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MEMORANDUM VI-L-135-1

COMMENTS ON BTL REPORT #3 TO ARDC "The Ground Environment Problem in Air Defense: An Appraisal of the Lincoln Transition System"

26 January 1954

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS

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BTL REPORT #3 TO ARDC
"The Ground Environment Problem in Air Defense: An Appraisal of the Lincoln Transition System."

Prepared by
The Staff of the Lincoln Laboratory

26 January 1954

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TABLE OF CONTENTS

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TABLE OF CONTENTS Continued:

I. GENERAL

Under Contract AF-18(600)-652 and dated December 17, 1953, the Bell Telephone Laboratories has submitted to the Air Research and Development Command a report entitled "The Ground Environment Problem in Air Defense: An Appraisal of the Lincoln Transition System."

The purpose of that report is to call military attention to possible Transition System shortcomings in time to take corrective actions. In doing this, the report is very helpful. In addition to raising some new points, it supports and emphasizes the importance of several programs which have recently been started by the Air Force and by Project Lincoln.

Persons associated with the Transition System feel that the report is correct in two of its three principal points, but that the third and several minor points are based on misunderstanding.

As we see it, the report contains three central themes:

A. Deficiencies in the Observation Phase (after Observation has been redefined as discussed in Chapter II of this paper).

We agree with the concern shown in the report for the inadequacy of the radar data, feel that this is the most important and constructive point which the report emphasizes, and feel that the importance of improving the observation (radar) phase of the system justifies a separate recommendation.

B. Desire for More Cape Cod Test Results.

In this, we agree on the importance of additional test data to establish a quantitative foundation for the Transition System. Data already exists on some of the points raised in the report; on the others, a high priority program is directed toward obtaining necessary data.

Points A and B will be discussed in more detail in Chapter III.

C. Authors' Preference for Decentralized Data Processing (which is called Observation in the report).

We feel that the borderline between centralization and decentralization is ill-defined, and that the arguments presented in the BTL report do not necessarily

justify the conclusions. Some further work is now being undertaken at Lincoln to investigate part of the "decentralization" problem. A fuller exposition by the writers of the BTL report would be welcome. There is some confusion concerning other areas of application. This will be discussed more fully in Chapter V.

To a lesser extent, the report raises operational and economic questions about the Transition System such as cost, personnel requirements, subdivision of military functions, purpose and areas of application, degree of departure from past practice, and proper size of basic building block. With some of these opinions we agree, but others seem to result directly from basic operational and economic philosophies in which the authors of the report differ from the designers of the Transition System. With some of these philosophies we agree, and we differ with others. These are treated more fully in Chapters II, III, IV, and V.

In the remainder of this memorandum:

Chapter II discusses some points of basic philosophy and viewpoint on which the Transition System is based and with which the authors of the BTL report seem often to disagree.

Chapter III discusses those points in which we agree with the BTL report.

Chapter IV lists some points of disagreement and errors of fact in the BTL report.

Chapter V discusses an important area in which there is a lack of common understanding.

II. BASIC PHILOSOPHY AND VIEWPOINT.

Evaluation of an air defense system must be carried out within some framework of philosophies and beliefs which define the objectives, resources and performance with which the system must be compatible. It is in this area of underlying philosophy and viewpoint that some disagreements with the BTL report arise. These will be discussed under:

A. Grouping of Air Defense Functions.

B. Scope of System.

C. Personnel and Cost.

D. Relation to Present Practice and Size of Basic Building Block.

E. Areas of Transition System Application.

However, it should be noted that the worth of an air defense system is judged not by its conformity to some arbitrary guiding philosophy, but in how well it "makes air defense."

A. Grouping of Air Defense Functions.

On Page 3, the authors divide military functions into three groups: Observation, Command, Guidance. By omitting Data Processing as a separate group a confusion is created which persists throughout the balance of the report. "Data Processing" is as separable as the other groups of functions. In many civilian and military tasks Data Processing is more closely associated with Command and Guidance than with Observation. However, grouping Data Processing with Observation, the authors are naturally led to several doubtful conclusions, including the one that data should be processed at the radar set where, indisputably, observation must take place. We believe that a more plausible and instructive grouping would be as follows (without thereby implying the geographical relationship of major or sub tasks):

1. Observation

   a. Radar Signal Detection.

   b. Direction Finding Data.

   c. Ground Observer Corps Reports.

A. Grouping of Air Defense Functions - 1.Observation continued:

d. Flight Plans.

e. Height Measurement.

f. Passive Detection of Enemy Signals.

2. Data Processing

a. Track Initiation.

b. Track Maintenance.

c. Correlation of Information (as for identification).

d. Display.

e. Cross Telling.

3. Command

a. Decision on Identification.

b. Threat Evaluation.

c. Weapon Assignment.

4. Guidance

a. Interceptor and Missile Mid-course Guidance.

b. Local Weapon Target Designation.

c. Interceptor Return-to-Base.

Each group of functions depends on results from the preceding groups. The first two groups (Observation and Data Processing) can be considered as service functions for the end-result groups (Command and Guidance). It is easy to criticize the presently existing air defense system for its deficiencies in Command and Guidance; this is, however, the focusing of attention on effect rather than cause.

The gross shortcomings of the present air defense system lie about equally in the Observation and the Data Processing groups. Both need many-fold improvement, and the improvement of one alone will give only

partial air defense enhancement. The radar part of the present Observation system is deficient in:

Low altitude cover (needing more radar sets closely spaced because of earth's curvature).

High altitude cover.

Ability to see moving targets in ground and see clutter.

Resolution.

Blip-scan ratio.

Speed of antenna rotation.

Reliability.

Discrimination against weather.

Present Data Processing is deficient in:

Capacity.

Speed.

Freedom from error.

Accuracy.

Clarity of Presentation.

Means for coordinated group action.

The present manual Data Processing would be nearly incapable of absorbing more information from the Observation phase, but, by contrast, a better data processing system should make improved use of presently available radar data. The Lincoln Transition System attempts to concentrate on breaking the Data Processing bottleneck, while simultaneously efforts are being made to improve the "Observational" process. As the BTL report stresses, full potentiality of the system can not be realized until both of these programs have been completed.

B. Scope and Flexibility of Air Defense Ground Environment.

An over-simplification of the air defense problem may result in a corresponding over-simplification of the solution. We believe this has happened several places in

B. Scope and Flexibility of Air Defense Ground Environment Continued:

the BTL report as a result of concentrating on only the radar as the data source and the manned interceptor as the weapon. Air defense is not a single-line information flow circuit but has many inputs, multiple outputs and many inter-acting cross-currents of information within the system.

We prefer to think of the Transition System, not as a certain specific information flow channel (the present large radar, SDV link, orthodox digital computer, display and interceptor of the BTL report), but as a matrix into which all detectors, many types of data transmission, missiles, picket ships, and weapons can all be fitted. Effective use of the gap filler and "Muldar" type of short-range all-altitude radar seems, for example, to be well fitted to the Transition System but ill fitted to alternate proposals in the BTL report.

The Transition System must have flexibility to cope with substantial changes in threat, observing equipment, forms of data transmission, and weapons and to serve and include all of these, not just one combination. For example, the BTL report discusses SDV data encoding (which has a valuable and important place in the system) to the relative exclusion of other automatic data encoding systems which encode radar data to higher accuracies and conserve bandwidth to a greater degree than does SDV. These are now in late stages of development after several years of study and basic experiment and will be operationally tested this summer.

As pointed out in TM-20*, the Transition System is the transition between the present system (with present radar sets) and the Future System (with improved Observation as well as Data Processing). Plans for improved radar sets are under way with more emphasis still needed.

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* "A Proposal for Air Defense System Evolution: The Transition Phase." Lincoln Laboratory Technical Memorandum No. 20, Second Draft, dated 2 January 1953.

B. Scope and Flexibility of Air Defense Ground Environment Continued:

After the transition phase, improvement in data observation will be the most necessary next step.

Since not all possible forms of this improvement can now be foreseen, we must question the philosophy of Pages 13 and 14 of the BTL report, where it is implied that flexibility for future development will be needed in the Command and Guidance phases but not in the Observation and Data Processing phases.

We believe that Observation and Data Processing must be adaptable to improvements and therefore require the same degree of flexibility as Command and Guidance.

C. Personnel and Cost.

In discussing personnel and cost, we feel the BTL report is founded on a different concept of the motivation for the system than that which has inspired the development. From the report (Page 23), "It seems clear that the most powerful tools possible are needed to solve the air defense problem and that, in particular, mechanization is needed to economize on the expenditure of human effort in an essentially standby function during what may be many years of cold war." We believe that emphasis should be primarily to "solve the air defense problem" and desirably, but quite secondarily, to reduce the number of people. We consider it fortunate that an increased air defense capability appears to be possible without requiring any increase in the present number of personnel.

The report implies that the Transition System is very expensive. Here the guiding philosophy should be based on a relative, not absolute, scale. On an absolute scale, the system might seem to be prohibitively expensive. On a relative scale, the entire electronic ground environment (including radars) will total less than ten percent of the cost of the weapon systems which it controls. If the Transition System can produce a ten percent increase in weapon effectiveness, it will break even; it will be disappointing if a several-hundred percent increase does not result.

C. Personnel and Cost Continued:

In implying that the Transition System is expensive, the report further implies that an unspecified alternative system can be cheaper. It is our belief that all of the alternative systems proposed to date will be less effective than the Transition System and more costly.

D. Relationship of System to Present Practice and Size of Building Block.

From the viewpoint of the BTL report, the Transition System is (Page 25) a "complete break from present operating doctrine and practice." We submit that, relative to the system improvements anticipated, only small departures from the present operating doctrine and operating practice are necessary. The basic unit of the Transition System is handled like the basic unit at present, with similar duties assigned to the Air Surveillance Officer, the Identification Officer, the Sub-sector Commander, and the Intercept Director. The Direction Center and the Combat Center perform substantially the same functions as at present.

True, the command area of the Combat Center has been increased four-fold but this hardly constitutes a complete break with the past because military units customarily encompass a wide range and variability of sizes. Some consolidation through better data processing and transmission can hardly be more radical than past changes following the introduction of the telephone, radio, or radar.

We have encountered no difficulty in training Air Force airmen and officers to operate the Cape Cod System. Basic skills of present Air Force personnel will carry over from the present system to the FSQ-7 Information Central. The "Thinking" and "Decision" jobs (evaluation, assignment, tactics) remain the same. Many individual tasks are simplified in the same way that assembly tasks are subdivided and clarified in making the change from a model shop to an assembly line.

The inherent flexibility of the Transition System computer makes it easy to adopt drastic departures from present day operating doctrine if desired. However, operating doctrine is the prerogative of the Air Defense Command, and the suggested doctrines have been studied by them.

D. Relationship of System to Present Practice and Size of Building Block Continued:

Undoubtedly, operating doctrine will be modified as the Cape Cod tests progress and will continue to evolve with military operating experience. Lincoln should provide for such evolution; the Air Force will control it.

E. Areas of Transition System Application.

The report seems to exclude several important areas of application for the Transition System. It, therefore, concludes that additional new development is needed in these areas along with ways of making this new development compatible with the Transition System. On Page 11, we find, "The system is intended primarily for areas of high traffic density;" and on Page 26, "Hence, the Transition System itself must ultimately be integrated into a larger defense system including advanced early warning and tracking systems and combat areas where traffic density does not justify a highly centralized system."

The meaning of "traffic density" is unclear, but it should be pointed out that selection of the Transition System is not directly affected by normal peacetime commercial and military air traffic. The system should be installed where there is threat of an air battle. It should be installed in any area which is to be chosen as a battle area and to which a significant allocation of weapons has been or is to be made. Again, the criteria might well be the relationship between weapon cost in an area and the expected enhancement in weapon effectiveness from an improved electronic ground environment.

With respect to a close tracking band (100 miles or more) beyond the weapon range, it is highly desirable that Observation radars covering this band be integrated as part of the Transition System (combine the first and second layers of the onion analogy on Page 6).

If the area is not manned with adequate defensive weapons to conduct an air battle, the role of the Transition System must be studied again. Conferences with the ADC indicated that the Transition System is now being considered only for those regions which will have defensive weapons systems.

III. AREAS OF AGREEMENT

In most recommendations and observations in the report, the Lincoln Laboratory agrees with the findings of the BTL report.

A. The Observation Function.

The report raises serious questions about the shortcomings of the input data to the system. The source of radar data is the most vulnerable part of the system, and it is here that one is working with the minimum signal thresholds and the minimum signal to noise ratios that occur at any point in the system. One must work subject to the natural limitations of resolution, range, earth's curvature and clutter as well as jamming by the enemy. If the observation function can be adequately performed, there is, in theory, no excuse for failing in the succeeding functions of data processing, command and guidance. To obtain adequate data many radar improvements are needed and most seem possible to achieve:

1. Low altitude coverage.
2. More power to see small targets.
3. High altitude coverage.
4. Better MTI.
5. Improved weather discrimination.
6. Improved resolution for better weapon control.
7. Increased antenna rotational speed.

In addition to getting more useful information in the radar returns, improvements are also necessary in the way in which this data is observed and made ready for use by the data processing equipment.

This agreement concerning observational deficiencies must be tempered with the realization that these deficiencies are common to all air defense systems which use radar data.

B. Selective Bandwidth Compression at the Radar.

The arguments for taking advantage of the potential information at the radar are most convincing. In truth, this became apparent a year or more ago when the Transition

B. Selective Bandwidth Compression at the Radar Continued:

System was initially conceived as requiring the interim use of present long range radars. At that time, it was recognized that a program would have to be undertaken to selectively compress radar bandwidth. The SDV was initially designed for the short range radar where the data compression was consistent with resolution capabilities of the basic radar. It will continue to be useful with interior radars where overlap is sufficient to make the longest ranges unnecessary. However, SDV is a marginal device for high accuracy guidance on the outer limits of the heavy radars especially on the perimeter. The compression of radar bandwidth will have to be done in a manner which retains the accuracy of the original data and discriminates against false information. Apparatus for selecting the coordinates of the radar return to an accuracy consistent with that of the original information has already been demonstrated for single targets on the CPS-6B and for a limited number of targets on the Mark X. The combination of this beam-splitting technique with noise and clutter rejecting devices will be operationally demonstrated this summer (1954). The area of disagreement is, therefore, one of technique rather than of principle, since we propose to use beam-splitting, selective information encoding, and transmission, but to retain the economic and operational advantages of tracking at the Direction Center. The measure of disagreement at this point is concerned with the need for additional equipment and personnel to discharge this tracking function at the radar, and the degree of added compression under high track density conditions which could be achieved by human intervention at the radar.

C. Magnitude of the Program.

The report correctly calls attention to the magnitude of the Transition System development, design and installation programs. The Transition System can hope to progress on schedule only if all interested persons provide their most effective help and if no major unforeseen difficulties arise.

D. Test Program.

The report properly stresses the urgency and importance of the test program being conducted on the Cape Cod Expermental System. The Lincoln Laboratory will carry this forward rapidly.

E. Automatic Tracking.

The report agrees with the idea of automatic tracking of radar data both explicitly as done in the Lincoln Transition System and implicitly by suggesting alternative data processing techniques which also use automatic tracking. This is encouraging since the concept of automatic tracking has been one of the most controversial technical issues in the past.

F. The Application of General Purpose Digital Computers.

On Pages 13 and 14, the BTL report concurs in the utility and growth potential of the general purpose digital computer. It emphasizes the need for easy conversation between computers. This, too, is an encouraging endorsement of a subject of past controversy.

IV. POINTS OF DISAGREEMENT.

There are a number of points in the BTL report with which we disagree. We believe that these arise for reasons given earlier.

A. Disagreement with Presentation or Implications of Report.

1. Effort Justified in Radar Data Processing.

The report on Page 15 correctly states that the processing of track data occupies about half of the central computing time. The implication is incorrect that this is unjustifiably high.

The generation of a clear, unconfused track situation is the most difficult and subtle part of the air defense problem, short of the actual observation of the airplane itself. This viewpoint is not inconsistent with alternative proposals which have devoted the major part of their equipment and personnel to the tracking problem and little to subsequent data processing. By using all of the available information in the system, such as aircraft identification, flight plans, orders transmitted to interceptors and knowledge of radar coverage, it is believed that some compensation can be made for deficiencies in the actual radar observation by aircraft. It should not seem surprising that half the capacity of the data processing part of the system should be devoted to the largest and most difficult task which must be accomplished. The same section of the report states: "In fact, there are no obvious technical or operational reasons why the observational and guidance functions should be centralized as the command functions must be." We would point out that there are no obvious reasons for the reverse, and that a careful examination of the cost and complexity of the two systems seems to show that the data processing is more closely allied to the command and guidance functions than it is to observation. The report presents no technical justification for what seems to us erroneous implications

1. Effort Justified in Radar Data Processing Continued:

that decentralizing the data processing would lead to either less equipment or higher quality performance. This is further discussed in Section V. below.

2. Amount of Information in a Radar Scan.

The report makes calculations on the amount of information in a radar scan. These are misleading and appear erroneous as a result of confusing "resolution" and "precision." In the radar signal, the calculation seems to conclude that because one can do beam-splitting to one-fifth of the beamwidth, that there can therefore be five resolvable airplanes in one beamwidth, at a particular range.

Our calculations of the number of resolvable cells in a single radar frame (AN/FPS-3) indicate

$$\left(\frac{360^\circ}{1.4^\circ} \text{ cells in azimuth}\right) \times \left(\frac{200 \text{ miles}}{1/4 \text{ mile pulses}} \text{ range cells}\right)$$

or about 200,000 resolvable cells. We are agreed with the Bell Laboratories that even this number of resolvable cells, although occupied in relatively low densities (i. e, 25%) exceeds the capacity of all presently known data processing systems.

A premise must therefore be established concerning the total number of objects which must be considered by the data processing system. If we make the premise that as many as 200 aircraft are in view of the ground radar (BTL on Page 8 suggests that 60 air objects may be more reasonable) and that there are 5 times as many other possible extraneous objects to be considered for each target (BTL on Page 9 suggests a 1 mile by 1 mile search box which can contain only 4 resolvable cells beyond 40 miles) and that each aircraft or other source of information be specified to 22 bits (an increase in precision of 16 times in azimuth and 4 times in range over SDV), then the total rate at which information is being generated is

2. Amount of Information in a Radar Scan Continued:

only about 2500 bits per second at present radar frame rates. Furthermore, we are confident that these capabilities are within reach of the proposed data encoding system and well within the capacity of an AN/FSQ-7 to process.

3. Overlapping Radars.

On Page 20 of the report, the second paragraph implies that the Transition System will and must track interceptor and target with separate radar sets. The Transition System can do this when necessary and this point distinguishes it from other systems. However, there is no necessity nor desire for doing the tracking in this way when one radar set is receiving good data on both target and interceptor.

4. Radar Data Overload.

In reference to the input buffer drum, on Page 20, fourth paragraph, in speaking of a way to eliminate input buffer drum jamming by a particular radar, the report states: "Practical effectiveness of this expedient is yet to be determined." It should be pointed out that in all the operations thus far there has not as yet been any need for the expedient. Its development consists at most of providing a counter, which is one of the simplest digital techniques present in the system.

B. Errors of Fact.

We feel that there are several errors of fact in the report. This is recognized by the authors on Page 13: "It is to be emphasized that the appraisal of the system ventured here is to be regarded as tentative and based upon broad system concept rather than upon a large amount of detailed factual knowledge." We do believe, however, that an evaluation and a broad system concept depend intimately upon the accuracy of details and that such errors should be corrected.

1. History

The report states that all development work toward the Transition System has occurred since 1951. While it is true that the first field experiments with automatic processing of real radar returns from real aircraft were conducted in the spring of 1951, this necessitated a considerable amount of preparatory work. Even if we ignore four years of related equipment design and of development of data links, and a similar period of study and discussion and evaluation of the use of digital computer equipment in military data processing, the present schedule still calls for installation of a first operational sector at least seven years after the beginning of the design of the experimental equipment. The authors are right that this is a short time for a system of this extent, but it is not as short a time as the report implies.

2. Automatic Hand-over and Cross Telling.

On Page 14, the report states that there is no automatic hand-over procedure between computer centers or between air divisions. This is incorrect since equipment and circuits for fully automatic operation are included as part of the FSQ-7 design.

3. Tracking Search Box.

The eight-mile square tracking search box discussed at the bottom of Page 18 does not in any way commit one to use all of the data and noise which might occur within this area. It is an area taken large enough to include all returns of possible interest even after a target miss due to a low blip scan ratio from the radar set. A small search box is placed within the larger and various criteria tested for the existence of data in one or the other, or both or neither of the boxes.

4. Combining Radar Data.

In the last paragraph on Page 19, the statement is made that superposition of radar data reduces the signal to noise ratio. This is incorrect because the radar returns are identified by source before being placed on the input buffer drums. The computer can and will have access to the data from individual radars separately so that the comments about decreasing signal to noise ratio are true only if the effect is found to be sufficiently unimportant and to be ignorable.

5. Mapping Operator.

Page 20 states that the map masking operation relies on the uncontrolled judgment of the individual operator to a possibly dangerous extent. Operators are under the guidance of a supervisor and individual judgment seems no more dangerous here than at many other points in the air defense system, and is certainly far less dangerous than that exercised by the human tracker suggested in alternative systems. Despite our lack of reservations on the danger of this procedure, basic experiments have been made on mechanizing this function in order to minimize personnel.

6. Slant Range Correction.

The second paragraph on Page 20 incorrectly states that the lack of slant range correction may cause trouble. The FSQ-7 system will make slant range correction on all radar returns where this correction is significant.

7. Buffer Drum Capacity.

In several places the report states that the input buffer drum represents a constriction on the flow of radar data. This is untrue since the input buffer drum can handle more data than can be processed by the system.

V. DECENTRALIZED TRACKING.

A. Decentralized Tracking for Continental Defense.

The authors of the BTL report strongly favor the decentralization of track data processing to the radar site. We feel that this partially results from not clearly distinguishing between the observation and data processing functions and from not having in mind any firm idea of what the suggestion implies in equipment complexity.

They suggested that the decentralized tracking could give some unit capability at the individual radar set. It would certainly be a step in that direction but some semblance of a complete system would be necessary before the amount of unit capability could be determined. In particular, we are agreed with BTL on the increased areas in which air battles will be fought with increased aircraft speeds. Unit capability in face of such possibility must be questioned. The likelihood that isolation of a radar set can occur due to communications failure should be studied carefully by the ADES organization and a value on continuity of service established by ADC. With this information an adequate standby communications system can be specified and we believe that adequate standby communications will be more practical and less expensive than providing standby operational facilities at the radar.

The suggestion that such decentralization would be simpler and more efficient has in the past been untrue of those systems which have progressed to the point where complexity could be evaluated. We believe that the excessive complexity in proportion to the return achieved is the reason that such a system does not now exist in usable form. A simple comparison of the number of tubes per track in different systems is frequently in error because of the failure of some systems designers to appreciate the magnitude of coordinating the tasks of track initiators, track monitors, and track users in large systems.

The suggestion of higher performance for the decentralized system, we believe, is also erroneous and the scant comparative information seems to so indicate. Almost any kind of automatic tracking can be made to function under conditions of one hundred percent radar blip-scan ratio, low noise, and low traffic density. It is under the often prevailing non-ideal

conditions that automatic tracking becomes difficult and its solution subtle. Here we believe the rigidity, inflexibility, and naivete of the special purpose equipment is dangerous.

The authors are right to the extent that some special equipment will be needed at the radar set. Video integration is needed with the SDV transmitter; a beam splitter will probably be required at the long range radars; under some circumstances, radar mapping may be employed. All these techniques fit within the framework of the Transition System and should be much simpler than any full reliance on tracking channels at the radar.

Since, according to the report, the decentralized systems are still very much in the experimental stage, it seems unlikely that they can arrive in time to be a part of the Transition System. Why such systems should still be in the experimental stage is interesting speculation. To our knowledge, the systems which employ variations of analog track-while-scan units were started before 1947 and have not as yet been successfully applied to the air defense problem.

As stated before, the inherent difficulties in the system arise in the simple observation function and not in where the data processing is done. With the introduction of gap-filler radars and the trend toward the multiple, short-range, all-altitude radar, the prospect of local data processing becomes even less attractive.

B. Decentralized Tracking for Non-Contiguous Defense.

The BTL report has recommended further that decentralized data processing be developed for isolated bases and other air defense situations. There is some uncertainty regarding the specific areas of application which were intended. It would be most helpful in the formulation of a development program if these ideas could be expanded to specify the particular situations for which decentralized data processing should be developed with illustrations from present and future operational concepts.

C. Lincoln Laboratory Program in Decentralized Data Processing.

To the extent such a decentralized data processing system for continental defense is compatible with the Transition System in techniques and concept, we are in favor of, and have such a program under way. This equipment is intended to encode data more accurately, conserve transmission bandwidth to a greater degree than SDV, and minimize the transmission of useless information. We believe that this fulfills the spirit of the BTL recommendation (within economic constraints) as applied to continental defense planning.

Beyond this, the Lincoln Laboratory would be happy to undertake the study of such specific alternative systems as may be proposed for any other specified situations. This commitment will have to be examined in light of specific proposals to insure that studies will not interfere with our primary program for making the Transition System operational and to establish that Lincoln Laboratory can make important contributions on such proposals in the face of present efforts.