PRELIMINARY INVESTIGATION ON THE APPLICATION OF ON-LINE CONSOLE/COMPUTER TECHNIQUES TO THE 473L COMMAND AND CONTROL SYSTEM

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1. INTRODUCTION

Many command headquarters, such as the AF 473L Command and Control System in Washington, are being equipped with advanced data processing and display systems. These systems are designed to assist the command personnel in the execution of their assigned tasks. Although considerable progress has been made in the application of data processing equipment to the solution of the complex problems in command and control, there is still a great need for further developments of operational concepts and procedures to provide optimum utilizations. Such developments have not matched either the growth of problem diversity and complexity or the potential capabilities of the processing equipment.

Consider the following. In most operational command and control problems, such as are the responsibility of 473L personnel, a large number of assessments must be made on the effects of individual decisions or on the effects of particular elements of the situation in determining the outcome of an operation. In addition, the overall data base of a command and control system is very large, covering many aspects of own force status, enemy disposition and activities, weapon performance data, and geopolitical factors. Thus, the solution to any given operational problem requires a careful selection of the pertinent parameters from the data base and then a careful assessment of actions to attain the desired goals. In a command and control system headquarters, it may frequently occur that the exact situation does not match any preplanned contingency situation for which a solution has been programmed. In such a case, the preferred solution would be the generation of a new program composed of a new combination of selected data to meet the peculiar operational situation. A less satisfactory but more normal answer, due to the permissible operational time factor, would be the employment of a modified or extrapolated existing plan or solution for meeting a given contingency.

This technical note reports favorably on a preliminary investigation of the application of the On-Line Console/Computer Technique to the field of command and control. A follow-up to this very preliminary work should be able to show that the above desired first approach to the solution of unforeseen command and control problems can be realized in many cases. The time required for developing the needed computer programs, using the on-line techniques, should be relatively short.

Section 2 summarizes the results obtained in this note. In Section 3 basic principles for determining the application of the on-line console/computer techniques to the 473L Command and Control System are discussed. This is followed (Section 4) by a brief description of certain features of command and control systems that will have a bearing upon the application of the on-line technique. Section 5 is a generalized discussion of the implementation of the on-line system to the command and control field, with particular emphasis on the objectives, programming implications, and operating procedures. These are illustrated in an examination of a postulated operational problem in the last section of the main body. A brief appendix describes the particular console/computer facility, the RW-400 system, used in developing the material of this note.

2. SUMMARY

The on-line console/computer operation has had a high degree of success in solving complex scientific problems by Drs. B. D. Fried and G. J. Culler of this Division. The intuition and experience of the scientist has been successfully mated with the processing capabilities of a large computer/display console set-up in achieving this goal, without requiring the scientist to have a detailed knowledge of either computing equipment or programming. A successful transfer of this on-line technique from the scientific field to the command and control field would permit the command personnel to combine their training, experience, and knowledge of specific military situations with the data retrieval, display, and processing capabilities of the computer system at the command headquarters. Sufficient similarities appear to exist between the two fields that transfer seems possible. These are substantiated by the analysis in this technical note.

It should be recognized that the use of the on-line technique is envisioned as a supplement to current preplanned computer programs. The preplanned or off-line programs will continue to provide solutions to those problems which have been evaluated many times before. The on-line technique holds promise of reducing the cumbersome time consuming chain of operations involved in computer solution to new or infrequent problems. This chain consists of command personnel presenting their problem to programmers who program the computer to solve the problem which is printed out and presented to the command personnel for evaluation. Many iterations of this operation are frequently required. The on-line technique should permit command personnel, quite unversed in computer and programming techniques, to obtain essentially direct solutions to their operational problems.

The preliminary investigations of this note do indicate that a feasible software system may be designed to expedite the solution of highly unstructured problems such as exist in the command and control area. Early in these investigations it became apparent that it would be helpful to list those characteristics of a computer that would aid

in the solution of on-line data processing problems rather than to select a given computer and attempt to implement the various processes in machine language. The desired characteristics include capabilities to:

a. Interpret and execute commands given in a problem-oriented language.
b. Manipulate variable length operands.
c. Permit the user to define operands at his discretion in the on-line system.
d. Modify on-line routines.

At the same time, since it was obviously impossible to design and construct a computer having the structure and logic capabilities listed above, it was decided to study the feasibility of simulating these characteristics on an existing computing system. The RW-400 system was selected, principally because it is now being used with the scientific on-line work within the Division.

The simulation of the above characteristics should be possible by implementing an Interpretive Program in which the instruction repertoire effects the manipulation of operands by transfers to and from a variable length Pseudo Accumulator. The operands are defined either by the identification of items displayed on the cathode-ray tube of the display console or by overlay techniques. In this simulation, the interpretive program must contain:

a. Control portion for the interpretation of console signals, and
b. Operational portion for the retrieval of the necessary parameters required for the execution of the desired commands.

Also it became apparent that a well defined file structure is required for the proper association of the various functions of the desired problems to the hardware through the interpretive program.

3. TECHNICAL APPROACH TO THE ON-LINE CONCEPT

The problem of man-machine communications has been the subject of many studies and investigations. Many different techniques have been devised to improve the man-machine relationships. One such technique was developed by the TRW Computer Division as part of an Air Force contract for a data processing system to reduce reconnaissance data. This technique involving the use of a display analysis console (DAC) allowed, in effect, direct communications between an operator (unversed in computer technology) and the computer. The console featured CRT displays and a set of pushbutton keys. The computer was preprogrammed to recognize the meaning of each key. The keys themselves were inscribed in the terminology of the operating personnel. A given problem solution involved a step-by-step routine of instructions (button pushes) by the operator, and performance and display by the computer. In many cases, the operator was given a choice of several alternatives at each step of the process.

Although this represented a significant advance in man-machine communications and allowed the operator a degree of flexibility, the fact remained that each of the steps in the process had to be carefully thought out and preprogrammed by conventional methods.

Recent extensions of these techniques have been successfully made by TRW with the development of the on-line computer technique to the solution of scientific problems. A scientist, without having to have a detailed knowledge of computers or programming, can impart his specialized knowledge, experience, and intuition at each step in the solution.*

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* G. J. Culler and B. D. Fried. "An On-Line Computing Center for Scientific Problems", TRW Computer Division, Report M19-3U3, on AF 30(602)-2762, 11 January 1963.

3.1 THE GENERAL ON-LINE CONCEPT

The on-line console/computer technique attempts to overcome some of the problems present in the area of man-machine communications. The term "on-line" is used to emphasize the fact that the user (command personnel, scientist, etc.) has the capability to direct, to control, to monitor, and to modify the computational processes being performed on the data processing equipment at each major step in the process. This is different from the off-line technique where the user must first explain the problem and proposed method of solution to a programmer. The problem is then programmed, run on the computer, printed out, and returned to the user. The user must analyze the result, and then will generally suggest revisions in the method of attack or in the parameters, requiring a re-run of this cycle.

The on-line scientific console/computer technique makes use of three features. These also appear to be equally applicable to the command and control field. The features as applied to the scientific area are:

a. Functional Orientation - The programming structure is such that the computer presents mathematical functions rather than individual numbers to the user. These constitute the basic elements, while a repertoire of "commands" consists of operations on functions (e.g., arithmetic, differential and integral operations, etc.).

b. Control and Display Capability - Central to the operation of the system is a control console having a number of pushbuttons or keys, which allow for user control of the computer, and having a CRT display (with line-drawing capability), which provides direct graphic representation of the computed results. A CRT with alphanumeric capability and an automatic typewriter provide numeric outputs when required.

c. Console Programming - A simple procedure allows the user to construct new subroutines directly at the console, using as building blocks an initial set of preprogrammed subroutines, plus any subroutines previously created by his "console programming" procedure.

These features allow the user to apply, simultaneously: (1) his own intuition and specialized knowledge, and (2) the very rapid and powerful computational capabilities of a computer to the solution of a given problem. These features further allow the user to create new and special routines or steps without learning conventional programming techniques. He is able, using only normal mathematical concepts, to create a computational language tailored to his needs, and to the particular problem.

3.2 APPLICATION TO COMMAND AND CONTROL

It should be emphasized that the intention of the on-line effort in the command and control field is not to transform command and control problems into mathematical equations for solution by present scientific on-line techniques. Rather, the purpose is to investigate the feasibility of applying the on-line concepts directly to the command and control field utilizing the language and concepts of the user.

The experience of the TRW Computer Division in the command and control field* and our preliminary analysis on the application of on-line console/computer techniques to command and control give every indication that this will be possible. This belief is based upon four points:

a. Analogy of Problem Solution - The generalized methods (not specific techniques or mechanics) used in solving complex command and control problems are quite analogous to the generalized methods used in attacking and solving complex scientific problems. In both cases, the solution is highly dependent upon the experience and judgment of the personnel concerned. Furthermore, as mentioned previously, the decision or solution can only be reached after numerous assessments of many factors. This requires a step-by-step process, with each step or alternative dependent upon the experience and intuition of the user in the evaluation of the previous step.

b. Common Features - Many command and control problems have common or similar features, and hence, would appear to be amenable to solution

* These studies have provided a very broad and detailed knowledge of command and control problems in the Air Force, Army, and the National Military Command Systems Support Center.

by similar techniques. The general techniques and methodology employed by command personnel in a given command post, such as 473L, appear to be very similar for a wide variety of specific operational problems such as those dealing with operations (general or limited war), logistics, and disaster.

c. Basic Language - It is considered that command and control problems have enough common features to allow the existence of a common basic language. The existence of such a language is a prerequisite for the application of on-line techniques.

d. Elemental Problem Formulation - Preliminary investigations, discussed more fully in Sections 5 and 6, indicate that command and control problems can be subdivided into basic elemental steps and processes. These steps appear to have universal application to many specific command and control problems.

From these four points, it appears that the three major features of the scientific on-line computation technique will also describe the command and control on-line technique. Of these, the last two, "Control and Display Capability" and "Console Programming", appear to be directly applicable. This does not mean that the same display formats and console key labeling will be employed, but rather the same basic concepts of the user having control of both the data to be presented and the method of presentation. The other feature, "Functional Orientation", must be redefined to meet the language and concepts of command and control rather than that of mathematics.

4. CHARACTERISTICS OF COMMAND AND CONTROL DATA PROCESSING

Before proceeding with the discussion of the application of the on-line technique to command and control, certain features of command and control systems should be presented. These features appear to have a significant influence upon the application of the on-line techniques to command and control. In many cases, these features are different in significant ways from similar features of scientific problems.

The first two features of significance are the size and character of the data base. The data base is generally very large, measured in terms of millions of items for such systems as 473L. The items are largely alphanumeric rather than numeric in nature. Typical extensive files in any one of these systems deal with such subjects as the status of forces and various contingency plans.

A third feature of interest deals with information presentation techniques. A commander most often uses data in tabular form or on maps to solve a specific command and control problem. Textual material is also frequently used, but mathematical equations or their graphical representations are seldom used.

These three features produce, in large measure, the fourth feature of interest, namely the processing operations employed by the command personnel. Pertinent selection and retrieval of data from the large data base are of prime importance. The actual selection criteria will depend upon the problem being solved. These selected data must then be presented to the requesting command personnel in an easily grasped manner. The operations performed on these recalled data consist largely in re-arranging and in matching (such as objectives with resources). The end results are an operational plan and the issuance of frag orders.

Another feature of command and control system data files deals with their continual updating. Specific entries, particularly in the status files, are being replaced by more recent information, while the general structure of the files remains unchanged. This operation is generally off-line from the command function.

Thus command and control system operations can be characterized by data selection and retrieval, display, re-ordering, entry, and storage.

Computations, in the mathematical sense, play a minor role.

Although these features may appear to be quite different from those present in scientific problem solution, there are actually similarities between the two. The scientific problem has a numeric data base in the functional parameters (frequently the real number system). This base is much less complicated from a data processing viewpoint than alphanumeric data. The presentation of the data obtained in scientific problem solution is usually tabular (all numeric), or graphical (used predominately in scientific on-line results). Finally, there are the scientific operational processes. These are the well-known ones of arithmetic and advanced mathematics.

Thus the problem in applying the on-line console/computer techniques to command and control is how best to adopt the man-machine interface through the console to the specific features of command and control operations. This note reports on preliminary investigations along this line.

5. BASIC PROGRAMMING ASPECTS FOR ON-LINE COMMAND AND CONTROL

The adaptation of the scientific on-line technique to the command and control field must be based upon developing an appropriate relationship between the command personnel at the console and the data processing system. This relationship must encompass the peculiarities of the command and control field.

Figure 1 illustrates this man-machine relationship. The console operator should use a command and control language both in viewing the console displays and in making entries with the control keys. The computer, on the other hand, operates in its own computer language. For a successful on-line system, interpretive programs are needed to link the two languages. Thus, when the operator depresses a control key, inscribed in command and control language, a signal is sent to the computer. The computer must then interpret this signal in its own language. Similarly with computer-to-man communications, the computer must generate signals which represent raster points on the display. These points must, in turn, be interpreted by the operator in his own command and control language.

5.1 ON-LINE OBJECTIVES

This subsection considers how two of the basic features of the online technique could be instrumented in fulfillment of the above discussed basic concepts of man-machine relationships. In doing so, they are required to lie within a framework of practical objectives and constraints which will, in the future, undoubtedly be augmented and modified continually as the various postulates are tested. These features are:

a. Capability of the user to communicate with the computer in a "problem oriented" (command and control oriented) language.

(1) Semantic Problems - Since we have not postulated the specific vocabulary to be used in the problem-oriented language, it is impossible to enumerate those words which will give rise to various interpretations by different users. However, it is interesting to note that the on-line system is designed so that the operator can define any item with which he is working in his own terminology. Semantic difficulties

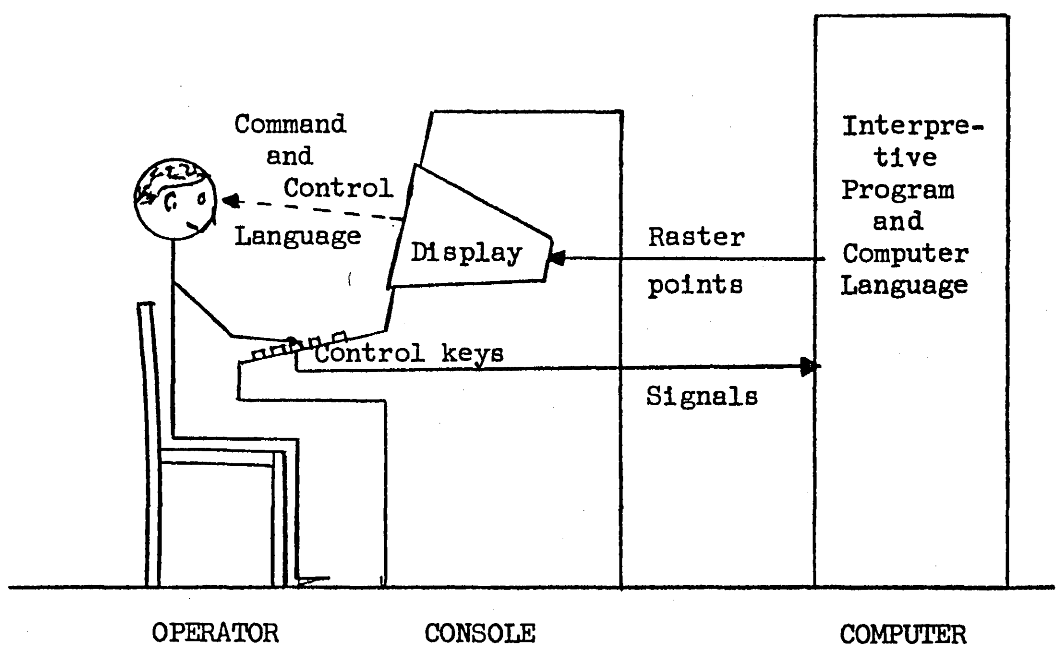

Figure 1. Man-Machine Relationship for On-Line Command and Control

should thus be minimized. This is true when an overlay on the console is used by the person who generates it. Quite possibly there may be explanations required if one person uses an overlay generated by another person. However, because of the similarity in background and experience, it is felt that the terms used by one person should be readily recognized and interpreted by a second.

(2) Syntactic Problems - Undoubtedly syntactic problems will arise as the study progresses. For instance, it is well recognized that various combinations of mathematical expressions are subject to strict rules of syntax. Extrapolation to a command and control language would indicate that a high probability exists that the ordering of commands as stated by the user may be different from the execution sequence. This re-ordering will have to be accomplished by means of syntactic rules, which must be carefully worked out in developing the software for an on-line command and control system.

(3) Instruction Phraseology - In addition, a very desirable characteristic would be the inclusion of the capability for the system to carry out a given task quite independent of the exact phasing of the inputted statement. Thus, two operators would not need to employ exactly the same phraseology and syntax in their instructions to the data processing system.

b. Capability for on-line modification of subroutines and creation of new subroutines.

(1) On-Line Console Programming - The nature of command and control problems dictates the requirement for on-line generation of routines. As with other unstructured problems, it is not possible to anticipate and enumerate the various contingencies that may arise; therefore, the system must have the capability of allowing the user at a console to alter the program in accordance with the circumstances of the moment. This will achieve great savings in time and efficiency.

(2) Program Implementation Techniques - Two techniques are available to implement on-line generation of programs. The first permits insertion of machine language commands into the system, while the second involves use of the "Program" key. With this key, a series of routines can be combined into a new single program, directly at the console, from previously generated subroutines. It is implicit that in an operating system the desirable capability should be vested in the Program Key rather than in the construction of routines in machine language.

As an aid to determining the feasibility of implementing the concepts of an on-line system in the command and control field, certain of the constraints that might be imposed by an operational system should be altered or relaxed. In particular, those characteristics imposed upon system operation by the selected data processing system (specifically those of the DAC console) will be used without modification. (Appendix A gives a brief description of the RW-400 computer/console facility used in this note.) Also, any constraints that an operational system might impose with respect to the time required for either data search or internal program execution will not be considered.

5.2 PROGRAMMING IMPLICATIONS OF ON-LINE CONCEPTS

Since we postulate that a command and control language should be the basic input to the operational programs (the operator at the console in Figure 1), it is evident that an interpretive program must recognize and respond to the various inputs. For the present study, it is assumed that inputs to the interpretive program are generated by means of signals sent from a display console. (Other inputs may be added later.)

Thus, if generic groups of keys can be assigned to generic functional groups of input instructions, a simplification to the interpretive program should be achieved. To date a specific vocabulary has not yet been postulated; thus, a modified and generalized concept will be employed by associating two major generic groups of keys on the console with Operands and Operators. This generalization should pertain to any language, and it is hoped that it will serve as an adequate vehicle for the transition between the machine language and a command and control language.

Following this premise of generic grouping, the work reported in this note is based on the assumption that the console display control keys, DCK's, will serve to define operands. These become the entities utilized in attempting to solve a specific problem. It is expected that in the command and control area, as in any class of problems, they will be limited in number. The on-line system must include an inherent capability to permit the operator to define operands as he desires.

Operations, on the other hand, will be assigned to the process step keys, PSK's, to effect transformations on operands. Study indicates there will effectively be two classes of operations; one hardware function oriented and the other class problem oriented. An example of the first class is the command "DISPLAY", and of the second or problem-oriented class "COMPUTE DISTANCE".

One logical conclusion reached from postulating the concepts of operations and operands is that a vehicle must be provided to effectively carry out operations on operands. Drawing upon the analogy of computer design, it appears that a "Pseudo Accumulator" would be expedient.

In analyzing these concepts for implementation, it becomes apparent that certain properties should be fixed. Among the most significant are the display capabilities of the DAC console. Specifically, only a maximum number of characters can be displayed on the alphanumeric 10-inch tube and a maximum number of symbols on each of the 17-inch tubes.

From the problem-solving aspects of the system, it seems apparent that:

a. Decisions and intermediate actions will generally be based on information that is displayed on these tubes, and

b. The console will serve as the principal input medium.

It is, therefore, tentatively concluded that operands should have a connotation with respect to the cathode-ray tubes as well as the display control keys. This also seems to be consistent in that it would be desirable in many cases to label an item that appears on the screen.

Two significant conclusions result from this concept of associating an operand with a display:

a. There is an implication that an operand will not be of a pre-assigned size. This in effect says that both operands and the pseudo accumulator should be considered to be of "Variable Length".

b. From a consideration of the types of information that would be called operands in a command and control system, it is obvious that any operand could be made up of parts. For example, a status report could very well be considered from a functional standpoint as an operand. However, it is just as obvious that there must be a capability of manipulating component parts as well as the whole operand. Each component part could be given the name "Sub-Operand"; however, it is felt that a better term is "Element".

We thus postulate that within the on-line system it is necessary to provide for the manipulation of elements as well as operands. Thus, operations will be defined, insofar as possible, to act similarly on either operands or elements.

5.3 PRELIMINARY PROGRAMMING SYSTEMS SPECIFICATIONS

5.3.1 Control Program

A control program must be in core at all times to recognize and interpret messages received from the DAC keyboard. Recognition is implemented via an alert or interrupt system. At the start these signals are locked out unless that computer is ready to respond. Interpretation of an interrupt signal, of course, depends upon the format of the message sent from the console keyboard.*

5.3.2 Interpretive Program

Signals sent by the console keyboard represent instructions from the human operator to the computer. Since the format of the signals generated by each key is unique, it is apparent that each must be interpreted within a specified framework which, in general, is an "overlay". By a process of labeling and programming, it is possible for the operator to assign functions at his discretion to specific keys within a generic group.

From these postulates two characteristics of the interpretive program can be specified:

a. The capability of identifying and retrieving all programs associated with a given overlay.

b. The capability for responding to the implicit request of a labeled key by means of the unique signal generated.

* For the message format used on the DAC, it is necessary to isolate the signature portion from both the message portion and the end of message portion. In general, the signature portion is used to identify a specific table which associates the depressed key with its specified task. The message portion is used to obtain a value from the table selected by the signature. The value in the table is then used to transfer program control to the proper place in the interpretive program.

It should be noted in this regard that Process Step Key No. 1 on the DAC initiates a unique interpretive program used to identify and retrieve the program for the overlay in position (Section 6.3.1).

In addition, the concept of generic groups of keys can be exploited for partially systematizing and characterizing the capability of the system to respond to signals through the interpretive program. The next two subsections give a more detailed explanation of the character of the interpretive program with respect to the display control keys and the process step keys.

5.3.3 Display Control Keys

This group of keys, devoted to designating operands and/or elements of operands, are the entities to be manipulated in the computer. The general conditions and restraints of their manipulation are specified below.

As with symbolic programming, an item is catalogued by its name by the user, and by its assigned location by the computer. In addition to its location within the computer, each item must have associated with it a number of other parameters. The first is a measure of size; i.e., the number of words or number of characters. This results from the variable length characteristic for both operands and the pseudo accumulator. For elements, an additional parameter is required, namely its relative location with respect to the operand of which it is a component. Conceptually, it may be required to add another associated parameter, the identification of the module of the data processing system which contains the specified item (tape, drum, etc.). This, of course, is a function of the computer system utilized.

In summary, for each item stored in the computer, a need exists for explicitly identifying up to four parameters. These will be utilized by the interpretive program. They are:

a. Module in which the item is stored.

b. Absolute location of item.

c. Relative location of item.

d. Size indication.

Several techniques can be proposed for making these parameters available to the program. For example, these could be included as a portion of the item itself or in a table of parameters for each DCK (Display Control Key Table). The latter is employed in this note.

5.3.4 Process Step Keys

These keys are used to identify the operations (manipulations) to be performed. In an operational overlay, it is probable that they will be rather complex sequences of simpler, pre-defined operations. The essential problem is thus to analyze the requirements imposed by the interpretive program at the machine level.

The employment of generic key groups has essentially specified that a command or instruction to the computer requires at least two key depressions; one to identify the operation and the other to specify the desired operand. In other words, the interpretive program needs a complete sentence consisting of a subject and a predicate to establish a meaningful statement. One without the other is meaningless.

Overall, the interpretive program will utilize the pseudo accumulator in a manner analogous to the utilization of an accumulator by a conventional computer. Thus most, if not all, of the interpretive instructions will use the pseudo accumulator as either a source or target location. This provides an insight with respect to the required groupings of machine instructions which make up the interpretive instructions.

In the first instance, it is apparent that the machine language instructions must be supplied with source and target locations. In those cases in which an operand is involved, this information is available from the associated Display Control Key Table. Also, because many operands may encompass multiple words, a loop must be formed to effect the desired results. This requires a counter to keep track of the number of times through the loop. The DCK Table should contain this information when pertinent.

Overall, some of the requirements for the proper execution by the interpretive program of process step key signals can be summarized by:

a. Machine language instructions

b. Address modification instructions

c. Loop counting instructions

d. Pre-setting instructions

e. Storage in relocatable form

f. Certain precautions with respect to instructions pertaining to the pseudo accumulator. Specifically, when instructions call for adding elements, it is necessary to ensure that the elements are added into the pseudo accumulator in their proper relative position.

5.3.5 File Organization

It is anticipated that it will be possible to construct and maintain overlay programs in some storage medium, such as magnetic tape. For this purpose it is expedient to have a rather explicit file structure for the component parts of the overlay programs. To this end, some of the component parts have already been indicated in the above section. Overall it appears that the file structure should consist of four records or parts:

a. An identification corresponding to the signature. This record should serve as a key for retrieving the remainder of the file.

b. A record consisting of a series of tables, one for each generic group of keyboard keys.

For these two records it seems possible to establish fixed length formats. For the DCK's, the required parameters will form one table (the DCK Table). For the PSK's, the location of instructions in auxiliary storage must be identified (Section 5.3.4). Similar tables will be required for every other generic group that is defined. At present it is not clear whether these tables should be kept in core storage for fast access at all times or whether they should be placed in auxiliary storage and brought into core on demand. If the latter is required, there must be an auxiliary table for retrieval of these records.

The last two records are:

c. A record of all operands ordered in accordance to DCK Table number.

d. Those groupings of machine instructions required to execute the command as expressed by any process step key.

Definitions for other records will depend upon the assignments allocated to other generic groups of keys. It is apparent that the last two records will, of necessity, be of variable length. This will require either a table or imbedded parameters to permit retrieval of specific groupings.

5.4 OPERATING PROCEDURES

This preliminary study indicates that the solution to a command and control problem by means of an on-line computing system requires following a fairly standard procedure. Eight steps have been formulated:

a. The problem must be analyzed to isolate its various component parts.

b. Each part must then be expressed in the "On-Line Command and Control Language". These expressions or parts naturally contain manual translations. This emphasizes the desirability of devising a language which is close to that used in the problem area. It should also be noted that the ordering of terms within these expressions must follow the syntactical rules or constraints established for the language.

c. As pointed out before, it is necessary to have complete statements for proper execution by the interpretive program. It thus appears that a subsidiary step must be taken in order to isolate:

   (1) Operands to be defined

   (2) Operations to be "programmed"

   This requires analysis of each statement to segregate the two parts stated.

d. By use of (1) a standard overlay containing operands pertaining to hardware characteristics, and (2) a set of standard operations which had been queued upon generation of the overlay, the operator must "define" all operands and label the corresponding display control keys.

e. A second queueing procedure must allow the operator to compile previously generated operations. This will essentially entail a retrieval of information from overlay file(s) which contain the required operation.

f. If a new operation occurs which is not in the "library", it may be necessary to program this in machine language and thus incorporate it into the basic program.

g. Upon assignment of all operations, operands, and any other grammatical terms that may occur, the operator should now be prepared to "Program" his operational overlay.

h. The final step, if taken, should be the generation of queueing lights under the PSK's and of queueing status lights for the DCK's. This step would be taken, primarily, to insure that the sequence of button pushes were ordered within the constraints of the syntactical rules. In those instances in which it is impractical to generate the required lights, the problem statements in the "command and control language" should suffice.

6. APPLICATION OF ON-LINE TECHNIQUES TO CONTINGENCY FORCE REROUTING

This section of the note illustrates how the just enumerated concepts of the on-line console/computer technique can be applied to a specific operational problem. Although the chosen operational problem may not be one that would involve the command personnel of the 473L Command and Control System, it is believed to be one that would involve personnel at a force command post level. Thus, it is felt that the chosen problem provides an adequate vehicle for showing how the commander and his immediate staff should be able to use the on-line technique for solving a new and unforeseen problem.

The discussion of this section first states the operational problem (Section 6.1), and then gives the steps that the top command personnel might perform at a console for solving the problem (Section 6.2). One of these steps is then broken down into its component parts through the interpretive program (Section 6.3). It should be emphasized that the analysis of the problem presented in this discussion is quite preliminary. However, sufficient analysis has been given to indicate that the on-line concepts enumerated in Sections 3 and 5 do appear to have application to a specific problem.

In order to be specific, the analysis has been applied to the RW-400 system. However, other display consoles and computers can be equally well applied to the on-line techniques by modifying the specific operations to fit the constraints of the specific equipment.

6.1 OPERATIONAL PROBLEM: CONTINGENCY FORCE REROUTING

It is assumed that an operational exercise, Project Unicorn, is scheduled for Western Europe during the latter part of April. This exercise includes the deployment of several squadrons of fighter-bombers and other aircraft from the ZI to West Germany.

Unexpectedly, on 25 April, the day a large part of the force is under deployment, a political situation arises in Germany. The situation is such that it would be to the detriment of the United States for a large military force suddenly to appear in Germany. Thus, the Project

Unicorn exercise is cancelled. However, there are various flights already enroute to Germany.

The problem facing the commander is how best to divert the forces enroute in order to minimize the political implications and to save the men and equipment. New destinations must be found for the airborne aircraft. These destinations must also fit within both the operational constraints and political constraints erected by the unforeseen situation in Germany. This is a problem, whose specific parameters and maybe even its general parameters, were not foreseen during the planning period for Project Unicorn. Solution time is very limited. This is a situation where the on-line technique should find its greatest usefulness.

6.2 ON-LINE SOLUTION BY COMMAND PERSONNEL

The on-line solution to the above operational problem requires a joint effort both by the senior operational personnel and by junior personnel who have some data processing training but are not programmers. It is envisioned that the operational personnel will first describe the problem, the suggested method of attack, and certain factors that must be considered by the junior personnel. The latter will then rapidly develop on-line the operational command and control overlay (program) for this particular operational problem from the basic overlays. The resultant Operational Overlay will then be used by the senior personnel in making the required command decisions by an on-line solution to the operational problem.

This section discusses the steps that the command personnel might follow using the Operational Overlay on the DAC console.

6.2.1 Set-Up

The initial step is to inform the computer that the Project Unicorn force diversion problem is to be solved. For this purpose, the Project Unicorn Operational Overlay (as generated on-line by the junior personnel) is placed over the process step keys (PSK) of the DAC. (Figure 2 is a layout of the DAC keyboard for this problem solution.) The console operator then pushes the first process step key START to inform the computer which overlay is in position.

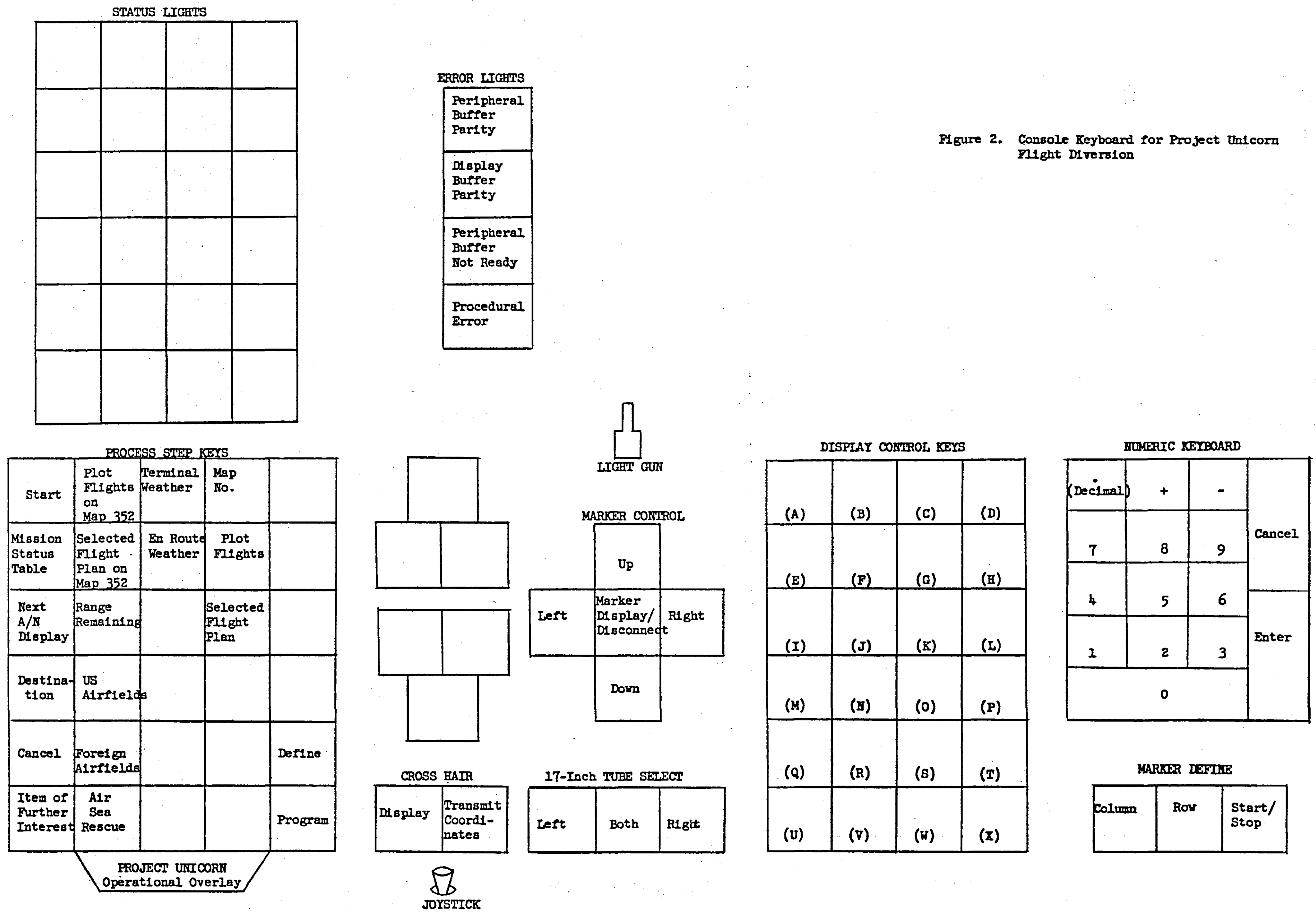

Figure 2. Console Keyboard for Project Unicorn Flight Diversion

6.2.2 Mission Status

The first operational step in the solution is to determine which flights need be diverted. For this purpose, the mission status is to be displayed on the alphanumeric tube. Due to the limited character capability of the tube (640 characters in 20 lines of 32 characters each), a clear plastic cover sheet is placed over the tube face (Figure 3). The column and row headings are inscribed on the cover sheet.

The console operator then pushes PSK MISSION STATUS TABLE. The display of Figure 4 then appears on the alphanumeric tube with the spacings shown. The second line of characters gives, on the left, the time (Greenwich mean time or Z-time) of this mission status report and on the right, the number of the group of mission status displays required to present all Project Unicorn flights. Since three displays are required and four flights are given per display, the console operator knows that there are between 9 and 12 flights involved. A given flight may be one or more aircraft.

Let us examine each of the flights in Figure 4 as to its requirement for diversion. Flight 15 is not scheduled until tomorrow (it is assumed today is 25 April). Thus the flight can be cancelled. To do this, the marker, a square shaped symbol on the DAC, is positioned on the alphanumeric tube under the item of interest. To do this, the operator pushes the key labeled MARKER DISPLAY/DISCONNECT to cause the marker to appear at the upper left of the tube. By successive pushes of the RIGHT button, the marker is advanced until it is under the "+" of Column 1 of the display. The operator now pushes the PSK CANCEL followed by the Marker Define Key COLUMN. This informs the computer of the cancelling of the flight and also notifies the appropriate operational personnel to issue the frag order.

Next is Flight 16. It is bound for Ramstein, Germany, with the designated alternate of Bitburg, Germany. This flight must be diverted. The first step in doing this is to indicate to the computer that Flight 16, Column 2, is of further interest. The marker is again used. Use of the RIGHT key will advance the marker until it is under the "+" of

MISSION STATUS

Column No.	1	2	3	4
Title				
As of Display No.				
Flight No.				
Mission				
Unit				
Aircraft				
No. Aircraft				
LTIOV				
Departure				
Date				
Time				
Destination				
Date				
Time				
Alternate				
Remarks				

Figure 3. Mission Status Alphanumeric Tube Overlay

MISSION STATUS

Column No.	1	2	3	4
Title		PROJECT	UNICORN	
As of / Display No.	133ØZ			1 OF 3
Flight No.	15	16	18	21
Mission	FERRY	FERRY	FERRY	FERRY
Unit	3Ø7TFS	9TRS	776TCS	612TFS
Aircraft	F1ØØ	RF1Ø1	C13Ø	F1Ø5
No. Aircraft	12	3	16	5
LTIOV	1322	1255	1245	1315
Departure	MYRTLE	SHAW	SEWART	POPE
Date	Ø426	Ø425	Ø21Ø	Ø425
Time	EØ8ØØ	AØ6Ø5	AØ8Ø2	A111Ø
Destination	RAMSTEIN	RAMSTEIN	DREUX	BITBURG
Date	Ø426	Ø425	Ø425	Ø425
Time	E173Ø	E15ØØ	E1815	E193Ø
Alternate	RUISLIP	BITBURG	LAON	RUISLIP
Remarks	3 FUEL	3 FUEL	1 STOP	2 FUEL

Figure 4. Mission Status Display for Project Unicorn

Notes on Figure 4, Mission Status Display

As of	-	Time of the information presented
Display No.	-	Number of this display out of total number required to present all of the mission status data
LTIOV	-	Time of last report
Date	-	Month and day
Time	-	Hours and minutes in GMT or Z-time
TFS	-	Tactical fighter squadron
TRS	-	Tactical reconnaissance squadron
TCS	-	Troop carrier squadron
E	-	Estimated time
A	-	Actual time
FUEL	-	Refueling
Ø	-	Zero character on display analysis console

Column 2 of the display. The PSK ITEM OF FURTHER INTEREST is pushed, followed by Marker Define Key COLUMN. This informs the computer that the material in Column 2 is of further interest.* In this specific example, it really means that Flight 16 is of further interest.

Flight 18 (Column 3) is bound for France and thus may proceed. Finally, Flight 21 is bound for Germany, but the flight plan alternate is South Ruislip, Great Britain. This flight should be immediately diverted to its designated alternate. To do this, the marker is moved to under the "R" of "Ruislip" in Column 4. The PSK DESTINATION is pushed, followed by pushing the Marker Define Key START, the marker is then positioned under "P" of "Ruislip", and the Marker Define Key STOP is depressed. This informs the computer and the appropriate personnel to issue a frag order to the pilot.

The console operator is now ready to investigate the second group of four flights on Mission Status. For this purpose, he pushes the PSK labeled NEXT A/N DISPLAY. Data on these flights, similar to that shown in Figure 4 for the first four flights, is now presented. Examination of the material indicates that three of these flights are of interest. The marker is used to define these flights as items of further interest in a manner similar to the operation just described for Flight 16. A second push of NEXT A/N DISPLAY key produces the third and last part of the mission status report. It is determined that no flights are of further interest on this display. The MARKER DISPLAY/DISCONNECT key is used to remove the marker from the screen. Thus there are four items (flights) of further interest in this operational problem.

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* An alternate procedure is first to move the marker under the "1" of the flight number "16". The PSK ITEM OF FURTHER INTEREST is pushed, followed by the Marker Define Key START/STOP. The marker is then moved with the RIGHT and DOWN keys until it is under the "L" of "3 FUEL" in the remarks row of Column 2. The START/STOP key is again pushed. These two pushes of the START/STOP key inform the computer that all material between the two key pushes is of further interest. In this case, this is the material in Column 2.

6.2.3 Flight Location

The console operator next wishes to determine the approximate location of the flights of interest (the four flights defined above). This is done using a map display on the right hand 17-inch tube of the DAC. The operator first places a clear plastic map of the North Atlantic over the tube face (Figure 5). This is assumed to have a file number 352. The use of such an overlay does not require the console-computer combination to generate the complex fixed cartographic background. The operator also pushes RIGHT of the 17-inch tube selection.

The display desired is generated by the programmed process step key PLOT FLIGHTS ON MAP 352. This key is programmed to plot three data points for each of the selected flights, defined by the marker in the previous step, and to the proper scale of Map 352.*

The points are:

- Present position (x)
- Destination (+)
- Alternate destination (o)

The data on Figure 6 covers each of the four flights designated as ITEMS OF FURTHER INTEREST in the previous operational step. Note, however, that on the figure, only three destination points (three +'s) and three alternate destinations (three o's) are shown at only four places. This means that two of the flights have the same destination, two the same alternate, and that the alternates for two flights are the destinations for two others (these pairs may or may not be the same).

(It should be noted at this point that the on-line program back of PSK PLOT FLIGHTS ON MAP 352 is quite complex. The data required for this display are the latitude and longitude of three locations for each flight, correctly normalized to the correct scale and map projection (as Mecator

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* If an overlay map other than No. 352 is used, the console operator must first push PSK MAP NO., followed by the map number from the numeric keyboard. He then pushes PLOT FLIGHTS. The same data as is shown in Figure 7 will be plotted to the designated map scale.

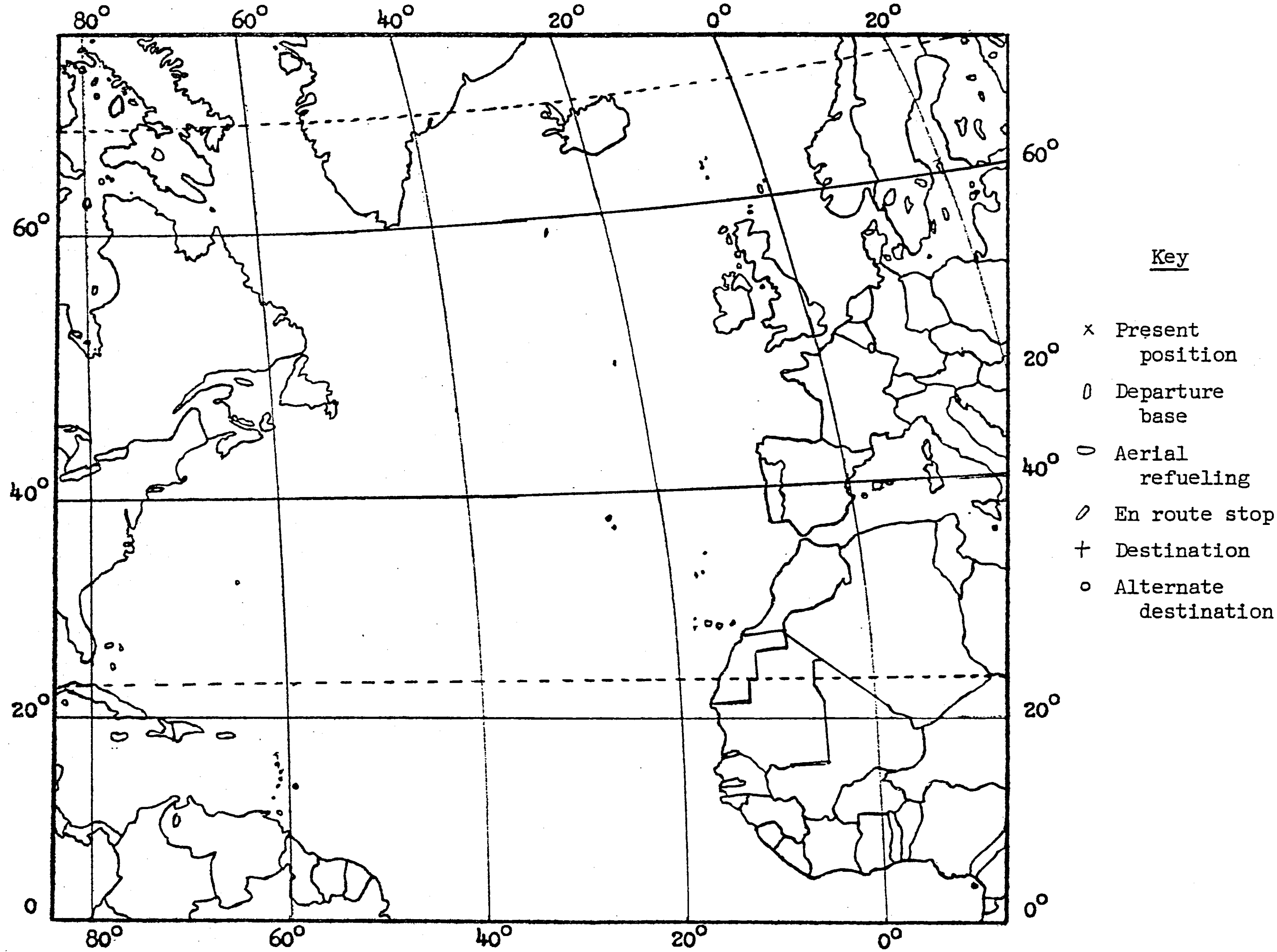

Figure 5. Overlay Map No. 352

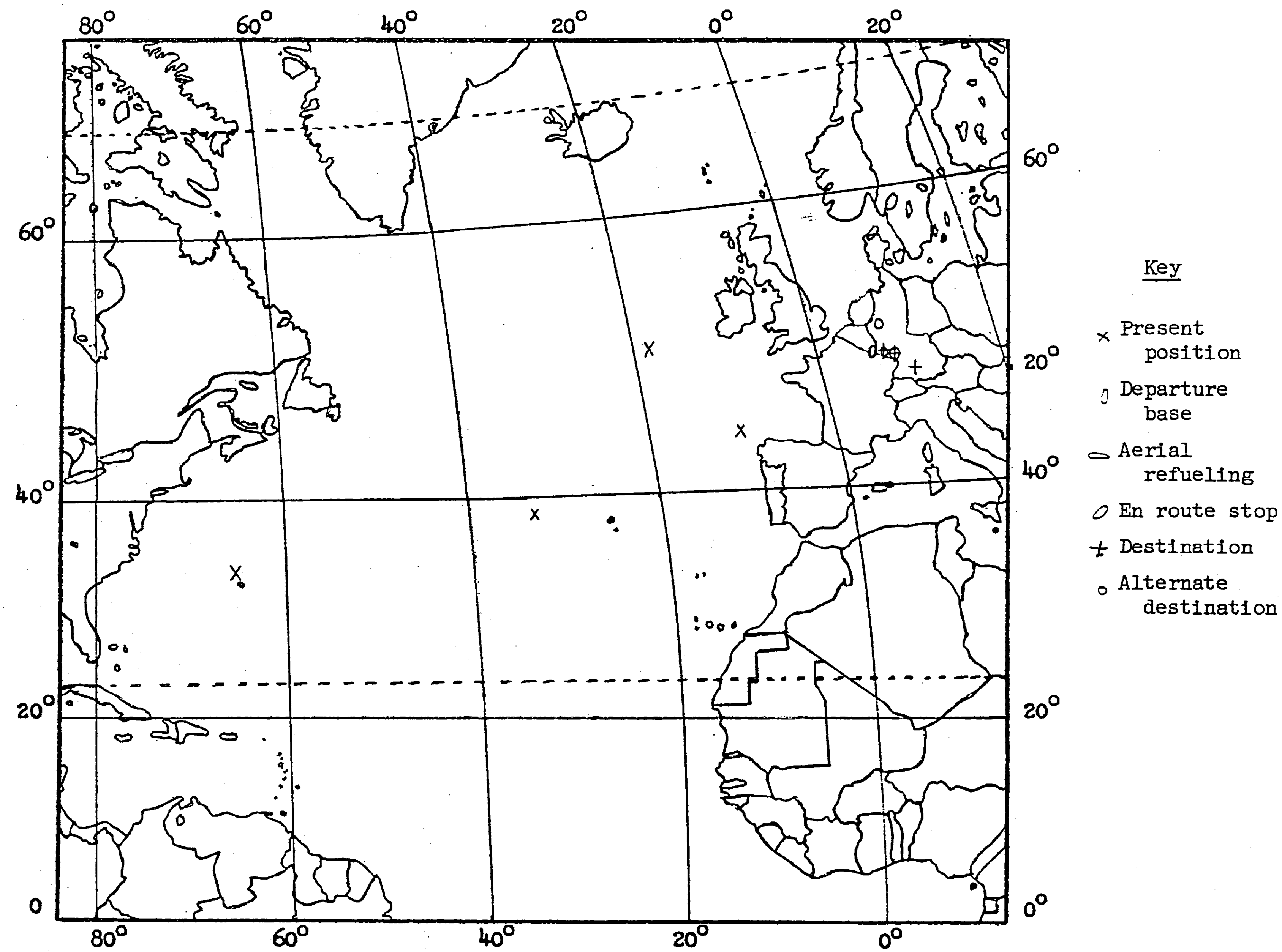

Figure 6. Present Locations and Destinations of Flights

projection) of Map 352. Now these latitude and longitude points were not given on the mission status alphanumeric display. Two of the points (destination and alternate) were given by place name, and the third (present location) was not given in any manner. The computer program must recognize that defining a column means interest is in certain data items of the complete flight plan for the flight in that column. Thus, the data desired for a 17-inch display need not be a part of the data on the alphanumeric display.)

6.2.4 Individual Flight Plan Modification

The command person at the console is now interested in rerouting each specific flight shown. To do this, he first points the light gun at the present position (x) of any flight.* The x then starts to blink.

The next PSK button push is SELECTED FLIGHT PLAN ON MAP 352.** This new push will produce both a cartographic display on the 17-inch tube and a new alphanumeric display. Since the operator may wish to retain Figure 6 on the display tube, he will first push the LEFT button of the 17-inch tube selection, and place a second Map 352 (Figure 5) over the left tube before pushing SELECTED FLIGHT PLAN ON MAP 352. The resultant 17-inch display is shown in Figure 7, and the alphanumeric display in Figure 8. It is assumed that Flight 16 (see Figure 4) has been selected. From Figure 8 it will be noted that a new flight report has been received (later LTIOV) which has included a new estimated arrival time at Ramstein of 1515 Z instead of 1500 Z. Also, since the data to be presented on the alphanumeric tube is more limited than for the mission status display, the headings are included in the display. From the map display (Figure 7) the operator can readily see that Flight 16 has

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* To cue the operator that this is the next step required, Status Light LIGHT GUN comes on following the pushing of PSK PLOT FLIGHTS ON MAP 352 (or PLOT FLIGHTS).

** If another map scale is used, the appropriate key pushes are PSK MAP NO., the appropriate numeric keys, and PSK SELECTED FLIGHT PLAN.

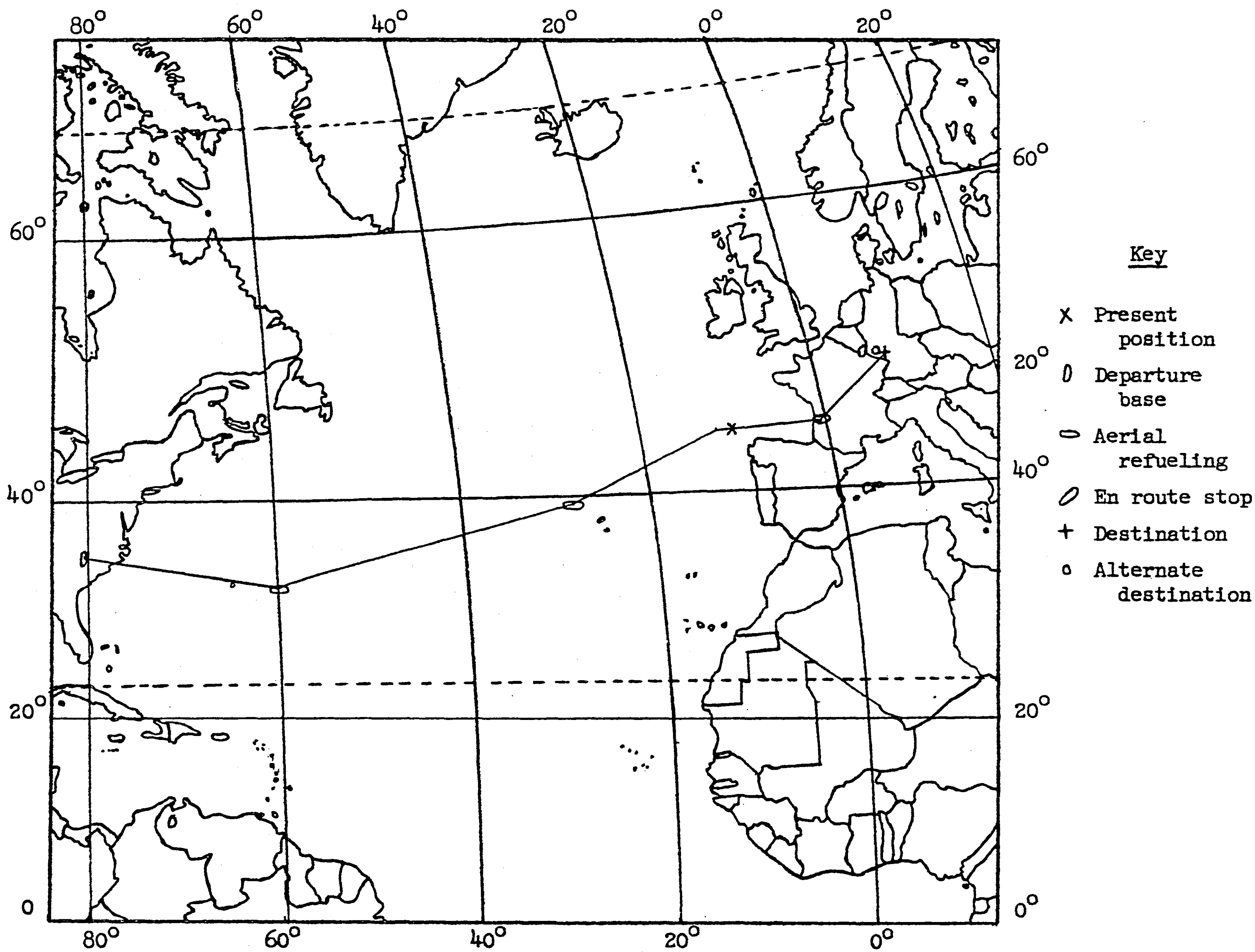

Figure 7. Flight Plan for Flight 16

```
                FLIGHT  16
          3  RF1Ø1  OF    9TRS
DEPART  SHAW       AØ625  FERRY
ARRIVE  RAMSTEIN  E1515
ALT     BITBURG

CONF 2  3ØØ  GAL  TANKS
FUEL  14ØØ  LBS
              LTIOV  13Ø2Z
   LAT  441ØN      LONG  1346W
   ALT  395ØØ      IAS   45Ø
                 ROUTE
 KINDLEY         AØ752
 3Ø31N  6Ø48W    AØ8Ø7  FUEL  427ARS
 39Ø3N  28Ø8W    A1116  FUEL  429ARS
 4358N  1434W    A1251
 4443N  ØØ53W    E1348  FUEL  42ØARS
 CHATEAUROUX     E1425
```

Figure 8. Alphanumeric Display of Flight Plan

completed two of three scheduled refuelings and is now approaching the coast of France.

If this flight is to be diverted to another base, the operator must determine whether sufficient range remains. For this purpose, he pushes PSK RANGE REMAINING and light guns a point on the flight (current position, say).* The 17-inch display is then modified by the addition of the range remaining about the present position (without any scheduled refuelings). Other points along the flight path may also be used as the center of the range remaining calculation. Figure 9 shows two range remaining curves, one about the present position, and one about the last scheduled refueling point for the flight.

The operator next wishes to determine what airfields under US jurisdiction are available and within range of the aircraft for this flight. For this purpose the PSK US AIRFIELDS is pushed. These now appear on the left 17-inch display as dots. The computer is programmed such that only those airfields having adequate runways for the type of aircraft in Flight 16 (RF-101's) are shown.

The operator notes that there are available airfields in southern Great Britain, France, and Spain. From a knowledge of the political situation that is causing this diversion of flights, the console operator knows that it will be politically unwise for combat type planes to land in France (C-130 transports of Flight 18, Figure 4, will not cause a political situation). This type of information cannot be readily preprogrammed into the command and control system data base. Primarily on

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* An approximate equation for this calculation is:

$$R = (V + W \cos \theta)\ (F/\dot{F})$$

where R = range remaining

V = airspeed of aircraft

W = wind

θ = bearing of wind from the flight path

F = fuel remaining less reserves at point that is light gunned

$\dot{F}$ = fuel consumption

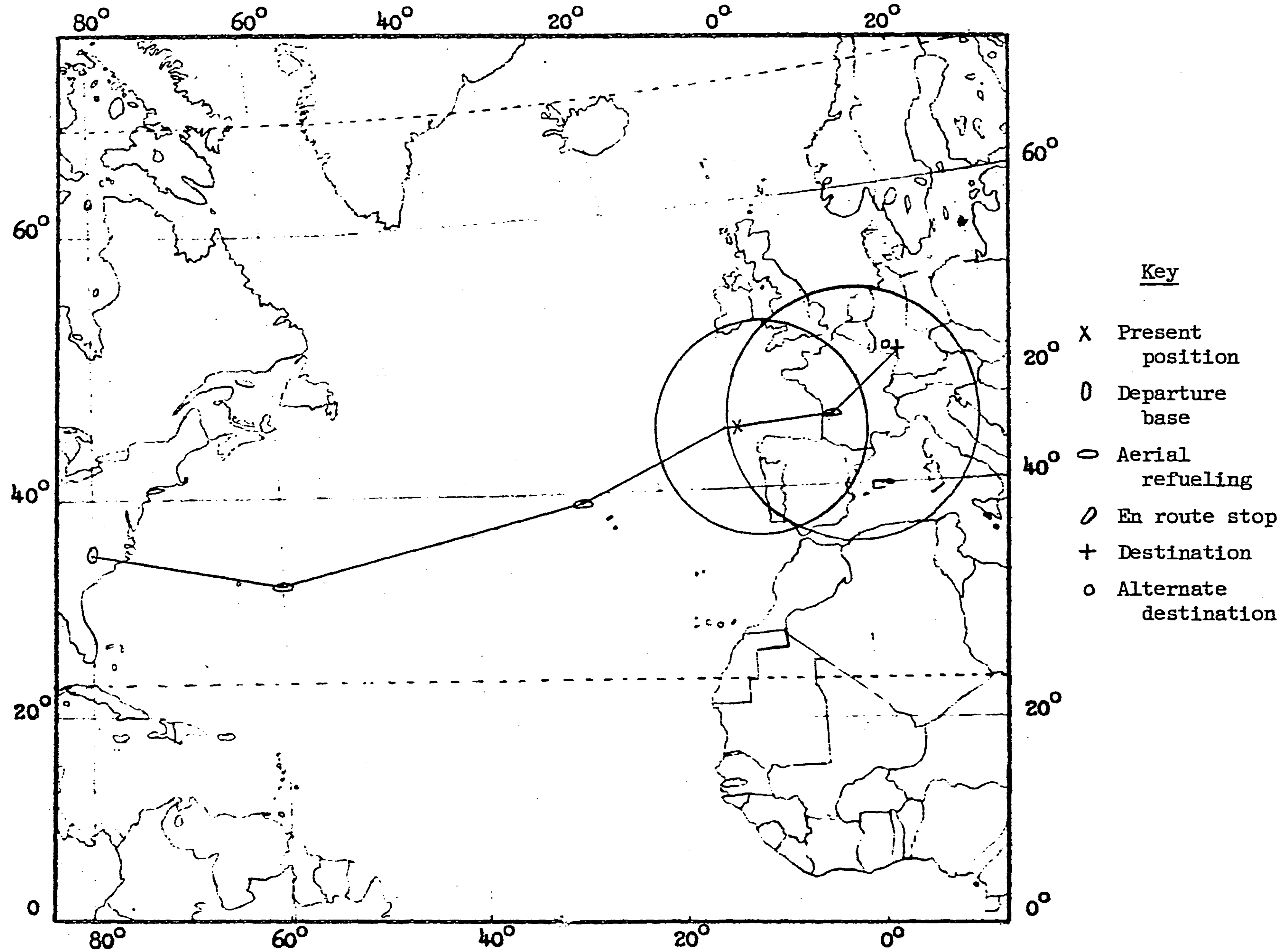

Figure 9. Range Remaining Curves for Flight 16

a political basis, the operator chooses a base in southern Great Britain. This is indicated to the computer and to other personnel by pushing the PSK DESTINATION and light gunning that base. The name of the destination now appears on the alphanumeric tube in place of the old one. (It should be noted that the PSK DESTINATION has two programs associated with it. One deals with the marker and the alphanumeric tube (Section 6.2.2); the other with the light gun and the 17-inch tube.)

The operator now returns to the right hand 17-inch tube (Figure 6), light guns another flight and repeats the above procedure. Other process step keys have been programmed to provide the operator with other choices in this problem of flight diversion. These include FOREIGN AIR-FIELDS, AIR-SEA RESCUE unit locations, ENROUTE WEATHER, and TERMINAL WEATHER.

6.3 UTILITY, SERVICE, AND BASIC PROGRAMMING FOR THE ON-LINE SYSTEM

The previous section showed how an Operational Overlay could be employed by a senior command person with the on-line technique for diverting the flights of Project Unicorn that were enroute to Germany. This section shows how the basic concepts and programming of the on-line system can be employed by the junior command personnel to generate this overlay. Specific attention is directed toward developing the on-line processing steps required to generate the Mission Status Display (Figure 4), the display generated by pushing the second process step key of the Project Unicorn Operational Overlay (Figure 2). It should be noted that the following is an illustrative rather than an exhaustive discussion of the utility, service, and basic programs required for the on-line generation of the operational program. However, it is felt that the analysis presented backs up the basic assumption that the on-line console/computer technique can be applied to command and control problems.

Before going into this discussion, the full significance of the first PSK START is explained.

6.3.1 PSK START

The START key is common to all process step key overlays on the DAC console. It is used to inform the computer of the overlay in position and, hence, must be the first key pushed after an overlay is put in position. The interpretive program uses the message generated by this key to:

a. Locate the program file associated with the specified overlay.
b. Read into core the required PSK and DCK Tables associated with the overlay.
c. Enter an idle loop awaiting subsequent key depressions.
d. Light for operator cue those PSK's which are program compatible for subsequent depression, a desirable but not necessary feature.

6.3.2 On-Line Programming for PSK MISSION STATUS TABLE

The second PSK on the Project Unicorn Operational Overlay (Figure 2) is labeled MISSION STATUS TABLE. The operand produced by pushing this key was programmed on-line by the junior command personnel, following a briefing on the operational problem. It was developed from:

(a) The basic command and control programs with their associated console overlays and tables, and
(b) The data base of the entire command and control system.

The initial problem is one of searching, selecting, and extracting all pertinent information relative to Project Unicorn. The second problem is to formulate the data extracted into the required format for display, and to program the PSK's of the Operational Overlay. A part of this task involves developing the desired associations between the successive steps in the Operational Overlay.

To see the problem in a slightly different perspective, it is necessary to extract from each flight record certain information needed for the display initiated by PSK MISSION STATUS TABLE. Additional information is required from the flight records (present location, destination, and alternate destination for PSK PLOT FLIGHTS). Finally, it is necessary to obtain those items required for PSK RANGE REMAINING. In addition, the operational overlay programs must contain data for properly interrelating these various displays about the same flights.

Thus, the following basic programming capabilities are required:

a. Search data base

b. Select items based on various criteria

c. Extract specified information

d. Compile extracted information into a working data base to be used with the Operational Overlay

For an operational environment it will be assumed that on-line programs have been developed to implement these rather standard data processing activities. These are enumerated on a PSK Utility Overlay. Such an overlay would thus be utilized for programming on-line the requested operational overlay process step keys. It is obvious that the user must supply parameter values required by each utility routine. The implementation of the PSK PROGRAM thus becomes a most important link in the communication between the operator and the computer.

6.3.3 Utility Overlay

This section will give a rather detailed elaboration of some of the standard data processing activities that make up an Utility Overlay (Figure 10). The function of each of the process step keys will be discussed relative to the generation of a command and control system Operational Overlay. The related display control keys will be discussed as they occur.

a. START - The function of this key was given above in Section 6.3.1.

b. SEARCH - With this key the computer is instructed to look for items described by subsequently pushed display control keys. The implementation requires an explicit statement of either or both

(1) Medium to be searched as drum, tape, etc.

(2) Operand identification.

Thus, if the implementation uses operand identification for a magnetic tape, file indication is needed; or for a drum, band or sector identification. In addition, the utility program

PROCESS STEP KEYS

Start	And			
Search	Or			
Select	(Execute)			
Extract	, (Comma)			
Compile	Display			Define
Format				Program

UTILITY OVERLAY

DISPLAY CONTROL KEYS

Data Base	Project Unicorn	Flight No.	
Working Data Base		Mission	
		Unit	
		Type A/C	

Figure 10. Utility Overlay

must deduce that if no complementary word follows, the operation applies to the entire storage medium.

In the proposed system, explicit definition of the storage medium is required in the Display Control Key Table (Section 5.3.3). This means pushing the DCK DATA BASE in the Utility Overlay (Figure 10).

c. SELECT - It is next necessary to specify the selection criteria. This will, in general, require pushing the PSK SELECT and one or more DSK's and/or PSK's depending upon the complexity of the retrieval request. Since it is recognized that the request can be a rather complex statement of logical and/or arithmetic descriptions, it is necessary to provide for these among the various process step key utility routines. In Figure 10 those PSK's labeled AND and OR are typical examples. The selected data is placed in the pseudo accumulator.

   For the specific operational problem, selection is required for those items in the data base under the label OPERATION UNICORN. It is thus necessary to DEFINE the operand Operation Unicorn and assign it to an unused DCK.

d. (Period) · - Because of the possible use of multiple PSK's to implement a given routine such as SEARCH and SELECT, it becomes apparent that the computer must be given a signal to execute; i.e., start the requested sequence. This is the function assigned the PSK "(Period) ·". The "." also aids in establishing a notation for the communication of problem statements.

e. (Comma) , - The comma is used to indicate to the computer that a type of parenthetical expression follows, in order to construct a meaningful statement.

Thus, with the utility overlay keys defined so far, the instruction might be given:

SEARCH DATA BASE, SELECT PROJECT UNICORN .

This will specifically identify the buttons to be pushed and indicate the proper place to commence execution. It is apparent that the command SEARCH DATA BASE is not by itself meaningful.

f. EXTRACT - Conceptually as soon as a selection is made and the data placed in the pseudo accumulator, all or certain parts of the selected record should be disposed of in a predetermined manner. This is actually a two step process: the tagging of those specific items wanted and the compiling of the new file. The PSK EXTRACT instructs the computer to extract or tag each of the items defined by subsequently pushed DCK's, each separated by the PSK ",". The operator will have defined the necessary DCK's for the items wanted on an Utility Overlay. Figure 10 includes several such as FLIGHT NO., MISSION, UNIT, and TYPE A/C. Because of the large number of distinct keys required to enumerate the items to be extracted, the PSK "." is used at the end to tell the computer when to start the extraction process.

A written statement of the actual console key pushes might be

EXTRACT FLIGHT NO., MISSION, TYPE A/C

As noted above, this instruction is not complete, in the sense that the ultimate disposition of the extracted items has not been made. This is the task of the next set of instructions.

g. COMPILE - The elements extracted from a selected record should be regrouped and filed. To do this, the operation of PSK COMPILE is used followed by the DCK denoting the location for the elements, in this case the working data base. The essence of this operation is a connotation that all items flagged in the pseudo accumulator as a result of the EXTRACT operation are to be placed in the working data base; however, the relative location of each element is determined only by the flagging sequence stated as a result of the display control key pushes after EXTRACT. The required statement for complementing the extract operation discussed above might thus be

COMPILE WORKING DATA BASE

h. DEFINE - In order to use the overlays in the manner described above, it is necessary for a console operator to "define" the operands labeled on the various display control keys.

Essentially, the information required to "define" an operand consists of those criteria needed to allow the interpretive program to access, manipulate, and store the items defined. More explicitly for each operand it is necessary to specify:

(1) Storage medium of the operand.

(2) Absolute address of the start of the operand.

(3) Relative address of the start of sub-operand or element.

(4) Number of words (or characters) in the operand, sub-operand, or element.

This information is assembled for each operation and element as a table to be associated with the corresponding display control key (the DCK Table in Section 5.3.3). This then becomes the function of the PSK DEFINE button, namely to assemble the tabular information required for use of the DCK's in the given overlay. This PSK will probably be present on all overlays.

It is interesting to note that the on-line system must have the capability of permitting the operator to use several techniques for "defining" operands.

(1) Selection of all or a portion of the information displayed on the alphanumeric tube.

(2) Selection by means of the light gun or cursor from the 17-inch tube.

(3) Direct entry of the tabular data from some external source such as a directory.

(4) Generation of the data on the basis of information extracted for an associated Display Control Key Table entry.

In general, this will be done prior to "programming" new process step key operations; however, it must be possible to permit the definition of operands that have not been anticipated.

i. PROGRAM - This PSK, common to all overlays, is used in the development of new programs for heretofore blank process step keys on a given overlay. The function provided by this key supplies one of the basic advantages of the on-line concept, namely the generation of new programs directly at the console.

To institute a new program, the PSK PROGRAM is pushed, followed by the key to which the new program is to be attached. Then the sequence of operations that will make up the new program is entered.

Up to this point we have indicated many of the principal on-line data processing routines required to construct a working data base from a given data base for eventual use in an Operational Overlay. It will be noted that the explicit steps required for formatting and placing the Mission Status Table (Figure 4) on the alphanumeric tube and for programming the required process step keys have not been stated. In order to do so, it is necessary to:

a. Define those items that make up the Mission Status Table.

b. Format the data to correspond to the actual display (Figure 4).

c. Display the data requested.

Carrying out these operations will require the use of the process step keys FORMAT and DISPLAY given in Figure 10.

In summary, the above analysis has been directed toward analyzing the utility routines necessary for implementing the Operational Overlay

PSK MISSION STATUS TABLE. A similar analysis should be carried out for each of the other PSK's on the Operational Overlay of Figure 2, in order to enumerate the desired Utility Overlay process step keys for achieving the required results. It is believed, upon completion of this analysis, that in many instances the same utility process step keys will be used in the generation of different operational overlay process step key operations.

6.3.4 Interpretive Instructions for Utility Overlay Generation

The last section indicated how the on-line technique could be utilized to (a) construct an Operational Overlay from a general purpose Utility Overlay, and (b) define problem oriented operands. The computer programs behind these end results would be synthesized by an operator at a console to meet the specific conditions of the operational problem.

The various programs in the Utility Overlay are essentially data processing routines. It is, therefore, desirable to describe the techniques by which these generic routines can be generated on line, and also the method by which they can be applied to specific problems. In general, each utility routine is programmed at the console using a sequence of interpretive commands which are executed by a basic executive program. It is seen that a parallel situation exists between the generation of an Operational Overlay from Utility Overlays, and that of an Utility Overlay from Basic Executive Overlays.

This section will illustrate the use of the basic executive program for the generation of some of the utility routines described in the previous section. By doing this, a part of the repertoire of interpretive instructions will be defined.

6.3.4.1 Search Data Base

As a first example, we shall look at the sequence

SEARCH DATA BASE

The operand DATA BASE will have in its associated DCK Table the information necessary to determine the specific basic instructions required for the generic operation search. Let us assume that the following tabular information is stored in the DCK Table for display control key No. 15, which has been assigned the operand "Data Base":

Signature	04
Octal Code	16
Storage Medium	Magnetic Tape
Absolute Address	0
Relative Address	0
No. of Words	E.O.F. (End of File)

Thus, from an interrogation of the DCK Table entry for key No. 15, it is possible to determine:

a. The operand, "Data Base", is stored on magnetic tape.

b. The number of words in the record is variable, since the basic instruction "End of File" determines the termination of the search.

To carry out the above steps, the interpretive program must select from a library tape a routine for reading one record from magnetic tape plus a second routine for testing End of File.

The selection of these routines and their proper ordering will be implemented or programmed by an operator at a console using a Basic Interpretive Instruction Overlay. For this example, the utility routine "Search", could be programmed from the following interpretive instructions:

a. READ TAPE

b. COMPARE EQUAL (TO) E.O.F.

with proper branching for E.O.F. Again this necessitates providing information in the Display Control Key Table. The manual sequence of button pushes for executing the first of these steps is:

PSK : READ

DCK : TAPE RECORD

This would access a machine language program to:

a. Connect the tape unit to the computer.

b. Start the tape drive.

c. Transfer one record to the pseudo accumulator.

Upon completion of the data transfer, queueing lights would be turned on under the next required sequence:

PSK : COMPARE EQUAL

DCK : E.O.F.

This again illustrates the use of the DCK Table because it is necessary to determine:

a. The portion of the pseudo accumulator to be used for comparison.

b. The location of the operand to be used for comparison with the selected portion of the pseudo accumulator.

The sequences illustrate the requirement for telling the computer to execute -- this, of course, will be implemented by the PSK "(Period).".

Thus far, we will have read a record from tape and compared a specified area of the pseudo accumulator with the bits that make up the E.O.F. character.

Since the "Compare Equal" operation gives rise to a branch, one of two exits will be effected. If the E.O.F. is not detected, a queueing light should indicate that an interrogation of the file label is in order. If the E.O.F. is detected, the end of file search has been accomplished and a different branching will be required.

6.3.4.2 Select Project Unicorn

At this point we come to the interpretive instructions required for the second half of the utility instruction, namely

SELECT PROJECT UNICORN

This first involves determining if the label is "Project Unicorn". It is assumed that the entire record is in the pseudo accumulator, and thus it is necessary to instruct the computer explicitly which portion of the pseudo accumulator is to be used for the test. This is slightly different from the requirement of indicating E.O.F. in that the latter, when it occurs, will occupy the entire pseudo accumulator, while only a portion is used for the label. It is, therefore, necessary to define the pertinent portion of the pseudo accumulator. In an automatic system, the capability of defining the relative location of a specified portion of the record requires a dictionary for fixed length records or identification of the number of characters, say for each generic group in a variable length file.

In the on-line sense we wish to establish a nomenclature or syntactic set of rules by which identification of elements of an operand can be located within the pseudo accumulator. Two techniques appear feasible at this time:

a. An operation, denoted by the Basic Instruction Overlay PSK FLAG, can be defined as the capability of isolating one particular group of characters within the pseudo accumulator. This group becomes the source data for the subsequent interpretive operation. In this case, FLAG will be followed by the operand denoted by a DCK LABEL. Pressing the key LABEL will extract from the DCK Table the necessary data for locating the required group of characters. In summary, the keys used are:

   PSK : FLAG

   DCK : LABEL

b. As an alternate procedure, a syntactic rule can be established to the effect that: "If an operand precedes an operation, then the source of the operation is determined by the contents of the DCK Table for the leading operand." Thus, the key pushes

   DCK : LABEL

   PSK : COMPARE EQUAL

   would imply that the "compare" operation would have as its source the portion of the pseudo accumulator determined by the relative position and number of characters in the DCK Table for LABEL.

The present investigation has not provided sufficient insight to determine the preferred alternate. Analysis of additional problems will permit an evaluation of the above techniques and provide a basis for recommending one or the other.

If we assume that the latter is preferable, the sequence of button pushes would be:

a. DCK : LABEL

b. PSK : COMPARE EQUAL

c. DCK : PROJECT UNICORN

which would effectively compare the specified portion of the pseudo accumulator with the identifier "Project Unicorn". We have thus specified a sequence to implement the specific request, SELECT PROJECT UNICORN.

6.3.4.3 "Search" vs "Select"

The above discussion can be used to illustrate the essential difference between the operations "Search" and "Select".

In the case of "Search", there is an on-line implication that a storage medium must be described and some connotation is required to denote when to end the search. In some cases it may be necessary to describe the search technique as to content or location address. In any case, it is possible to describe the search desired with very few descriptive terms. As such, this lends itself to the concept of implementation via a general purpose or Utility Overlay.

On the other hand, the operation "Select", in many instances cannot be described so succinctly and, in addition, may be constrained by various problem-oriented parameters. It thus seems necessary to provide the capability for such operations as "Select" by means of special overlays. These special overlays will be called "Service Overlays". They will be characterized by the fact that

a. the operands are problem-oriented,
b. a limited set of process step keys are utilized,
c. specialized applications are of frequent occurrence.

6.3.4.4 Service Overlay

As an example, the Service Overlay, "Select" (Figure 11), contains those interpretive instructions which can implement this function of choosing by various criteria. These would include comparison for equal to, greater than, smaller than, and for various logical and arithmetic delimiters.

The operator would thus form a "program" for a particular problem using this Service Overlay. This program would be transferred to specific process step keys by use of the PSK PROGRAM on either the Utility Overlay or directly on the Operational Overlay.

6.3.5 Summary of Software System Characteristics

The above discussed software system is predicated upon the existence of a magnetic tape file associated with each console overlay. This file contains the parameters, data, and programs required for the execution

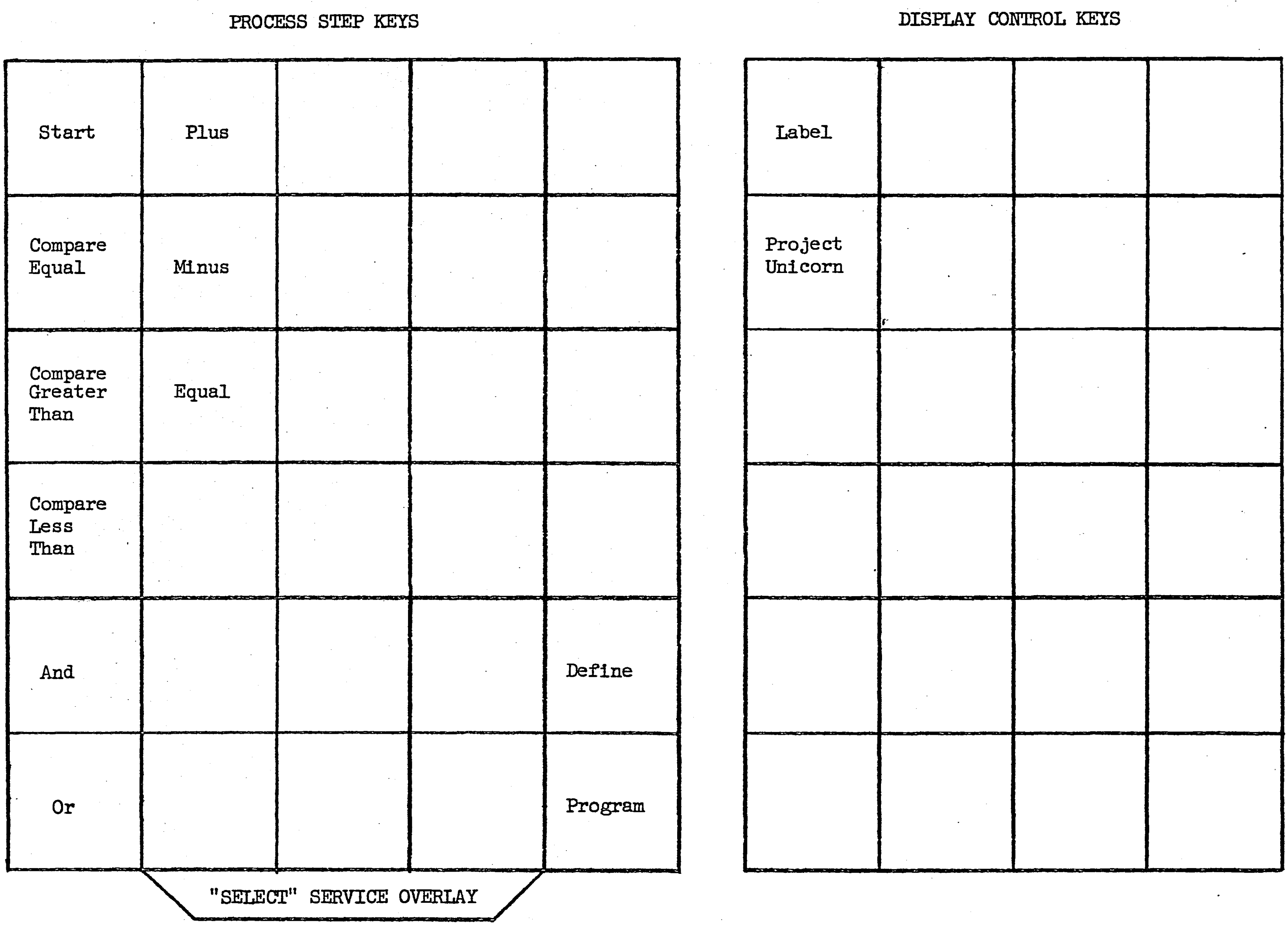

Figure 11. "Select" Service Overlay

of the commands as specified by the depression of console keys.

Thus, one of the most important aspects of implementing an on-line command and control system appears to be the incorporation of a capability for the generation of these files. This note has briefly described several preliminary items that should be included in the display control key and process step key tables. The various programs associated with the process step keys are undoubtedly susceptible to modification because of syntactic rules. It is thus envisioned that these routines will probably have to be stored on tape in a relocatable binary form.

Several levels of coding can be enumerated at the present time - as further investigation is made, it may be necessary to list other levels. They are:

a. Machine level coding of the interpretive control program and the various interpretive commands of the interpretive system repertoire. This is at the basic machine programming level.

b. Utility overlay routines which are mainly concerned with manipulation of data within a given configuration of hardware. These would include such programs as "Search Drum", "Search Tape", "Display on Alphanumeric Tube", "Display on 17-inch Tube", "Print", etc.

c. Service overlay routines which are primarily application dependent data processing programs such as "Select", "Sort", etc.

d. Operational overlay programs which are at the top of the hierarchy of overlay programs, being composed of programs generated at the previously mentioned levels.

Among the duties of the interpretive control program will be the following:

a. Interpretation of signals from the console.

b. Transfer of control to specified locations in accordance with stipulated syntactical rules.

c. Dissemination of error and warning messages when required.

d. Monitoring of the sequential operations having the pseudo accumulator as either the source or target location.

It is thus conceived that the available repertoire of basic interpretive instructions would be available on one or more overlays. These will generally be combined by a "systems operator" into special purpose, service, and utility overlays similar to those described herein. Operational overlays could then be compiled on-line using all of the overlay tools previously developed, including a capability of using machine language programs if and as required.

APPENDIX A

THE RW-400 DATA PROCESSING FACILITY

The specific data processing facility including the console, used in the discussion, is the AN/FSQ-27 or RW-400 system. This system has been successfully employed in the TRW on-line scientific problem solution system. It should be emphasized that, although the discussions deal with the RW-400 system, the on-line technique can be modified to meet the peculiarities of other computer systems.

A-1. RW-400 DATA PROCESSING SYSTEM

This system is made up of modules connected to each other through a central switching device -- the Central Exchange. For use in on-line command and control applications, the following modules are considered pertinent:

a. Computer Module, a general-purpose, parallel, binary, two-address fixed-point, two's complement arithmetic digital computer with 1,024 words of random access magnetic core memory.

b. Central Exchange, a central switching device with its own magnetic core memory which allows the programs to use symbolic address and provides for a master computer to force disconnect other modules in the system.

c. Drum Module, a magnetic drum used for intermediate storage with a 17 ms maximum access time, 8192 words of storage, and 61,000-word-per-second transfer rate.

d. Drum Module B, a large magnetic drum having a storage capacity of 79,872 words with 13 ms access time and a transfer rate of 50,000 words per second. It is anticipated that this drum will be the principal medium for auxiliary storage of programs and data at the working level.

e. Buffer Module, a unit designed to provide buffering between the high-speed computer, the computer module, and low-speed peripheral equipment, and also to provide search and other slow-speed operations while the computer is performing other operations. Each half buffer has a 1,024 word core memory and a data transfer rate with the computer of 75,000 words per second.

f. Display Buffer, a source of regenerative digital data for generating symbolic or alphanumeric displays on the DAC. Computer words can be transferred at the rate of 15,000 per second.

g. Tape Module, an Ampex FR 300 unit with 90-inches-per-second normal and 150-inches-per-second high speed capabilities. The tapes have a density of 139 words per inch and are provided in 2,500 foot reels. All overlay programs (Section 5.2) will be permanently stored on magnetic tape.

h. Display Analysis Console (DAC), the module which provides the interface required for expedient man-machine communication. Because of its importance to the on-line system, further details are provided in the following section.

A-2. DISPLAY ANALYSIS CONSOLE

The Display Analysis Console (Figure A) contains two 17-inch cathode-ray tube displays for line drawings, dots, and other special symbols and one 10-inch alphanumeric display tube. The last has a capacity for 640 characters in 20 rows of 32 characters each.

For data retrieval, presentation, and control, the console contains several keyboards and other controls. The Process Step Keys (PSK's) consist of a group of 30 pushbuttons, each one of which generates a unique code when depressed. Plastic overlays with holes in them for the keys to pass through can be placed over the keys. When any one of the 62 overlays is in position, it automatically sets a group of switches for notifying the computer of the overlay in place. These keys are used to designate operations in the on-line command and control system of this note (in the scientific system, they designate the functional operations as add, integrate, etc.).

Each of the 24 Display Control Keys (DCK's) generates a typical signature and a unique message when pressed. These keys are used in the on-line command and control system to designate the various application-oriented operands of a specified overlay. In general, the meanings of the individual keys vary in the same manner as the programmed assignments made to the process step keys vary for each overlay. For one PSK

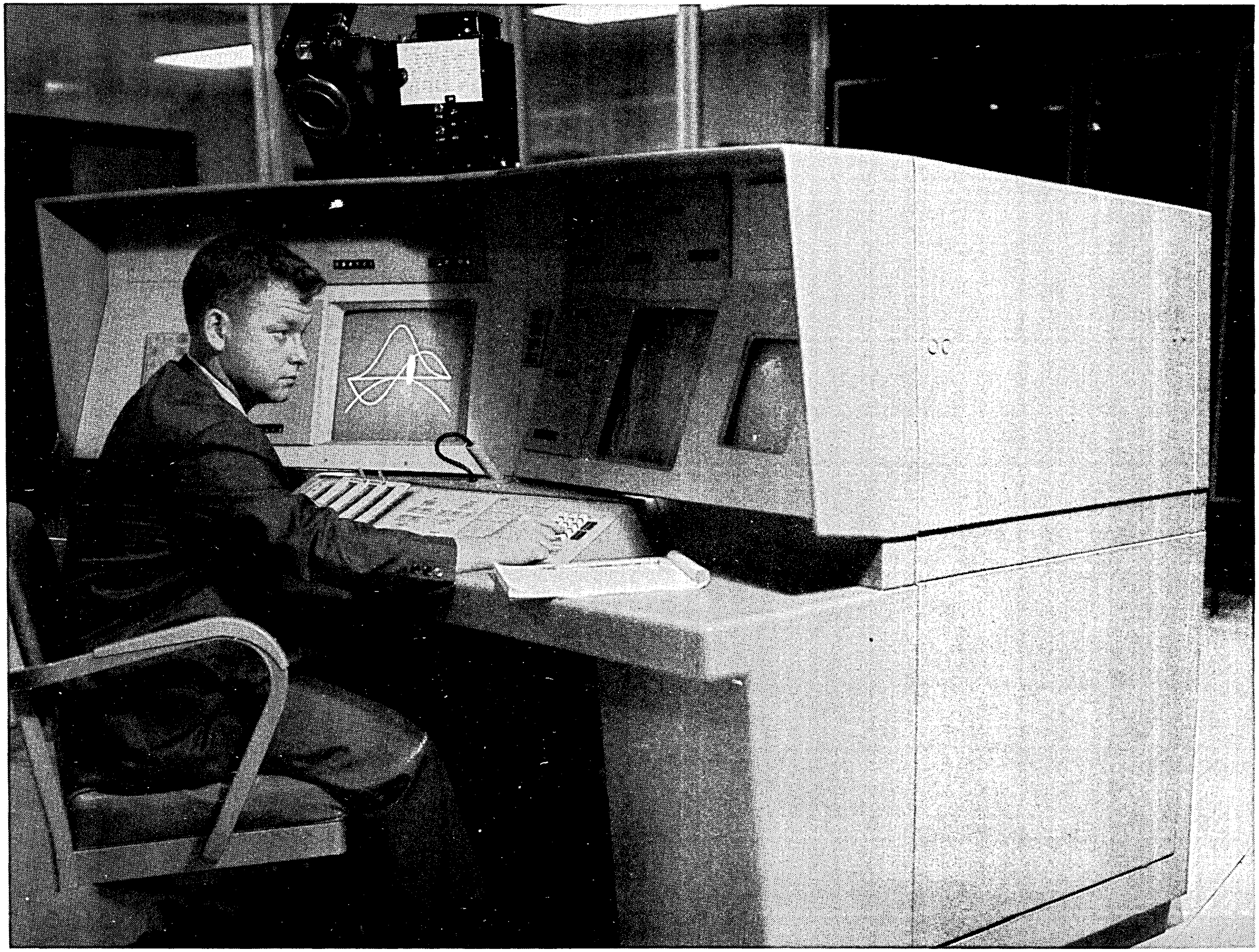

Figure A. Display Analysis Console

overlay, the DCK's are programmed for alphabetic entry onto the 10-inch alphanumeric tube. (There is a separate numeric entry keyboard.)

Other control panel features of the DAC include:

a. Light gun used on either 17-inch tube for specifying the storage cell of a symbol light gunned.

b. Cross hair cursor used on either 17-inch tube for indicating the raster points of the intersection of the cross hair.

c. Square shaped symbol used as a marker on the 10-inch alphanumeric tube. Conventionally it has been used to indicate, under program control, the location of the next symbol to be entered on the tube. In a different context the marker can become a vehicle for the retrieval of information displayed on this tube.