed, and used by command personnel, or command personnel could be trained to specify at some language level their requirements so that a professional programmer could code the program. Which option to choose in this spectrum is not clear. Both the selection of an option and the implementation of that option would seem to require considerable research and development.

(f) Effect of Stress: It has been recognized for years that the ineffectiveness of a human is a U-shaped function of environmental stress. A little stress is a good thing; too much stress causes deterioration and disruption of effective human behavior. In the centers of the hardened and isolated command, control, and sensor systems of the immediate future, all that the human operator will know of the "real world" will be highly unreal. The raw data of reality will have been sensed, filtered, and processed by means the operator cannot fully understand. Everything the operator receives from the outside world can be simulated and not be a "real world" event at all. In undergoing training, the operator could be made to think that he is fighting a total war and then suddenly find out he was only shadow-boxing in preparation for such a war. The operator's uncertainty as to what the real-world situation actually is will be increased continually as he is trained. His hunger for real-world data and his suspiciousness of the credibility of the data flowing within the system may give a new, completely unanticipated dimension to the effect of stress on human behavior. A thorough investigation into these phenomena is strongly recommended.

5. SENSING EQUIPMENT

The numerous facets of the sensing equipment field seem to be receiving, at present, the majority of the funds expended by USAF for research and development in connection with components for use in the L-systems. The Winter Study Group believes, however, that the following aspects of work in sensors should be re-examined by USAF to insure that the level of on-going activity is and will remain appropriate to the increased demands being made on sensors as a result of the rapidly changing nature of the threat from air-breathing to missile-satellite weapons.

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(a) Electromagnetic Propagation: In relation to radar surveillance and tracking, a continuing requirement exists for information on the effect, over a wide range of frequencies, of aurora, Faraday rotation, galactic noise, atmospheric fluctuations, nuclear detonations, and artificial ionization.

(b) Electromagnetic Target Characteristics: Although large amounts of money are being spent for air-target reflection studies, some additional development may be needed in polarization matrices for target discrimination, interaction of electromagnetic energy with plasma, relative contribution of vehicle areas to target reflectivity, and bistatic reflection of widely separated frequencies. More data is needed over the whole range of the electromagnetic spectrum on the specific radiation and reflection characteristics of nose cone and booster plumes.

(c) Radar Transmitters, Modulators, and Tubes: Notable developments in these components are presently in progress, but achievement of the high powers and large bandwidths that are necessary characteristics of modern radars remains difficult. The efficient coupling of rf structures is not readily obtained; increased attenuation of spurious signals is needed to reduce interference. The generation of high power at millimeter wavelengths is a complex problem. Consequently, research and development programs should be encouraged to provide new and more reliable techniques for overcoming these problems.

(d) Radar Antennas: Because of the potential advantages offered by phased arrays with respect to rapid scanning, control of beam, and power-handling ability, further effort should be devoted to 1) understanding the theoretical properties of such arrays, 2) developing more stable components, 3) designing automatic controls for beam positioning and scanning, and 4) operational testing of representative prototypes. Also, considerably greater emphasis is needed on research and development programs for antennas that can better withstand the effects of nuclear blasts.

(e) Radar ECM Vulnerability Reduction: Despite the recent advances in this area, which offer grounds for increasing optimism over the performance of surveillance radars in the face of ECM, a continuing research and development program will be needed if USAF is to maintain the dynamic anti-jamming capability necessary to anticipate extensions in the countermeasure art.

(f) Advanced Radar Concepts: Advanced radar concepts should continue to receive vigorous research and development support. Before undertaking costly programs, however, unconventional radar techniques that impose severe requirements on the basic components or on data-processing methods should be carefully analyzed to determine their technical feasibility and operational utility.

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(g) Advanced Radar Concepts: Advanced radar concepts should continue to receive vigorous research and development support. Before undertaking costly programs, however, unconventional radar techniques that impose severe requirements on the basic components or on data-processing methods should be related to improvements in system configuration leading to reduced effective background noise. From near infra-red through visible and ultraviolet and shorter wavelengths, photoelectric detectors are now available which have much greater sensitivity than other photo detectors and thermal detectors available for the longer wavelengths. Research is desirable to develop systems which can use these more sensitive detectors.

(h) Optical Sensors: Susceptibility of optical systems to resolution deterioration because of thermal and mechanical effects presently places a significant limitation on optical and infra-red sensors. A research and development program to overcome these difficulties is recommended.

(i) Vehicle Stabilization: Vehicle-borne sensors are sensitive to the stabilization of the vehicle, and positional accuracy of targets is dependent upon this stability. In spite of recent advances, deficiencies in satellite stabilization still impose serious limitations on the sensors being carried. An accelerated program is needed to develop and test reliable techniques for precisely stabilizing the attitude of orbiting satellites.

6. VULNERABILITY

Command, control, and sensor systems and their components, are vulnerable to a great variety of man-made and natural phenomena including such diverse items as nuclear blast, electronic countermeasures (ECM), and other deleterious effects. In principle, vulnerability can be reduced by sufficient design effort; the problem is, however, to achieve the greatest survivability for the least effort.

The Winter Study Group believes that a research and development program related to vulnerability should be directed toward a) feasibility and value of mobile control centers, b) ECM-resistant techniques for detecting and tracking aircraft, missiles, and satellites, c) nuclear-blast and radiation-resistant electronic and optical hardware, d) nuclear-blast and radiation-resistant structures, e) chemical, biological and radiological (CBR) sensors and collective protection facilities for command and control centers, f) rf instrumentation for measuring and controlling electromagnetic interference, and g) maximizing the performance of command and control systems which have been degraded or partially destroyed.

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CHAPTER V: RECAPITULATION OF SPECIALTY PANEL STUDIES

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CHAPTER V: RECAPITULATION OF SPECIALTY PANEL STUDIES

Approximately three-quarters of the manpower available for the Winter Study Group was assigned to twelve panels, each of which studied one of the following subjects related to the design and implementation of command, control, and sensor systems.

1. Communications
2. Cost
3. Data Processing
4. Design Methodology
5. Display
6. Logical Concepts
7. People
8. Sensing Equipment
9. Special Studies
10. Threat
11. Vulnerability
12. Weapons

The appendixes to this document are the reports of these panels. These reports do not, in all cases, represent a unanimous view of the panel members; nor does the Winter Study Group, as a group, endorse all of the ideas expressed. Nevertheless, there is a strong thread of common understanding that supports the overall conclusions of the Winter Study.

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1. COMMUNICATIONS

Two main communication functions exist in a command and control system: (1) the transmission of information from one point to another; and (2) the switching or interconnection of transmission facilities for communication between points. Demands on communication systems will vary in volume, kind and method of transmission for different degrees of peace, cold war, or hot war. Information used by a command and control system is collected from many sources, both remote and nearby. After collection and sometimes filtering at the sources, the information is transmitted to one or more central points where it is distributed, i.e., switched, to its destination, often a computer that reduces the information for use in a command post. This processed information and commands based on it are then disseminated.

In general, the Communications Panel has concluded that efficiency will be greatly reduced if the present trend continues to be followed, that is, developing individual communication systems to serve the individual needs of specific command and control systems. The panel recommends instead that an integrated communication system be developed whose switching and transmission facilities can be shared by all points requiring communication. Such a system should emphasize common-user operation and should take the form of an evolutionary development, beginning as soon as practical with available facilities. Advantage should be taken of advances in the art as they occur, and a gradual transition should be made from present equipment to the common-user system. Such an evolutionary approach is both necessary and feasible.

In wartime and under conditions of communication harassment, vulnerability will be the major problem. It is not expected that the full communications required can be maintained in the face of enemy action. It is recommended, therefore, that supplementary, highly invulnerable, backbone communication facilities be set up to maintain the more basic command and control systems in time of crisis. At the same time, it will be necessary to devise command and control procedures that will be able to function with the minimal communications that would likely be available under conditions of severe attack.

1.1 Communication Problem Areas

One of the most striking aspects of proposed command and control systems is the sheer quantity of communication capacity being demanded. The method used to establish requirements is partly responsible, and both peacetime needs and national custom will tend to work against obtaining much reduction in the communication capacity now being sought. Yet, a serious danger is inherent in having

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large communication capacity in a command and control system in that, if the users of the system become so dependent on the transmission of large quantities of data, the command and control system will break down organizationally when the flow of data is curtailed, as it is certain to be during a crisis. Pre-planning of operations and exercising of the command in peacetime, but with restricted communications flow, is of greatest importance if this pitfall is to be avoided.

Today, the slowness with which commands are conveyed and implemented is incompatible with the decreasing time scales imposed by modern weapons. Technical communication elements enter into the picture, and much is being done to cut down communication delays caused by faulty communication trunks and inefficient use of them. However, it is not universally recognized that most of the delays occur during the non-electric communication time, i.e., from human originator to electrical transmitter, human intervention at relay centers, and from electrical receiver to human decision-maker. Neither is it generally recognized that people are the major source of message error.

Of even more concern is the problem of communication vulnerability. There are two situations of importance: (1) harassment during a cold war; and (2) destruction during nuclear attack. There is no single L-system, as presently designed, that can be expected to have much capability in the face of an all-out attack.

During a critical cold-war period, overseas communications can be seriously impaired by enemy action, short of war, such as cable cutting and HF jamming. The Greenland tropo link can reduce this vulnerability to transatlantic communication, but there is no immediate prospect of reducing similar vulnerability in other areas. The "Needles" orbital scatter technique, if feasible, may provide a reasonable amount of resistance to jamming and covert destruction.

During a period of mass nuclear attack, it is unlikely that the amount of communication required for operation of complex command and control systems will survive. Communication facilities are needed that "decay gracefully" under attack, that is, have the capacity to continue operation by selectively reducing the less important communications and processing operations as the damage increases. It does not appear that systems that would suffice over a wide range of degradation can be realized. Instead, the panel recommends that supplementary, highly invulnerable, backbone (note: backbone not backup) communication facilities be provided to maintain basic command and control functions. A complete common-user network is not contemplated, but rather a few low-speed facilities capable of working between hardened or mobile command posts and the surviving weapons. The choice of particular facilities will depend on the type

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of command post; portable tropo with small antennas would be preferred for mobile ground posts, UHF for airborne posts, and probably some form of VLF transmission for underground posts. A Needles system using small antennas may have promise. Backbone communications must be planned for in advance, and improvisation at a time of crisis cannot be relied upon.

It should be noted that the belief that communication destruction is seldom a profitable strategy for an enemy is false. A doctrine that enemy jamming of communications constitutes warning is equally false if the enemy uses any degree of skill.

Next to the question of whether and where the communication links exist and can survive, the method of switching is most important in large command and control systems. While flexible interconnection is one reason for switching systems, they also serve the important function of concentrating traffic on the transmission facilities so these facilities can be used efficiently and offer more alternate routings in the event of failure. Further, a switching system will also frequently incorporate storage and often code translation as an adjunct to data-handling. The principal problem in the area of switching is the tendency to design numerous communication complexes to meet the specific requirements of individual command and control systems. Subordinate problems in switching arise because of the tendency to seek large steps forward while deferring plans for the orderly transition from the present switching system to the new until the new system is well into the process of being implemented. A solution may be found in an evolutionary, common-user communication system using circuit and message switching for handling both data and voice. Such a system might be implemented in the immediate future, using existing or very near-future art, and be aimed at an orderly transition from present start-stop teletype equipment to the use of higher-speed, synchronous systems as justified by traffic requirements.

The need for assuring message security is an important limiting factor in switching-system design. Present plans are to encrypt all messages, link-by-link, for transmission over outside plant facilities, but to have messages pass through the switching centers in the clear. This plan minimizes some problems in encrypting that arise with end-to-end encrypting, namely, the need for widespread distribution of the key and the need for transmitting addresses in the clear to control the switching mechanisms. On the other hand, encrypting link-by-link leaves the message in the clear in the switching center, with the possibility that a high-security, clear-text message may be inadvertently delivered to someone not entitled to receive it. The present approach to solving this problem is by screening switching center personnel and by confining high-security messages to a special network within which an error in switching could not be as devastating as in a common-user system. There are

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in theory, however, a number of alternative ways in which security could be maintained in a common-user system, and the practicality of these alternatives needs to be explored further with the security services.

Priority communications are a scarce commodity that must be allocated by the command, and constantly monitored and disciplined, especially during crises. The present system under which priority is assigned by the user fails under conditions of crisis. Constant exercise of priority control under overload or degraded conditions is necessary.

The key to the general problem of communications proliferation, as with the more specific problem of control of priorities, lies in adequate policing from above.

Standards are necessary for individual parts of a system to operate together as a complete system. As the common-user concept develops, the need for standards increases because of the large number of users of such a system, its wide geographical scope, and the variety of signals and communication needs with which the system must cope. However, standards must not be established in such a manner as to inhibit progress, either by specifying standards in a way that would prevent the application of advances in the art, or by including within the specification requirements that are either not universal in need or cannot be met without an inordinate amount of development.

1.2 480L Communications Project

The broad objectives of the 480L project is to provide communications to meet all USAF needs. It is, therefore, the logical place to assign responsibility for planning a USAF common-user system. It also appears to be the organization for planning the hard-core communications necessary to maintain basic command and control functions during attack and to serve as an order-wire during restoration of the main common-user network.

The 480L project is new and as yet has not had a great impact on existing communications or on planning for command and control systems. A number of command and control systems which were started earlier expect to have circuits outside the U.S. obtained from the 480L network when established, but these systems are developing their own switching apparatus, since the switching for 480L is in a preliminary proposal stage. The panel recommends that planning for a common-user switching system should be expedited so that future command and control systems can build on the common-user concept wherever practical.

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While the Communications Panel feels competent to deal only with the technical and not the organizational factors of communication, it has observed a number of organizational problems in communications which should be resolved in the near future. For example, as presently constituted, the 480L ESSPO does not seem to have line authority to implement plans or standard procedures. Instead, this ESSPO operates largely in a staff engineering or advisory capacity. It is questionable whether the most efficient communication system will result under such an arrangement.

1.3 465L SAC Control System

SAC appears to be well aware that the 465L system as presently conceived may be expected to be mostly inoperable after a nuclear attack, partly because of communication vulnerability, but also because of vulnerability of the control centers. As a command and control system to prepare the strategic offensive force, 465L appears necessary and fairly well thought out. Large volumes of communication, data-processing, and display facilities are needed for training and controlling a manned aircraft force, but it was the panel's feeling that this volume might decrease as the ratio of missiles to planes in the force increases. Although the communication capacity of 465L appears to be most needed in connection with manned bombers, 465L planning appears to have gone insufficiently far in overcoming the problem of communicating with them, either on the ground or in the air.

In connection with 465L, AFBMD appears to be sufficiently concerned about protecting communications from the level of the missile launch control center downward, but the problem of survivable communications from the missile launch control center level up the chain of command seems to be in less satisfactory shape.

Development of the switching apparatus for 465L is nearing completion and any attempt to accomplish the objectives of the system by means of a USAF common-user system would only result in delays that cannot be tolerated because of the importance of the SAC need and mission. Instead, it is recommended that the 465L system proceed as planned, but with a tie-in to the common-user system when it becomes available. If economically feasible, provision should be made in 465L for handling administrative and logistics traffic from SAC bases, possible by teletype techniques where traffic load does not require high-speed terminals.

1.4 COMLOGNET

This system is also nearing completion and no purpose would be served by stopping the message-switching portion of the

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system, which is capable of expansion and has considerable flexibility, since it will handle teletype as well as synchronous binary data up to 4800 bits per second. This switching portion should be considered as a candidate for the prototype of a common-user system. The proposal for circuit-switching for the COMLOGNET system is too vague to determine whether it is a worthwhile adjunct of switching needs of a common-user system. The possibility of using other circuit-switching systems that are available or near completion needs to be looked into.

1.5 Other Command and Control Systems

The other command and control systems being planned should be designed, insofar as possible, to share a common-user communication system. The systems transmitting highly sensitive data, such as the 466L intelligence system, present special problems, since security must not be violated either by switchroom personnel or through inadvertent transmission of messages to wrong addressees. Solution to this problem is theoretically possible, but considerable study is still required and should be pursued vigorously by the contractor and the ESSPO concerned.

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2. COST

The Cost Panel established two primary objectives for its analysis of the costs of the L-systems:

- (a) Acquisition of background knowledge for general Winter Study use by costing one likely configuration of each of 15 L-systems for the 10 years, FY 1961-1970,
- (b) Initial development of unique methodologies for determining the cost of L-systems.

Subsequently, the Cost Panel concentrated on providing cost analyses related to specific activities within the Winter Study by: (1) furnishing cost information to the panels concerned with particular system configurations and analyses; (2) responding to individual requests from the specialty panels for cost information and similar assistance; and (3) participating in the formulation of general Winter Study Group recommendations.

The observations and conclusions of the Cost Panel result both from numerous visits to the ESSPO's, contractor plants, and a number of pertinent headquarters (USAF, ARDC, AMC, NORAD, ADC, and SAC) and from discussions with various groups within the Hanscom Field complex. The Cost Panel also found it desirable to extend beyond its specialty area, since the scope of the investigations to develop system costs required the adoption of a broad view of the L-systems and of the problems associated with their management, implementation, and operation. In addition, the nature of the analysis required an examination of all activity related to these systems, including personnel requirements, equipment, facilities, supplies, and the support required from USAF overhead commands, such as AMC and ATC.

2.1 Need for Cost Analysis in Military System Planning

The first major conclusion reached by the Cost Panel is that cost analysis is decidedly needed in military system planning. Military planning involves the continual selection of particular courses of action from available alternatives, selections that hopefully will maximize military effectiveness with the resources and within the time expected to be available. An appropriate means of accomplishing effective military system planning is to measure the trade-off possibilities of three important variables: (1) the relative effectiveness of the alternative system, (2) the relative time required to achieve the mission objective under each alternative, and (3) the relative cost of each alternative in terms of resources. However, for a complete system analysis these possible trade-offs,

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which exist only to the extent that the variables are independent of each other, need to be examined over the full practical range of the values of the variables. Cost analysis, the determination by methods of analysis of the implications of proposed courses of action on economic resources, must be an integral part of a complete system analysis.

The Cost Panel believes that three specific types of cost analysis activity needed by the Hanscom complex may be distinguished as:

- (a) Support of total force-structure costing,
- (b) Group L-system costing,
- (c) Individual L-system costing.

The force-structure planning of USAF involves the specification of the composition, deployment, and operational concepts for one total force for USAF. This type of planning, to be effective, requires the costing of many total-force compositions over several long periods of time and involves the costing not only of weapon systems and command-control-sensor systems, but all of the supporting USAF overhead activities, e.g., AMC, ATC, as well. The Hanscom complex should support the USAF force-structure planning by providing total cost data on systems for the proper exercise of the functions of command, control and sensing and criteria for the selection of an appropriate system mix for the various force structures considered in future planning.

Once a particular total force-structure plan is proposed by Hq USAF, the Hanscom complex should develop an integrated group of systems that will maximize the operational effectiveness of the total force, insure compatibility, avoid duplication, permit joint use of the facilities where appropriate, and provide proper time-phasing of personnel and equipment requirements. A cost analysis is required to support this activity.

The third type of major cost analysis activity required in the Hanscom complex is related to the individual L-systems. A capability to cost either alternative configurations of a given system, or alternative systems, is required. Cost sensitivity analysis can be a useful analytic technique for this type of analysis. In this technique, the sensitivity, or insensitivity, of cost to changes in the system's parameters is measured.

2.2 Present Cost Analysis Capability of the Hanscom Complex

The second major conclusion of the Cost Panel is that a sufficient capability does not exist today in the Hanscom complex to provide the previously described cost analysis in the L-system

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area. This conclusion is based on observations which show that the complex lacks four important elements necessary to an adequate cost analysis capability:

- (a) An organization with responsibility for the function,
- (b) Trained personnel,
- (c) An adequate data base,
- (d) Developed cost methodologies.

No specific organization within the complex appears to be charged with the responsibility for cost analysis, except as may be provided by the Program Office of Mitre in support of its line departments. The cost orientation of the ESSPO's, for example, is certainly not in this direction, but rather appears to be concerned with the budgeting and procurement processes. Neither of these existing orientations provides a complete system costing for even one configuration or employment plan of a system, much less for the range of alternative configurations or plans needed to perform cost analysis. On the contrary, the cost estimates reviewed by the panel were found to be related primarily to hardware and to operational installations, with much less regard for total personnel requirements and other required resources.

The Cost Panel also found no personnel in the Hanscom complex who can be considered fully trained in the complex field of system cost analysis. This does not imply, however, that there are not many people there, highly qualified in their particular field, who could not be so trained.

An adequate data base, giving the operational and technical parameters of equipment, is an essential part of a cost analysis capability. The initial development of such a data base is time-consuming, requiring as much as several years to accomplish. The panel did not observe any comprehensive compilation, much less analysis, of basic cost data on the resources required by L-systems. Only assemblies of a piecemeal nature were observed in most of the USAF offices visited, in contrast to the needed systematic and regular gathering and analyzing of the basic pieces of cost information from which time-phased system cost estimates can be prepared.

Finally, a series of cost methodologies must be established for the L-systems, one for each major class or type of L-system. The panel observed no such methodologies being developed at Hanscom. The panel has made some progress toward developing such methodologies, but it must be stressed that much research is needed before adequate methodologies can be developed.

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2.3 Other Comments

In addition to the preceding observations that the panel as a whole has reached, a majority, but not all, of the members have made other observations pertaining, in general, to the broad subject of L-system planning:

(a) Judging from the present status of the L-systems, planning has been uncoordinated and inadequate; the close relationship which should exist between L-systems, weapon systems, and other portions of the total force-structure has not been properly recognized.

(b) The development, implementation, and operation of future command and control systems will require an increasingly greater planning effort and an increasingly greater amount of the nation's resources.

(c) Current planning by ARDC and AMC is focused on problems of research, development, and implementation; insufficient attention is devoted to potential operational problems with these systems.

(d) Command and control systems are not generally programmed and budgeted as systems, but rather as individual items of hardware and installations.

(e) Many alternative configurations have been proposed for most systems; it is not always clear which configuration is the official plan authorized for implementation.

(f) Present configurations for command and control systems do not recognize that evolutionary changes or improvements to the systems will be required.

(g) Planning for the L-systems does not seem to be based upon sufficient study of the trade-offs available between cost, effectiveness, and time for alternative courses of action.

(h) Time does not appear to be treated as a variable, but rather as a constant in the process of evaluating L-systems.

2.4 Recommendations

The major recommendation of the Cost Panel is that a system cost analysis activity should be established within the Hanscom complex.

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Further, the Cost Panel recommends that:

- (a) The Hanscom cost analysis activity should be an integral part of the system planning activity.
- (b) Cost analysis should actively participate in a system analysis from the inception of the study.
- (c) The cost analysis activity should develop a capability in both individual and group L-system costing.
- (d) The system analysis activity and the cost analysis activity should support total force-structure planning efforts of higher headquarters by the development of (1) data on the command, control and sensor needs of the USAF for a wide range of force structures and missions; and (2) criteria for the selection of an optimum aggregate mix of command, control, and sensor systems given any proposed plan for a total air force.
- (e) The cost analysis activity should be staffed by trained cost analysts having the appropriate mix of backgrounds, including personnel who are system engineers.
- (f) The cost analysis activity should establish two major research goals: (1) the development of an adequate data base, and (2) the development of specific methodologies for the costing of L-systems.

Other recommendations of the Cost Panel, not necessarily concurred in by all panel members, but corresponding to the comments contained in Section 2.3 above are:

- (a) Planning for command, control, and sensor systems should be based primarily on total force-structure analysis; criteria must be developed which lead toward a proper mix of USAF weapons and command, control, and sensor systems.
- (b) An integrated activity for overall L-system planning should be established within the Hanscom complex.
- (c) Planning by ARDC and AMC should give increased attention to the operational problems and should also follow through the life cycle of command, control, and sensor systems.
- (d) In the programming and budgeting process throughout the USAF, L-systems should be treated as systems and not as groups of equipment.

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(e) The latest authorized system configuration planned for implementation should be clearly specified, and changes should be rapidly disseminated to all USAF offices concerned.

(f) Attention should be directed to means for predicting, and including in system design, provisions for a continuing growth potential in future command and control systems.

(g) Planning decisions regarding command, control, and sensor systems should be based on continual examination of the trade-offs available between cost effectiveness and time in the light of changing strategies and technology.

(h) The evaluation process should include an examination of alternative development periods, production lead times, implementation schedules, and operational periods; techniques for estimating these factors should be improved.

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3. DATA PROCESSING

With respect to the present and future states-of-the-art of data processing equipment, it was found that the data-processing problems needing attention were common to most of the currently planned L-systems. Using information and opinions gathered from contractors, ESSPO's, and others concerned with the work statements of various L-systems, and the previous experience of the panel in the field of data processing, the panel has endeavored to indicate the direction for future research, the special problem areas associated with the L-system data-processing requirements, and certain of the problems observed in systems already being implemented. These findings and recommendations have been organized into four areas:

- (1) Equipment and its relation to component development,
- (2) Processing techniques,
- (3) Program production techniques,
- (4) System and subsystem interface problems.

3.1 Equipment and Components

The data-processing equipment available and planned is numerous. Because of the magnitude of the stated requirements of most of the L-systems, only the middle- and large-scale digital computers have been thoroughly investigated. One comment to be made about the current and anticipated future state of the art is that a natural obstacle, the maximum signal transmission speed (that is, the speed of light) is rearing its head. The maximum signal transmission speed is about a foot in one millimicrosecond, a period of time soon to become significant in computer technology. Despite this perhaps ultimate obstacle, probable improvements within the next five years will lead to a computer 100 times as fast as those available today. However, this improvement appears to be close to a natural limit. Only radically new organizations of machine components will allow progress beyond this point.

Searches for patterns in arrays of bits that represent a complex relationship are made time consuming by the current organization of machines. A process may need to be developed for the association and pattern recognition capabilities needed in the 438L intelligence data-handling, 473L Hq USAF command, and 425L NORAD COC systems. Some of the newer machine organizations, such as the AN/FSQ-27, reflect a design goal of growth potential in several of the important parameters without excessive initial cost or extensive downtime and reprogramming at the time of expansion.

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The ability of the computer field to anticipate coming developments is improving; thus, building-block computers that can have older modules replaced by those of the newer design and larger capability are now both possible and practical. In addition, modularity and flexible interconnecting devices allow the addition of computing capacity without reducing the usefulness of previously devised computer programs and staff procedures.

There now appear to be two situations which are delaying the faster development of better data processors. One of them is that a large part of component and subsystem research and development is funded as part of system design or improvement contracts (e.g., a weapon system development contract), which has several deleterious effects:

(a) Many of the research or development programs whose output cannot be "guaranteed" to be available within the "lifetime" of the system contract go begging.

(b) Usually only the prime contractor gets money to develop his ideas and to maintain or build a competent staff in the newer areas.

(c) A company that is in an advanced position with respect to the state-of-the-art, but relegated to a subcontractor level, may wither on the vine waiting for research support while the prime contractor rapidly becomes a competitor.

The second situation that is delaying development is the parochial nature of the machines of the larger companies. While the Government is supporting research and development of many good subsystems, it is seldom that the best of "best buy" equipment appears as part of one integrated computer complex.

The recommendations of the panel in the area of data-processing equipment and components are as follows:

(a) Whenever possible, component research and development should be funded separately from system design and improvement contractors.

(b) Manufacturers must be encouraged to design sets of compatible data-processing subsystems and flexible interconnection devices. Where possible, compatibility of the components of separate manufacturers should be encouraged.

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3.2 Processing Techniques

Although most studies consider the evaluation of computers as a problem in the equipment area, it is becoming increasingly obvious that any machine evaluation made independently of the problem to be solved and the solution technique can be misleading. In the absence of a theory to relate the parameters and structure of a machine to a specific or a standard set of problems or techniques, the best approach to an evaluation is to construct computer programs for the machine. These programs would solve the standard problems using the procedure suited to the particular machine or machine configuration being evaluated and would allow comparisons of different machines or alternative configurations of the same machine. Considerable study is required to determine a set of appropriate problems. After such a program has been undertaken, a machine can be evaluated against new problems by classifying the new problem as some combination of the standard set or by expanding the standard set.

Since processing equipment can be evaluated only against a particular problem and solution background, it is recommended that the selection of data processing equipment for an L-system be deferred until an adequate analysis of the system's "problems" allows a rational decision between equipment alternatives. Further, the initial analysis of the data processing functions of the system should be directed toward discovering the constraints imposed by available equipment upon solution techniques. After such constraints have been evaluated, the development of additional equipment should be funded only if the analysis shows such development fully necessary. Certainly, this analysis must be done by a party not interested in selling equipment.

Solution procedures and techniques are important. From a study of the stated requirements of some of the L-systems, it is apparent that many tasks are assigned to the data processing complex for which no proven procedure exists for performing the task. In fact, there is currently no theoretic or pragmatic background that will allow any but the most simple tasks to be performed in the area of information processing. Tasks such as automatic indexing, automatic request analysis and subsequent retrieval, and automatic data correlation, except in simple cases, are beyond current capability. There are, however, many inadequately tested proposals; it is felt that advances will be made only if the more promising proposals are put to the ultimate test, that is processes are developed and applied. It is also felt that such testing should not be done as part of a production contract and that no system contract should be let that assumes that the solution to these problems is just around the corner.

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Something else that has been observed to cause trouble in every commercial data-processing system is the existence of contradictory or erroneous input data, a difficulty that may be of tremendous proportions in the larger files of the L-systems which contain information items of long life. In the absence of known general solutions to this problem, it is imperative that it be recognized during the design of the system.

One approach that would tend to reduce the load, but not the character of the data-processing problems, is filtering the data inputs as near the input end of the system as possible, preferably before indexing for filing.

The recommendations of the panel in the area of data processing techniques are as follows:

(a) More money must be spent on the development and testing of large-scale information-processing procedures and techniques, especially for fully automatic indexing, file interrogation, and information correlation.

(b) The selection of data-processing equipment for a given system must be deferred until adequate analysis of the requirements allows a rational decision.

3.3 Program Production

In many of the L-systems, a much larger programming effort probably will be required for system design and system testing and evaluation than for the production of programs to do the operational tasks of the system. Simulation, gaming, and similar evaluation and optimizing techniques will be needed not only as part of the operational programs but also as significant system design tools. Application of these techniques will allow the following:

(a) Unanticipated aspects of the systems will be dramatically brought to light early.

(b) The performance of special-purpose gear can be simulated before freezing hardware design.

(c) Alternatives for solution may be tested for validity and effectiveness at an acceptable cost.

Since such problems are so immediate, a special facility designed for such functions should be developed around a large data-processing complex organized to permit expansion. Such a facility should be under the control of AFCCDD, must have more flexibility

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and capacity than is required to handle the problems in an operational environment, and would take about one year to design, about two years to build, and cost in the range of \$30 to \$40 million for installation with annual operating costs near \$4 million.

In the area of program production tools, it is felt that industrial development of computer programming languages is proceeding with sufficient rapidity to make USAF funding of work in this area unnecessary, except for an unavailable language. Appropriate use of available languages is important, however, because major gains can be made in the time and manpower costs of obtaining an initial system capability. Further, the problem of documenting computer programs is eased by the use of languages that permit the statement of computer programs in a more natural fashion. The use of more abstract coding techniques permits a relatively rapid determination of the effects of modification upon complex programs.

If funds were applied toward the evaluation of program organization, sequence of implementation, testing techniques, and documentation design, the programming production problems would be better understood, performance would be improved, and more valid estimates of cost in terms of time, manpower, and computer time would be made.

The panel makes the following recommendations for program production:

(a) The USAF should establish a facility which will provide extensive data-processing capacity for use in system analysis and evaluation.

(b) The impact of new developments in programming languages on the organization and techniques for program production should be studied.

3.4 System Interface

A serious interface problem can result whenever systems use a common communication net. Already decisions have been made in certain systems which will have serious effects upon the lengths and rates of transmission of the messages exchanged between computer complexes and the ease with which messages can be prepared for transmission and deciphered when received. Just how deep the communicators should peer into the messages carried within the communications network is a trying question. Most data processors would prefer to use arbitrary, but formatted, binary strings for the communication of fixed-content messages. Most communicators and laymen, however, are much happier if the message is coded using teletype characters or a rough equivalent. The question is moot whether communications must be in a fashion that allows a drop

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to be made to a printer at any point along the circuit. The additional question of whether such a printout is then intelligible, forgetting normal security garbling, is even more disturbing. Such requirements would expand, by several binary orders, the magnitude of the messages being exchanged. These requirements also would increase the encoding and decoding required in the sending and receiving complex.

A less serious, but costly, system problem is the multitude of formats used by the various sensor systems in recording the same types of information. Specially designed input devices are the most expensive of the data-processing components used in some of the current or contemplated systems. A portion of these costs could be reduced and processing expedited in future systems if attention were paid to the development of standards in media and format for recording in sensor systems collecting the same types of data.

The panel's recommendation in the area of system interface is as follows:

The USAF should initiate a specific group to study the impact of the communications network between the various systems on their data-processing capacity. This group should have representation not only from the communicators and the system users, but from any group that is to handle the information directly from the net.

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4. DESIGN METHODOLOGY

The problems encountered in the design of some of the L-systems already under way have been identified. The systems that have been considered are primarily the SAC Control System 465L, MIDAS and SAMOS 117L, Continental Aircraft Control and Warning 416L, Air Weapon Control 412L, and BMEWS 474L. The nature of management-of-design problems being experienced have been discussed in detail with representatives of ARDC, the using command, and contractors. Technical design problems such as bit-rate limitations on communications have not been considered; rather, the work has been directed toward the general design considerations and the proper management steps in the process of conceiving, developing, and installing large command and control systems as differentiated from large sensor systems.

Some reflection on command and control systems is appropriate. Every military organization has a procedural system intended to provide that organization, particularly its commander, with a mechanism for performing tasks appropriate to the organization's fulfillment of its mission. This procedural system may well be termed a command and control system and may have many characteristics that are also common to management systems. It is useful to distinguish between command functions and control functions in the military organization. The command functions are those of establishing policy, procedures, budget estimates, training requirements, and strategies, while control functions are those which direct and regulate operations, employ resources, provide real-time planning and replanning, and assure that military objectives are achieved within the context of the command requirements. These two functional areas are obviously highly integrated, and the procedural command and control system, including data flow and information requirements, serves both areas. There is certainly a control function in a command organization and vice versa.

4.1 Problem Areas

The following problems in implementing command and control systems have been identified. Other problems were reported, but are not reflected here because they are believed to be peculiar to a particular system. Although some of the problems may not be related directly to design methodology, their effects are significant.

(a) The fundamental problem in present and proposed command and control systems is widely acknowledged to be a lack of understanding of the problem to be solved by the system for which

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the man-machine complex is being developed. Usually grossly inadequate analysis and little planning have been followed by frenzied emphasis on engineering and implementation. Yet, no time has been saved by this "crash-to-crash, unhindered-by-plan" approach.

(b) The statements of requirements for most systems show an obvious lack of concern about their specific external boundaries, resulting in difficulties in the interfaces between these systems and elements of the environment.

(c) Diverse groups work briefly on "bits and pieces" related to the command's and commander's problem and then turn to extensive studies of hardware. Continuity of effort applied to analysis of a command's and commander's problem, from which system requirements for a command and control system are generated, is practically non-existent.

(d) Inappropriate focus is placed early on equipment and its configurations, thus severely restricting subsequent system design efforts.

(e) Using commands tend to demand, even at the highest levels, an inordinately large volume of data and the display of a significant part thereof. There is general feeling that if enough bits of data are available they can be analyzed on the spot to provide appropriate information for the best decisions and actions.

(f) The tendency to design inflexible operational procedures and practices into a system, while the system is still under development, severely restricts the spectrum of operational choices that may be available in the future, which condition is complicated further by the lack of acceptance of the notion that a command and control system must adapt continually during its useful life to changes in the environment in which the system operates.

(g) Many people who are to use a system simply do not understand what its performance capabilities will be when the system becomes operational. Further, during the design and implementation work, new requirements are placed on the system which are not consistent with the previous requirements.

(h) The USAF management organizations for the L-system programs simply do not possess the strength required to direct adequately the various projects. It is difficult to determine whether the high degree of interference in the management and technical directions of the project by outside organizations and individuals result from the weaknesses of the project management or is a cause of such weakness.

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(i) The delegation of design responsibilities is incomplete and indefinite; the prerogatives to change and influence design resides with many organizations and individuals.

(j) Many "requirements" imposed on a system are derived from today's isolated problems rather than from the perspective of the needs of the command and commander during the period in which the man-machine complex will be operative.

(k) It is characteristic of all L-system programs that schedules are underestimated.

(l) Erratic funding has created, or at least complicated, many problems---schedule slippage, alteration of design and concomitant degradation of capabilities, inefficient manpower programming and employment, delayed implementation, etc.

(m) Responsiveness to needed operational changes and to the need for orienting systems toward operational simplicity is lacking.

(n) Only sporadically are the experiences gained in the development of one system (or one of that type) either requested by, or available to, another system program.

(o) In those systems which interact with the intelligence community, as well as within intelligence projects themselves, there is virtually no access to the intelligence information needed for designing the system.

(p) Little effort is directed toward the potential threat to a system, and such knowledge that exists is not seriously considered in the design.

(q) Dependence on appreciable research and technological development in order to implement a system has almost invariably led to schedule slippage, increased cost, redesign, and redirection of system capabilities.

4.2 Discussion and Recommendations

A command and its commander are responsible for defining a command and control system's functions and for evaluating the system's performance, as contrasted to the next higher command which is responsible for explaining the mission and evaluating the mission performance of its subordinate. A commander must insure that his command and control system performs functions appropriate for fulfilling the command's mission. This responsibility of the

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commander cannot be delegated. Mission-evaluation criteria for the mission and operational test criteria for the command and control system must be stated early by the commander to provide clear guidelines to the system designer and operators. It is only by a critical review of these criteria that judgment can be made whether or not a satisfactory operating system description can be developed. Further, exercising a command and control system is mandatory, not only for system evaluation, but also for system training. The normal functioning of a system in peacetime is not a suitable basis for evaluation of its ability to handle a stress load properly. In summary, a user command and its commander must be intimately involved in the functional design of the command and control system associated with them.

The functional variables in a command must be recognized and provided for before a system can be "engineered" for that command. Commitment to a hardware configuration must be made only after a satisfactory analysis has been made of what the system is to accomplish. The USAF needs much more WHAT before an attempt is made to define HOW. Further, the analytic work required to define a system must have a continuing nature. It cannot be a one-shot exercise by a few people for a short time. Even if such an exercise were completely successful in precisely relating all of the selectable and controllable variables to the understanding and agreement of all personnel concerned, the system's design would need to vary with time by virtue of the uncontrolled and unpredictable variables (threat, environment, even technology), all of which vitally influence the objectives and capabilities required. Finally, the continuing nature of the analytic effort does not preclude settling on a given hardware configuration to meet a specified operational capability at a specific time. Instead, the continuing system analysis will provide the mechanism to define and plan how to evolve from one hardware configuration and operational capability to the next as the command's needs change.

This continuing analysis team should be organized from the time that a command first realizes that its existing command and control system is not (or may not be) adequate and that something has to be done. Complete access to the command resources must be provided. All user command personnel, particularly at the highest echelons, must be available for consultation and interview. From the first, this analysis team must be of significant size and must have the promise of continuity, financial support, and freedom to look at the command's whole problem as objectively as possible. While it is necessary that user-command personnel be integral members of the analysis team, it is also important to keep this team administratively and organizationally independent of command structure.

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When and if it is established by the analysis team that an equipment program is needed to help solve the difficulties in the command's command and control system, then an ESSPO, or more appropriately, an SPO - System Program Office - should be established, the chief and co-chief of which should come from AFCCDD and the user command, respectively. The co-chief would be the senior project officer of the user command. A high-level AMC representative who reports in a line relationship to Hq AMC, and who has procurement responsibility and authority for the program should also play a major role in the SPO. This AMC representative should also have a staff authoritatively representing the maintenance, supply, production, and installation areas of AMC. The continuing analysis team then would report to and support the SPO by continuing the team's efforts to detail the command's mission and functions, study the threat, and generally explain the problem which the new command and control system is to help solve. This team would initially determine the goals and functions of the new command and control system and would continually re-examine and redefine these goals and functions as necessary. The analysis team would configure the functional subsystems to perform the required tasks and would rigorously evaluate such configurations. The team would perform, or direct the performance of, appropriate operational experiments; it would undertake, or contract for (through the SPO), feasibility studies. This team would help in the preparation of statements of work to be included in requests for proposals to equipment contractors and would provide assistance in the evaluation of ideas and proposals submitted by private industry.

The SPO, given strength by the analysis team, high-level user-command participation, and adequate AMC support, would be in charge of the program. It would direct the preparation of statements of work, schedules, phasing plans, and budget requirements. Through the use of the analysis team and with the technical assistance of ARDC laboratory agencies, the SPO would monitor the work of implementing the system.

In a phased program such as exists for the L-systems it is almost trite to say to management that they should put their effort where the problem is. In the area of command and control systems, the problem is that the operations commands need now command and control systems capable of continually evolving, that is, systems without fixed "requirements" for the equipment, etc. No outstanding success can be expected from a command and control standpoint until this unappetizing critical problem is addressed full face by USAF management.

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5. DISPLAY

Early in the Winter Study, it became obvious that the term "displays" was commonly used in two importantly different ways: displays as transducer equipment, and displays as media for communicating effectively with system operators. Both meanings of displays have been taken into account in the panel's work. It also became obvious to the panel members that system designers, implementers, and users tend to attribute system difficulties to displays without a clear understanding of what constitutes a "display problem."

The display requirements of the currently proposed L-systems, the state of the art of display equipment, and the problems of selection and use of displays have been considered. In addition, some display principles were developed that are believed to be useful for system designers, implementers, and users.

In any discussion of displays, it is helpful to distinguish clearly between display equipment and display function. Display equipment is a transducer and the function of displays is to communicate. The distinction between equipment and function is useful because it helps avoid the illusion that communication occurs simply because transduction takes place. Displays are the last stage in the process of communicating with operators, but all too frequently the need to communicate is not well served by the preceding stages. Unless the confusion between transducing and communicating is removed, all problems of communicating with men are likely to be considered display problems, and the equipment may be blamed erroneously for communication shortcomings. Consequently, attempts to achieve better displays will be directed too much toward fancier equipment and too little toward better communication. The way to better displays is to be found in the science of communicating with men who operate systems; in the methods of specifying communication requirements, and in changing the habits of men who operate systems.

When studying communication with operators, information must be distinguished from data. Information is the answer to a question, and data are the raw materials from which information is extracted. What are actually transmitted to a man are bits of data, and his output indicates what information he has extracted from these bits. How effectively the data are processed, organized, and arranged before presentation will determine how effectively the man can and will extract the information he requires from his display. Too frequently these two terms, data and information, are confused, and the statement, "I need more information," means rather, "I want more symbols." The reason is usually that the required information is not being extracted from the data. Unless

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the confusion between data and information is removed, attempts to increase information in a display are directed at obtaining more data, and the trouble is exaggerated rather than relieved.

5.1 Sequence in which Systems are Developed

Many of the difficulties encountered in the selection and use of effective displays are inherent in the way systems are presently built. In today's development of systems, the necessary sequential order of steps toward an adequate display system is usually violated enough to limit the acquisition of relevant knowledge of display techniques and its timely application. When a system's function depends upon proficient operator behavior, an improper linkage between man and machine will contribute to the system's falling short of its intended performance. Unfortunately, awareness of display deficiencies usually occurs late in the system's history. Attempts to correct display inadequacy so late in the game can be little more than choosing between basically unsatisfactory compromises. Symptoms of a system's troubles therefore are attacked piecemeal, while the underlying illness remains uncured. One way out of this dilemma would be to avoid built-in deficiency by following a different procedure for implementing systems, a procedure that would more effectively permit technical capability to influence the course of events in the selection and use of displays.

The important fact to be faced is that display selections should follow, rather than precede, a detailed statement of how the display is to be used. The more that is known about display use, the more intelligent can be the selection. Putting this principle to work in system development is a matter of management, and management must realize that the specifications of system functions and the production of the related hardware must be developed in a proper sequence, not all at the same time or in reversed sequence as in the present mode of implementation.

5.2 Relationship Between Computer Programs and People

Generally, people are used in systems to make decisions. However, with the amount of data that must be analyzed and the time restrictions imposed on human reactions in many systems, it is unlikely that these systems can afford the luxury of having people extract information and make decisions from a display of relatively unprocessed data. On the other hand, automatic decision-making devices that can be completely divorced from human operators are equally untenable. Even though the technical difficulties of programming accurate decisions could be overcome, there still exists the problem of whether the responsibility for making

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such decisions should be given to a machine. Some compromise between these two extremes is necessary. How effectively this compromise is carried out is one of the important problems in the present design of systems and has direct effects on the development of displays.

The preposterous amount of data that is scheduled to appear on the displays in some of the command and control systems, and the degree to which these data are invalid, indicate that this compromise between men and machines has not been carried out successfully enough to avoid making display problems out of what are really system design problems. No amount of ingenuity in the coding of the data or in the development of elaborate display equipment can produce adequate displays under such circumstances. Further, a reduction in the amount of data or an increase in its validity, or both, cannot be accomplished merely by more extensive automation of decision-making functions. The proper compromise will require both the development of better methods of using people and the development of better computer programs. Some suggestions are made for the joint use of people and computer programs that may result in operator jobs for which adequate displays can be developed.

5.3 Job Descriptions in Designing Displays

Perhaps the most disturbing element observed in all display work in command and control systems is a widespread failure to appreciate the value and importance of good, usable, detailed descriptions of what is expected from an operator. Job descriptions, as they are called, are usually looked upon by system designers as rather noisome "personnel problems" and their construction is to be left to outside contractors, and then only in response to pressures arising late in system development. As a consequence, these job descriptions are nearly useless as devices for determining requirements for equipment, because the equipment is already under construction and minimally susceptible to modification; the job descriptions are written after equipment constraints are placed upon them. The greatest impact of these job descriptions is upon what the messages are that are to be communicated, but even here their effects are severely limited. The fact is simply that the critical information and communication requirements, and the criteria for equipment design and operator configurations, are to be deduced from detailed statements of what the operators are expected to do. Since the job descriptions have to come first, any value in their late construction is happy accident.

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5.4 Determining Information Requirements

The determination of information requirements and knowledge of the manner in which the information is to be used operationally in the human decision-making process are critical for effective design of displays. Preliminary examination of the stated quality of the information requirements for the USAF L-systems shows a lack of valid or realistic information requirements. This lack of requirements has resulted in a desire for all available "data" to be sent to all systems "instantaneously," regardless of the needs of the systems. The pressures imposed by both private contractors and USAF in terms of time, money, and manpower, have forced the system designers to seek a hardware approach to the solution of their design problems. The requirements for display design that come out of a hardware approach are formulated around component equipment performance rather than the system requirements.

5.5 Options Available in Design of Displays

It is frequently forgotten that the aim of presenting symbols and sets of symbols on visual displays is to influence the actions of an operator. In order to direct the operator's behavior in this fashion, it is necessary to provide visual stimuli which satisfy both the perceptual requirements of the human visual apparatus and the interpretive or decoding capabilities of the operator's intellect. The operator has to recognize the signal for action, he must recognize immediately what action is being signaled for, and he must have the detailed knowledge needed for the action. To ensure appropriate and timely operator action, the symbols must be properly coded.

The operator must be capable of extracting from his displays information that enables him to determine quickly and accurately the classes, subclasses, and details of appropriate actions he is to take. In order to accomplish this purpose of the display, several options may be available to the display designer for organizing the data that is presented:

- (a) The operator can be given the class of action he is to take and details of the action.
- (b) The operator can be given the details of the action, and he has to figure out the class.
- (c) The operator can be given the class of action and the details of the situation, and he has to apply a learned rule to

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determine class of situation and then figure out the details of the action.

(d) The operator can be given the class of situation and details of the situation, and he has to determine the class of action and figure out the details of the action.

(e) The operator can be given some of the details of the situation from which he has to figure out the class of situation, apply a learned rule to determine the class of action, and then figure out the details of the action from the details of the situation.

(f) The operator can be given the details of the situation and he has to figure out everything else, including his own rules for action.

It is seen that in organizing the data to be presented to an operator who is to extract information from it, the amount of figuring out left to the operator increases from Option (a) to Option (f). Also, the operator takes longer to learn the job and longer to perform that job for each option from (a) to (f). One interesting revelation from this analysis is that "flexible" in respect to displays means "unorganized," or even, "I don't know what you'll need, so I (the system designer) will give you all the data available." What is needed is better organization in system implementation for better communication and performance after the system is in use.

"Prethinking" in system design is essential. In order to communicate, one must know beforehand what is to be communicated. If it is argued that the contingencies that probably will arise cannot be anticipated to an appreciable degree, the panel would argue that those contingencies must be anticipated because there will not be enough time to figure out what should be done when they do occur. This is the main reason for stressing the importance of useful job descriptions. It must be decided what an operator will be experiencing at any given moment in order that a display may be so designed as to ensure operator detection and comprehension of his visual messages. Of course, a good display is valuable in a system only when the rest of the operator's facilities take advantage of the display's effectiveness by facilitating the operator's response.

5.6 Coding Dimensions of Displays

The final choice of display-generating equipment should be based on many considerations. System design requires that it

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be compatible with other equipment for data processing and communication. Functional requirements dictate such things as display capacity, processing rate, updating time; human capabilities and limitations guide the choice of the coding dimensions and formats.

The initial decision that must be made in displaying data to operators is which of the sensory modalities is to be used. Taste and smell seem to be of little use for systematic information display. Kinesthesia (balance) is an important display modality in the dynamic control of vehicles, but seems to be of very limited utility in command and control systems. Touch has some potential in presenting patterned information (as in Braille reading), but is limited for display purposes by several factors. It requires some kind of direct application of the input device to the operator, and if this device is attached to the hand or fingers, it may interfere with the manipulative tasks required of the operator; also, because of this requirement for direct contact, tactual displays must be individual displays; finally, the display of information through arbitrarily coded tactual inputs presupposes special and extensive operator training.

Remaining are sight and hearing. Both of these modalities can operate at a distance and permit a wide variety of patterned inputs for the organization of information. Audition is characterized by the fact that it is essentially non-directed; the operator does not have to "look at" an auditory display in order to receive inputs from it. Auditory signals, therefore, are frequently used as warning or attention devices, but should not be used for more formal display purposes when direct verbal communication is also required.

Vision is, of course, the most useful and versatile modality for information display, to the extent even that the word "display" is often used to mean only visual display. Visual displays can present data by variations in time of a number of dimensions including shape, size, color, brightness, flicker rate, resolution (focus), and spatial position. Because of human limitations, some of these potential coding dimensions are much less useful than others. Hardware limitations may make it impossible to use certain of these dimensions in any particular display system. Two dimensions of current high interest are color and depth (3-D).

Color is useful as a means of redundant coding to provide visual separability of classes of displayed information; hostile vs. friendly tracks, damaged vs. intact installations, available vs. potential weapons, and so on. As such, color is generally a helpful, rather than a necessary, display feature, and in some applications may be unjustified in terms of equipment costs, slower update times and decreased display reliability.

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The display of information in depth is a similar case in that the sum of equipment penalties may outweigh potential usefulness in any particular application. Depth display would be most useful in situations where information is needed regarding the relative positions of objects in real space, e.g., the close-in terminal guidance required in air traffic control, would be successful only to the extent that they simulate or are actually presented in three spatial dimensions. Binocular cues alone (convergence and stereoscopic vision) provide a very limited perception of depth, since in ordinary vision an operator is accustomed to relying on many other depth cues, including relative size, interposition, linear perspective, aerial perspective, monocular movement parallax, patterning of light and shade, and accommodation. Although some of these binocular cues are relatively unnecessary for display purposes, certain of them based on head movement by the viewer are critical. A display system based on illusory depth does not provide these cues and may, as in the case of Iconorama, actually break down visually as a result of sudden head or eye movements.

In general, there is a clear reciprocal interaction between the selection of display coding dimensions and the capabilities of display generating hardware.

5.7 Large Common-Surface vs Individual Displays

Many of the currently proposed L-systems have stated requirements for large common-surface displays. As to selecting and using them in proposed L-systems, it should be noted that large and small displays are equivalent in the amount of data that can be presented under optimal conditions. A large display may be an economical substitute for several smaller individual displays in situations where all members of a group have the same informational requirement. In such an application, large displays would compare unfavorably in terms of system reliability, and perhaps vulnerability. In general, the functional justification for large displays is based on their use with individual display facilities to present data required for common reference by a group of people. Various historical factors and non-functional considerations exist, however, that can lead to the uncritical advocacy of large displays even in situations where they are not required or where they may even detract from effective system operation.

5.8 Selection of Display Equipment

The final choice of display generating hardware for a particular L-system must, of course, take into account equipment limitations and capabilities. Various display equipment currently

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available and presently under development has been reviewed. It has been concluded that presently or potentially available display equipment will adequately meet the functional requirements of the proposed L-systems and that satisfactory progress in the state of the art is being made.

5.9 Recommendations

(a) The Display Panel believes that USAF will not get presently proposed L-systems to do their required jobs unless the admittedly difficult task of determining the detailed requirements for each system is tackled forthrightly instead of being bypassed. The system requirements must be determined before hardware is specified and purchased.

(b) Display, communication, and data-processing functions in systems will be helped immeasurably by careful distinction between data and information and by an intelligent use of filtering and coding techniques. Nevertheless, in order to use filtering and coding techniques intelligently, an adequate inventory of techniques must be available. Research on filtering, coding, classification, and the like, is urgently needed, and such research should be strongly supported.

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6. LOGICAL CONCEPTS

The Logical Concepts Panel studied the following three topics:

- (1) Weapon allocation and retargeting,
- (2) Logical design of military organizations,
- (3) Best use of weapons, i.e., "force against force" or "force against value."

The intent has been to clarify fundamental questions concerning the expenditure of military resources for the defense of the national value. The approach has been theoretical, but the investigations are intended to have some permanent value, and the implications of various underlying models have been studied with a reasonable degree of mathematical rigor.

6.1 Weapon Allocation and Retargeting

The theory developed for the allocation of a weapon force against a collection of targets having known values has taken into account the probabilities of weapon destruction in an enemy attack and of weapon malfunction, assuming that the weapons survive.

Four classes of targets were considered:

- (a) Undefended targets (the probability of target kill, $p = 1 - e^{-Kb}$, where b is the number of weapons expended against the target),
- (b) Defended targets (the probability of target kill is zero if fewer than n weapons are expended simultaneously to saturate defenses),
- (c) Retaliatory "population" targets (the number of targets is large, but their total value is finite),
- (d) Tactical-type targets (a finite number of targets having approximately equal value).

Five methods of using weapons were considered:

- (a) Dispersed (the weapons are placed so that their individual survival is an independent chance variable),
- (b) Clustered (the weapons are clustered in squadrons),
- (c) Unretargeted (weapon allocation is not changed on the basis of what has survived an attack),
- (d) Individually retargeted (the survival or destruction of every weapon is ascertained and the force retargeted accordingly),
- (e) Retargeted by groups (weapons within initially defined weapon groups are retargeted).

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The optimum allocation of weapons, that is, the numbers of weapons assigned to each target was determined in each case and the mean value of destruction on the enemy computed. The effectiveness of retargeting also was computed in terms of an equivalent augmentation of the weapon force to determine the relation between the value of retargeting and the cost of weapons. The increase in mean enemy value destroyed in a retargeted force ranged between 20 and 80 per cent in typical cases, and the equivalent augmentation factor of the weapon force ranged between 1.7 and 3.0. The costs of increasing the utility of a force (measured by the mean enemy value it can destroy) by (a) increasing weapon production, and (b) making provisions for retargeting, could then be compared.

Because of the effectiveness of retargeting demonstrated by these studies, the cost and feasibility of the required communications, data processing, and weapon control equipment should be investigated.

6.2 The Logical Design of Military Organizations

A general logical design of decision-making organizations has been determined on the assumption that the modern formulation of the theory of decision-making under uncertainty is correct and in addition that it is logically complete. This design was then applied in block diagram form (see Fig. 10) to the synthesis of military organizations. It was then attempted to determine:

- (a) The functions that are logical and that, in principle at least, can be carried out by computers;
- (b) The functions that are extra-logical and require humans;
- (c) The nature of the data-processing functions;
- (d) The effectiveness of the organization in terms of the capacity of the information channels between various elements of the organization;
- (e) The minimum set of working hypotheses that is implied, if not explicitly stated, from which may be obtained a model of the organization's data base, including, for example, a hypothesis of the relations between effort and results, such as the expenditure of weapons and the destruction of enemy force or value;
- (f) The sources of adaptive behavior in an organization for correcting conditions such as where the expenditure of resources by the organization fails to achieve the anticipated results.

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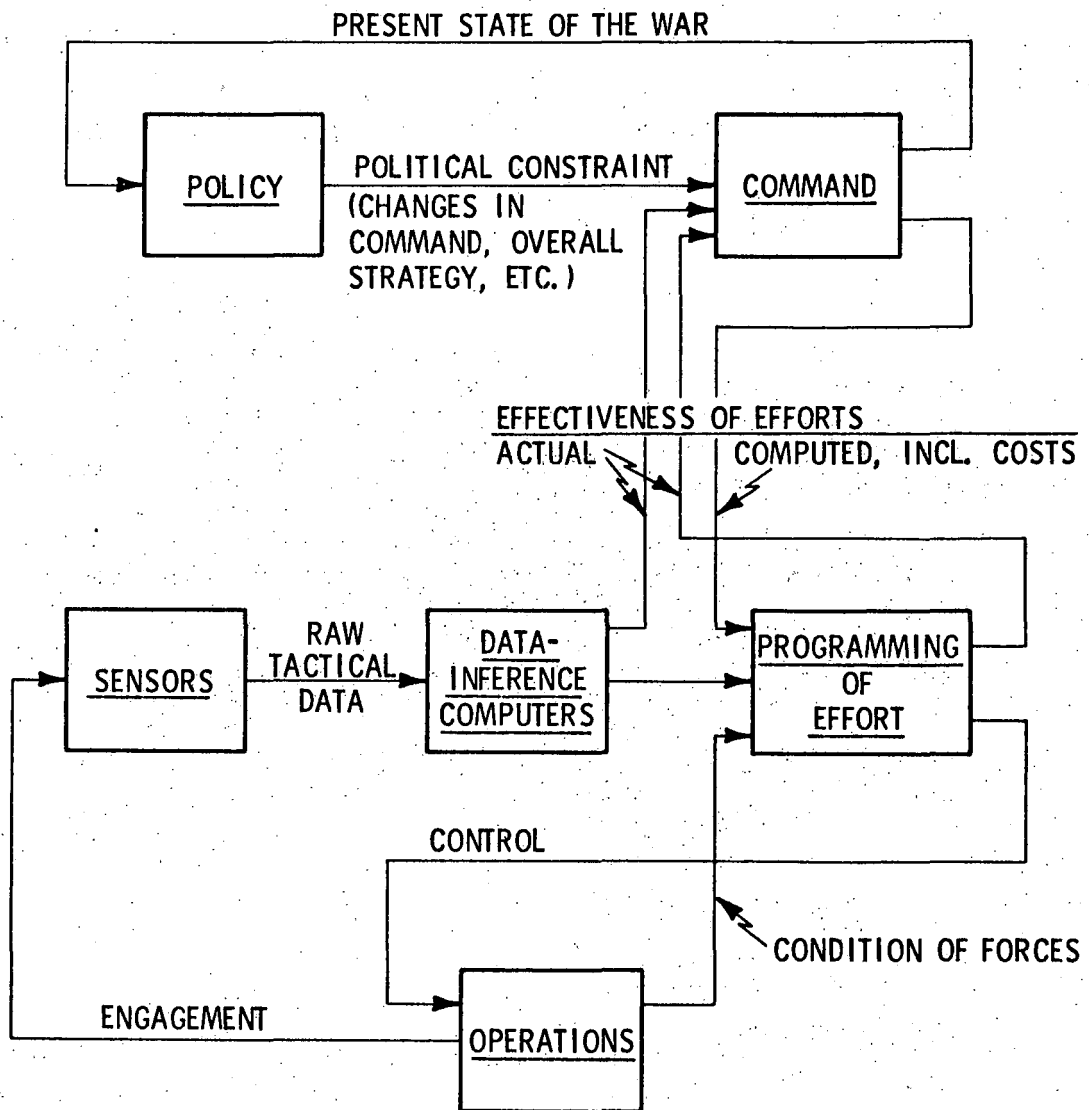


FIG. 10 A LOGICAL DESIGN OF A DECISION—
MAKING ORGANIZATION AS APPLIED TO
THE SYNTHESIS OF MILITARY ORGANIZATIONS

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This general logical design has far-reaching implications. For example, it shows that the logical elements of a military organization can be described as:

- (a) Sensors (radar, intelligence data, prisoner interrogation, etc.),
- (b) Data inference (TLQ-8, 438L, etc.),
- (c) Programming of effort (strategic and tactical command),
- (d) Operations,
- (e) Extra-logical elements.

The first four of these elements comprise a functioning organization with specific data-flow channels; their response should be as reflexive as possible. The fifth element supplies the working hypotheses and determines when the other elements and these hypotheses are to be altered and how. The fifth element, in general, represents the unpredictable adaptive behavior and is the chief factor in the success or failure of the organism.

Work on the logical design of organizations has barely scratched the surface, however, and continuation of this study is recommended. It may eventually have a first-order effect on our future defense effort, particularly with respect to command and control.

6.3 The Best Use of Weapons

This study was made to provide a quantitative evaluation of the use of weapons for:

- (a) Second strike against enemy value, enemy force, or both;
- (b) Pre-emptive strike against enemy value, enemy force, or both;
- (c) Determining the conditions under which a potential enemy can be prevented from "winning" a war;
- (d) Computing the best use of the force to prevent the enemy from winning.

Quantitative results were developed under very restrictive, simplified assumptions which show that the optimum strategy is dependent upon the relative initial sizes of the two forces and the ratio (k) between the number of weapons (targets) destroyed and the weapons expended (force versus force). If $k > 1$ (almost certainly the case of ICBM's) the weaker side does not pre-empt; whereas, if $k < 1$ he does pre-empt and uses his force to attack enemy force.

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The minimum force for preventing war (maintaining parity) is related to the enemy force, enemy value, and k.

The case studied was restricted to spasm warfare where all forces are committed instantly. Where an exchange of attacks extends over a time comparable to or longer than the time needed to deliver a weapon, the analysis becomes more complicated, and the possible strategies become more numerous.

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7. PEOPLE

The "people problems" in L-systems are best understood in terms of the diversity of such problems. These problems range from (1) the complex ones associated with the management of personnel procurement, selection, training, assignment, retraining, and reassignment of manpower, through (2) the problems related to the fact that human beings are all too human in the habits they generate, the pressures they feel, and the ways they respond when stressed, and on to (3) the problems that arise in the design of man-machine systems where the hardware characteristics are known, but the characteristics of the human operators are unknown since the system design influences the interaction between men and machines.

Much of what was "found" is clearly experimental and "state-of-the-art-ish" and drawn from three sources: experience with operations in large man-machine systems such as the manual system of air defense, the SAGE system, SACCS, and industrial systems; documents and briefings related to the proposed L-systems; and the bodies of knowledge which compose the behavioral sciences.

7.1 Manning the L-Systems

In tackling the problem of whether or not USAF will be able to man the L-systems with qualified military personnel, it was possible to make some head counts and estimates. Since the study covered the period up to 1970 and much of the data needed was not yet in existence, it was necessary to make and to accept estimates. An example of such estimating is in the Air Training Command's projections of manpower requirements in L-systems for which qualitative personnel requirements information has not yet been generated. The ATC personnel made their estimates by a series of approximations. If a system is to have a certain type of computer, the ATC people looked for a similar computer now in operation and used its manning requirements as the basis for estimating the projected system's requirements. Thus, the ATC personnel were able to generate a fairly credible set of estimates. They hasten to point out, however, that their procedures assumed no breakthrough in hardware that would materially alter the manning requirements. In any event, these ATC-estimated numbers were used to explore the probability that USAF will be able to man the new system within the constraints of personnel procurement and employment policies and practices.

A personnel management concept was evolved especially for command and control systems. The concept established a context for implementing ARDC's general definitions of a personnel subsystem

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and suggested the essential elements, relationships, and problem areas in a command and control personnel subsystem. Designing the personnel subsystem in a command and control system is a task perhaps more complex than that associated with hardware development, in that the use of humans in the systems is a function not only of the same considerations involving the use of hardware, but other factors as well. Consequently, a technical personnel subsystem design group, acting in parallel with engineering design groups, should be established to conduct research on the use of humans in systems and to develop personnel procurement and assessment techniques.

The activities of many of the people involved in the operations of L-systems could probably be grouped into six classes as follows: (1) command staff activities devoted to the management of resources and the setting of policy; (2) sensing operator activities, essentially connected with initial screening; (3) surveillance activities, associated with comparing screened input data with long-term trends to produce status information; (4) applications activities, associated with the devising and testing of hypotheses whose purpose is to generate indicators and threat trends; (5) weapon-release and direction activities; and (6) process-control activities associated with monitoring on-line system functions.

The probability that adequate manning would be available for the L-systems was explored. The resources available limited the exploration to enlisted personnel; the exploration of adequate manning of officer positions was not completed at the time of this report.

As to the availability of draft-eligible males of sufficiently high aptitude there appears to be no problem. This, of course, presumes no major increase in the programmed inventory of the USAF. The increase in the birth rate following World War II was sufficiently great to make the quantity of men a matter of no great concern. The recent advent of ARDC's "Personnel Subsystem Management Concept" appears to provide the USAF with a coordinated policy for the actions necessary to properly introduce a new weapon or support system into the USAF inventory. If this proves to be the case, it is not expected that future L-systems will be plagued with non-availability of qualified personnel. The restrictions imposed by the Department of Defense on quality procurement, in one form or another since 1952, now have been lifted almost entirely. Unless these restrictions are once again imposed, it appears that USAF should be able to recruit the needed numbers of high-aptitude airmen.

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In 1958, USAF discontinued the use of the free Airman Classification Battery, AC-2A. An abbreviated form of the battery is now being used as a pre-screening test in the USAF Selective Recruiting Program. It is recommended that the effect of this truncated testing on classification and assignment be evaluated. It is also recommended, in the face of expected heavy demands for highly technical personnel in L-systems, that established minimums be reviewed for their continued appropriateness and, where possible, downgraded.

7.2 Critical Roles of People in the L-Systems

It is understood that, not long ago, a number of Bomarc missiles started to prepare themselves for firing automatically as a result of noise in the computing circuits, later traced to radio transmissions from a passing truck. Because such things can happen, and will happen, war-making systems cannot be turned over to machines. Automatic aids will be highly useful, but men must remain in control of the situation.

Although men are vitally necessary and must take the critical roles in a system, the system designer must recognize the fact that men, in playing such critical roles, represent a very real threat to successful operation of the system. These men probably will not recognize in time the clues that could provide warning of attack. Even when it becomes clear that the U.S. is actually at war, the men in command and control systems will tend not to believe that it has happened. Many may simply fail to comprehend direct orders that run counter to their expectations. Finally, some people may rise to the occasion in an emergency and take wholly unauthorized courses of action. Such initiative could help overcome the inadequacies of a system, but it could also lead to disaster.

The implications are clear: While a command and control system must depend upon men, we must circumscribe their authority to prevent catastrophic unauthorized actions. As long as centralized control is possible, it must be exercised by the highest levels. Only when there is no longer any capability of centralized control should the decentralized mode of operation be resorted to. A Minuteman squadron commander, for instance, must be denied the right to launch his force in the absence of authenticated orders unless a set of criteria, carefully established in advance, has been satisfied. Analogous rules must be established for theater forces. Limited war task forces must similarly be kept under tight control.

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Finally, in designing command and control systems and establishing military organizational patterns, we must insure that the machines are subordinate to the men, not the men to the machines. It must also be accepted that because machines break down and because men react in unprogrammed ways, there will always be a certain amount of irrationality in the most rationally designed systems. We must strive to limit the extent of this irrationality through rational design of systems, establishment of organizational patterns, selection of people for critical positions, training of people, and system exercises.

7.3 Human Behavior Under Stress

Human behavior under stress must be taken into account in the design of systems. Such crises as Lebanon, Suez, and Formosa clearly reveal that military people are after all only human. They react to crises in often noble, but system-confusing ways. To be certain that a message gets through, its priority is raised. With everyone upping priorities, communication lines become overloaded. One commander, in order to do more than his job and really be of help, may assemble his crews in record-breaking time and get his aircraft airborne hours ahead of schedule, only to have them arrive overseas at an overloaded field and be dispersed to numerous other fields with a consequent delay in their mission. Although, in a limited war, this might be only a nuisance, in an all-out war it might result in irretrievable loss in effectiveness. During the early phases of an all-out war, unless there has been a great deal of extremely realistic training, we can expect certain stress behavior. Everyone will feel isolated. The urge to communicate will be great. Much time will be consumed in "making certain" that the war is on. The urge to act will dominate judgment, and men are apt to fire first and ask what the target was later. The very newness of a nuclear all-out war will cause a great deal of stress. Men will be fighting a type of war they have never fought before with weapons they have never fought with before, and they will have to depend on sensors that are electro-mechanical and at great distances away. No one will be able to view the battle from a mountain top; many actions will be taken based on inferences. The exercise of each system as a whole, and of systems together, becomes more and more necessary as the systems become more and more complex and more and more interdependent.

7.4 Training

The next dimensions of complexity that future USAF systems will bring to training were analyzed. One of these dimensions follows from the continuous retrofitting which characterized the 416L SAGE system, and which brings about redefinitions of operator and

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maintenance tasks with a consequent need for "change-training," i.e., training for a change in tasks. A second dimension which also demands frequent change-training is the rapid and continuous change in the characteristics of the military objectives to which the L-systems are directed. These dimensions are not new to the USAF, but what is new is the projected rate and scope of them.

The slowly evolving and complex nature of the L-systems creates real difficulties in specifying sufficiently early the training requirements, in the updating of training, and in the provision of training that is sufficiently complex and diverse. USAF may be planning to rely too strongly on contractor personnel for system maintenance and system programming with a resultant lack of systematic study of and planning for a USAF capability to take over. A lack of early development of analytical information on training requirements may lead to an unjustifiable emphasis on one training strategy or technique as a panacea.

Developments in automated teaching are believed promising of eventual reductions in training time and of broadening the access to and the availability of training throughout the USAF. Operational experience with command and control systems has made it apparent to even the most casual observer that computerization is not equivalent to automation. Computers are powerful tools for mastering many functions that are vulnerable to human error and human sluggishness but they are, as yet, conspicuously lacking in the flexibility to handle the unusual situations, or those not anticipated by the system designer. An illustrative sample of functions involved in most command and control systems is listed below, grouped into three classes roughly corresponding to how well they can be automated.

The first group of functions can be automated more or less readily. An adequately designed system can be expected to substantially reduce the necessity for human involvement in these functions. These functions will not, therefore, require much training. The first group is as follows:

- Arithmetic operations;
- Output encoding, input decoding;
- Recording;
- Bookkeeping, tabulating, information transfer;
- Formatting of information;
- Display composition.

The second sample of functions can likewise be automated, although with varying degrees of success. The amount of training required for these functions will be determined to a large extent by (1) the amount of sophistication incorporated into the system

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design and (2) the adequacy of the design implementation. Training requirements exhibit a reciprocal relation to the above two factors. A sophisticated design will reduce training needs, but only if the system is effectively brought into being. The second group is as follows:

- Monitoring, alerting,
- Error and noise detection and rejection or correction,
- Priority determination,
- Trouble detection, self-evaluation, regulation,
- Load regulation, priority shifting.

The third sample of functions can be handled effectively only by people at the present time, although they may be assisted by a computer. Although major advances can be expected in this area in the future, it is unlikely that they will come early enough to affect the proposed configurations of the L-systems before they become operational. Success in these functions will remain dependent, to a large extent, upon the application of human intelligence and skill. The third group is as follows:

- Complex problem-solving,
- Integrative decision-making,
- Pattern recognition, Gestalt evaluation,
- Policy and strategy,
- Creative thought.

7.5 Classification of Manpower

The development of classification procedures was traced from the narrow "general intelligence" testing of World War I, through the greatly broadened "aptitude test battery" of World War II, to a prediction of the development of automated, job-sample simulation tests, which will not test aptitudes singly, but in the essential configuration in which they appear in USAF jobs.

The central role that people must play in the large systems has been repeatedly stressed during the course of the development of the L-systems. At times it has seemed that people are like the weather; everyone talks about it but no one does anything about it. This concern for the importance of tying people into a system, yet a simultaneous disregard of how they are tied in, is somewhat understandable. Until relatively recently there has been no good model to guide the system designer. The knowledge of the behavioral scientists has been largely compartmented into fields such as psychology, sociology, and anthropology. Each had its

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area of interest. Each had relatively little it could contribute to the system designer, if for no other reason than the language barrier. Each could point out that certain considerations were important, yet in the past there was little that they could tell the system designer as to what he should do about it. However, with increasing involvement in the training of large systems, with increasing involvement in the redesign of large systems, and with recent developments in the theory of how self-organizing systems behave, it is believed that an increasing body of concepts is becoming available, couched in system engineering terms that can be put before the system designer---concepts about the proper use of people in systems which the system designer can and should use in future systems.

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8. SENSING EQUIPMENT

Existing and proposed L-systems that have a major requirement for sensing equipment were studied. Sensors considered were those which operate by radar, active and passive detection, infra-red, and optical techniques. Detectors for temperature, pressure, humidity, particle radiations, X-rays, etc., were excluded from the study. The panel attempted to answer such questions as: Can the presently planned sensors meet the system requirements? If not, is it within the present state of the art to meet these requirements? Is there undesirable duplication or ineffective use of sensors in present or proposed systems?

Lacking definitive realistic system requirements, a threat model was postulated against which to measure sensor capabilities. The threat is summarized for the 1965 era as (a) the ICBM will be the predominant Soviet weapon, with a bomber force retained for low-altitude attacks, mop-up, etc.; (b) the missiles will carry decoys but no ECM; heavy ECM on bombers will be available for use where advantageous; (c) sneak manned-aircraft attacks are to be expected in the early 1960's but probably not in 1965 or later; and (d) satellite weapon-carriers or other advanced systems are not considered a threat until much later.

In evaluating the sensors in the L-systems, an attempt was made to identify the more critical sensor problem areas arising from major system performance requirements. It was found that the problems can be solved with varying degrees of difficulty depending on the specific operational requirement authorized for a particular L-system. The more important of these sensor problem areas, with examples of some of the L-systems more critically affected by them, are as follows:

(a) Reliability is a major problem in the satellite-borne sensors of the MIDAS and SAMOS 117L system which must operate for months without maintenance.

(b) Physical hardening of antennas is most critical in any sensor-dependent system that must function during and after initial attack. Such systems are 416L Continental Aircraft Control and Warning, and 412L Theater Air-Weapon Control.

(c) ECCM is of major concern in sensors for use in air-breathing surveillance systems like 416L, 412L and 413L DEW Line.

(d) The problem of identification arises in both the air-breathing and missile environment, but is most critical in the BMEWS 474L system, as direct identification is made only through recognition of ballistic trajectory.

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(e) The resolution of satellite sensors is limited more by sensor aperture-vehicle compromise than by sensor technology. There is a good possibility, however, that atmospheric limitation on 117L SAMOS resolution under average conditions may be very near the requirement of approximately 5 feet.

(f) Accuracy: Positioning of the 117L MIDAS vehicle to the specified ± 1 degree will cause a 600-mile area of uncertainty along the earth's surface and will make even rough detection of launching sites very difficult.

(g) Excessive false alarms being encountered on the AN/FPS-23 fluttar radar in the DEW 413L system have made this sensor practically useless.

8.1 General Conclusions and Recommendations

The present state of the art of sensor equipment is inadequate to meet the defense requirements represented by the primary threat, ICBM, envisioned after 1963, since techniques do not now exist for achieving the resolution and identification capability necessary to sort missile nose cones from decoys. Further, it is anticipated that the development of such techniques will require an extensive, high-priority research and development program.

Sensors for the express purpose of missile warning such as BMEWS and MIDAS are within the state of the art. Continued research, development, and testing is necessary, however, in order to improve reliability and to establish the level of confidence required.

ECM is still a threat in the air-breathing situation. ECCM techniques should be intensely pursued because of present inadequacies in the areas of passive location, resolution, and identification. As a by-product, these techniques will be very valuable for future use in missile systems as an ECM threat develops in this area.

Study, basic research, and development of large electronically scanned array radars should be continued. Such radars offer the best possibility for extremely high power and high resolution with a hardening capability of more than an order of magnitude greater than conventional present-day antennas. A full-scale array of this type is needed for research, development, and experiment. The scaled-down versions built to date have neither adequately answered such questions as steering accuracy and side-lobe performance, nor fully revealed the operational limitations and capabilities.

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Despite certain limitations, infra-red and optical sensing have unique capabilities not found in conventional radar sensing techniques. Efforts should be supported to exploit these advantages which tend to complement radar sensors.

8.2 L-System Analysis

8.2.1 MIDAS, 117L

The MIDAS program should continue as presently planned. The initial system, however, appears to have certain limitations which require continuing research and development. It is recommended that every effort be made to keep the initial operational system flexible so that major changes can be incorporated if necessary.

A southern readout station would greatly increase the coverage of MIDAS, because many of the U.S.S.R. launching sites are below the 55° latitude line-of-sight readout station-to-satellite line. Continued improvement in the infra-red detection sensitivity must be undertaken because future rocket development will likely permit order-of-magnitude attenuation of flame signals.

There should be no hope held for useful trajectory information, since the missile is viewed only in a part of its powered flight that precedes its ballistic trajectory.

8.2.2 SAMOS, 117L

This system is also in an early developmental state, and there is room for considerable research and development to improve reliability and resolution. The extreme temperature control requirements of the optical system, complicated by varying solar illuminations during portions of the orbit and low-altitude effects, have not been adequately solved.

8.2.3 Theater Air-Weapon Control, 412L

The sensing equipment, as well as the system ground environment of the 412L system is too large, complex, and cumbersome for use in a fluid tactical situation, since the field installations are relatively fixed and require many vehicles, an excessive amount of time, and considerable manpower to move to a new location.

In the design of this system, local operation at the sensor has been eliminated in favor of remote operation through the

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ground environment. Because of the high physical vulnerability of ground links and control centers, manual operational capability and local communications facilities should be restored to sensors such as the AN/TPS-27.

Because of navigational techniques, other than airborne emitters of pulsed microwave energy, available to the enemy bombers, and because of its dependence on operating ground environment for correlation, the value of the AN/MLQ-21 passive-detection equipment appears to be small; cancellation of this requirement therefore is recommended.

To provide the most reliable and greatly needed passive-detection capability for operating under intense jamming, the AN/TIQ-8 equipment should be considered, since it operates with local processing links to the sensor site and does not depend upon survival of the central processing equipment. The search radar, AN/TPS-22, requires the addition of the presently omitted side-lobe cancellation for effective use as a passive-detection sensor.

8.2.4 DEW, 413L

In view of the reduced threat represented by manned aircraft and the ability to increase the high-altitude coverage to better than 100,000 feet by tilting the AN/FPS-19 antenna, it is not recommended that the AN/FPS-19 radars be replaced by AN/FPS-30's on the main DEW line.

A technical evaluation of the CW doppler bistatic radar technique, including employment of the doppler spectrum analyzer, is recommended for determining whether the AN/FPS-23 fluttar radar should remain as operating equipment on the main DEW line. This evaluation is necessary because the increased manning and the altered mission of the line have so increased the ambient traffic that the AN/FPS-23 suffers severely from false alarms. If the low-altitude alarm capability must be provided, the use of alternative techniques which may be simpler and more satisfactory should be considered.

8.2.5 Continental Aircraft Control and Warning, 416L

The 416L system is highly dependent upon the ground equipment that is characterized by the SAGE system. Analysis of the nature of the threat for the period after 1962 has shown that SAGE would probably not survive an initial missile attack of nuclear weapons, and that only portions of SAGE or individual sensors would

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probably be functioning in isolation at the time a follow-on, air-breathing attack arrived in the U.S.

Some air-defense capability could be retained for use after missile attack if radar sites were provided with the equipment, manpower, and communications required for local operation and single-site control. Recommended action to obtain this capability includes:

- (a) Providing prime radar sites with a passive detection capability as independent as possible of SAGE, such as the AN/TIQ-8, for use in jamming environments;
- (b) Installing "burn-through" radars, using state-of-the-art components and techniques at prime sites, to greatly increase the effectiveness of the passive-active local site capability in jamming environments;
- (c) Installing frequency-diversity radars, strategically located, thus giving the maximum single-site control capability;
- (d) Updating existing radars with ECCM fixes, etc., and retaining local control.

Evaluation of gap-filler radars, which are useful only in conjunction with the associated prime site using a SAGE interconnection, has shown inadequate provision for operating in the presence of natural and man-made clutter. In addition, reliability is unsatisfactory for unattended sites. Further deployment of these radars should be studied carefully in view of their deficiencies and present deployment.

8.2.6 Weather, 433L

The sensors for the 433L system are considered adequate. The problem of furnishing adequate weather information is presently more dependent upon communications and the use of the data supplied by the sensors than upon the accuracy of the data. This in no way suggests, however, that the kind of information such as will be obtained from a meteorological satellite is not greatly needed.

8.2.7 Electromagnetic Intelligence, 466L

The only important deficiencies in 466L sensors lie in requirements for improved accuracy of azimuth fixes at low frequency, increased range of interception, and interception of burst transmission. Continued research and development is recommended to provide better understanding of the properties of electro-

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magnetic propagation and to provide better techniques for interception of burst transmission.

The equipment under development for 466L is expected to be satisfactory, except as specified above. Propagation research is recommended to gain knowledge which will permit increased use of ducting, ionospheric propagation, and artificial propagation mechanisms for long-range reception. Azimuth accuracy at low frequencies is limited by antenna size, which in turn is limited by cost and problems in obtaining suitable sites. Techniques should be sought for obtaining improved accuracy without the use of larger antennas.

8.2.8 BMEWS, 474L

The presently planned BMEWS sensors are considered adequate for the initial ICBM threat. It is anticipated, however, that with the current U.S.S.R. missile technology as a foundation, a more advanced threat which the present system cannot detect will evolve in the near future. Among U.S.S.R. missile capabilities considered as part of this future threat are trajectories which circle the earth, low-angle trajectories which impact the BMEWS sites undetected, or high-angle trajectories designed to traverse the beams so rapidly as to escape detection. Because of the rapid advance expected in the future threat, site selection and design of adequate sensors should be initiated immediately.

Trajectories are computed from discrete observations of targets in two beam positions in which angle, range, and range-rate are obtained. Identification of trajectories as ballistic is dependent upon correlation of data on all of the observations made on all targets to exclude false alarms, impossible trajectories, and satellite orbits. Trajectories of hostile objects then are separated from other trajectories. As indicated by this process, a high-density attack or the presence of numerous targets and false alarms will result in overloading the computer and complicating the identification process, perhaps yielding excessive false alarms. This problem should be reduced by the more sophisticated radars required to cope with the future threat.

A proposal has been made to install a "Texas-Tower"-like barge-mounted complex of sensors, computers, communications equipment, etc., off the coast of Greenland, known as "Interim Site III." This proposal has come about as a result of a breakdown of negotiations for construction of the Site III in the U.K. Unforeseen technical problems of implementing this alternative will certainly arise, the \$50,000,000 cost would certainly increase, and excessive delays would be introduced. It is recommended that this

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BMEWS Interim Site III not be considered and that the funds saved should be expended to expedite early completion of a permanent Site III in the U.K.

BMEWS sites should be equipped with bomb-alarm detectors and hardened alternate communication circuits so that immediate notice of attack is provided in the U.S. The AN/FPS-49 tracking radars provide little additional capability and should not be installed at Sites I and II.

8.2.9 Spacetrack, 496L

If, as is generally believed, the function of 496L does not include tactical warning, and if missile detection is eliminated from 496L and handled by 474L BMEWS, there seems to be no valid requirement for the cataloguing of new satellites in less than 15 hours.

It is recommended that:

(a) Efforts should continue toward improving the liaison between 496L and existing sensor systems in order to obtain an immediate improvement in the present capability of 496L.

(b) System 496L should obtain as soon as possible the full-time use of some existing radar such as the AN/FPS-49. Control of such a radar would appreciably increase the detection capability of the system.

(c) Plans for the design, development, and installation of a single improved radar for 496L should continue. This radar should be designed to satisfy the requirement for detection and cataloguing within 15 hours of all satellites out to ranges of 3000 miles.

(d) Plans for the extension and improvement of the optical network for the detection of all satellites beyond 3000 miles should continue. The extended use of light amplifiers in these detectors should be considered.

(e) New or modified antennas should be installed at 466L sites to permit 466L to fulfill its requirement for the collection of intelligence data from radiating space vehicles.

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8.2.10 Atomic Strike Recording System (ASTREC), OSR-62

The sensors for ASTREC are believed to be adequate for accomplishing the primary purpose of locating atomic strikes on enemy targets. Since, because of spherics, the identification of returns from observing stations depends upon knowledge of the approximate location and time of burst, it would be difficult to convert ASTREC to a bomb-alarm system to which such information would not be available. The extensive communication links and the sites of ASTREC represent a survivability problem.

8.2.11 Bomb Alarm System, OSR-290

Installation of this system as presently planned is recommended. Some modifications to the sensors being suggested in order to obtain further information, such as height of burst and yield, would result in the present, simple system becoming a more complicated system and would necessitate further development effort and more extensive communication facilities. Such modifications are not recommended unless the need for still additional information is critical. Instead, effort should be expended toward making the present, simple system more dependable. In particular, arrangements should be made to place the test lamps far enough away from the sensing surface to prevent surrounding the whole by an opaque shield, such as a tin can, which would allow the lamp to continue to function, but would prevent the sensing surface from seeing a nuclear burst.

8.2.12 IFF Mark X and XII

Research and development for Mark X, Mark X (SIF) and Mark XII is essentially complete and the sensors are adequate. Continued research and development is not recommended, because of (a) the decreased importance of the air-breathing threat and the reduced probability of mass engagements and (b) the lack of any valid requirements for electronic IFF in presently planned spacecraft. Systems of this type will probably again be required in the future, but these requirements are too indefinite at this time to support an effective research and development program.

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9. SPECIAL STUDIES

The requirements for intelligence information in command and control systems are complex and many-sided, and they vary in volume, speed, and function. Nevertheless, they are all aimed at answering for the commanders questions of tactics, strategy, force composition, enemy capabilities, enemy targets, enemy technological status, and imminence of enemy action. Further, the multiplicity of these requirements places severe demands for faster and better information on intelligence collection and processing facilities - faster information about new items or more complete information on old items - information which places varying loads on the intelligence collector and sensor systems, as well as on intelligence data processors and people.

Since the function of command and control is largely one of maintaining an effective force and properly applying it at the right time, intelligence information must be available to the force commander in the face of any type of strategic challenge, and the intelligence function must perform in any type of strategic environment. Furthermore, this intelligence function must be switchable from one strategic challenge to another, since strategic situations are extremely dynamic.

The system for providing a commander with intelligence information must be configured so that the commander will not be limited in his ability to respond to a developing situation. Response times, both of collectors and sensors and of data-handling devices that aid in the decision-making process, thus have to be considered. Response time is one of the most basic ingredients in the intelligence process, and undoubtedly is the element that creates the need for a revitalized approach to the intelligence data-reduction problem. Already, the time element has caused the U.S. to spend millions of dollars on new intelligence data-collection devices, which has resulted in a virtual deluge of raw data since 1946. It is estimated that these new intelligence data-gathering devices deliver 15 times more data than was available 14 years ago. This volume factor alone has caused intelligence data-processing systems to slow down, and if a requirement to reduce the response time to cope with new weapon capabilities is added to this expanded volume, the present intelligence system would be slowed to a crawl.

9.1 A Proposed Intelligence System

Since two requirements, time and volume, tend to cascade the intelligence problem, the panel proposes that a new intelligence system be developed that will allow a dual set of data-handling

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channels. One of these channels would cope with the intelligence data that must be handled quickly to be of value, and the other would cope with that data which comes in large volume, but by its very nature can be handled more slowly.

The slow-response channel might include such intelligence sensors as photography, ELINT, COMINT, collateral, open sources, and acoustic detectors. The fast-response channel might include such intelligence sensors as MIDAS, radar (BMEWS and ionosphere), acoustic and seismic detectors, bomb alarm, ELINT, and real-time television photography.

In the slow channel, inputs cannot in themselves produce intelligence information. The type of data that is collected must be interpreted, correlated, and analyzed before intelligence information can emerge. For example, photographs must be viewed by people trained as photo interpreters. The interpreters need to compare one picture with another, read collateral and supporting data from COMINT, and often review ELINT data before factual intelligence information can be produced. This factual information may be brief, but it is based on a high volume of original data. In this example, the intelligence information produced is subject to individual interpretation and will vary between interpreters. But, the same raw data can support factual intelligence information in more than one field. A photograph of a military airport to one interpreter may indicate the existence of a particular aircraft needing long runways and to another interpreter may support a study of refueling bases or air defense installations. Such studies, by their very nature, take time and so they have been grouped in this proposal under the slow-response channel. The desire is to make each channel more efficient and useful and to separate data requiring inherently slow correlation and analysis sequences from data that can and must be interpreted fast.

In the fast-response channel the intelligence data gathered lends itself to a much narrower spectrum of uses than the data in the slow channel. A MIDAS or radar signal means only one thing. The reason for collecting a special piece of COMINT for the fast system is self-evident, and the data needs less interpretation than the data collected in the slow-response channel. The fast-response channel also lends itself to digital techniques more readily than the slow-response channel. The end use of the data can be stated, i.e., warning, retargeting, or enemy force deployment. The rules for correlating and reaching conclusions for the fast-response channel can be much more clearly determined than for the slow-response channel.

The slow-response channel would feed into a slow correlation device and the results of this correlation would be fed to

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display devices for command decision. The fast-response channel would feed into a fast correlation device, and this also would feed displays for command decision.

A feature of the fast-response channel would be that the sensor elements would be configured to allow special requests from a commander to the sensors whenever he may need particular information. While this feature is lacking in any of the presently planned L-systems, it is considered vital to the decision-making processes that use intelligence data.

In the development of the slow-response channel, it is recommended that research and development efforts be pursued in the following areas:

- (a) Indexing techniques specifically oriented to the kind of data which must be handled in the intelligence center;
- (b) Indexing techniques for defining high-speed, search-selector, indexing devices;
- (c) More efficient storage devices capable of handling a variety of data, both graphic and digital;
- (d) Reading devices for printed and graphic material;
- (e) Pattern recognition techniques;
- (f) A trend-analysis computer for the intelligence center.

In the development of the fast-response channel, it is recommended that the areas of sensor control, targeting and re-targeting, and survivability and hardening be the subjects of detailed studies.

9.2 Data Flow and Compatibility

Perhaps the most difficult problem in implementing the above concepts is recognizing the need for data flow in enough detail between channels to provide adequate compatibility. This problem has many aspects and consequently must be examined in some detail before a solution can be reached.

In the fast-response channel, the main emphasis must be placed on the data from the fast sensing devices that can contribute to the correlation needed to obtain warning. A detailed look at each sensor must be made to ascertain how data can be processed at the source without removing valuable data from the central correlation device.

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In the slow-response channel, the separation of data for filtering at the source and correlation at the intelligence center presents more of a challenge. In many cases the data will be words or pictures or both. The filtering function will be done by people and will be a subjective interpretation varying between them. The exact division of the load between filtering and analysis will need study, experiment, and continuing evolution and learning.

Compatibility of format and equipment becomes important after functional rules have been established. Automatic aids will force compatibility requirements which will pose difficult problems for the designer. It becomes apparent early that the slow-response channel must support the fast and the fast must also feed into the slow whenever time allows. Both these channels must be compatible to a degree and must have a crosstelling capability.

9.3 Advanced Sensing and Detection Development

Present intelligence sensing devices become obsolete even faster than weapons because of the following two factors:

- (a) The enemy can deny the use of some sensors by technical and even political action,
- (b) The enemy could develop new technology that would demand a new type of detector.

In the first case, enemy denial, the more effective a given detector, the higher the probability that the enemy will attempt to deny its use. If electromagnetic detectors are used to gather data, the enemy may install more land telephone lines to avoid the radiation. The results of the U-2 incident is a prime example of denial by political action.

New weapons or new uses of current weapons can also obsolete sensors. The large bomber airfield is difficult to hide. The 1960 version of an ICBM site is also a sprawling installation. The missile-launching sites of 1965 to 1970, however, may be difficult to find; the Polaris submarine is a prime example.

The gathering of intelligence data in the face of difficulties should not be considered hopeless, but rather a reason for accelerated effort in the sensing and detection area. The element of technical surprise can be used to advantage. A steady emergence of new sensing devices poses a difficult problem for enemy counter-activity, either technical or political.

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History has already shown that much can be done by concentrated research and development effort in the detecting and sensing area. Time has not permitted an analysis of present sensing devices to determine their value. The mention of ionosphere radar, acoustic detectors, and real-time television photography have been used as examples of new techniques now emerging from research laboratories. Each of them could prove equally useful.

9.4 Future Trends

The U.S. national policy for deterring war is expected to continue through 1970. The key for effective deterrence appears to be effective command and control of the deterrent forces supported by successful intelligence systems. To deter without complete knowledge of what is to be deterred is difficult, if not impossible. Further, for maximum deterrence the enemy must understand the ability of the intelligence system to discover and report on his activities. Thus the collection and dissemination of intelligence becomes a prime tool in maintaining a national deterrent posture in this period.

Accepting this, the design of intelligence systems must be predicated on an understanding of probable weapon systems of the period under consideration. Intelligence data-gathering systems must be paced for effectiveness in revealing the enemy's weapon systems before, rather than after, the fact. Present techniques for organizing intelligence systems, selecting processing hardware, and testing applicability require several years, often more time than is required for technological advances in the enemy's weapons. Planning must be far enough ahead to overcome this delay; 1965 to 1970 is not so far in the future as to be beyond our ability to arrive logically at the most likely requirements. Now is the time to do this planning.

The present rapid advances in missiles and space programs clearly portend the nature of the time ahead. There can be little question that the requirement for the intelligence coverage has already moved into space. Future intelligence systems must satisfy not only the requirement to provide surveillance of earth from space, but also to survey space from earth. Indeed, it already appears that a third requirement of surveying space from space is necessary.

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9.5 Recommendations

The panel recommends that the Air Force:

- (a) Authorize a system management group to control the problem of intelligence collection, processing, and dissemination; to plan, program, and finance all future long-range intelligence systems; to modify, expand, or limit present systems; and to insure compatibility and reduce redundancy between present and future intelligence systems.
- (b) Revise the present intelligence data-handling system and reduce the mounting volume of intelligence data so that it will be compatible with the needs of national decision-making.
- (c) Specify a bifunctional, dual-channel, intelligence system for the USAF which will serve all commands needing intelligence information, one channel for the intelligence data that must require slow human judgment for analysis and correlation; and the other for real-time, fast response in the areas of warning, retargeting, and weapon deployment associated with imminence of attack or post-attack action.
- (d) Find ways and means to attract and hold high-calibre people in the vital positions of intelligence analysts.
- (e) Continue and expand such experimental work as in the 438L Intelligence Data-Handling system while concurrently carrying on development and installation of operational systems. In particular, permit enough technical experts to cross the security barriers to experiment with the reduction of data gathering from several sensing devices and to take advantage of the powerful factor of correlation of the data between sensors.
- (f) Support basic studies in the areas of indexing, abstracting, and file-search mechanisms to aid the intelligence analyst in his search for supporting data. These studies should be carried out on the intelligence problem and not in the abstract library area.
- (g) Recognize the need for fast-response sensors to aid the fast-response intelligence system in serving the commander with increased confidence. In particular, support strong development of ionosphere radar, acoustic detectors, real-time television photography, and real-time ELINT.
- (h) Support a thorough study of all sensing and detecting devices for intelligence with increased emphasis on pertinent advance devices. In addition, authorize a central group both to direct heavy research and development support and to introduce new devices into the field before older devices become obsolete.

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10. THREAT

Intelligence information from available sources has been examined to determine, insofar as possible, the Soviet military programs that may be expected to evolve from 1960 to 1975. Ranges of values are used to indicate the strategic flexibility that should be considered in designing and evaluating future L-systems. Since the confidence with which the threat can be predicted varies inversely with time, the estimated values of the threat increase with time. The upper values of the 10- and 15-year predictions have been tested for feasibility against similar predictions for analogous U. S. military programs. The risk of overestimating Soviet potential can, it is believed, be more than offset by providing adequate growth potential in the design of future L-systems.

The Soviet's forces and capabilities from 1960 to 1975 have been analyzed, using the information obtained from intelligence reports and briefings by various USAF agencies, including AFCIN, ATIC, SAC, and NORAD, and a number of contractor organizations, such as RAND, Boeing, and Convair. Where intelligence data was unavailable, information on the current and foreseeable state of the art in the U.S. was used to estimate Soviet capabilities.

Since the specific technical and operational characteristics of Soviet forces 10 to 15 years hence will depend, in some measure, on unforeseen technological, political, and economic developments, both in the West and within the Soviet Bloc, and because the inherently secretive nature of Soviet society will frustrate attempts at obtaining a clear picture of their technological progress and intentions, any estimate of strategic offensive capability can, at best, be viewed as a spectrum of capabilities rather than a specific point on a curve.

To make the analysis as logical as possible, therefore, specific statements of Soviet capabilities have been judged in terms of (a) whether the statements are within the realm of known intelligence data or, (b) where intelligence data is lacking, whether the statements are reasonable in terms of operational and technical feasibility.

It was also noted that over the 1960 to 1975 period a variety of military and non-military threats to U.S. security would perhaps materialize, but the Soviet Union was chosen as the most likely candidate now and for the foreseeable future, since it is possible to engage in only the broadest of generalities about our future enemies, and since it is generally agreed that to build the diversified and complex arsenal required to fight a general war, a nation would require a large, well-established, scientific and industrial base,

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backed up by abundant natural, human, and economic resources. Only two nations appear to fulfill these criteria: the United States and the Soviet Union.

10.1 Soviet Strategic Offense

The U.S.S.R. is creating a deterrent/retaliatory strategy for the pre-1965 period supported by a strategic arsenal consisting of ballistic missiles, sited in hardened and mobile land bases or carried by submarines and manned aircraft. This capability will be supplemented in the post-1965 period by orbital bombing systems and perhaps weapons based on the moon. This varied and highly dispersed force will be used (a) to deter a U.S. preventive or pre-emptive strike by raising the level of doubt in our minds as to the outcome of such action, and (b) to retaliate against our national survival resources, that is, people, cities, and industrial facilities, should they fail to deter us. The Soviet strategic arsenal will also be designed to support a strategy based on a massive preventive or pre-emptive attack against the U.S.-Allied military capability, if and when the requirement arises.

From 1965 through 1975, the capability within the Soviet arsenal should enable them to neutralize or destroy any fixed facility, hardened up to 2000 psi, with aerodynamic and ballistic weapons having CEP's ranging from 0.3 to 2.0 nm, and yields varying from tens to hundreds of megatons. Such attacks could be initiated from terrestrial as well as spatial bases, at altitudes ranging from 1000 feet to possibly several thousands of miles above the earth, at velocities of 600 to 35,000 feet per second, or more, with minimum warning times of 5 minutes or less.

10.1.1 Soviet Force Composition

From now until 1975 the Soviet aero-space weapon arsenal will be gradually modified to emphasize diversity and flexibility. For example, by 1965 their current manned-bomber/ICBM force will be supplemented with supersonic chemical or nuclear-powered aircraft; short-to intermediate-range ballistic missiles launched from conventional submarines and later nuclear-powered submarines; air-launched aerodynamic and ballistic air-to-surface missiles with ranges of 300 to 1500 nm; ballistic missiles with global ranges of 10,000 to 20,000 nm; and possibly a supersonic, mach 3, low-altitude, nuclear, cruise missile. This essentially terrestrial force will be supported in the pre-1965 period by manned and unmanned orbital and aeroballistic vehicles used initially for reconnaissance, warning, and communication and later possibly as global bombing systems.

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Beyond 1965 and through 1975, the Soviets will improve rather than diversify terrestrial weapon systems, with the emphasis on development, diversification, and deployment of spatial weapons, in particular those systems designed to operate in the low-earth (≤ 500 nm) and 24-hour (20,000 nm) orbital zones. Between 1970 and 1975 the Soviets may attempt to build a military base on the moon.

The emphasis on diversifying and dispersing the arsenal will result in a concomitant expansion of the East-West conflict environment from a terrestrial, essentially two-dimensional mode, to a spatial, three-dimensional mode.

10.1.1.1 Aerodynamic Vehicles

Manned aircraft are now the primary weapons in the Soviet strategic arsenal, but after 1963 they will be used less as high-altitude gravity-bombing vehicles and more as low-altitude penetrators and airborne launching platforms for short-to-intermediate range aerodynamic or ballistic air-to-surface missiles. The total aircraft inventory will be kept at approximately 1000 to 1500 vehicles up to 1965 by converting manned bombers to low-altitude penetrators and missile-launching platforms. After 1965 the inventory will be reduced as subsonic vehicles are phased out and supersonic and nuclear aircraft become operational. By 1970 supersonic and nuclear aircraft could comprise the total long-range aviation inventory. Between 1970 and 1975 aircraft could be used exclusively for support roles, e.g., decoy carrier, ECM, cargo transport, air-breathing booster systems, and any requirement for selective high-altitude bombing could be met by aeroballistic and orbital space weapons.

The Soviet Union has limited numbers of aerodynamic cruise missiles similar to Matador, Snark, and Regulus assigned to operational units or undergoing some phase of flight testing. Before 1965, they could develop a low-altitude, nuclear ramjet cruise missile with a mach 3 capability. The difficulty in establishing a firm military requirement for cruise missiles, in the face of a growing ballistic missile arsenal, however, may result in program cutbacks and minimum operational inventories.

10.1.1.2 Aeroballistic Vehicles

There is no specific intelligence information that indicates that the Soviet Union is developing a Dynasoar-type, aeroballistic vehicle to meet either scientific or military requirements. Nevertheless, the advanced state of Russian aircraft and

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rocket technology, as well as information on the boost-glide principle, appearing in various professional and semi-professional Soviet journals, indicates that the capability for creating such a weapon exists in the U.S.S.R. today.

Assuming the Soviets have a Dynasoar research and development program under way since 1958, it can be estimated that an operational prototype could be fully flight-tested between 1961 and 1963 and a unit initially operational between 1964 and 1965. Designed around a winged, hypersonic glider with a gross weight, including payload, on the order of 30,000 to 50,000 lbs, the operational prototype could be coupled to a liquid-fueled, rocket-booster system similar to those which launched the Sputnik series. The estimated gross weights of the gliders for 1965 may be conservative, inasmuch as ATIC has estimated that by then the Soviets could be capable of placing recoverable payloads of 100,000 to 150,000 lbs into low-earth orbits or aeroballistic trajectories. Between 1965 and 1970, as the aeroballistic vehicle attains its full operational potential, it could be used as a multipurpose weapon, i.e., a maneuvering, recallable, ballistic missile, a winged satellite with sustained patrol capability, or a high-performance aircraft.

10.1.1.3 Ballistic Missiles

The technical and operational characteristics of Soviet ballistic missiles will improve through the 1960 to 1975 period and will result in maximum ranges in excess of 10,000 nm, accuracies of better than 1 nm, payloads ranging from 1000 lbs to as high as 100,000 lbs, or more if required, reaction times of 5 minutes or less through the use of storable and solid fuels, operational reliabilities of 0.7 to 0.9, employment of maneuvering re-entry vehicles, sophisticated decoys, ECM and terminal guidance systems, and a reduction in the vulnerability of the force through (a) construction of hardened, dispersed launching complexes, (b) the use of missile trains and barges, and (c) the use of long-range, chemical and nuclear-powered aircraft, submarines, and ultimately, space vehicles as mobile, missile-launching platforms.

Soviet ICBM force levels will build up rapidly from an estimated 50 to 100 missiles in 1960 to an estimated 1000 to 2000 missiles in 1965, with the capacity for doubling or tripling this production between 1970 and 1975.

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10.1.1.4 Space Vehicles

An offensive force could be developed between 1965 and 1975 that would consist of manned and unmanned orbital space systems operating at altitudes of 500 and 20,000 nm above the earth, and, by 1975, from lunar bases. Weapons employed could be high-velocity ballistic or aeroballistic, and in the latter part of the period such exciting weapons as focused particle-generators or atmospheric control devices.

10.1.2 Conclusions and Recommendations

Through consideration of the nature of the 1960 to 1975 Soviet offensive threat, the following conclusions were reached:

(a) The increased diversification and dispersal of the Soviet strategic arsenal, terrestrial as well as spatial, will place additional data collection, processing, and discrimination loads on such intelligence and surveillance systems as 466L ELINT-COMINT, 496L Spacetrack, and 438L Intelligence Data-Handling.

(b) The 1960 to 1975 period will see a further widening of the gap between the offensive and defensive capability, as well as a shifting of the focal point of any pre-emptive or preventive attack from terrestrial to aero/space bases.

(c) If the Soviets lead in the development of space and construct military bases on the moon, they will be able to control the earth if, and only if, these space weapons can neutralize the earth-based deterrent/retaliatory forces aimed at the Soviet heartland. If they cannot, Soviet space vehicles and bases on the moon can be considered as simply additions to their total arsenal. Far more important than its significance as an earth-control element or a strategic deterrent, development of space and the establishment of a moon base by the U.S.S.R. could give that nation a decided advantage for the exploration and control of our entire solar system. Such a possibility could have economic, political, and military implications far beyond the scope of any current terrestrial conflict.

The following recommendations are made:

(a) A missile-detection system should be deployed on a global scale before 1965 to provide warning of an omnidirectional missile attack in the post-1960 period.

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(b) The U.S. offensive-defensive force should not be coupled to a few massively hardened command and control centers that would provide the Soviets with fewer, rather than more, targets to attack and thus defeat the objective of dispersing and diversifying the U.S. force.

(c) In the face of a growing threat from submarine-launched ballistic missiles the USAF's existing and proposed missile warning systems should be coupled to the Navy's Anti-Submarine Warfare effort.

(d) Some means must be devised for discriminating between military and scientific vehicles.

10.2 Soviet Strategic Defenses

The Soviet military program reveals the effects of an aggressive foreign policy. Consistent with the policy, the prime characteristics of Soviet military establishments are:

(a) The military is offense-oriented, with capabilities ranging from limited war with conventional weapons to general war supported by thermonuclear strike forces.

(b) Defense of the strike forces is achieved through a diversification of weapons and delivery systems and dispersion of hardened or mobile firing units.

(c) Active defense counterforces are assigned to the protection of population and industrial concentrations.

It must be accepted that the Soviets will press for a capability to react across the entire spectrum of possible U.S. preventive or pre-emptive action. The building of a strong and large ICBM force will serve to create an imbalance favorable to the Soviet Union in the forces capable of pre-emptive action. Such an imbalance will exist as long as the manned bomber remains the primary delivery system for U.S. strategic weapons and the Soviet Union maintains a significant ICBM force. While this imbalance lasts, defense of cities and industrial complexes against air attack will have a high priority in the U.S.S.R. As the U.S. increases its ICBM forces, the Soviet defense strategy may shift to the development of anti-ICBM systems. Again, in a condition of mutual deterrence, priority would be given to defense of cities and industrial areas. While the emphasis on active defense systems may shift with the tide of the threat, the civil defense programs, i.e., shelter construction, training, and evacuation drills, promise enduring benefits to the defense posture in the event of war and

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contribute to the deterrence from war. From now until 1970, progress in Soviet strategic defense relates to defenses against the manned bomber and the ICBM.

10.2.1 Manned Bomber Defenses

The history of development of Soviet components for defense systems attests to a strong emphasis on system reliability. Improvements are often gradual, since reliability is achieved in simplicity of design and current requirements are met by brute-force modifications.

In predicting the course of development of Soviet defense systems, a study of the distribution of potential targets is necessary. The population and industrial centers of the Soviet Union homeland are apparently more uniformly distributed than U.S. centers. For example, the top 10 cities of the U.S. have a total population approximately equal to the 40 most populated cities of Russia. While the Russian centers of population are evenly distributed, they are confined to an area of only about 1000 by 1000 miles. Other strategically important centers, however, lie on the Siberian perimeter.

From trends in the development of U.S. bomber forces and from trends in development of Soviet defense components, as well as the distribution of target complexes, some predictions may be made:

(a) Gaps in early-warning radar coverage along the perimeter of the Soviet Union will be filled. Priority will be given to protection of approaches from the Arctic regions.

(b) Isolated targets along the Siberian perimeter will be defended by point defense weapons, missiles with salvo capability, and high-speed, short-range interceptors.

(c) To counter the high-performance bomber and the air-to-surface cruise missile, the depth of their defense will be increased by development of long-range, surface-to-air missiles and all-weather fighters. There is no direct intelligence available on Soviet development of a long-range surface-to-air missile system. Intelligence information is available, however, on components which would constitute some of the major subsystems.

(d) For the air defense of the Russian homeland there will be a gradual growth toward an area defense system emanating in all directions from a center in Moscow and extending throughout the 1000-by-1000 mile heartland. The surveillance system

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will integrate inputs from a sufficient number of fixed radars for at least double coverage. Passive tracking techniques, among other possible counter-countermeasures, will be used for ECM attacks, and MTI techniques will be used to filter chaff.

(e) The air surveillance and weapon assignment functions will become more centralized by the development of data-processing centers to present an air situation over a large area and to exercise the command functions of weapon deployment and weapon assignment. On the other hand, the weapons will be controlled from missile batteries and interceptor control centers. Reliable information indicates that the Soviets have a large staff of engineers involved in the development of an air defense system similar to the U.S. SAGE System. The Soviet system is reported to use electronic computers and to display on a large wall the complete defense situation over the entire Soviet Union.

(f) Long-range, ship-borne, surface-to-air missile systems could be deployed to deepen the peripheral area defense of coastal areas which border the Black, Baltic, Barents, Bering, and Caspian Seas, and the Seas of Okhotsk and Japan, and thereby contribute directly to the local air defenses of important coastal targets such as Leningrad, Riga, Baku, and Vladivostok. Soviet ship-borne, surface-to-air, missile systems would directly affect the missions of both U.S. Air Force and Navy air power, since they could conceivably use a 100-mile missile, modified for ship-borne handling and storage. Initially at least, the target and missile-tracking radars could be colocated on the missile-carrying ship, although target detection and tracking capability would affect the interception-range capability of the system. The Office of Naval Intelligence estimates a 75-nm range for a ship-borne missile system by 1961.

(g) Intelligence sources that were consulted attribute to the Soviet defense only token performance against low-altitude penetration. Low-altitude surveillance apparently needs improvement, and no weapon (conventional artillery is mentioned) is efficient at low altitudes.

10.2.2 Anti-ICBM Defenses

A Soviet anti-ballistic missile defense system, capable of destroying an ICBM or IRBM nose cone in a decoy environment produced by the missile itself, would require very complicated and elaborate radar and computer facilities that could be outmoded by relatively simple changes in the decoy environment. An AICBM system, capable of destroying the missile before such decoys could be used, would require an elaborate satellite surveillance system with tremendously effective interceptor missiles for interception

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near the ballistic missile's apogee. Such anti-missile systems would need the support of a most advanced electronics manpower and would be a considerable drain on other weapon system development programs. The expenditure of this effort for a defense system which could not be available until several years after the basic threat became existent and which would be of doubtful effectiveness against second-generation ballistic missiles, is a step which the Soviets do not seem likely to take. On the other hand, the development of satellite surveillance and communication systems for inspection and reconnaissance is probable.

10.2.3 Conclusions and Recommendations

There are two general conclusions which appear inevitable from a digest of intelligence relating to Soviet strategic defenses:

(a) Against the manned bomber, the Soviets will rapidly improve an early-warning network, significantly deepen their defense, and improve its traffic-handling capacity.

(b) Against the threat of the ICBM, satellite reconnaissance will be developed for adequate determination of states of alert and of the disposition of visible, mobile U.S. ICBM and IRBM task forces.

The general implications affecting design of L-systems are as follows:

(a) Improved manned bomber defenses will made penetrations by individual or small groups of SAC bombers prohibitive. The situation can be reached wherein significant rerouting of attack routes and retargeting will be required to guarantee a stress to the Soviet defense system sufficient for penetration to a minimum of targets.

(b) Satellite reconnaissance may reach the efficiency and precision necessary to significantly reduce effectiveness of proposed U.S. mobile strategic forces. Almost certainly the geodetic error contributing to the inaccuracy of weapons will be significantly reduced. Efforts to conceal locations of vital U.S. military targets are well-advised.

10.3 Soviet Limited War Capability

Limited war beyond 1965 was not considered, because limited war is considered to be fought with conventional weapons, since

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the forecasting of development trends for conventional weapons beyond 1965 is almost completely neglected by sources of information available to the Winter Study group.

Nevertheless, in the post-1965 era, the Soviets are expected to retain the philosophies of brute-force design and of designing for mobility of all types of weapons, both of which produce a superb capability for limited action. Therefore, the level of capability of the Soviet Bloc nations for waging conventional war is not expected to diminish after 1965.

For the purposes of the analysis made, limited war was considered to have three salient characteristics:

- (a) Limited war is limited as to participants.
- (b) Limited war is limited as to objectives.
- (c) Limited war is limited as to weapons. Specifically, plans must be based on the use of conventional warheads only, since the decision to use nuclear weapons will not be made by the military.

Evidence indicates that throughout the 1960 to 1965 era, the Soviet Bloc will possess a superb capability for waging limited war in any theater on the periphery of the bloc. Requirements which Soviet Bloc forces meet to give them this capability are:

- (a) Many aircraft readily adaptable to limited theater operations, notably fighter-bombers and light bombers;
- (b) Mobility and portability of ground environment and support equipment;
- (c) Simple, rugged design of mechanical and electronic equipment;
- (d) Effective weapons for air defense against low-flying aircraft, notably gun artillery.

It is concluded that the Soviet Bloc nations can quickly assemble enough air force elements to support any land or amphibious action at the time and place of their choosing. Such a force may contain air defense fighters, guns, and missiles; electronic support including radars, fire control systems, air traffic control systems, air navigation and bombing aids, and communications; surface-to-surface cruise and ballistic missiles; attack aircraft including fighter bombers, light bombers and medium bombers; logistical support aircraft, such as assault helicopters and transports, and medium-range transports; and such ground support for maintenance and replenishment as the local situation may require.

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Whereas general war requires that the L-systems have some mixture of instantaneous reflex and survivability, the conditions imposed by limited actions are markedly different, being more stringent in some ways and less in others.

Taken in sequence, the actions in limited operations are:

- (a) Response of command to the situation in its early phase;
- (b) Deployment of forces suitable to the locality and scale of operations;
- (c) Establishment and maintenance of communications from the theater to the ZI;
- (d) Participation in the action in the following spheres:

Close support of ground and naval forces,
Logistical support of all forces,
Air defense within the theater,
Reconnaissance,

- (e) Withdrawal from the theater when the situation requires it as, say, at the termination of hostilities.

The response of the command may be a matter of hours, or even days, and the deployment of forces may also be relatively slow compared to strategic, or general war situations. Communications within the theater and to the U.S. are vital, and, insofar as possible, they should be ready in advance of the operations requiring them. The elements of participation require frequent exercises within all services, as well as accurate methods of logistical control, and complete systems for local air defense and air traffic control. Efficient withdrawal is a planning function, and plans may be prepared before or during actual operations.

The constraints on the use of nuclear weapons demand that the force be supplied with adequate conventional weapons and that they be frequently exercised in their use. Uncertainties as to locality of the action demands that weapons and systems be designed for mobility, even as the Soviets design their weapons and systems.

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11. VULNERABILITY

The problem of vulnerability of command and control systems is vital, since present concepts for controlling our forces depend so heavily on the survivability of these systems. Consequently, a first objective of the panel was to develop methods for estimating the survivability of presently planned L-systems and those command and control systems yet to be devised and, later, to seek ways and means for increasing the survivability of those systems in war environments ranging from peace to all-out general war.

Though it is desirable to be able to state general survivability principles which are applicable to any command and control system, this statement is not easily achieved. True, it may appear better to disperse, multiplex, and be mobile rather than to remain stationary at fixed bases and centers, but a quantitative estimate must be made of the relative value and cost of these changes before an intelligent choice can be made for a particular application. In short, an operational analysis, that is, a cost, value, and technical investigation, is needed in each situation.

Three errors contributing to the vulnerability of the presently planned L-systems are (a) preoccupation with peacetime operation, (b) colocation of facilities, and (c) 1965 versus 1970 threat.

Based on information obtained, the L-systems now appear to be chiefly concerned with peacetime operation. Since at least some of the justification for these systems rests on their operation in wartime, much more thinking should be done toward incorporating wartime capability. In short, the presently planned L-systems are greatly lacking in wartime survivability.

The problem of location is a serious one because many of the planned L-systems are to be installed at existing SAC and ADC bases, or near cities. The results of such colocation may be, of course, a bonus to the enemy during an attack.

There has been an overemphasis on trying to assess the 1963 to 1965 threat and applying it to the planned L-systems, probably because of the difficulty of obtaining an accurate threat estimate for 1963 to 1965, to say nothing of that for 1965 to 1970. Nevertheless, the trouble with this approach is that in the majority of cases the L-systems are slated to become operational between 1963 and 1965, which means that if a 1963 to 1965 threat is assumed against which to design the system, then obsolescence will have set in before any reasonably useful lifetime can be obtained. To obtain a useful operational lifetime, the L-systems need to be designed against the 1965 to 1970 threat.

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11.1 Vulnerability Factors

General vulnerability factors which affect command and control system survivability are: enemy action, natural phenomena, shortcomings in system design, errors in system operation, effects of U.S., neutral, and allied political systems. Under each of these factors, there are several areas of vulnerability, which, together with some more obvious "curves," are shown in Table 1.

The above factors are of such a general nature that with the exception of a qualitative study considering all these factors (see Section 11.2.1 below), it seemed expeditious to concentrate the study on enemy action. In particular, quantitative consideration was given to fixed versus mobile systems; chemical, biological, radiological (CBR) warfare; electronic countermeasures; electronic interference; and the nuclear effects on an airborne command post.

11.2 Conclusions and Recommendations

The major recommendation regarding vulnerability is that a permanent group be set up to study the vulnerability problems of command and control systems. The purpose of this permanent group should be: (a) to maximize system survivability (b) to improve the match between needed functions and specified requirements for systems.

After listing five major vulnerability factors ranging from enemy action to influence of political systems, the Panel made a qualitative study of the vulnerability of presently planned L-systems. In addition, brief quantitative studies were made of several areas such as physical damage, ECM, and electromagnetic interference. Specific conclusions and recommendations drawn from these studies are given in the following paragraphs.

11.2.1 Qualitative Study of L-System Vulnerability

A qualitative study was undertaken to classify the expected and needed survivabilities of the presently planned L-systems as a function of war environments from peace to all-out war. The conclusions drawn from this analysis are as follows:

(a) From the survivability aspect, the presently planned L-systems are designed for peacetime operation.

(b) Insufficient effort has gone into making the L-systems countermeasure-proof.

(c) The L-system requirements and needed functions are not always well matched.

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The recommendations are as follows:

(a) Where L-systems need wartime survivability, a serious attempt should be made to achieve it, or it should be recognized and stated that they possess only peacetime capability.

(b) Countermeasures considerations should be included in new L-system design from the beginning and on an equal footing with the design itself.

(c) The requirements for L-systems should be matched with what is actually needed to carry out their intended functions, and this matching must also be more closely thought out from the beginning in any new L-system design.

11.2.2 Fixed vs. Mobile Systems

Based on the assumption that the L-system centers will not be prime targets, but rather that SAC bases will, calculations were made of the number of enemy weapons, delivered by ICBM's and manned bombers, needed to destroy these bases to a kill probability of 0.9. Because of the colocation of many of the L-system centers with the SAC bases, these centers will probably be destroyed as a bonus. Similar calculations were carried out for the case of a superhard control center, both with and without an AICBM defense. The conclusions drawn from these calculations are as follows:

(a) Presently planned L-system centers are highly vulnerable to a hotwar strike.

(b) Presently planned L-system centers are collocated with SAC bases to such extent that many will be destroyed as a bonus.

(c) The enemy will probably be able to destroy superhard fixed centers (2000 to 3000 psi) whether these centers are defended (AICBM) or not.

The recommendations are as follows:

(a) Those L-system centers whose functions must survive a hotwar strike should be made more survivable; this survivability might be achieved by resorting to mobile control centers, or greatly increasing the number of fixed centers, or both.

(b) Colocation of L-system centers with SAC bases should be avoided to minimize the number that will be destroyed as a bonus of an attack on SAC.

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11.2.3 Chemical, Biological, Radiological (CBR) Warfare

The attrition of our force and population centers from an all-out nuclear attack has been extensively discussed. Methods to counter this type of an attack for command and control systems have been suggested through the use of hardening, dispersal, redundancy, mobility, etc. If it becomes economically infeasible for an enemy to destroy the effectiveness of these systems through nuclear weapons, other methods may be used to degrade or destroy them. One such method is the use of CBR warfare. A study was made of the survivability of the planned L-systems to CBR warfare. The conclusions drawn from this study are as follows:

(a) Presently planned L-systems are vulnerable to CBR warfare by either covert or overt attack.

(b) According to AFCIN and the U.S. Army Chemical Corps., the U.S.S.R. is capable of large-scale employment of CBR warfare. Offensive warfare, using CW and BW weapons, is within the capability of even "weak" nations.

(c) The use of CBR warfare is being neglected in the design of USAF command and control systems. (In only four instances have any of the effects of CBR warfare been taken into account in the design of L-systems).

(d) For the present, there is no clear-cut pattern of USAF policy on the CBR threat or protective methods. Instead, the present "policy" is one of no action and a calculated risk.

(e) No requirement has been stated nor any policy adopted for CBR decontamination of USAF facilities by the Chemical Corps.

(f) No research or development work is being undertaken by the Chemical Corps to meet any USAF requirement. To date, there are no requirements for the U.S. Army Chemical Corps, who have DOD cognizance for CBR warfare, to supply collective protectors or any other protective devices to the USAF.

Inasmuch as the cost for adequate CBR protection is small (about \$16,000 for direct labor and materials to protect 100 people, according to the Chemical Corps) and the threat is far from negligible, it is recommended that adequate CBR protection of USAF command and control and other key facilities be provided. Specific recommendations are as follows:

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(a) Install collective protective systems in all key system facilities, that is, add to present systems and integrate into future systems. Sponsor development of better protective equipment to meet USAF needs, including blast closures, decontamination facilities, filters, and system designs.

(b) Use available CBR sensors and sponsor development of new sensors and alarms to obtain desired reliability and warning.

(c) Change and update USAF regulations and directives on CBR warfare, so that all units will be afforded equivalent protection. (AFR-355-3 is presently being revised).

11.2.4 Electronic Countermeasures (ECM)

The ECM vulnerability of command and control systems, especially their sensing and communication subsystems, was reviewed. Although experience on large-scale systems to date is almost completely confined to the air defense function, an attempt was made to apply this experience, not only to future defense systems, but also to other USAF missions. Suggestions are made as follows for conducting future command control system developments so as to attain adequate performance in ECM:

(a) Any military system whose operation relies upon the transmission of electromagnetic waves from one point to another is vulnerable to electronic countermeasures (ECM). The degree of vulnerability of any particular system must be determined by an evaluation of the technical, operational, economic, and political considerations involved.

(b) Presently planned and operational I-systems range in ECM vulnerability from very low to very high. At the low end are many systems, particularly those related to command, which appear safely invulnerable to ECM in a cold or all-out hot war. In the intermediate-to-high category are communications links that would be involved in limited wars. At the high end are the systems directly involved in air defense; they are now dangerously vulnerable to ECM. The situation on I-systems for intelligence is not clear. Collection systems seem vulnerable to deception although there is some feeling that this vulnerability depends on the skill of the personnel employed in data-processing centers. If this hunch is correct, that is, if human experience and judgment are our best protection against deception in the intelligence game, then there is great danger in the trend to automate the intelligence data-processing function.

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(c) The current air defense concept of detecting, tracking, and attacking individual targets has resulted in systems that are highly vulnerable to ECM, because they are based on the ability of radars to provide highly accurate tracking data, and their weapons require such data. In the presence of ECM, the radars cannot supply such data and the weapons become nearly useless. Addition of passive subsystems to the radars will produce some restoration of detection and tracking capability. However, present information indicates that this capability will not be adequate.

(d) On the general question of ECM vulnerability of command and control systems, we believe that there is a useful lesson to be learned from our experience with SAGE, the only large-scale electronic system we have built and operated to date. The lesson is very simple; we must wage electronic warfare right from the inception of the system. Putting off ECM considerations until later, on the philosophy that "we'll get the system operating among friends first and worry about the electronic enemy later", does not work. It turns out that a vulnerable system cannot be properly "fixed" later by the addition of counter-countermeasure (CCM) modifications. Unless the ECM-CCM contest is kept active during the conception and design of the system and its components, technical choices will invariably be made which lead to serious ECM weaknesses, and the removal of these weaknesses at later times will require difficult, expensive, and time-consuming revisions.

The recommendations regarding ECM vulnerability are as follows:

(a) The defense concept in the U.S. and overseas theaters should be re-considered, re-evaluated, and modified so that the weapons, delivery systems, and weapon control equipment will perform effectively with the expected accuracy and capacity of the sensors under ECM.

(b) Command and control system, subsystem, and technique designers should be kept continually aware of the effects of the ECM threat and required to design appropriate CCM capability into future systems. Previous research and development experience indicates that the only reliable way to do this is to make the design groups responsive to a qualified electronic warfare group charged with responsibility for evaluating the system performance against the ECM to be expected from a technically competent enemy.

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11.2.5 Electromagnetic Interference

Work in this area consisted of (a) a survey of the present interference problem and the direction in which it is going, (b) an examination of the developments that led to this situation, and (c) a statement of a possible method of alleviating the problem. The conclusions drawn from this work are as follows:

(a) The electromagnetic spectrum is becoming very crowded. Over 500,000 licensed stations involving over 2,000,000 transmitters are operational in the U.S. in addition to the military electronics. The VHF and lower bands are overcrowded and the growth is rapidly increasing in the UHF and microwave bands where the USAF is developing and producing very high-powered radars.

(b) Serious interference problems exist today, and worse ones are yet to come. Military radars now experience a high level of mutual interference. Future plans can be expected to increase this problem, not only for radars but also for other military electronic operations; in addition, they will lead to problems of interference with non-government services. The introduction of frequency-diversity radars into the field will cause television interference in Pittsburgh and several other places. In addition, serious interference will be encountered by industrial, public safety, and land transportation services in California, Pennsylvania, and elsewhere.

(c) The present spectrum allocation seriously complicates the interference problem. The frequency spectrum where high-powered radars are planned is divided into many narrow bands, alternating between Government and non-Government services. There seems to be no clear way out of this problem without a drastic revision of the allocation in certain portions of the spectrum.

(d) The ARDC applied-research program is directed toward radars in the VLF, LF, and HF bands as well as P, L, S, C, and X bands. Clearance to radiate on the low frequencies is extremely doubtful since international agreement and authorization will be required and the interference to communication in these bands would be very serious.

(e) The state of the art in measurements has not kept pace with the requirement generated by the increases in effective radiated power of modern radars and the sensitivity of receivers. Off-frequency radiation of emitters and acceptance characteristics of receivers can be measured at levels of about 70 to 80 db down from the fundamental, but 100 to 110 db is required. Also, electronic standards and specifications do not now specify:

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TABLE I
VULNERABILITY FACTORS RELATING TO COMMAND AND CONTROL SYSTEMS

<u>AREA OF VULNERABILITY</u>	<u>ENEMY ACTION</u>	<u>CURE</u>
1. PHYSICAL DAMAGE (SABOTAGE; NUCLEAR BLAST)	"POUR CONCRETE", MOBILITY, DISPERSAL	
2. NUCLEAR EFFECTS IN ATMOSPHERE AS A PROPAGATION MEDIUM	CHANGE FREQUENCY OF PROPAGATION RADIATION	
3. NUCLEAR EFFECTS ON ELECTRONIC COMPONENTS	USE LESS SUSCEPTIBLE ELECTRONIC COMPONENTS SHIELDING	
4. NUCLEAR EFFECTS ON MAN	SHIELDING	
5. ECM (INCLUDING DECOYS)	MODIFY CONCEPTS TO OPERATE IN ECM. ECCM TECHNIQUES	
6. CBR AGENTS (EITHER SABOTAGE OR OTHERWISE)	FILTERS, GAS MASKS	
7. POLITICAL OR ECONOMIC PRESSURES	DESIGN FOR INSENSITIVITY TO EXTERNAL PRESSURES. DESIGN SYSTEMS FOR APPLYING COUNTER-PRESSURES.	
8. SPOOFING OR IRRITATION	DESIGN SYSTEMS FOR SPOOFING ENEMY. DESIGN SYSTEMS TO MAKE SPOOFING MORE EXPENSIVE. FIND WAYS TO DISCOURAGE SPOOFING, DECOY SYSTEM TO CONSUME ENEMY SPOOFING CAPABILITIES. IMPROVE DATA ANALYSIS AND COMMUNICATION SECURITY.	

NATURAL PHENOMENA

1. WEATHER	WEATHER FORECASTING (LONG RANGE), WEATHER CONTROL
2. AURORA	CHOOSE OPTIMUM LOCATION AND FREQUENCIES
3. VAN ALLEN BELTS	SHIELD AGAINST RADIATION
4. EARTHQUAKES	STRUCTURAL STRENGTHENING

SHORTCOMINGS IN SYSTEM DESIGN

1. EM INTERFERENCE	IMPROVE FREQUENCY ALLOCATION METHOD. COLLECT AND DISSEMINATE ENVIRONMENTAL DATA. DESIGN SYSTEMS TO AVOID INTERFERENCE. IMPROVE RF MEASURING TECHNIQUES.
2. PEACETIME vs. WARTIME DESIGN	ESTABLISH REALISTIC REQUIREMENTS. IMPROVE EXERCISING AND EVALUATION.
3. LIMITATIONS IMPOSED BY COST	DESIGN SO THAT LEAST MONEY SPENT FOR LEAST VULNERABLE PARTS.

ERRORS IN SYSTEM OPERATION

1. FUNCTIONAL INTEGRATION AMONG SUBSYSTEMS	SYSTEMS INTEGRATION
2. UNEXPECTED OPERATING SITUATIONS	WAR GAMES, SIMULATED AND LIVE
3. ERRORS IN JUDGEMENT	BATTLE SIMULATION TRAINING

EFFECTS OF U. S., NEUTRAL, AND ALLIED POLITICAL SYSTEMS

1. SABOTAGE	SECURITY
2. FUNDING	UNDERSTAND AND ACT UPON THE INTERACTION BETWEEN FUNDING AND SYSTEM DEVELOPMENT, I. e., RELATE ALL COSTS OF ALL AF SYSTEMS TO ANTICIPATED AF BUDGETS.

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(1) Maximum permissible radiated signal level outside the normal band (spillover modulations, harmonics, and spurious signals).

(2) Maximum receiver acceptability for off-frequency signals using various types of modulation.

The recommendations regarding electromagnetic interference are as follows:

(a) The interference problem cannot be solved within one service and must of necessity involve the three services, other government agencies, and industry. Therefore, it is recommended that the USAF request DOD to establish a technically competent group to represent the three services and:

(1) Work with FCC, industry, and non-military governmental departments to plan a long-range program for better spectrum assignments. Particular consideration should be given to clearing parts of the spectrum where super-high-powered radars could be operated effectively with minimum interference.

(2) Collect data on all electronic equipment, solve interference prediction problems, and establish adequate standards and specifications for interference controls.

(b) The Air Force should:

(1) Take immediate action to fund its interference measurements program and to investigate and solve, by prevention if possible, the interference problem associated with the installation of the frequency-diversity radars.

(2) Require the selection of a particular portion of the spectrum for future radar development to be fully coordinated with the frequency control agencies, in order to allow advance planning for frequency clearance and to minimize interference problems.

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11.2.6 Nuclear Effects on an Airborne Command Post

The SAC airborne command (or control) post, proposed to be in a KC-135 aircraft, has been examined for vulnerability to nuclear effects in the following areas: communications, airframe, personnel, and electronic components. The intent has been to provide quantitative data wherever possible. The conclusions drawn are as follows:

(a) Any line-of-sight or ground-wave communications link will suffer little or no degradation due to nuclear effects. This conclusion is based upon the 1958 Hardtack series of tests, and upon the analysis conducted by GE TEMPO under contract AF 18(600)-1808.

(b) The airborne command post is relatively invulnerable because the radius of vulnerability for rupture of the airframe by a 5- to 10-MT burst, colatitude at 40,000 feet, is 6 to 7 miles, and the vulnerability radius for complete and immediate incapacitation of the crew (at the 5000 r level) is about 4 to 5 miles. These calculations were based upon "The Effects of Nuclear Weapons" (AEC-1957), and the NOVA study (RAND-1957).

(c) The electronic components of the airborne equipment will fail due to irradiation at ranges considerably shorter than those in (b) above. Indeed, some components will not fail unless irradiated to levels found only in or near the fireball. These conclusions are based upon reports of the Battelle Memorial Institute (1959).

Based upon the above it is recommended that the airborne command or control post be considered for supplementing other vulnerable links of the command and control processes. It is recommended that all communications with the airborne command post be line-of-sight, or line-of-sight to the ground and ground-wave to remote ground locations.

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12. WEAPONS

Information concerning capabilities, numbers, and deployment of USAF weapons which probably will be used in the two periods 1960-1965 and 1965-1970 was collected, and command and control problems posed by each weapon system in this anticipated arsenal were considered.

12.1 Force Structure 1961-1965

The inventory, deployment, and characteristics of the strategic, tactical, and defensive weapons of USAF from 1961 thru 1963 have been determined from the official documents available. The determination of strategic weapons has been extrapolated to a general estimate, in the absence of official documents, of what the strategic weapon inventory of 1965 can reasonably be expected to be.

Table II is a summary of the total inventory and deployment of active USAF weapons of FY 1961 thru FY 1963.

Existing and programmed strategic weapons consist of the B-47 (expected to phase out of essentially active operational use by 1965), B-52 and B-58 manned bombers; SM-62 Snark; SM-65 Atlas, SM-68 Titan, and SM-80 Minuteman ballistic missiles for deployment in the U.S. and SM-75 Thor and SM-78 Jupiter for deployment overseas. Tactical weapons planned and programmed consist of the F-100, F-104, and F-105 manned fighter-bombers and the TM-76 Mace and TM-61 Matador aerodynamic cruise missile, all deployed in overseas theaters. The existing defensive weapons consist primarily of the F-106, F-101, and F-102 manned interceptor aircraft and the IM-99A and IM-99B and Nike Ajax and Hercules guided interceptor missiles. Strategic support units consist of the KC-135 and KC-97 tankers and C-124 transport aircraft and the RB-47 reconnaissance aircraft. Tactical support units consist of the KB-50 tanker, RB-66 and RG-101 reconnaissance aircraft, H-21 helicopter, and TB-57 tow target.

By 1965, it is predicted that the characteristics of the strategic offensive arsenal of the United States will have undergone substantial changes. The Strategic Air Command will probably then contain a total of 1500 to 2000 weapon units: 700 to 850 B-52 aircraft, 100 to 150 B-58 aircraft, 500 to 600 KC-135 tankers, 150 to 200 Atlas missiles, 150 to 200 titan missiles, 300 to 400 hardened and dispersed Minuteman missiles, and 100 to 200 mobile Minuteman missiles. With the exception of 100 to 150 bombers and 75 to 100 tankers, all of SAC's 1965 weapon systems are expected to be located in the U.S.

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TABLE II - SUMMARY OF WEAPON AND WEAPON SUPPORT FORCES

FY 1961, 1962, 1963

	<u>Outside U.S.</u>			<u>Within U.S.</u>			<u>Total</u>		
	<u>61</u>	<u>62</u>	<u>63</u>	<u>61</u>	<u>62</u>	<u>63</u>	<u>61</u>	<u>62</u>	<u>63</u>
A. STRATEGIC WEAPONS									
B-58				36	108	108	36	108	108
B-52	60	60	60	557	632	632	617	692	692
B-47	287	287	287	967	787	632	1254	1074	925
SM-68 Titan				10	40	90	10	40	90
SM-65 Atlas				50	90	120	50	90	120
SM-62 Snark				45	45	45	45	45	45
SM-80 Minuteman						150			150
SM-75 Thor	60	60	60				60	60	60
SM-78 Jupiter	45	45	45				45	45	45
<u>Support</u>									
KC-135	28	28	28	382	442	522	410	442	550
KC-97	259	259	259	569	549	469	828	808	728
C-124	114	114	114				114	114	114
B. TACTICAL WEAPONS									
F-100	568	524	556	450	450	450	1018	974	1006
F-105	168	243	318	72	72	72	240	315	390
B-57	80	80	80	14	14	14	94	94	94
B-66	64	64	64				64	64	64
TM-76 Mace	138	174	174				138	174	174
TM-61 Matador	80	80	60				80	80	60
<u>Support</u>									
RB-47	25	25	25				25	25	25
KB-50	54	54	54	40	40	40	94	94	94
RF-101	90	90	90	36	36	36	126	126	126
C. DEFENSIVE WEAPONS (ADC)									
F-106				270	270	252	270	270	252
F-101				324	324	324	324	324	324
F-102				240	192	218	240	192	218
IM-99A Bomarc				210	210	210	210	210	210
IM-99B Bomarc		60	60	180	390	420	180	450	480

D. DEFENSIVE WEAPONS (USARADCOM)

By mid-1961 USARADCOM's Nike Ajax and Hercules point defense systems are expected to be completely operational and to consist of the following:

No. of points to be defended: 38; cities 24, SAC 14.

No. of batteries: 268: Ajax 147, Hercules 102, combined A & H 19.

No. of Missiles: 6014; Ajax 4512, Hercules 1502.

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In addition to SAC's weapon capability in 1965, the U.S. is also expected to have (1) a naval force of 20 to 25 nuclear-powered submarines, armed with a total of 192 to 320 Polaris missiles (16 per submarine), (2) aircraft with thermonuclear capabilities assigned to the operating fleets, and (3) some tactical aircraft and missiles in the European and Pacific inventories.

12.2 Force Structure, 1965-1975

Many people assert strongly that at least until 1975 there will be targets that can be successfully attacked only with manned bombers. The phasing-out of bombers will depend on many developments, including military map-making; intelligence; missile CEP and warhead yield, missile re-action time; hardening, mobility, and dispersion of missile installations and aircraft bases; and defense against missiles and aircraft. Looking forward from 1960 past 1965, we must anticipate, therefore, a mixed force of aircraft with speeds bounded by those of the B-52 and the B-70, plus missile and satellite weapons.

12.2.1 General War Arsenal

There are no B-47's scheduled for operation after 1965. Nevertheless, it will be surprising if SAC actually retires these aircraft; it seems more likely that there will be some hundreds still flying well after 1965. There are presently scheduled more than 650 B-52's in 1965. Many of them will be relatively new and will last long into the 1965 period. The B-70 may be procured in some quantity; if so, deliveries of operational models could begin by FY 1965, and the numbers of B-52's would probably be reduced. There may be nuclear-powered aircraft in the late 1960's. They will be slower than B-70's (Mach 0.9), but they will be able to stay airborne alert for days. There will be several hundred KC-135's, which were designed for refueling B-52's, but since B-70 can fly as slowly as 500 knots, the KC-135's can be used for refueling B-70's as well. There will be a few B-58's. There will be a number of air-launched missiles (AIM) to be used from heavy bombers.

For some time after 1965, the U.S. will have Thor and Jupiter missiles abroad, and some Atlas's and Titans in the U.S. with many Minutemen. It will be feasible to build missiles much larger than Titan, to carry payloads of 25,000 to 100,000 pounds, but at present it seems more likely that satellite weapons will be built instead. It would not be realistic to try to specify characteristics of military satellites so far in advance.

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12.2.2 Limited War Arsenal

The information available in the inventory of tactical fighters and fighter-bombers goes only through FY 1963, when there will be over 1000 fighters, F-100's, F-101's, F-104's, and F-105's, stationed in the U.S. and abroad, but it seems highly probable that there will be at least several hundred of these in service after 1965. We also expect some hundreds of tactical missiles which will be improved versions of those which will be in service before 1965. A number of AIM's are under development, but no new fighter aircraft. Undoubtedly satellite vehicles and weapons will have some usefulness in limited war, but one cannot yet tell how they will be used. VTOL transport vehicles will be used late in the 1960 decade.

12.3 Command and Control Implications

The command and control problems concerning the present SAC, TAC, and ADC forces have been examined elsewhere in this report. Nevertheless, it is worthwhile to state again that, under existing laws and procedures, the efficacy of SAC as a retaliatory force is critically dependent upon the survival of communications from the President and JCS to SAC headquarters and then to the aircraft and missiles.

The new weapons being added to the USAF arsenal in the 1960-1965 period probably will influence the design of systems for commanding and controlling them in the following manner:

(a) B-70: The war planning problem will be considerably more severe, because of the high speed of the aircraft. Much more accurate planning will be required for each stage of each mission - take-off, refueling rendezvous, penetration, and arrival over target.

(b) Nuclear-Powered Aircraft: Nuclear-powered aircraft will have a speed of only about Mach 0.9. They will not need refueling aloft. Their outstanding characteristic will be their ability to remain on airborne alert for days. Hence, the war planning problem will differ from those of both B-52's and B-70's, but there is no apparent reason why this problem should be more severe with nuclear-powered aircraft than with the B-52's. If these nuclear aircraft are assigned to stations aloft in the polar region, new means of communication will be needed.

(c) Satellites and Soaring Vehicles: The applications of satellites and of boost-glide and other soaring vehicles are not yet sufficiently well understood to permit predicting their characteristics except in the most general way. By 1965, and after, it is expected that:

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(1) Our own satellites, and those of other nations, will exist in large numbers.

(2) Extremely complicated observing and data-processing systems will be needed to catalog them.

(3) A worldwide communication system will be needed to talk with the satellites, to control them, and to receive sensing information from them. Some of these satellites themselves may become parts of the communication system.

(d) VTOL aircraft: We do not anticipate that novel vehicles other than those for general war will create any new command and control problem.

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ADDENDUM A USAF L-SYSTEMS

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ADDENDUM A: USAF L-SYSTEMS

The USAF is considering eighteen systems that are directly related in one or more aspects to the operational military forces of the United States. Fifteen of these systems fall into four functional groups as follows:

Command

465L, SAC Control System
473L, Hq. USAF Command System
425L, NORAD Combat Operations Center System

Intelligence and Warning

438L, Intelligence Data-Handling System
466L, ELINT-COMINT System (ELICO)
117L, MIDAS-SAMOS System
474L, Ballistic Missile Early-Warning System (BMEWS)
496L, Space Track System
413L, Distant Early-Warning System (DEW Line)

Control

416L, Continental Aircraft Control and Warning System
(of which the SAGE System is a part)
412L, Theater Air-Weapon Control System
431L, Traffic Control and Landing System (TRACALS)

Support

480L, USAF Global Communications Management Project
433L, USAF Weather System
470L, Communication Satellite System

Three other systems considered in the Winter Study, but not in as much detail as those above and not included in this addendum to the Winter Study Report, are as follows:

423L, Communications Logistics Net for AMC (COMLOGNET)
OSR-290, Bomb-Alarm System
OSR-62, Atomic-Strike Recording System (ASTREC)

All except the last three systems have been analyzed in enough detail to arrive at cost estimates that are believed reliable enough for determining the general financial direction in which the systems seem to be going. The first fifteen systems of the above list are briefly described and a summary of the cost analysis performed on each is given. Research, development, test,

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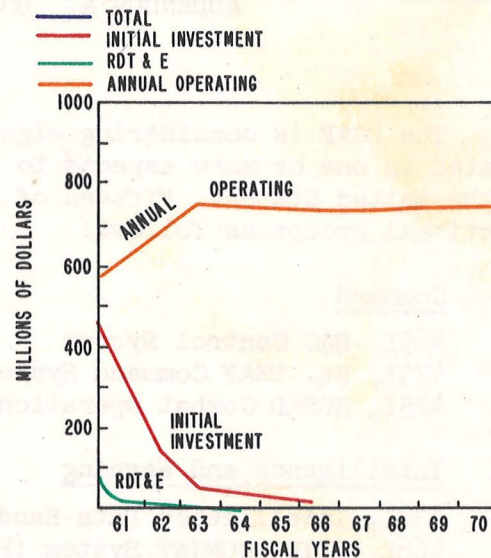
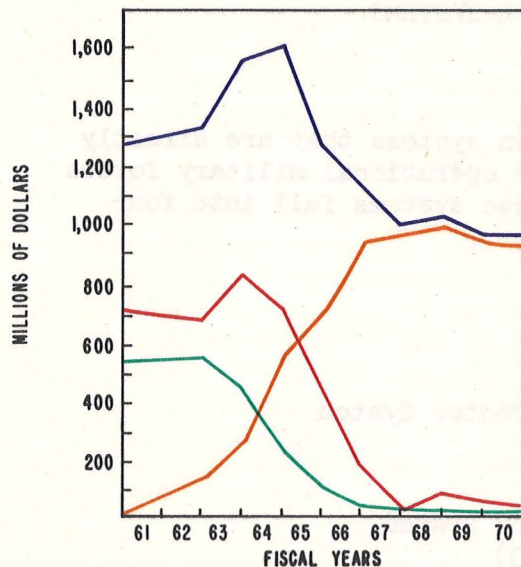


TABLE 1 SUMMARY OF L-SYSTEM COSTS.

FY 1961 THROUGH 1970						
	RDT&E (P-600)	INITIAL INVESTMENT	TOTAL INITIAL COST	ANNUAL OPERATING COST	TOTAL COST BY END FY 1970	TOTAL COST BY END FY 1965
465L	\$ 58,600,000	\$ 184,900,000	\$ 243,500,000	\$ 237,000,000	\$ 480,500,000	\$ 322,500,000
473L	3,000,000	31,532,000	34,532,000	1,400,000	35,932,000	32,400,000
425L	9,500,000	39,700,000	49,200,000	45,100,000	94,300,000	58,300,000
438L	107,000,000	176,400,000	283,400,000	403,300,000	686,700,000	310,300,000
466L	133,000,000	217,200,000	350,200,000	352,700,000	702,900,000	319,500,000
117L	623,300,000	488,700,000	1,112,000,000	1,527,300,000	2,639,300,000	1,663,600,000
474L		207,800,000	207,800,000	1,133,400,000	1,341,200,000	840,200,000
496L	257,000,000	586,700,000	843,700,000	945,200,000	1,788,900,000	949,000,000
412L	32,200,000	111,100,000	143,300,000	193,200,000	336,500,000	215,000,000
431L	54,630,000	1,295,360,000	1,349,990,000	1,044,230,000	2,394,220,000	1,151,760,000
480L	171,900,000		171,900,000		171,900,000	108,900,000
433L	16,800,000	240,200,000	257,000,000	112,400,000	369,400,000	283,800,000
TOTAL	\$1,466,930,000	\$3,579,592,000	\$5,046,522,000	\$ 5,995,230,000	\$11,041,752,000	\$6,255,260,000
413L		53,600,000	53,600,000	1,100,000,000	1,153,600,000	603,400,000
416L	99,600,000	448,300,000	547,900,000	6,238,900,000	6,786,800,000	3,595,800,000
TOTAL	\$1,566,530,000	\$4,081,492,000	\$5,648,022,000	\$13,334,130,000	\$18,982,152,000	\$10,454,460,000
470L	651,000,000	133,500,000	784,500,000	565,900,000	1,350,400,000	823,900,000
TOTAL	\$2,217,530,000	\$4,214,992,000	\$6,432,522,000	\$13,900,030,000	\$20,332,552,000	\$11,278,360,000

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and evaluation (RDT&E, P-600) costs are separated from initial investment (primarily P-800, Procurement) which consist of facilities installation, equipment and spares, personnel training and travel, stock and other items, and computer programming. Estimated annual operating costs are also given where available.

The L-system cost data represents obligational authority. That is, it is not called out year by year in terms of what will be spent in those years, but what money Congress must obligate in those fiscal years. It is the money that will be spent; it does not include money that has been spent on any of these systems before FY 1961. RDT&E, initial investment, and annual recurring costs are included for FY 1961 through FY 1965. The annual recurring costs only have been stated for FY 1966 through FY 1970, since a more or less static capability is assumed after 1965. Only fifteen of the L-systems that are currently planned are costed, and most important, except for 416L SAGE and 413L DEW, the costs are incremental costs only. That is, they are in addition to the current USAF budget. For example, in the 465L SAC Control System, the communication network will replace the current primary alert and teletype network. Therefore, zero dollars are costed for communications services of the 465L system.

Fig. 1 shows the yearly cost of the L-systems, except SAGE and DEW but including the satellite program for MIDAS and SAMOS. As shown, the RDT&E costs go from about \$550 million down to essentially zero in 1966, but the annual operating costs build up rapidly to about \$1 billion a year in 1965. These are again incremental annual operating costs over and above the present annual operating costs. Fig. 2 shows the costs of SAGE and DEW, which are total costs, that is, both incremental and budgeted. Again the initial investment falls off rapidly. The annual operating cost is roughly \$800 million for both systems. The initial investment includes the installations themselves, the equipment and spares, personnel training and travel, and stocks and computer programming. The annual operating cost includes equipment and installation replacement and maintenance, pay and allowances, communication services, and computer programming. Table 1 is a summary of the costs of each system.

Fig. 3 shows the FY 1961 funding. Current plans and schedules for the L-systems call for \$171 million for RDT&E (P-600) funds in 1961. Other procurement (P-800) fund needs amount to \$490 million. SAGE is shown separately, and DEW costs are not included. The current ceilings are represented by the top of the white bars. It is clear that the plans have to change as of today, if these ceilings are held. For example, the ceiling of P-600, exclusive of satellite programs and SAGE, is currently only \$58 million as compared to the indicated needs of \$171 million.

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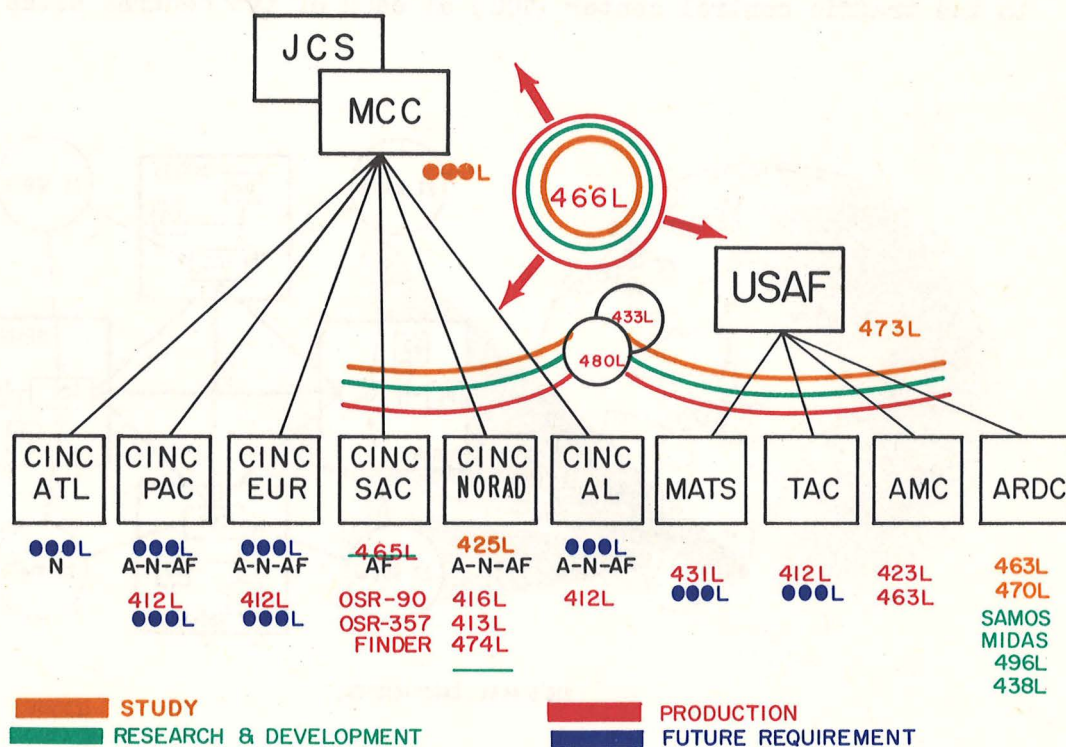
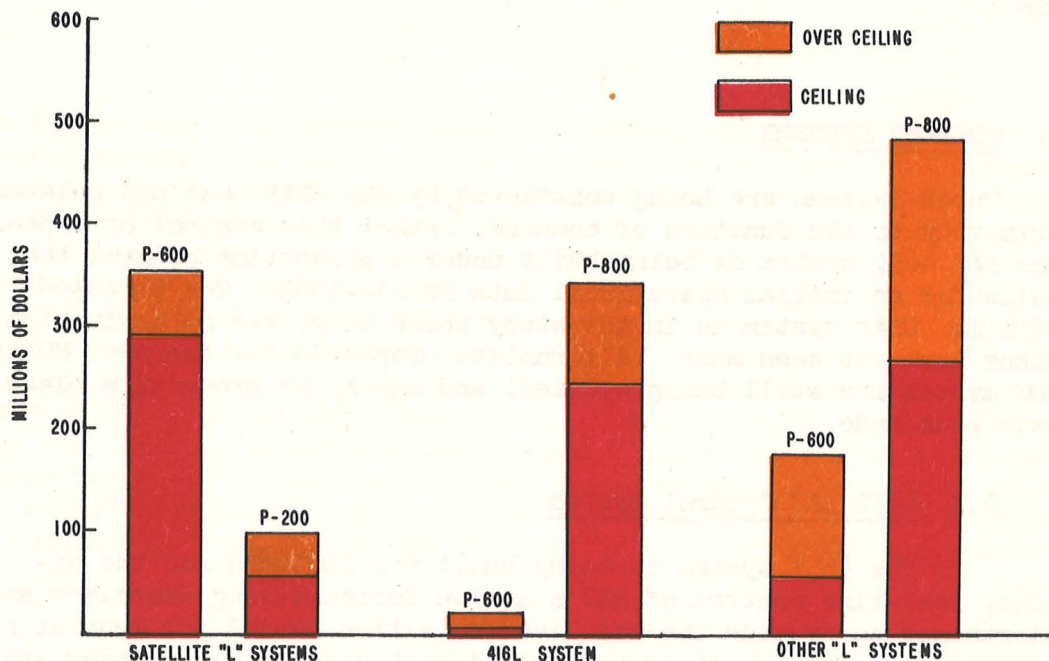
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Fig. 4 shows the presently planned systems in terms of their command and organizational responsibilities and their status. With the exception of the 412L Theater Air-Weapon Control System, all of the systems in production are for the support of SAC or NORAD, or both. The systems currently in research and development are all intelligence and warning systems, and are all oriented toward the strategic war problem. There are very few systems being developed to support the theater problem, or the limited war problem. It seems likely that the sixteen systems in Fig. 4 form only a small part, perhaps not more than half, of what might be required in coming years to support command and control and sensor needs. The systems identified in the chart as future requirements are those that might be needed - a TAC control system, a MATS control system, a PACAF control system, a USAFE control system, control systems for each one of the theater CINC's.

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1. COMMAND SYSTEMS

Three systems are being considered by the USAF that are related primarily to the function of command, rather than control or sensor. The SAC 465L system is being built under a production program that calls for an initial operational date of mid-1963. The proposed 473L Hq. USAF system is in the study phase only, and no production plans have yet been made. Alternative proposals for the 425L NORAD COC system are still being studied, and again, no production plans have been made.

1.1 465L SAC Control System

The 465L system is being built for SAC both for the on-line, real-time control of SAC's active forces during exercises and alerts and to provide the off-line facilities needed for generating war plans. Although it is understood that significant changes are being made to it, the official 465L program studied by the Winter Study Group calls for the facilities shown in Fig. 5. The four central sites, one each at Offutt AFB in Nebraska, March AFB in California, Westover AFB in Massachusetts, and Barksdale AFB in Louisiana, will be interconnected with 2400-bps data lines so that the information at any one center can be transferred to any other. Each of the 108 remote communication complexes (RCC's) will be connected to the traffic control center (TCC) at each of two central sites.

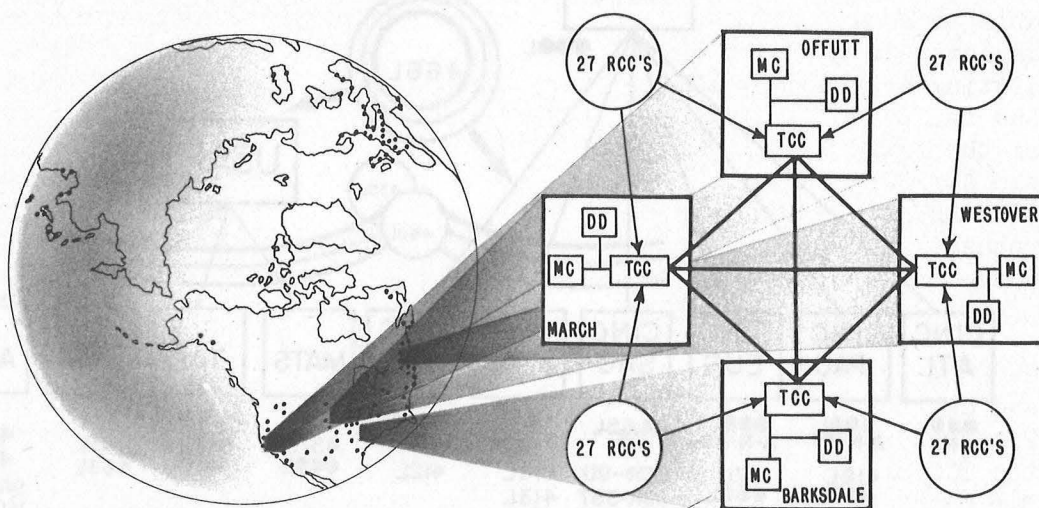


FIG. 5 465L, SACCS SYSTEM

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The concept of SAC operation for which the 465L system is being designed, is one of centralized control. At any one time, only one of the four central sites will do the on-line job, i.e., control of the entire SAC force, such as required, for example, during a real alert. A second computer at a different central site will be receiving data continuously from the first and will serve as a follower and backup so that it can at any time take over the function should the first computer become inoperable. A third computer at a third central site will be used for off-line data processing, for example, generating war plans or simulating exercises. The fourth computer at the fourth central site will be on scheduled maintenance. At any one time, only one central site will be in command and control of the SAC force. The computers will be switched automatically to various jobs in accordance with a pre-established priority and without the knowledge of the system operators.

The 465L system is programmed to become initially operational in mid-1963. At that time, 75 of the 108 RCC's, one of the military computers, one data display, and four duplexed TCC's are planned for installation. The other three computers and displays will not be in and operating. The results of testing and experience with the initial system will determine the configuration of the system implemented to meet a complete operational date scheduled for 1965.

Each of the four central sites will contain a traffic control center (TCC) which will be the communication link between all the other parts of the 465L configuration, and which consists of a stored-program computer and switching facilities. Each TCC will be able to communicate with up to 70 other 465L facilities, and this capacity is expandable to 120. A local communication complex consisting of message composers, keyboard inputs, hard-copy printers, and fault and facility controls is also a part of each TCC. Each of the four central sites will also contain a military computer, the AN/FSQ-32V, which is basically a transistorized version of the SAGE AN/FSQ-7 vacuum-tube computer, a display system consisting of request panels that are connected directly to the TCC and military computer, large-screen displays, and hard-copy printers.

A remote communications complex (RCC) will be located at each of 108 airbases, both within the continental United States and overseas, to which SAC manned aircraft are deployed and at SAC Titan and Minuteman missile bases. Every RCC will be connected to the TCC at each of two central sites. Every RCC will have a device for batching messages and will thus control message transmission and reception. This device, called a concentrator, will also have a buffer storage and a scanning capability, and it will be able to generate and check parities. It will be able to accept messages from the up to 32 input devices, keyboards, and message composers

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that will also be a part of each RCC. It will operate with up to 32 hard-copy printout devices that may be high- or low-speed. In addition to the concentrator and input and output devices, each RCC will also have an alert panel for receiving alarms from whichever of the four central sites is controlling the force; a fault facilities control for error detection and correction; two crypto devices, one for encrypting and one for decrypting messages; and two modems, one for data transmission and one for data reception.

In addition to the TCC's located at each of the sites in the continental United States, the 465L program calls for a TCC to be installed in the United Kingdom. The possibility of installing a TCC at Guam has also been stated. A TCC only would be installed at either Europe or Guam and not the military computer or the display facilities as at the central sites in the U.S. The TCC planned for the United Kingdom is included in the cost analysis, but not that being proposed for Guam.

Table 2 is a summary of the complete cost analysis of the 465L system. The total cost of producing the 465L system as described above is about \$129,980,000, which is summarized in Table 3.

TABLE 2 SUMMARY OF 465L SYSTEM COST ANALYSIS

RESEARCH, DEVELOPMENT, TEST, AND EVALUATION, 1961-1965	\$ 58,600,000
INITIAL INVESTMENT, 1961-1965	<u>184,900,000</u>
TOTAL INITIAL COST	\$243,500,000
ANNUAL OPERATING COSTS, 1961-1965	<u>79,000,000</u>
TOTAL COST, 1961-1965	\$322,500,000
ANNUAL OPERATING COSTS, 1966-1970	<u>158,000,000</u>
TOTAL COSTS TO 1970	<u>\$480,500,000</u>

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TABLE 3 465L SYSTEM PRODUCTION COSTS

TRAFFIC CONTROL CENTER (TCC):

4 @ \$8,140,000 \$32,560,000

1 @ 3,976,000 3,976,000

(TRANSFERRED FROM TEST, SO COSTS LESS)

EFFICIENCIES (SAVINGS STATED IN PHASING (4,200,000)

AND FUNDING PLANS:

IEC, 6 NOV 59.)

\$32,336,000

OTHER COSTS

5,491,000

(ENGINEERING, TRAINING, SPARE

PARTS, ETC.)

\$ 37,827,000

LOCAL COMMUNICATIONS COMPLEX:

5 @ \$372,000 1,860,000

OTHER PRODUCTION COSTS 1,010,000

2,870,000

MILITARY COMPUTER:

4 @ \$7,168,500

28,674,000

(INCLUDING ENGINEERING, SPARE

PARTS, ETC.)

DISPLAY:

1 SYSTEM @ \$3,278,600 3,278,600

3 SYSTEMS @ 1,981,600 5,944,800

OTHER PRODUCTION COSTS 6,580,600

15,804,000

REMOTE COMMUNICATIONS COMPLEX (RCC):

104 @ \$243,000 25,355,000

(THE COST OF FOUR OTHERS THAT WILL BE
TRANSFERRED FROM TESTING; MAKING A
TOTAL OF 108, IS CONSIDERED PART OF THE
RDT&E COSTS)

START UP COSTS FOR 104

142,000

\$25,497,000

OTHER PRODUCTION

11,217,000

36,714,000

DATA MODEM:

542 UNITS AT VARYING UNIT COSTS (INCLUDING
OTHER PRODUCTION)

8,091,000

TOTAL PRODUCTION COST

\$129,980,000

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1.2 473L Hq. USAF Command System

The 473L system has been proposed to provide Hq. USAF with an automated command post and improved facilities for large-scale simulation. The 473L system would receive data from all other USAF systems, process it, and provide to USAF whatever information is needed for USAF to carry out its assigned missions. An initial operational capability for the installation in the Pentagon has been estimated as early 1963. This capability would require the equipment more or less as represented in Fig. 6 and would cost, it is believed, roughly \$35,000,000 as shown in Table 4.

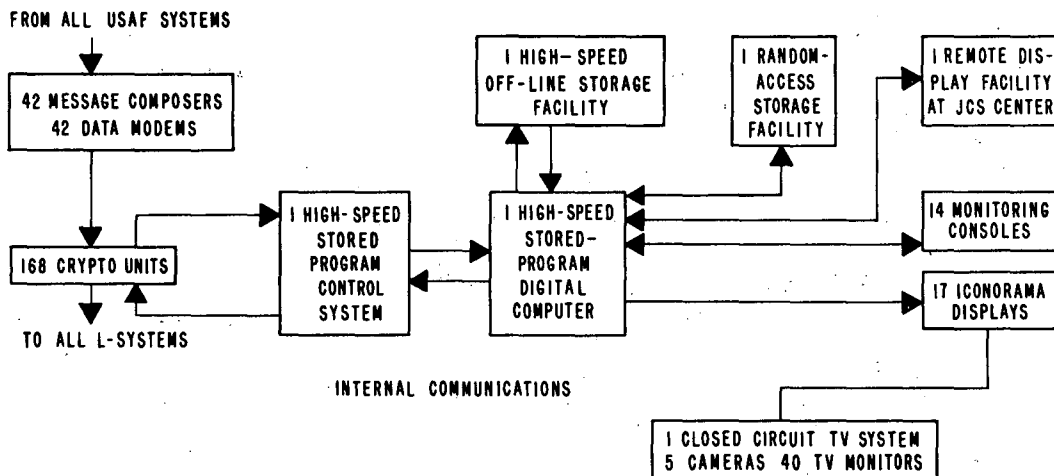


FIG. 6 473L, HQ. USAF COMMAND SYSTEM

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TABLE 4 SUMMARY OF PROPOSED 473L SYSTEM COST ANALYSIS

RESEARCH, DEVELOPMENT, TEST, AND EVALUATION		\$ 3,000,000
PERSONNEL TRAINING AND TRAVEL	\$ 800,000	
COMPUTER PROGRAMMING	<u>4,600,000</u>	<u>5,400,000</u>
TOTAL INVESTMENT TO OPERATIONAL DATE		\$ 8,400,000
42 MESSAGE COMPOSERS	\$ 1,050,000	
42 DATA MODEMS	3,076,000	
168 CRYPTO UNITS	1,260,000	
1 HIGH-SPEED, STORED-PROGRAM CONTROL SYSTEM FOR AUTOMATIC MESSAGE RECOGNITION, ROUTING, AND DATA SELECTION AND PRESENTATION	2,850,000	
1 HIGH-SPEED, STORED-PROGRAM, DIGITAL, CENTRAL COMPUTER	6,420,000	
1 HIGH-SPEED, OFF-LINE STORAGE FACILITY FOR EVALUATION AND ANALYSIS ACTIVITIES	1,090,000	
1 RANDOM-ACCESS STORAGE FACILITY WITH A CAPACITY FOR 20,000,000 CHARACTERS	1,020,000	
1 REMOTE DISPLAY FACILITY AT JCS CENTER AT FORT RITCHIE	80,000	
14 DISPLAY CONSOLES FOR MONITORING OPERATIONS FROM THE MEZZANINE AND AIR COUNCIL ROOM	900,000	
17 ICONORAMA, REAR PROJECTION, MULTI-VIEWABLE DISPLAYS	3,500,000	
1 CLOSED-CIRCUIT TV SYSTEM CONSISTING OF 5 HIGH-RESOLUTION CAMERAS, STUDIO FACILITIES, A CAMERA-CONTROL CONSOLE, A DISTRIBUTION CENTRAL, AND TV MONITORS	1,080,000	
1 HARD-COPY PRINTOUT FACILITY	210,000	
1 MULTIPLE-HEAD, LARGE-CAPACITY, MAGNETIC TAPE STORAGE FACILITY FOR MESSAGE DATA, VIDEO, AND VOICE RECORDING	120,000	
INTERNAL COMMUNICATIONS	1,100,000	
INITIAL SPARES	<u>2,376,000</u>	
TOTAL INITIAL INVESTMENT		<u>26,132,000</u>
TOTAL INITIAL COST TO OPERATIONAL DATE		\$ 34,532,000
ANNUAL OPERATING COSTS TO 1970		<u>1,400,000</u>
TOTAL COST TO 1970		<u>\$ 35,932,000</u>

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1.3 425L NORAD COC System

The proposed 425L system calls for replacing the present manual NORAD combat operations center at Ent AFB, Colorado Springs, with an automated, hardened facility built into Cheyenne Mountain near Ent. The system is in the study phase only and one study group consisting of members of the Winter Study, NORAD, and ARDC has configured one system that could be operational in 1963 and that could be built for an initial investment of roughly \$50,000,000 including research, development, test, and engineering. This system is functionally represented in Fig. 7 and consists of a deep-underground, hardened installation equipped with a large-scale data-processing and display system with the necessary hardened communication lines and facilities. Table 5 is a summary of the cost analysis of this system. After the initial operational date, the 425L system as described above is expected to cost between \$7,000,000 and \$8,000,000 annually to operate.

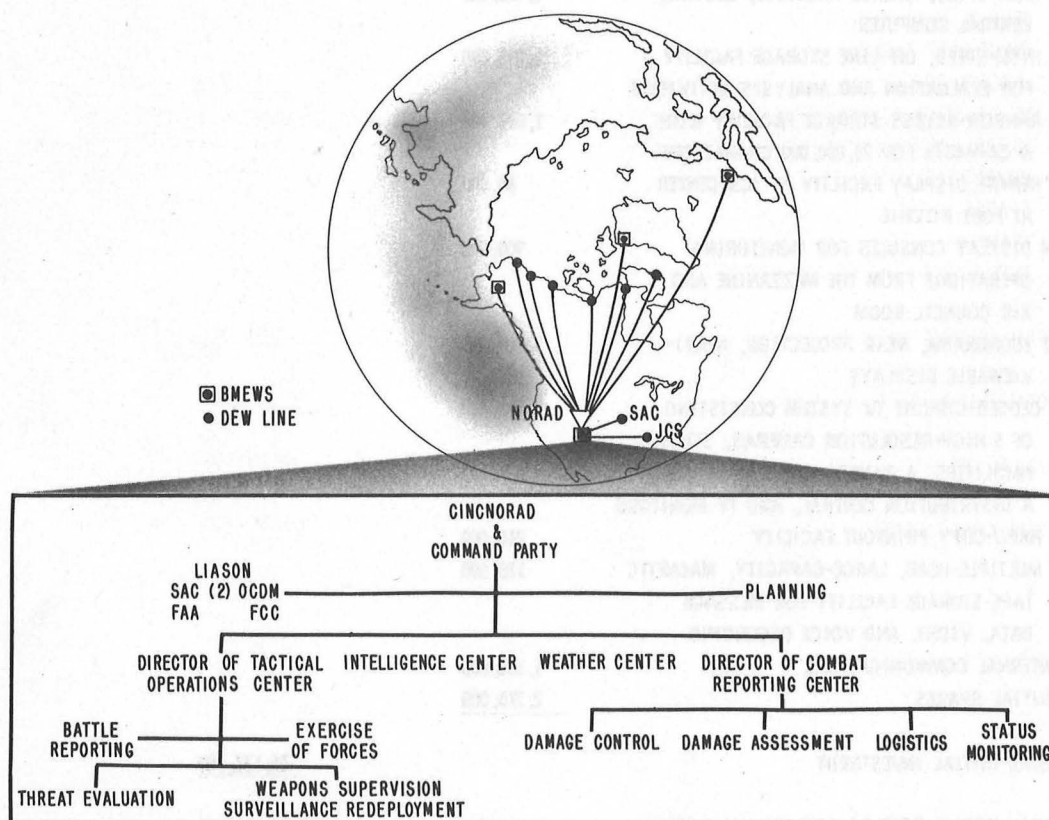


FIG. 7 425L, NORAD COC SYSTEM

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TABLE 5 SUMMARY OF 425L SYSTEM COST ANALYSIS

RESEARCH, DEVELOPMENT, TEST, AND

ENGINEERING:

R&D ON LARGE-BOARD DISPLAY	\$ 1,000,000	
COMPUTER PROGRAMMING (INCL 1 1/2 YR. MACHINE RENTAL)	4,000,000	
SYSTEM TESTING	2,150,000	
SYSTEM ENGINEERING	<u>2,350,000</u>	\$ 9,500,000

INITIAL INVESTMENT:

HARDENED FACILITY	20,000,000
CENTRAL COMPUTER SYSTEM	5,100,000
INPUT-OUTPUT SYSTEM	4,000,000
LARGE-BOARD DISPLAY	1,000,000
15 SITUATION DISPLAY CONSOLES	1,250,000
50 TABULAR DISPLAY CONSOLES	1,500,000
CRYPTO FACILITIES	900,000
SPARES	1,200,000
TRAINING	2,500,000
INITIAL COMMUNICATIONS CHARGES	<u>2,250,000</u>

TOTAL INITIAL INVESTMENT	<u>39,700,000</u>
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TOTAL INITIAL COST TO OPERATIONAL DATE	\$49,200,000
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ANNUAL OPERATING COSTS TO 1970	<u>45,100,000</u>
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TOTAL COST TO 1970	<u>\$94,300,000</u>
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2. INTELLIGENCE AND WARNING SYSTEMS

USAF has or is considering seven systems that are related to gathering, processing, or using intelligence or warning data. Experiments on the 438L Intelligence Data-Handling system for processing intelligence data are being conducted at SAC headquarters to determine if automation will really help the intelligence analysts and the intelligence community in connection with warning. The 466L system for collecting electromagnetic intelligence data will be added to existing collection equipment. The SAMOS part of the 117L SAMOS-MIDAS system will use both photographic and electromagnetic sensing satellites for collecting intelligence data; the MIDAS part will use satellites with infra-red detection equipment to detect actual launchings of missiles. The 474L BMEWS system for detecting a mass missile attack on the U.S. from the north is being installed in Alaska and Greenland and a third installation somewhere in the U.K. is being negotiated. An initial capability for the 496L Space Track system for detecting new satellites and maintaining a catalog of the satellite population is operating at Hanscom Field, Bedford, Mass. The 413L DEW Line system for detecting manned aircraft coming toward the U.S. from the north is in various stages; the 57 stations of the main DEW Line, extending from Cape Lisburne, Alaska, to Cape Dyer in northeastern Canada, are already operational as are the six stations of the western extension in the Aleutian Islands; four more stations will by 1962 extend the DEW Line eastward to Greenland.

2.1 438L, Intelligence Data-Handling System

The 438L system, as presently proposed, is intended to furnish the common intelligence data needed by the intelligence community and to provide for the transmission of all the intelligence data needed by a particular operational command to that command, processing it, and then transmitting intelligence information as necessary to that command's organization. The configuration of the system studied by the Winter Study Group includes the central facilities as represented in Fig. 8. The NORAD, SAC, ATIC, and three AFCIN centers within the U.S. are proposed to be installed first; the USAFE and PACAF and other overseas centers as well as the centers for TAC, air attaches, and an alternate USAF headquarters will come in later. The centers are proposed to become operational beginning in 1963 with the last one coming in in 1966. An experiment presently being conducted at SAC is focused on the use of 438L as a warning device. Because of the sensitive nature of the intelligence function, however, the details of this experiment are not available. No equipment list for the 438L system has been available, but a summary of the estimated cost, based on information received primarily from the ESSPO, is shown in Table 6. The operating costs have been estimated from a low of \$200,000 in 1961 to roughly \$63,000,000 per year from 1965 on.

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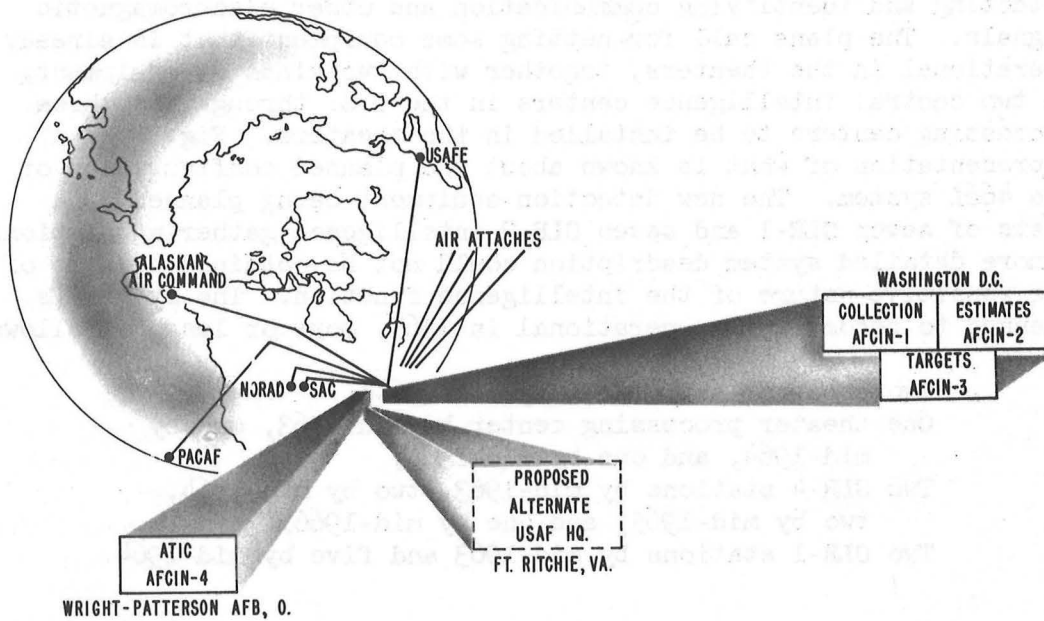


FIG. 8 438 L, INTELLIGENCE DATA - HANDLING SYSTEM

TABLE 6 SUMMARY OF 438L SYSTEM COST ANALYSIS

RESEARCH, DEVELOPMENT, TEST, AND EVALUATION:

ENGINEERING	\$16,000,000	
HARDWARE	<u>91,000,000</u>	\$107,000,000
INITIAL INVESTMENT		<u>176,400,000</u>
TOTAL INITIAL COST		\$283,400,000
TOTAL ANNUAL OPERATING COSTS TO 1970		<u>403,300,000</u>
TOTAL COST TO 1970		<u>\$686,700,000</u>

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2.2 466L, ELINT-COMINT (ELCO) System

The 466L system is being planned as a device for passively detecting and identifying communication and other electromagnetic signals. The plans call for netting some equipment that is already operational in the theaters, together with two kinds of equipment, to two central intelligence centers in the U.S. through the three processing centers to be installed in the theaters. Fig. 9 is a representation of what is known about the planned configuration of the 466L system. The new detection equipment being planned consists of seven GLR-1 and seven GLR-2 intelligence gathering stations. A more detailed system description could not be obtained because of the sensitive nature of the intelligence function. The system is planned to become fully operational in 1965, more or less as follows:

- Two centers in the U.S. by mid-1964;
- One theater processing center by mid-1963, one by mid-1964, and one by mid-1965;
- Two GLR-4 stations by mid-1963, two by mid-1964, two by mid-1965, and one by mid-1966;
- Two GLR-1 stations by mid-1963 and five by mid-1964.

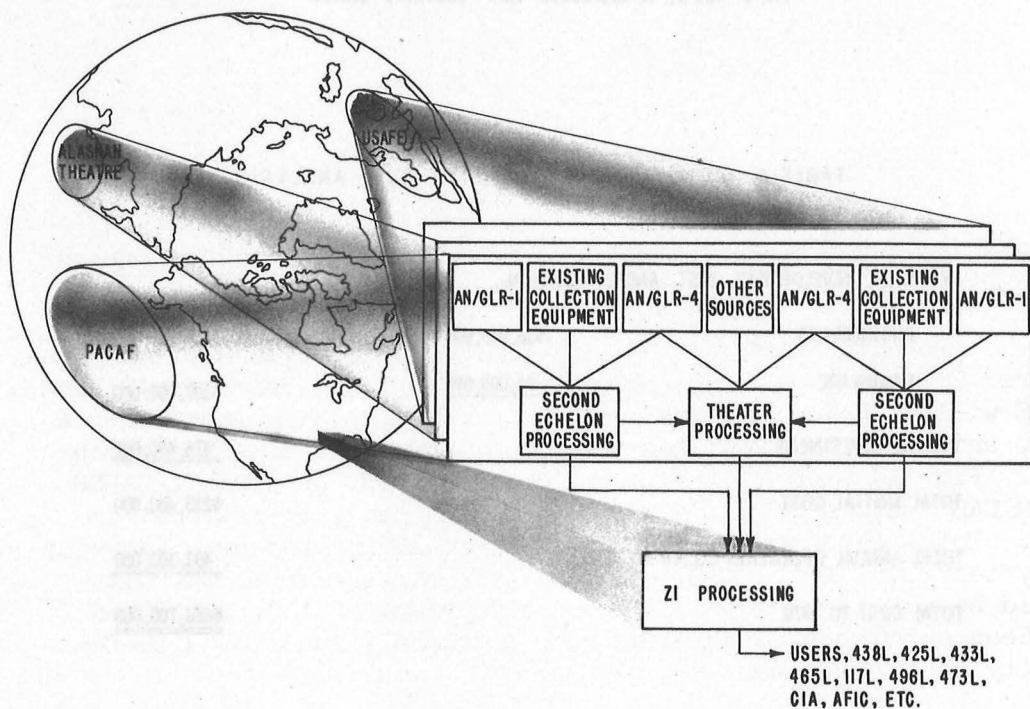


FIG. 9 466L, ELINT-COMINT "ELCO" SYSTEM

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The costs of the system have been estimated over the period FY 1961 through FY 1970 based on information received primarily from the ESSPO. Table 7 is a summary of the cost analysis. The annual operating costs are expected to vary from a high of \$98,100,000 in 1962 to \$71,300,000 in 1965. By 1970 the total cost of research, development, test, and evaluation will be about \$133,000,000 and the total initial investment about \$217,200,000. Annual operating costs will vary from \$59,200,000 in 1966 to \$64,600,000 in 1970.

TABLE 7 SUMMARY OF 466L SYSTEM COST ANALYSIS

RESEARCH, DEVELOPMENT, TEST, AND EVALUATION	\$133,000,000
INITIAL INVESTMENT, INCL. SPARES, PERSONNEL TRAINING, AND COMPUTER PROGRAMMING	217,200,000
TOTAL INITIAL COST	<u>\$350,200,000</u>
TOTAL ANNUAL OPERATING COSTS	<u>352,700,000</u>
TOTAL COST TO 1970	<u>\$702,900,000</u>

2.3 117L SAMOS, Advanced Reconnaissance Satellite System and MIDAS, Missile Defense Alarm System

Both the SAMOS and MIDAS programs originated with the Discoverer Program, and will jointly use many ground-based facilities. SAMOS will be a reconnaissance device for collecting intelligence data, and MIDAS is being developed for warning of missile launchings. Fig. 10 represents the system configuration of 117L SAMOS and MIDAS that is scheduled to become completely operational in 1963. Total initial cost through 1963 including research, development, test, and evaluation is estimated at \$1,112,000,000. It should be noted, however, that no production for 117L operation has been authorized. The program is presently restricted to feasibility demonstrations.

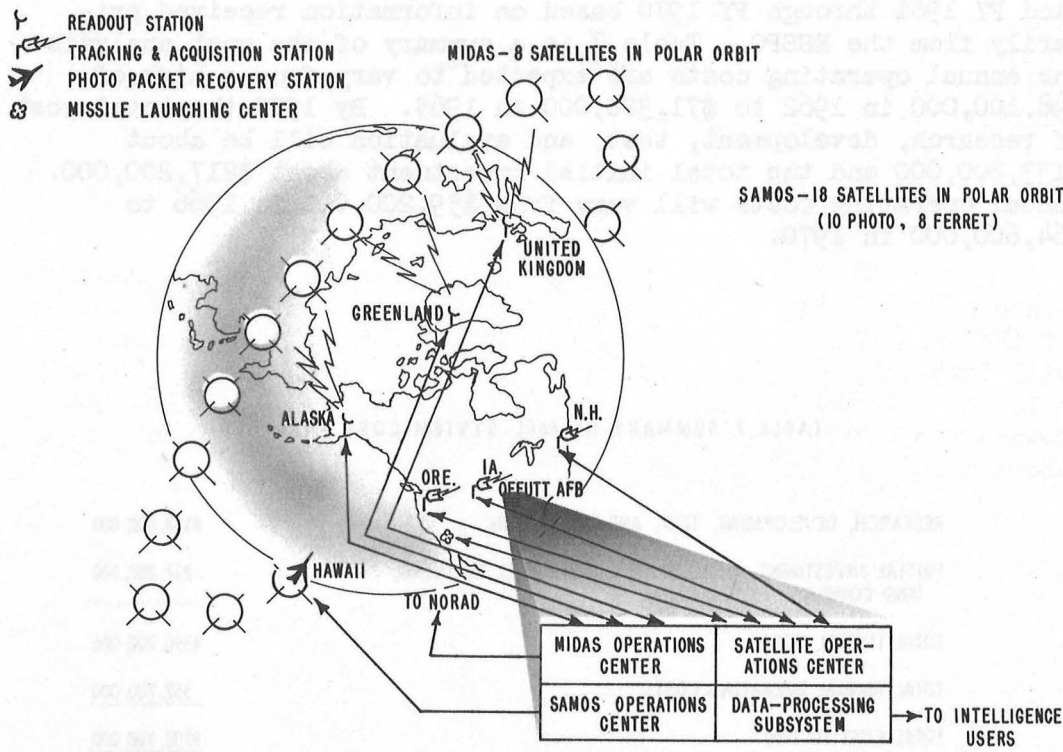


FIG. 10 117L, SAMOS-MIDAS SYSTEM

2.3.1 SAMOS

The SAMOS satellites will collect intelligence data by surveying and mapping photographically enemy territory and by detecting electromagnetic radiations. Ten of the 18 SAMOS satellites will have the photographic capability and 8, called "ferrets," will have the electromagnetic capability. The SAMOS satellites will communicate with the tracking and acquisition stations in Oregon, Iowa, and New Hampshire, and the satellite operations center will control the satellites through these stations. The packets of film ejected by the photo satellites will be picked up by recovery aircraft that will operate from Hawaii. All data gathered by SAMOS will be processed by the joint SAMOS/MIDAS data processing facility that has been called Subsystem I.

2.3.2 MIDAS

All eight MIDAS satellites being developed are for sensing actual missile launchings and will have detection equipment that will scan Soviet launch areas to detect infra-red emanations from the exhaust of ICBM's that have been launched. Each satellite will transmit all detections of missile launchings to the nearest readout station. Warning will be flashed to the MIDAS operations

center and thence directly to NORAD, SAC, and other interested agencies. The MIDAS satellites will be controlled and monitored from the joint MIDAS/SAMOS satellite operations center through the tracking and acquisition stations, using the joint data-processing facilities as necessary.

2.3.3 Costs

The costs of MIDAS and SAMOS were analyzed together since so many facilities are common to both. Table 8 is a summary of the analysis. Estimates of cumulative annual operating costs will total about \$1,527,300,000 from FY 1963 through FY 1970, with a low of \$47,800,000 in 1963 and a high of \$272,500,000 in 1964. Toward the end of the decade, they are expected to level off at about \$176,400,000 per year.

TABLE 8 SUMMARY OF 117L SYSTEM COST ANALYSIS

RESEARCH, DEVELOPMENT, TEST, AND EVALUATION	\$623,300,000
INITIAL INVESTMENT, INCL. SPARES, PERSONNEL TRAINING, AND COMPUTER PROGRAMMING	<u>488,700,000</u>
TOTAL INITIAL COST	\$1,112,000,000
TOTAL ANNUAL OPERATING COSTS	<u>1,527,300,000</u>
TOTAL COST TO 1970	<u>\$2,639,300,000</u>

2.4 474L, BMEWS

The Ballistic Missile Early Warning System, 474L, is being produced to give 15-minute warning of a mass ICBM attack on the U.S. from the north. Three sites equipped with detection or tracking radars, 7090 data-processors, and transmitting equipment will transmit data to the NORAD COC in Colorado Springs. The display information will be displayed essentially simultaneously at SAC headquarters at Omaha.

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Fig. 11 represents the system configuration of the BMEWS that is scheduled to be operational on 1 March 1963. Site 1 at Thule, Greenland, will be supported by the nearby SAC base there and will have four AN/FPS-50 detection radars with no tracking capability. Site 1 and Site 2 will both be operated and maintained by RCA, the system manager and prime contractor. Negotiations for installing Site 3 at Fylingdale, England, have not been completed, but the plans for Site 3 call for three AN/FPS-49 detection radars that will also have a tracking capability. Site 3 will be operated and maintained



FIG. 11 474 L, BMEWS

by England, but USAF would provide military liaison and RCA technical representatives. All three BMEWS sites will communicate with the display processor at NORAD by two 750-bps data links and one teletype link. In addition, there will be one voice link, two order links, and two standby links. Dual routing of the data links will be by submarine cable, tropospheric scatter radio links, microwave, and commercial facilities.

The entire BMEWS system is scheduled to become operational on 1 March 1963. Site 1 at Thule will have an initial operational capability on 1 October 1960 and is scheduled to be completely operational on 1 January 1961. The initial operational date of 1 October 1961 for Site 2 at Clear, Alaska, is hoped to be moved up to 1 August 1961; the date for complete operation is 1 January 1962. The schedule for Site 3 in England calls for an initial operation by 1 January 1963 and complete operation by 1 March 1963.

Table 9 is a summary of the cost analysis of BMEWS. Annual operating costs will build up from about \$69,300,000 in 1961 to a high of \$120,200,000 in 1964, where they will remain more or less constant through 1970.

TABLE 9 SUMMARY OF 474L SYSTEM COST ANALYSIS

RESEARCH, DEVELOPMENT, TEST, AND ENGINEERING	(ALL P-600 COSTS APPLIED BEFORE 1960)
INITIAL INVESTMENT	\$ 207,800,000
TOTAL ANNUAL OPERATING COSTS	1,133,400,000
TOTAL COST, 1961-1970	\$1,341,200,000

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2.5 496L, Spacetrack System

Several configurations for the 496L system have been proposed for peacetime space surveillance and real-time defense warning. The system configuration studied and costed by the Winter Study Group consists of 15 sensing sites with both radar and optical (camera) sensing equipment, a hardened processing center at NORAD, and the necessary communications and other facilities, as shown in Fig. 12. This system represents a total expenditure by the end of FY 1965 of about \$949,000,000 including research, development, test, and evaluation, initial investment, and annual operating costs. This system could become operational in 1966.

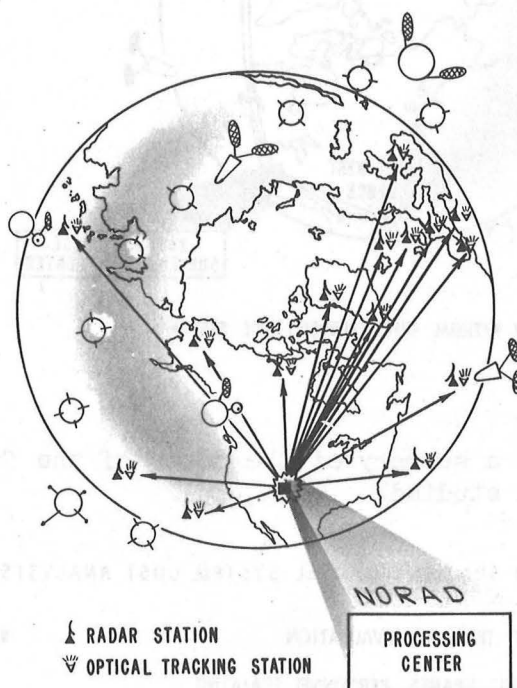


FIG. 12 496L, PROPOSED SPACE TRACK SYSTEM

There is now a national space surveillance and warning center at Hanscom Field that is run by ARDC. This center is represented in Fig. 13. It has a number of people and a 709 computer for processing incoming data that is received from as many as 172

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agencies in the U.S. and 26 in foreign countries. The Navy's East-West fence radars, one installation in southwest U.S. and the other in southeast U.S., and the radars in Turkey are presently the only ones that send information 24 hours every day.

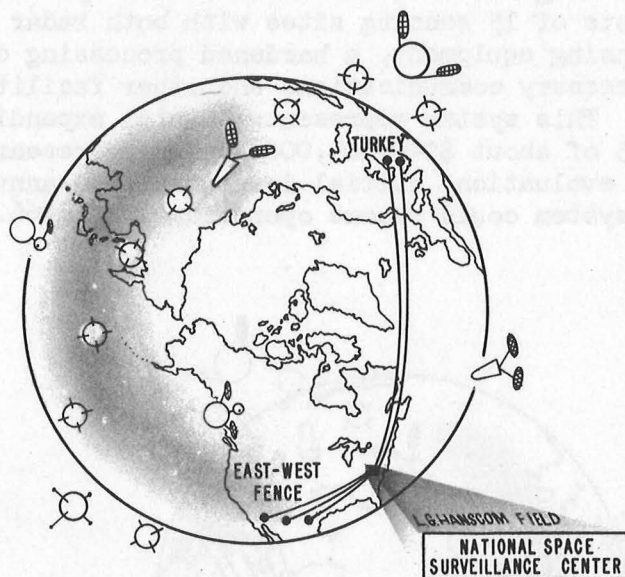


FIG. 13 PRESENT NATIONAL SPACE SURVEILLANCE SYSTEM

Table 10 is a summary of the costs of the future configuration that has been studied.

TABLE 10 SUMMARY OF 496L SYSTEM COST ANALYSIS

RESEARCH, DEVELOPMENT, TEST, AND EVALUATION	\$ 257,000,000
INITIAL INVESTMENT, INCL. SPARES, PERSONNEL TRAINING, AND COMPUTER PROGRAMMING	586,700,000
TOTAL INITIAL COST	<u>\$ 843,700,000</u>
TOTAL ANNUAL OPERATING COSTS	<u>945,200,000</u>
TOTAL COST TO 1970	<u>\$1,788,900,000</u>

2.6 413L, DEW Line System

The DEW Line is the most nearly fully operational of the L-systems considered. It is a network of long-range search and flutter radars for detecting aircraft approaching Canada and the

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A map of the Arctic region showing the NORAD HQ. COLO. SPRGS. and the MID CANADA LINE. The map includes labels for Cape Sarghef, Point Barrow, Barter, Cape Parry, Cambridge Bay, Repulse, Cape Dyer, and Anchorage. A network of lines connects these points, illustrating the radar coverage area.

FIG. 14 413 L, DEW LINE SYSTEM

The cost of the DEW Line between 1961 and 1970 was analyzed, including the radar stations of the Alaskan Air Command. In summary, the initial investment from 1961 through 1963 will be about \$53,600,000 and the annual operating costs will be about \$110,000,000 per year through 1970, totaling \$549,800,000 by end FY 1965 and \$1,100,000,000 by end FY 1970.

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3. CONTROL SYSTEMS

Three of the systems being considered by USAF fall into the category of control systems, since their primary purpose is to guide and control the flights of aircraft. The 416L system which includes the SAGE System has been designed to defend the continental U.S., excluding Alaska and Hawaii, against an enemy manned bomber attack by detecting such enemy aircraft, determining their position, and directing manned interceptor aircraft or guided missiles to them. The 416L system is already partly operational and should be essentially complete in 1962. The 412L theater air weapons control system is designed to provide a mobile capability similar to that of 416L in overseas areas of operation. The 431L project is an improvement program for the present FAA air traffic control and landing facilities, USAF, TACAN, and other military control facilities, and for providing air traffic control systems that can be air-lifted to theater areas whenever contingencies require them.

3.1 416L, Continental Aircraft Control and Warning System

The 416L system for the active defense of the United States, excluding Alaska and Hawaii, against a manned bomber attack is already partly operational and is expected to reach essentially complete operation in 1962. The system that has been studied and costed is represented in Fig. 15 and consists of only the air defense ground environment (no weapons) as follows:

- 22 SAGE direction centers
- 3 SAGE combat centers
- 4 manual direction centers
- 7 manual combat centers
- 140 long-range radar sites in the U.S., 83 of which are frequency diversity
- 30 long-range radar sites in Canada
- 194 gap-filler radars in the U.S.
- 45 gap-filler radars in Canada
- 3 Texas Towers
- 3 airborne long-range radar stations that require 3 squadrons of 10 aircraft each
- 138 time-division data link sites, 25 with high-power directional antennas, 80 with low-power omnidirectional antennas, 33 with high-power omnidirectional antennas.

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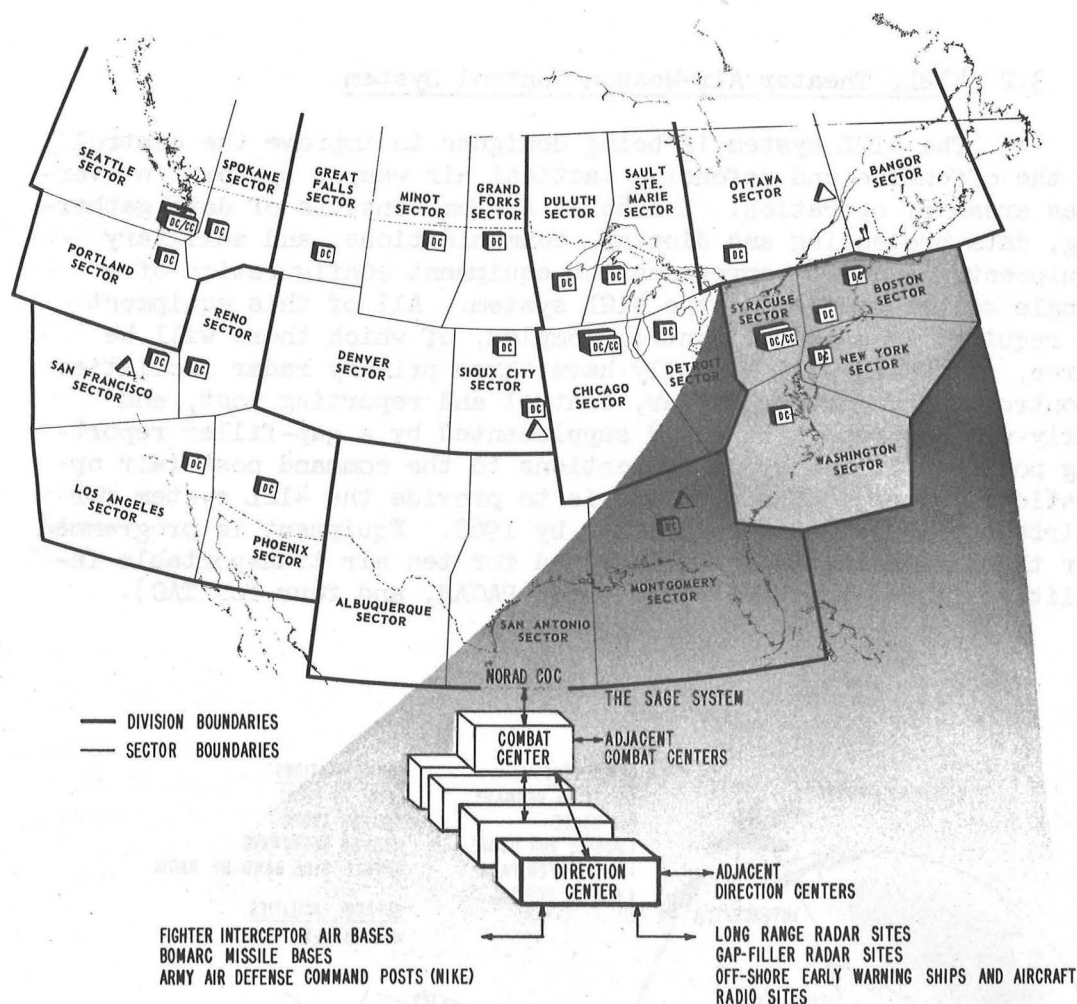


FIG. 15 416L CONTINENTAL AIRCRAFT CONTROL AND WARNING SYSTEM
(INCLUDING THE SAGE SYSTEM)

Table 11 is a summary of the cost analysis of the above system configuration. Annual operating costs will go from about \$524,400,000 in 1961 to a high of \$644,100,000 in 1963 and will level off to about \$638,200,000 from 1965 on. The cumulative total of operating costs through 1965 is \$4,047,900,000 and through 1970, \$6,238,900,000.

TABLE 11 SUMMARY OF 416L SYSTEM COST ANALYSIS

	FY 1961 THROUGH FY 1962	FY 1961 THROUGH FY 1965
RESEARCH, DEVELOPMENT, TEST, AND EVALUATION	\$ 53,900,000	\$ 99,600,000
INITIAL INVESTMENT, INCL. SPARES, PERSONNEL TRAINING, AND COMPUTER PROGRAMMING	400,100,000	448,300,000
TOTAL	<u>\$454,000,000</u>	<u>\$547,900,000</u>

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3.2 412L, Theater Air-Weapon Control System

The 412L system is being designed to improve the control of the offensive and defensive tactical air weapon systems in overseas areas of operation. The basic system consists of data-gathering, data-processing and display, communications, and auxiliary equipment. Fig. 16 represents the equipment configuration of a single sector complex of the 412L system. All of this equipment is required in a sector control complex, of which there will be three, and which will normally have three primary radar facilities (control and reporting center, control and reporting post, and early-warning reporting post) supplemented by a gap-filler reporting post and linked by communications to the command post (air operations center). The plan now is to provide the 412L system for thirteen primary radar facilities by 1962. Equipment is programmed for three fixed sites in Germany and for ten air transportable facilities (three for USAFE, three for PACAF, and four for TAC).

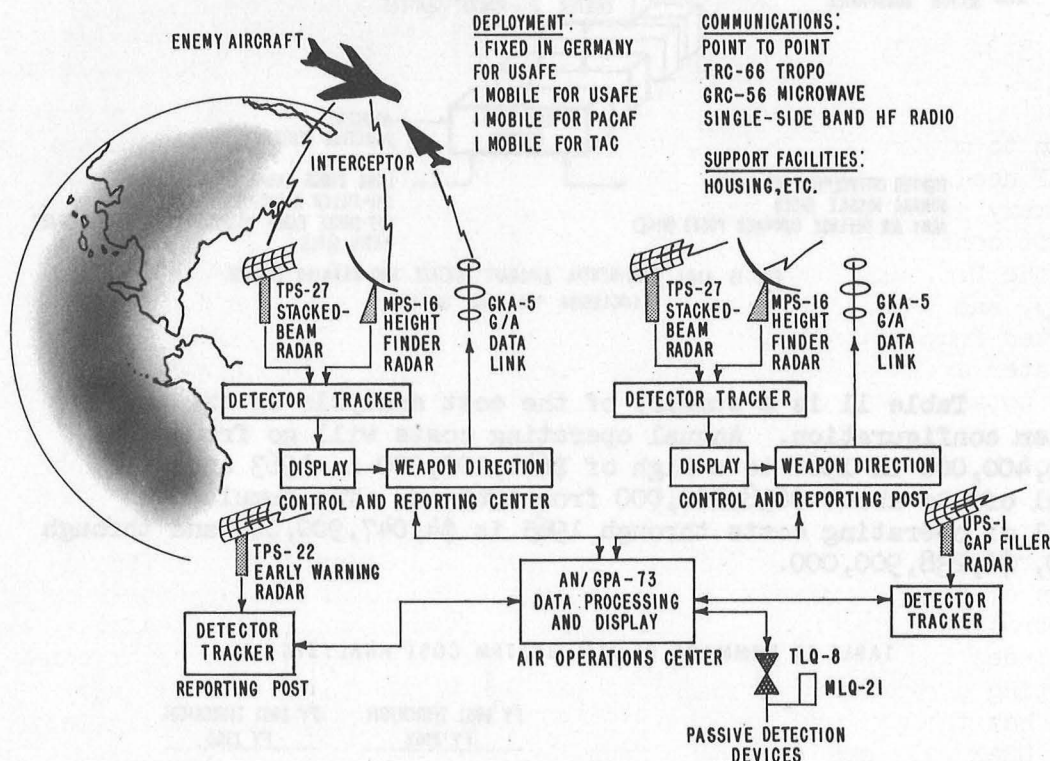


FIG. 16 412L THEATER AIR-WEAPON CONTROL SYSTEM, CONFIGURATION OF EQUIPMENT IN A TYPICAL SINGLE SECTOR OF THE SYSTEM

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Table 12 is a summary of the cost analysis of the system as described above, which is scheduled to become operational in 1963. The annual operating costs will go from a low of \$700,000 in 1961 to a relatively constant \$24,300,000 from 1963 on. By 1965 the system will have cost a total of \$61,700,000 to operate, and by 1970 the cumulative total will be about \$193,200,000.

TABLE 12 SUMMARY OF 412L SYSTEM COST ANALYSIS

RESEARCH, DEVELOPMENT, TEST, AND EVALUATION	\$ 32,200,000
INITIAL INVESTMENT, INCL SPARES, PERSONNEL TRAINING, AND COMPUTER PROGRAMMING	111,100,000
TOTAL INITIAL COST	143,300,000
TOTAL ANNUAL OPERATING COSTS	193,200,000
TOTAL COST TO 1970	\$336,500,000

3.3 431L, Air Traffic Approach and Landing System

The 431L project is not really a system, but rather a program to modernize the traffic control and landing systems that the USAF needs in addition to that provided by the FAA. There are two primary parts to the 431L project, a program for improving aircraft control by modifying some 15,000 aircraft and 400 airbases in the U.S. and overseas that are and will be in the USAF inventory, and a mobile control and guidance system that can be air-lifted from seven USAFE, seven PACAF and four U.S. bases to the theater areas whenever contingencies requiring such support arise. The total cost including research, development, test, and evaluation, initial investment, and annual operating costs from 1961 through 1970 is estimated to be \$2,394,220,000.

The improvement program consists of modifying the present control facilities of FAA and the TACAN and other military facilities of USAF to improve enroute control, approach and departure control, and control of final approaches and landings. It also includes the provision of a crash locator and rescue subsystem consisting of emergency communications equipment for post-crash use. FAA has the primary responsibility for developing these facilities, but USAF will monitor the effort.

The emergency mission support (EMS) system consists of modifying the present "Four Wheels" system of MATS to make it less cumbersome (ten C-130's are needed to move a present Four Wheels facility), easier and quicker to set up, and more efficient. The

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EMS improvements will be made in three steps. Modification 1-A will be installed and operating in early 1962, 1-B will be installed and operating in late 1964, and Modification 2, representing the final configuration, will be installed and operating early in 1970.

Table 13 is a summary of the cost of 431L through 1970.

TABLE 13 SUMMARY OF 431L SYSTEM COST ANALYSIS

RESEARCH, DEVELOPMENT, TEST, AND EVALUATION:		
IMPROVEMENT PROGRAM	\$ 39,180,000	
EMERGENCY MISSION SUPPORT	<u>15,450,000</u>	\$ 54,630,000
INITIAL INVESTMENT:		
IMPROVEMENT PROGRAM	\$1,168,430,000	
EMERGENCY MISSION SUPPORT	<u>126,930,000</u>	<u>\$1,295,360,000</u>
TOTAL INITIAL COST		\$1,349,990,000
ANNUAL OPERATING COSTS		
IMPROVEMENT PROGRAM	\$1,004,190,000	
EMERGENCY MISSION SUPPORT	<u>40,040,000</u>	<u>\$1,044,230,000</u>
TOTAL COST TO 1970		<u>\$2,394,220,000</u>

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4. SUPPORT SYSTEMS

The three L-systems that fall into the general category of support are the 480L project for standardizing and integrating the communications of USAF; the joint Department of Defense, Department of Commerce and FAA 433L weather system program for developing and implementing improved weather observing and forecasting facilities to provide for greater safety in flying without duplicating effort; and the 470L communication satellite system for which only a requirement has been stated and no system configuration proposed.

4.1 480L, Global Communications Management Project

The 480L project is not a system, but rather a program to standardize and integrate USAF communications facilities. The stated long-range objective of 480L is to help USAF establish an integrated, high-speed, world-wide network to handle both digital-data and voice communications. Switching service and full-time private lines would be available as appropriate, with the transmission facilities within the U.S. leased from commercial carriers in most cases. The 480L transmission facilities overseas would be owned and operated by the military services, but local commercial circuits would be used for feeders and overflow. Both commercial and government facilities would be used for communicating across the seas. Switching apparatus would presumably be owned and operated by the military, but within the U.S. might be leased.

The 480L project differs significantly from the other L-systems. In the 480L project, the ESSPO and contractor are not charged with implementing any system. Instead, their function is largely that of a staff engineer group to establish standards, determine circuit requirements, and to make future plans. The way in which such future communication plans will be implemented, however, has not been determined. Under existing regulations, any command needing communication submits its requirements to Hq. USAF for approval without consideration of 480L. Presumably, Hq. USAF would coordinate various requests and grant approval only for construction consistent with 480L concepts.

To date, a number of important steps have been taken under 480L. Engineering standards have been written so that any communication channel can serve as a link in a world-wide connection without contributing more than a proper share to the overall transmission degradation. Further, with these standards, any communication channel will be compatible with, and capable of being connected to, commercial communication networks in the U.S. and abroad. Another activity in 480L has been the study of requirements for circuits and the configuration of a communication grid

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for a world-wide network. Based on this study, tentative plans have been devised which could provide an efficient set of trunk groups, connecting and feeding main communication centers with suitable provision for alternate routing.

Only research, development, test, and evaluation costs (P-600) can be determined for the 480L project since it involves no hardware, no installation, and no responsibility for actual operation. Initial investment and annual operating costs would be a part of the costs of the systems for which recommendations from 480L are implemented. These P-600 costs for 480L have been estimated as shown in Table 14 for the years FY 1961 through FY 1970.

TABLE 14 ESTIMATES OF RDT & E COSTS OF 480L PROJECT

		CUMULATIVE TOTAL
1961	\$28,200,000	
1962	20,700,000	48,900,000
1963	20,000,000	68,900,000
1964	20,000,000	88,900,000
1965	20,000,000	108,900,000
1966	15,000,000	123,900,000
1967	12,000,000	135,900,000
1968	12,000,000	147,900,000
1969	12,000,000	159,900,000
1970	12,000,000	171,900,000

4.2 433L, Weather Observing and Forecasting System

The 433L system is a joint Department of Defense, Department of Commerce and FAA six-year research and development program for modernizing the present aviation weather systems, both civilian and military, to help attain greater flying safety without duplicating efforts. The program is directed toward establishing a National Aviation Weather System and a world-wide weather system. The FAA is responsible for the meteorological research and development related to the national system, and the Department of Defense is responsible for the studies related to the world-wide system that are peculiar to the air warfare and primarily of military concern. Fig. 17 is a representation of the 433L system scheduled to be completely operational by end FY 1965.

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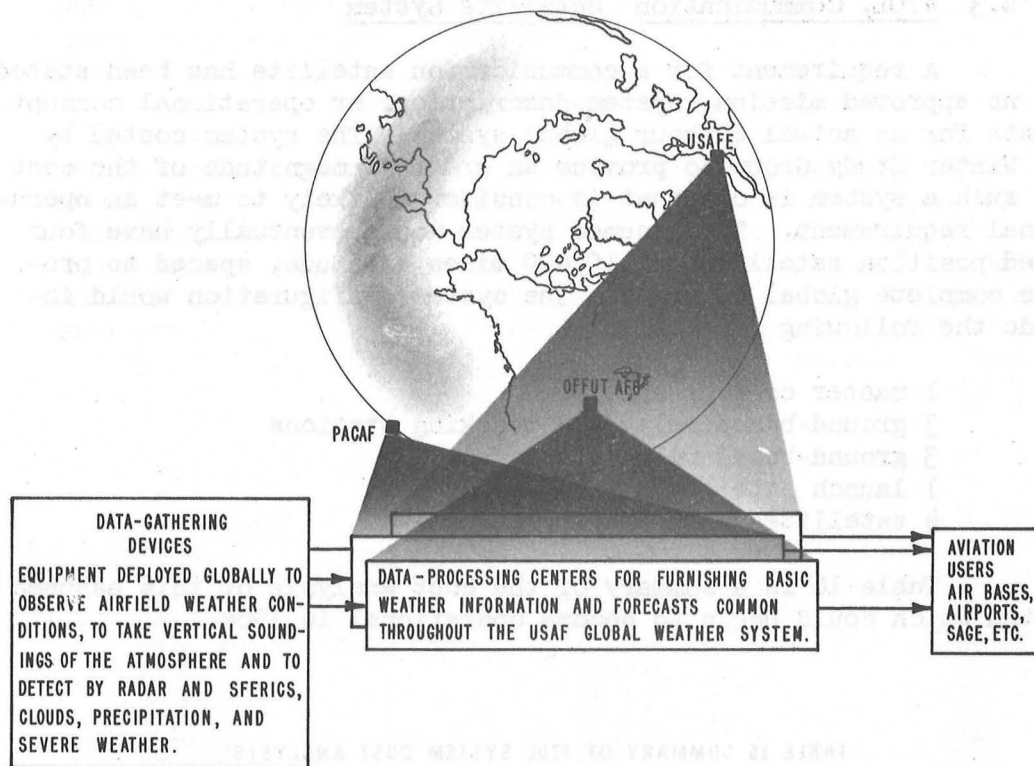


FIG. 17 433L, USAF WEATHER SYSTEM

Table 15 is a summary of the estimated USAF costs for the 433L system. Operating costs of USAF for the 433L system from 1966 on are expected to be roughly \$17,200,000 per year.

TABLE 15 SUMMARY OF 433L SYSTEM COST ANALYSIS

	<u>1961-1965</u>
RESEARCH, DEVELOPMENT, TEST, AND EVALUATION	\$ 16, 800, 000
INITIAL INVESTMENT	<u>240, 200, 000</u>
TOTAL INITIAL COST	\$257, 000, 000
ANNUAL OPERATING COSTS	<u>112, 400, 000</u>
TOTAL COST TO 1970	<u>\$369, 400, 000</u>

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4.3 470L, Communication Satellite System

A requirement for a communication satellite has been stated, but no approved mission, system description, or operational concept exists for an actual 24-hour global system. The system costed by the Winter Study Group to provide an order of magnitude of the cost for such a system is one that is considered likely to meet an operational requirement. The assumed system would eventually have four fixed-position satellites at 19,400 miles altitude, spaced to provide complete global coverage. The system configuration would include the following facilities:

- 1 master control station
- 3 ground-based relay and tracking stations
- 3 ground-based relay stations
- 1 launch site
- 4 satellites with orbit control.

Table 16 is a summary of the cost analysis of this assumed system which could begin to become operational in 1964.

TABLE 16 SUMMARY OF 470L SYSTEM COST ANALYSIS

RESEARCH, DEVELOPMENT, TEST, AND EVALUATION	\$ 651,000,000
INITIAL INVESTMENT	<u>133,500,000</u>
TOTAL INITIAL COST	\$ 784,500,000
TOTAL ANNUAL OPERATING COSTS	<u>565,900,000</u>
TOTAL COST TO 1970	<u>\$1,350,400,000</u>

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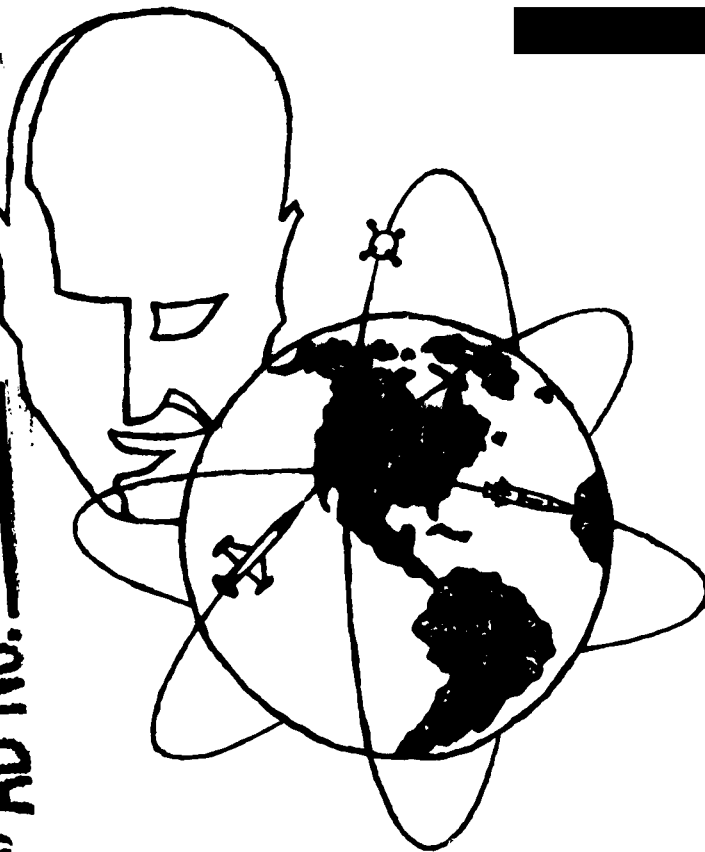


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WINTER STUDY REPORT:

the Challenge of Command and Control

THE CHALLENGE of COMMAND and CONTROL

MAR 31 1961

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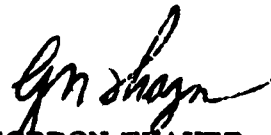
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TO THE READER:

The Winter Study Group was asked to examine the technical realism of the current and planned USAF command and control systems. Early in the study, it became evident that a thorough look into the technical aspects of all the systems would be impossible during the time allotted.

The Winter Study Group did accomplish the noteworthy task of leaving the USAF with ~~some advice on command and control system design and implementation -- organized ways~~ of thinking about the problem.

Since the whole command and control field was in dire need of central planning, the Winter Study Group recommended means for managing the command and control effort which should help to further strengthen and sharpen the general approach that the USAF had already taken.



GORDON THAYER
Director of the Winter Study



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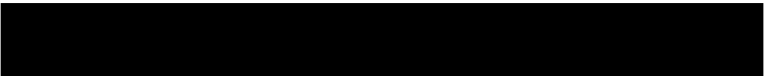
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FOREWORD FOR INDUSTRY

This condensation of the Winter Study Group's Report is published for the purpose of acquainting both industrial and military organizations with the highlights of that report, its general scope, and major recommendations.

The contents of this document represent the opinions of the Winter Study Group and not the USAF.

The industrial reader will be primarily interested in those parts of this condensation that show where emphasis is required in various technical areas that are basic to the design of future Command and Control Systems.

The Winter Study Group basic recommendations on management were, in essence, implemented in April 1960 with the establishment of the Air Research and Development Command's Command and Control Division (AFCCDD) and the Air Materiel Command's Electronic Systems Center (ESC). The establishment of those organizations plus their co-location with other military and industrial organizational elements, on or near Hanscom Field, Mass., provides the centralization essential to the efficient management for the development and procurement of Command and Control Systems. These geographically co-located groups are frequently referred to collectively as the Hanscom Complex.*

The Winter Study Group discussions relating to national policy (not necessarily USAF policy) and/or strategy are of academic interest to Industry and of more direct interest to those in the Government who formulate the

*Hanscom Complex definition on p. 32.



official positions on such matters. Approved Air Force policy and strategy are, of course, reflected to Industry through system study requirements, system specifications, and other related documents that describe those Command and Control Systems for which there are validated requirements.

This does not purport to be a true abstract of the Winter Study Group report. It is rather a condensation of essential material -- almost a shopping list of facts taken from the original text -- combined with necessary additions clarifying certain USAF policies.

March 31, 1961

1

THE CHALLENGE OF COMMAND AND CONTROL

Military forces during the past fifteen years have been radically reshaped by exploding weapon technology. Range, speed, firepower -- all have been increased by many orders of magnitude. No one in the world has had actual combat experience in employment of such forces. Hence, the commander's "mind's eye view" of the war he must be prepared to fight is rather abstract - blips and patterns on display scopes - rather than concrete mental images.

Likewise, range, speed, and firepower have drastically reduced the time available to the commander in which to make decisions. At the same time, they make the consequences of his decisions more and more far-reaching and irretrievable. His decisions must be good ones the first time. There will be little opportunity to "fall back and re-group."

Fortunately, the same technology which has created these problems for the commander carries within it the seeds for their solution. During the time that range, speed and firepower of weapons have increased, the technical means of gathering, processing, storing, and displaying data have likewise reached hitherto undreamed of levels of effectiveness and sophistication.

The purpose of command and control systems, then, is to harness the new capabilities in such fields as electronic reconnaissance and warning, communications, computing, data processing, and display in ways calculated to serve best the needs of the individual commander, the force as a whole, and, ultimately, the needs and aims of the nation.

Command and control systems, properly designed and utilized, can increase the time available to the commander to weigh conflicting factors



[REDACTED]

and arrive at sound decisions. They accomplish this by decreasing the time required to accumulate, process, and display the data on which sound decisions must be based.

In effect, they serve to free the commander from the shackles which weapons technology has imposed upon him. They allow him to use the precious minutes available to him to decide how best to use his force. They give the commander time in which to exercise the art of command. Indeed, it is quite possible that the possession of this capability may well spell the margin of victory, or defeat, in a thermonuclear war.

Historically, the technology of command and control systems has tended to lag behind the development of the weapon systems they are designed to complement.

The United States Air Force, faced with the responsibility for operating increasingly sophisticated weapon systems, early recognized that history must not be allowed to repeat itself and that there was a need for equally rapid development of sophisticated command and control systems. Requirements were generated, research and development projects undertaken, contracts let, and, in many cases, production begun. These are the so-called "L" systems, to which reference is frequently made.

As time went on the requirements for L-systems began to burgeon. Operational, technological, and economic factors dictated a second look to insure that the parts added up to a sensible whole, to eliminate redundancy, to insure compatibility within and among systems, to take full advantage of the growth potential indicated by the state of the art and required by on-coming weapon systems and changing force structures.

It was with this in mind that, in the fall of 1959, Headquarters, Air Research and Development Command directed the establishment of an ad hoc

[REDACTED]

organization, known as the Winter Study Group. It was composed of 139 technical people drawn from military, government, and contractor sources. The group gathered at the Bedford, Massachusetts facility of The MITRE Corporation to work for six months under the direction of Mr. Gordon N. Thayer, Vice President of the American Telephone and Telegraph Company. (An organization chart and roster of panel members appear on page 30.) At the same time a Scientific Guidance Group was set up under the aegis of the Secretary of the Air Force to furnish advice and guidance to the Winter Study Group. Chairman of the Scientific Guidance Group was Dr. A. G. Hill of the Massachusetts Institute of Technology. (The members of the group are listed on page 31.)

The Scientific Guidance Group was asked to guide the Winter Study Group to:

"...examine critically and objectively from a technical viewpoint the existing and planned complex of command and control systems, examine for technical realism the needs and objectives of the individual elements, and study the problems associated with the integration of the various systems."



GENERAL FINDINGS

The output of the Winter Study Group has been:

First, a conceptual framework within which the whole subject of command and control can be better understood and more fruitfully discussed.

Second, it has commented on fifteen of the eighteen planned and proposed L-systems. These comments are not included here.

Third, it has considered the state of the art in command and control system components and has suggested some needed research and development programs.

Finally, its most important recommendations refer to system management rather than to engineering details of present systems.

Effect of Strategic Choices

Strategic choices have a critical effect on the design of a command and control system. A specific long-term strategic choice which has a prime influence on the nature of command and control systems is the balance between first strike and second strike capability.

A policy which includes selective hardening of the Command and Control facilities would provide the greatest survivability and thus provide the greatest possible capability to enhance the reconstitution phase of a general war. Therefore, survivability should be emphasized in all phases of planning in the Command and Control area.



[REDACTED]

A second strike capability, however, would place greater emphasis on survival of the force and a basic command and control capability. This would provide for a controlled reaction based on longer consideration of the situation.

The implication of this strategic choice on control and sensor system requirements is obvious. A first strike capability places stringent requirements on sensor systems, which are relatively high priced compared to command systems.

In the short term, the nature of the command and control systems should not restrict the manner in which the available forces can be used any more than they are restricted by their own characteristics.

Long term strategic decisions can directly influence the nature of the command and control system.

With respect to the L-systems, it is concluded that too little emphasis has been placed on the problem of surviving an attack, controlling our reaction, and exercising the post-attack operation.

Survival of High Command

In general war one cannot expect most of the peacetime functions to survive. The peacetime functions should be differentiated from the wartime functions. The wartime functions must be hardened and duplicated to the extent that any attack sufficient to destroy the high command functions would also be heavy enough to justify uncontrolled retaliation with the surviving force. By use of mobile command centers, central control must be retained even if stationary command centers are destroyed. Plans should be made to exercise the transfer of command from center to center.

Command Systems

Operational command is concerned with planning and directing forces in being. Command systems should be completely coupled to the military

[REDACTED]

THE L-SYSTEMS - OR SPOs

(USAF assigns suffix letters L through Z to system numbers to connote support systems.)

- 412L - AIR WEAPONS CONTROL SYSTEM**
An oversea theater tactical air weapons control and warning system.
- 413L - EXTENSION OF DEWLINE**
A distant early warning system for detecting hostile air-breathing threats approaching the North American Continent from the north.
- 416L - SAGE AIR DEFENSE SYSTEM**
A semi-automatic area air weapons control and warning system for detecting, identifying, tracking, and providing interceptor-weapon direction against air-breathing threats to the United States and Canada.
- 425L - NORAD COMBAT OPERATIONS CENTER**
A system which collects, processes, and displays data to assist the Commander in Chief, North American Air Defense Command (NORAD) in commanding and controlling his forces.
- 431L - TRAFFIC CONTROL AND LANDING SYSTEMS**
A program to satisfy Air Force traffic control requirements by working with the Federal Aviation Agency (FAA) and development of equipment peculiar to Air Force needs.
- 433L - WEATHER OBSERVATION AND FORECASTING SYSTEM**
A global semi-automatic electronic system for observing, forecasting, and handling weather information. It is being developed in conjunction with FAA and the U. S. Weather Bureau.
- 438L - INTELLIGENCE DATA-HANDLING SYSTEM**
A system for high-speed processing of worldwide intelligence data.
- 465L - STRATEGIC AIR COMMAND AND CONTROL SYSTEM**
A system which collects, processes, and displays data to assist the Commander in Chief, Strategic Air Command (SAC) in commanding and controlling his forces.
- 466L - ELECTROMAGNETIC INTELLIGENCE SYSTEM**
A worldwide system for collecting intelligence by electromagnetic means and processing for transmission to users.
- 473L - AIR FORCE CONTROL SYSTEM**
A data processing and display system to assist Headquarters USAF in making command decisions.
- 474L - BALLISTIC MISSILE EARLY WARNING SYSTEM**
A system to provide early warning of a mass ICBM attack on the North American Continent from the north.
- 480L - AIR COMMUNICATIONS SYSTEM**
A system to assure inter- and intra-system communications services to support global Air Force operations.
- 496L - SPACE TRACK**
A system for detecting, tracking, identifying, and cataloging orbiting objects.

In addition to the above L-systems, all of which are developed under the ARDC's Command and Control Development Division at Hanscom Field, Bedford Mass., the Winter Study Group considered the following, which are under the management of ARDC's Ballistic Missile Division, Inglewood, California.

- 117L - MIDAS**, satellite system for detecting and giving an alarm on infra-red emanations from the exhaust of launched missiles, and **SAMOS**, satellite system for gathering photographic and electromagnetic intelligence data.
- 470L - Communication Satellite System** with a requirement for a 24-hour global capability hasn't yet been approved as to mission, system description, or operational concept.

organization and only loosely coupled to the rapidly changing weapons systems. They should provide continuity and stability to the command organizations and assist it in adapting to the changing environment in which it should operate.

Command systems are relatively less costly than control and sensor systems and are less sensitive to technological changes.

The Winter Study Group emphasizes the following concepts for application to command systems:

The military is responsible for exercising command; this function should not be delegated inadvertently to engineers or machines.

Operational command is a single, continuing management problem. Whereas forces and functions phase in and out year by year, the command function must grow continuously under direction of the command.

Operational command must be adaptable to uncertainties in threat, policy and technology. It must respond to these major contingencies in weeks and months, not years.

Within a command, there is a severe need for effective communicating among intelligence, operations, material, and plans functions as they relate to the total operational command role.

The need for improved communication and information handling to strengthen operational command is predominantly for pre-combat capability. This is the essence of the forces-in-being concept. Peacetime operational command generates and exercises the simpler plans and procedures that are required for combat.

Commands must develop a stronger linguistic framework as an aid to rapid, succinct consideration of their problems and capability and coordination of these with higher and adjacent commands.

Communications and coordination between commands and with JCS command must be expanded to include more joint planning and exercising during the pre-combat phase.

In order to strengthen operational command, three approaches must be pursued together:

(a) An increasing use of automated communications, data processing and display can help. This capability is required primarily in peacetime; it should be provided early and in gradual steps as increments become available. Present plans for command L-systems are often too long-range and too ambitious.

(b) The commands require much more on-going technical assistance not only to aid them with appropriate automation but equally to strengthen the analysis, planning, exercising and evaluation which are needed as more complex systems become part of the force structure.

(c) Finally, the lines of operational command must be clarified and strengthened, a stronger service-independent JCS command center must be evolved, and guiding operational concepts and standards for all command centers must be developed.

The following principles should be observed in applying automation to command headquarters:

(a) Each command should apply automated communications and data processing in modest, successive phases so that capability and understanding can be built on previous command experience. Initial use of automated capability in any phase should leave considerable spare capacity for growth and change.

(b) During all phases of adding automation, a commander's or "capping" system is required which acts as a "staff" cutting across the organizational lines of operations, intelligence, materiel and plans wherever these functions support operational command. This planned growth of automation in a command

[REDACTED]

should be directed toward the building up of a data-base or command model. The data base would be stored in the command's computing machines and would represent all the data, procedures, plans, and experience pertinent to the operational command function.

(c) The command organization should participate in the design of automated procedures and models as part of their command job. Many steps could be taken today with available techniques to increase this participation; requirements for command L-systems have not included this capability.

(d) Design of command systems should include capabilities for the discussion and evaluation of performance and the development of a command language. Presently planned L-systems usually include a greatly improved capability for performing known tasks, not a capability for considering how important tasks are and how well they are being performed.

(e) One of the major factors which caused delay of the L-system program and then the establishment of the Winter Study Group was a stated need for more "integration" between the L-systems. It is important to distinguish between functional and technical integration. In the latter, the emphasis is on such needs as use of standard equipments and programming languages, or sharing of a single facility for several tasks (such as common communication systems for several users). In the case of functional integration, the stress is on clear and effective and realistic allocation of roles to commands, close coordination within commands and between commands in planning and support, and effective higher command of subordinate commands.

Adequate functional integration at this time is much more important than technical integration. A strong requirement for early technical integration is technically both infeasible and undesirable; undue emphasis on technical integration threatens early needed strengthening of operational command capability

[REDACTED]

at individual commands. Stronger functional integration will gradually result only as individual commands and JCS command are strengthened under the broad guidance of overall functional and technical plans.

Control and Sensor Systems

The cost, complexity and lead times of control and sensor systems are highly sensitive to strategic and tactical doctrines, operational parameters (response time, mobility, survivability) and to vehicle and sensing element characteristics. Compared to command systems, their cost is relatively high. They are more dependent on the state of the art. They are not normally evolutionary in nature and have little post-operational growth.

The design and implementation of these systems should apply the following concepts:

System analysis based on a foundation of broader mission and command analysis must be performed to bridge the gap between broad goals and detailed design and implementation. This system analysis must include adequate time/cost/effectiveness studies and must be a part of on-going technical assistance to using commands in planning, exercising, and evaluating.

Research and development programs with long-range goals which are tied to a broad base of strategic objectives are needed. These programs should have as an objective the development of component subsystems applicable to a mobilization base which can be used to assemble systems in accord with the strategic objectives of the time. This approach offers the only hope of reducing lead time and slowing the obsolescence of systems needed for changing strategic situations. Alternative approaches must not be ruled out on the basis that they do not fit today's strategic objectives.

Directed assignment of a control or sensor system to a single operational command should be made as soon as possible for any system which is necessary to the operational command function and which will be used by more than one command.

On-going, operationally oriented studies must be performed to formulate and determine: (a) strategic and tactical doctrines and situations under which these classes of systems will be used: (b) realistic reliability and survivability requirements which distinguish between peacetime and wartime needs and allow for the peacetime exercising of these systems under both of these conditions.

Adequate functional integration of control and sensor systems within a command and between commands must be emphasized even more than technical integration. This emphasis must be placed in three areas:

- (a) Development of a communication language of increasing abstraction from the sensing elements themselves back to the command is necessary in order that data from many systems can be processed and correlated at the command.
- (b) Communications from a command to its sensing elements must be provided which are able to implement a method to dynamically control the operation of the sensors from the command in accord with the existing operational situation. Resources must be capable of rapid commitment to test hypotheses and to obtain more information on a particular situation seen at the command headquarters. This is especially true in the intelligence area.
- (c) The design and implementation of the sensing vehicles, such as satellites and ground-based data gatherers, and their associated communications systems, must be done in a context which considers

the functional integration of these elements with the data processing facilities and procedures of a command which is to use the data from these systems.

General Conclusion

The Winter Study Group believes that automated command and control systems can contribute in a major way to the effectiveness of the military. To avoid the pitfalls of a compartmentalized approach, the group believes that a central agency, technically skilled and operationally oriented, is required to aid the USAF in the planning, design and implementation of these systems on a continuing basis. This group must be guided by USAF command and staff people and must have day-to-day access to the operations they seek to improve. The Winter Study Group believes that only in this way can a sound comprehensive plan for the L-systems be formulated.

MANAGEMENT RECOMMENDATIONS

The Winter Study Group was asked to examine the proposed and planned L-systems to determine whether they were realistic and technically sound. In the course of this examination and in their reports, the panels commented on various aspects of the management of the current L-systems and made suggestions about what should or could be done in the future to improve the process of generating and managing command and control systems. In the main, the panels found that the L-systems were being managed separately and that taken together, there did not appear to be a consistent set of operational objectives, agreed upon strategic and tactical plans, or a set of standards and general plans for the orderly introduction of command and control systems into command. The following, then, is a management concept consistent with these observations which appear throughout the Winter Study Report:

(a) Concentrate the responsibility and authority for making command and control system engineering decisions at an appropriate geographical location, and staff that complex with the appropriate mix, quality, and number of experts in operations, cost, equipment, systems production, and installation.

(1) Those parts of the operational commands' headquarters staff at the complex (SAC, TAC, NORAD, ADC, Hq. USAF, theater commands) that are concerned with design of the future command and control systems for the commands should have the confidence of and be attached to the highest level of the commands.

(2) Hq. USAF should use the information generated by the organization at the complex to supplement its own work on command and control matters.

[REDACTED]

(3) The concentration of this authority and responsibility should be gradual, geared to the build-up of capability of the complex.

(4) The command and control decision-making process should be focused around the decision to buy operational systems for the commands.

(5) The level of competence at the complex should be great enough to maintain the confidence and respect of this military, industrial, and scientific community.

(6) This group should be responsible for establishing concepts, configuration, and program control to minimize duplication and to insure a single, compatible, aerospace control environment for all command and control systems, including those closely associated with weapon or sensor systems.

(b) They should establish at the complex a central planning activity that will treat the whole command and control problem in its operational equipment, time, and cost context to develop the concepts that will guide the decision-makers.

(1) The planning activity must cover the objectives, expected performance schedules, and costs of the total force structure, or at least the USAF force structure, and develop a methodology for estimating performance, schedules, and costs of proposed systems.

(2) It must develop methods for integrating weapon systems and command and control systems.

(3) It must understand the objectives of the individual commands and develop measures of the effectiveness and cost of the systems and commands need.

[REDACTED]

(4) It must establish the general principles (policies and standards) concerned with the development of command and control system components (people, displays, computer programs, communications, etc.)

(5) It must develop the guidance for concepts which guide the design, development, and implementation of command and control facilities.

(c) Establish a development activity for command and control systems that will be a focus for the development of command and control operational techniques, equipment standards, maintenance procedures, etc.

(1) The development people should be competent in the fields of specialty required in the command and control system area — operations, human factors, computers, and computer programming, communications, displays and sensor equipment. This competence should be great enough to command the respect of industrial technical personnel.

(2) Enough of the actual operational experiments, component tests, etc., should be done at this activity to maintain the competence of its personnel and to establish it as the leader in the field.

(3) Operational experiments performed at other places must receive their technical direction from the complex when the technical competence eventually exists. Operational experiments that are incremental changes to present operational command capability should be distinguished from those that result from major changes in command force, or sensor structure, or command organizational changes. Incremental changes should be guided by the operating elements of the command which needs it, acting through the complex. Major changes and those incremental changes requiring Hq. USAF approval should be guided by the planning elements of the command or Hq. USAF.

(4) The development activity should be responsible for guiding the development of a generally useful line of components, i. e. , computers, communications, sensors, programming techniques, etc. , for command and control systems. This development should not all be directly related to particular L-systems. A substantial portion of this work should be funded separately from system contracts.

(d) The operating command (or Hq. USAF) is a customer for command and control systems. It is also one of the principal system designers. The operational commander is responsible for the design of command and control systems in the same sense that he is responsible for the design of his organization. The operating command should be provided consultant help on the cost/time/effectiveness of alternative systems, in estimating and stating requirements, and in performing operational experiments, etc.

(1) The system which a commander uses to command and control his force is an organization of people, computer files, communication gear, rules of information flow, etc. The L-systems are pieces of this system and should not be considered outside its framework by the managers or technical directors of the program. Thus the equipment should not be thought of as separate from the command organization.

(2) The operational commander must consider the design of the command and control systems he uses four or five years in the future in its proper environment, as determined by the command organization, the weapons available, and the threat. He should not confuse today's problems with tomorrow's. He should separate these things both in his thinking and in the way he organizes his staff.

(3) Predictions of requirements for command and control systems will be continually modified due to changes in threat, force structure,

organization, etc. The management organization for the L-systems must treat this as the norm rather than as an exception to the norm.

(4) The commands should receive consulting help from a competent sustaining staff on current operational systems as well as future systems. This help should consider the operations/technical/time/cost problems of the command, and the phasing between the present system and the future systems should be coordinated within the complex. Mission evaluation and test criteria should be started early to act as guide-lines for the system design.

(5) Exercising and training requirements should be planned along with the system.

(e) Plans that cover the need, objective, general system design, and employment of a command and control system and that are based on the proper cost/time/effectiveness studies and experiments should be produced before contracts are let and should be used as the basis of the work statements for the contractors.

(1) The preparation of these plans requires a system design based on the proper level of functional analysis, a schedule estimate based upon requirements, and an analysis and determination of the system's cost. An appropriate methodology must be established for performing all these tasks.

(2) The preparation of these plans may require various study contracts, experimental investigation, etc.

(3) Standards and general policies should be developed as guide-lines for the preparation of these plans.

(4) The preparation of these plans should include the proper participation of the operational, logistics, and development personnel.

HIGHLIGHTS - RESEARCH AND DEVELOPMENT OBJECTIVES

1. SENSING EQUIPMENT

Care must be taken to insure that the level of current activity is, and will remain, appropriate to the increased demands made on sensing equipment by the changing nature of the threat - from air-breathing to missile and satellite weapons. Increased activity would appear to be in order in the following areas:

- * Electromagnetic Propagation
- * Electromagnetic Target Characteristics
- * Radar Transmitters, Modulators and Tubes
- * Radar Antennas
- * Radar ECM Vulnerability Reduction
- * Advanced Radar Concepts
- * Optical Sensors
- * Vehicle Stabilization

2. COMMUNICATIONS

While considerable work in this field is currently in progress, additional effort should be made in the following areas:

- * Reduction of delays incurred through intrusion of the human element into communication network.
- * Survivable low-volume supplementary systems that are reasonably invulnerable to cold-war harassment and thermonuclear attack.
- * Flexible, economical circuit and message switching apparatus.
- * Methods to protect message security in networks that carry both high-security and unclassified traffic.
- * Techniques for policing and control of communication priority.
- * Standards for communication apparatus that will permit a network to become operational without inhibiting application of advances in the state of the art.

3. COMPUTING

The state of the art in computers is advancing so rapidly that additional emphasis is needed to insure:

- * Achievement of modularity and the flexible interconnecting devices so that additional computer capacity can be built into existing L-systems.
- * Machine organizations to permit discovery and use of complex data relationships.
- * A theory to relate machine characteristics to data processing requirements.

4. DATA PROCESSING

The area of processing procedures is virtually unexplored. A high level of research and development effort must be started and continued in:

- * Higher-order programming language.
- * Utility support programs.
- * Tools for program testing.
- * Methods of understanding and communicating program organization.
- * Procedures for automatic indexing, file interrogation, and information correlation.
- * Operational translator programs.
- * Techniques for modeling and simulation of subsystems and complete systems.
- * Application of modeling and simulation to design analysis, program testing, and system testing and evaluation.
- * Use of linear programming, dynamic programming, game theory, general decision theory, and Monte Carlo methods for war gaming allocation of resources, etc.
- * Role and relationships between men and computer program complex, and
- * The effect of a highly automated data-processing environment on human organization and decision making.

5. HUMAN FACTORS AND DISPLAY

Little emphasis has been given to human factors in large, highly automated command, control, and sensor systems. A considerable effort should be given to research and development in the following human factor areas:

- * Effect of change on total performance.
- * Human communication in networks.
- * Human intervention.
- * Level of data abstractions.
- * User participation in the design and implementation of automatic data-processing procedures.
- * Effect of stress.

6. COMMAND SYSTEMS

Accelerated research and development is required in command systems in four major areas:

- * Basic work to develop the theoretical foundations of information processing.
- * Development of standards for tying together of components and modularity in design so that command systems can be expanded and improved without disrupting operations.
- * Methods of conducting operational experiments in an operational environment.
- * Development of a command center technology.

RESEARCH AND DEVELOPMENT OBJECTIVES

SENSING EQUIPMENT

At present, the numerous facets of the sensing equipment field seem to be receiving the majority of the funds expended by USAF for L-system component research and development. The Winter Study Group believes, however, that the following aspects should be re-examined by USAF to insure that the level of current activity is, and will remain, appropriate to the increased demands being made on sensors as a result of the rapidly changing nature of the threat--i.e., from air-breathing to missile-satellite weapons.

(a) Electromagnetic Propagation: In relation to radar surveillance and tracking, a continuing requirement exists for information on the effect, over a wide range of frequencies, of aurora, Faraday rotation, galactic noise, atmospheric fluctuations, nuclear detonations, and artificial ionization.

(b) Electromagnetic Target Characteristics: Although large amounts of money are being spent for air-target reflection studies, some additional development may be needed in polarization matrices for target discrimination, interaction of electromagnetic energy with plasma, relative contribution of vehicle areas to target reflectivity, and bistatic reflection of widely separated frequencies. More data is needed over the whole range of the electromagnetic spectrum on the specific radiation and reflection characteristics of nose cone and booster plumes.

(c) Radar Transmitters, Modulators, and Tubes: Notable developments in these components are presently in progress, but achievement of the high

[REDACTED]

powers and large bandwidths that are necessary characteristics of modern radars remains difficult. The efficient coupling of rf structures is not readily obtained; increased attenuation of spurious signals is needed to reduce interference. The generation of high power at millimeter wavelengths is a complex problem. Consequently, research and development programs should be encouraged to provide new and more reliable techniques for overcoming these problems.

(d) Radar Antennas: Because of the potential advantages offered by phased arrays with respect to rapid scanning, control of beam, and power-handling ability, further effort should be devoted to 1) understanding theoretical properties of such arrays, 2) developing more stable components, 3) designing automatic controls for beam positioning and scanning, and 4) operational testing of representative prototypes. Also, considerably greater emphasis is needed on research and development programs for antennas that can better withstand the effects of nuclear blasts.

(e) Radar ECM Vulnerability Reduction: Despite the recent advances in this area, which offers grounds for increasing optimism over the performance of surveillance radars in the face of ECM, a continuing research and development program will be needed if USAF is to maintain the dynamic anti-jamming capability necessary to anticipate extensions in the countermeasures art.

(f) Advanced Radar Concepts: Advanced radar concepts should continue to receive vigorous research and development support. Before undertaking costly programs, however, unconventional radar techniques that impose severe requirements on the basic components or on data-processing methods should be carefully analyzed to determine their technical feasibility and operational utility.

[REDACTED]

(g) Optical Sensors: Susceptibility of optical systems to resolution deterioration because of thermal and mechanical effects presently places a significant limitation on optical and infra-red sensors. A research and development program to overcome these difficulties is recommended.

(h) Vehicle Stabilization: Vehicle-borne sensors are sensitive to the stabilization of the vehicle, and positional accuracy of targets is dependent upon this stability. In spite of recent advances, deficiencies in satellite stabilization still impose serious limitations on the sensors being carried. An accelerated program is needed to develop and test reliable techniques for precisely stabilizing the attitude of orbiting satellites.

COMMUNICATIONS

Considerable research and development work in the field of communications for L-systems is already in process. The Winter Study Group considers, however, that some additional effort should be expended to obtain as soon as possible:

- (a) devices for reducing existing "non-electrical" communication times, e.g., the delays in the flow of a message from human originator to electrical transmitter, electrical receiver to electrical transmitter when humans are involved in message relaying, and electrical receiver to intended human user of the message;
- (b) survivable facilities for low-volume supplementary communication between command posts (fixed, mobile, and airborne) and between command posts and weapon facilities that are reasonably invulnerable to intensive harassment during a cold war and to thermo-nuclear attack;

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- (c) flexible, economical circuit and message-switching apparatus that can handle a high volume of digital and analog data, operate with a variety of message formats, and recognize transmission errors;
 - (d) non-time-consuming methods to obtain message security, even with switching errors, in a common-user communication network that carries both high-security and unclassified traffic;
 - (e) techniques to permit effective policing and control, by appropriate authority, of communication priority;
 - (f) standards for communication apparatus that will allow the implementation of a common-user network, but at the same time not inhibit the application of advances in the state of the art to that network.

COMPUTING

The equipment now available or planned for the near future in the field of data processing is numerous and well advanced. Over the next five years, normal improvements in the state of the art for computers will probably result in machines 100 times faster than those available today. Consequently, the Winter Study Group is of the opinion that additional emphasis in the area of computer equipment is required to develop only:

- (a) modularity and the flexible interconnecting devices to allow the necessary addition of computing capacity to L-systems without reducing the usefulness of previously devised computer programs and operating procedures,
 - (b) specific machine organizations to permit the use of processes that search for patterns to determine the existence of complex relationships in the data, and
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- (c) a theory to relate machine characteristics to data processing requirements to facilitate the selection of command and control system equipment.

DATA PROCESSING

The associated area of processing procedures, unlike computing equipment, is virtually unexplored. To meet the minimum needs for command, control, and sensor systems during the next ten years, a great amount of research and development effort must be started immediately and continued in:

- (a) higher-order programming languages,
- (b) utility support programs,
- (c) tools for program testing,
- (d) methods of understanding and communicating program organization,
- (e) procedures for automatic indexing, file interrogation, and information correlation,
- (f) operational translator programs,
- (g) techniques for modeling and simulation of subsystems and complete systems,
- (h) application of modeling and simulation to design analysis, program testing, and system testing and evaluation,
- (i) use of linear programming, dynamic programming, game theory, general decision theory, and Monte Carlo methods for war gaming, allocation of resources, etc.,
- (j) role and relationships between men and computer program complex, and

- (k) the effect of a highly automated data-processing environment on human organization and decision making.

HUMAN FACTORS AND DISPLAY

Present research and development programs appear to give little emphasis to the increasing need for basic information on the performance of humans in teams within large, highly automated command, control, and sensor systems as opposed to the performance of an operator of a piece of equipment. Accordingly, it is the opinion of the Winter Study Group that a considerable effort should be applied to the following human factor areas without delay.

(a) Effect of Change on Total Performance: The sudden introduction of large quantities of equipment, highly automated procedures, etc., (i.e., the introduction of a new data-processing system) is known to reduce operating effectiveness of an existing organization for an appreciable time. On the other hand, it is also contended that a continuing series of much smaller changes to equipment and procedures may cause as great or greater deterioration in total performance than a single large change. Some experimental literature is now available concerning the effects of large and small changes in industrial organizations; much further work is needed in this general area to determine the consequence of various kinds of change on command, control, and sensor systems and to develop the training and other techniques necessary to reduce the deleterious effects of changing these military systems.

(b) Human Communication in Networks: Experimental and pragmatic observations of humans in communication networks show that the effectiveness of communication between humans is greatly affected by the configuration of the network. Much more experimental work must be undertaken, however,

before this effect of network configuration on human communication can be properly related to the design of large command, control, and sensor systems.

(c) Human Intervention: Human operators handle messages before electrical transmission and following electrical reception. Human operators establish the priority rules for message transmission and then violate these rules. Very little is known now but much systematic knowledge is needed of why and how human operators in large command, control, and sensor systems influence the flow of communications and of what can be done to retain the desirable characteristics of these human operators without having them seriously degrade the planned communication function.

(d) Level of Data Abstraction: Too high a level of abstraction of data may cause a human in a system to misunderstand or doubt the validity of the information being presented. An example is when a human reacts negatively to a conclusion simply because he does not feel he knows the evidence upon which the conclusion was based. On the other hand, too low a level of abstraction of data leaves to the human in a system the often impossible task of analyzing, classifying, and filtering the data to extract the required information. Research and development programs leading to principles governing the proper level of abstraction and to techniques for filtering, coding, and classifying data are urgently needed.

(e) User Participation in the Design and Implementation of Automatic Data Processing Procedures: There is a continuum of ways for users to participate in the design and implementation of the data-processing aspects of command systems. At one extreme, user personnel might be selected and trained to undertake the entire task. For example, some personnel would be selected so that they will be trainable as computer programmers, and then trained so they are computer programmers. This course of

action would require research into how to select and how to train computer programmers. At the other end of the spectrum computers and utility programs might be designed so that a system operator could talk to a computer in English and thereby instruct the computer to perform the required work. In between, intermediate languages could be developed, and used by command personnel, or command personnel could be trained to specify at some language level their requirements so that a professional programmer could code the program. Which option to choose in this spectrum is not clear. Both the selection of an option and the implementation of that option would seem to require considerable research and development.

(f) Effect of Stress: It has been recognized for years that the ineffectiveness of a human is a U-shaped function of environmental stress. A little stress is a good thing; too much stress causes deterioration and disruption of effective human behavior. In the centers of the hardened and isolated command, control, and sensor systems of the immediate future, all that the human operator will know of the "real world" will be highly unreal. The raw data of reality will have been sensed, filtered, and processed by means the operator cannot fully understand. Everything the operator receives from the outside world can be simulated and not be a "real world" event at all. In undergoing training, the operator could be made to think that he is fighting a total war and then suddenly find out he was only shadow-boxing in preparation for such a war. The operator's uncertainty as to what the real-world situation actually is will be increased continually as he is trained. His hunger for real-world data and his suspiciousness of the credibility of the data flowing within the system may give a new, completely unanticipated dimension to the effect of stress on human behavior. A thorough investigation into these phenomena is strongly recommended.

RESEARCH AND DEVELOPMENT FOR COMMAND SYSTEMS

Finally, we consider some of the elements of the research and development program that must be undertaken to improve future command systems.

Perhaps the most important factor to be recognized in this regard is that our present capabilities to build hardware components for use in systems is well beyond our knowledge of how to assemble these components into efficient systems. While over the past few years we have learned something about computers, displays, and automatic communications as separate devices, we must obtain an increased understanding of basic information processing before we can either handle the interactions between these elements or compose these elements into fully effective command systems.

For example, in the design of a command system there is a critical, but largely unexploited, tradeoff between computer capability at central locations and computer communication capabilities between locations. Similarly, tradeoffs exist between machine hardware and computer programming, and between the role of men and the role of automation. This lack of knowledge with respect to information processing exists because the field is extremely new, cuts across classical engineering specialties, and has not developed top-level experienced specialists. Consequently, the first essential element in a research and development program for command systems is basic work to develop the theoretical foundations of information processing.

The second major requirement in a research and development program in connection with command systems is in the equipment area. Increased sophistication in components (communications, displays, computers) is not the urgent need; what is required is the development of standards for tying such components together, and modularity in design so that the capabilities in

command systems can be expanded and improved without disrupting operations. This latter development should then result in families of expandable computers, display devices, input devices, and communication devices such that the information processing centers of future command systems can be designed by using individual items of equipment from these families which can be easily integrated into a system.

The third important element in a research and development program for command systems is the conducting of operational experiments in an operational environment. Such experiments should seek methods of using automatic information processing to solve specific operational problems, but these experiments should not be directed merely to the development of prototype systems for particular commands. More important, in every case these experiments should attempt to develop and improve automatic techniques that can be used in various fashions by many commands. For example, one capability particularly needed for some command systems is the development of a strategic attack language so that detailed war plans can be generated by computer programs that are given only very general inputs on the nature of enemy defenses, possible attack strategies, and the tactics to be used by both sides. With such a comprehensive language, it would then be possible to generate and evaluate many alternative strategies within a short time. An experiment to develop such a language (which could be used by the military) might be undertaken at SAC, but any such a language would be extremely useful to JCS, Hq. USAF, and other unified commands which have a strategic attack mission.

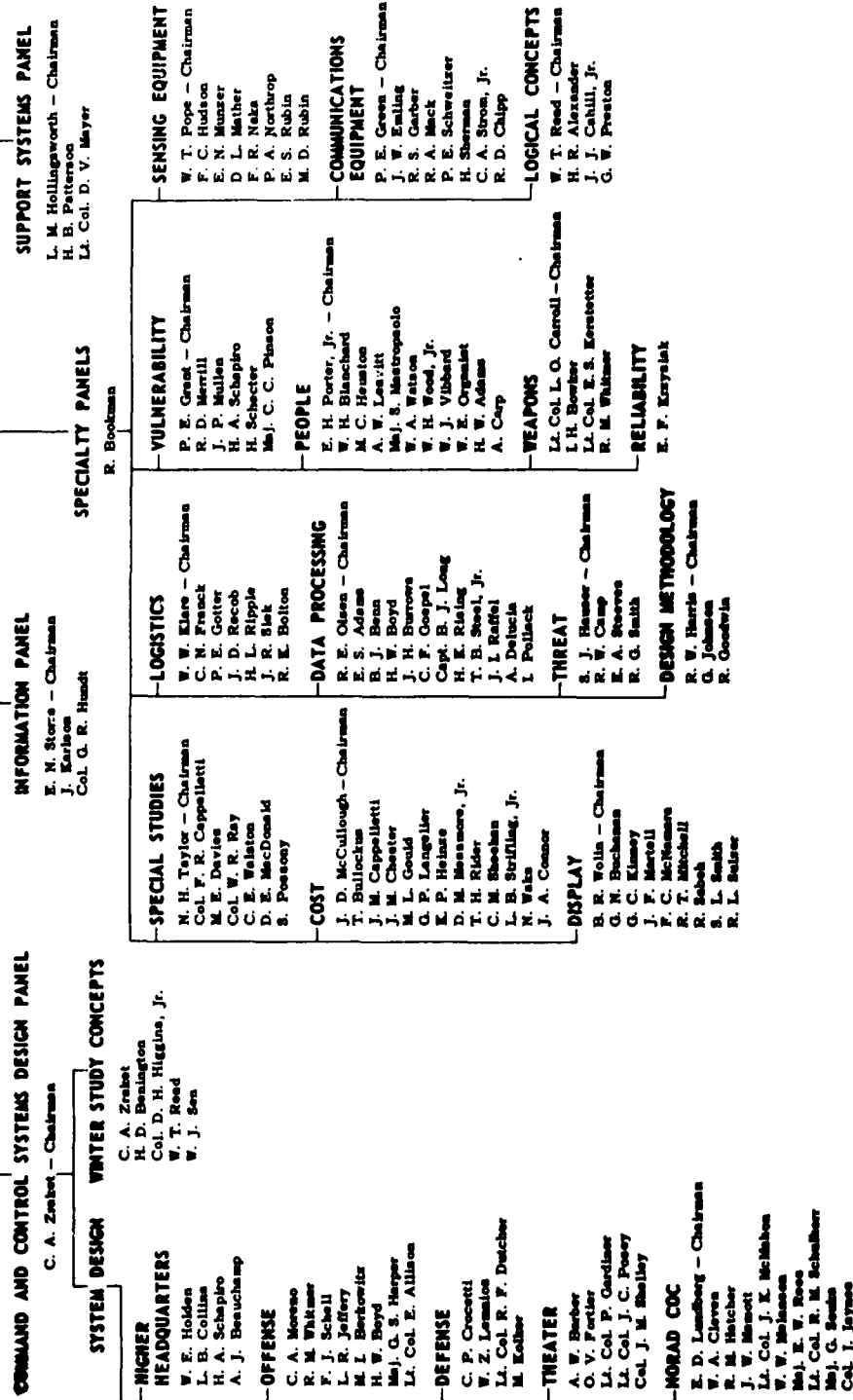
The fourth element that should be sought in research and development programs related to command systems is the development of a command center technology. How do command centers operate? What is the proper role for men and machines? How can operational personnel properly direct

automatic portions of the system? How do command centers grow in a command environment? How can large data bases be created and manipulated so that the data base can be controlled and exercised by many operational personnel?

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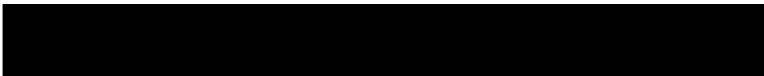
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THE HANSCOM COMPLEX

The "Hanscom Complex" includes such electronic system management organizations as ARDC's Air Force Command and Control Development Division (AFCCDD), AMC's Electronic Systems Center (ESC), ADC's Command and Control Defense Systems Office (CCDSO), other Air Force operator-user command systems offices, and the System Program Offices (SPOs).

THE HANSCOM COMPLEX also includes the Air Force Research Division's Cambridge Research Laboratories which conducts and sponsors basic studies in electronics and geophysics. Massachusetts Institute of Technology's Lincoln Laboratory, with its specialized scientific competence, and The MITRE Corporation with its scientific advisory staff, are members of the complex. In addition, the Rome Air Development Center (RADC), although located at Rome, New York, outside the physical confines of THE COMPLEX, is considered conceptually a part of it.

