A DESIGN METHODOLOGY FOR AN INFORMATION EVALUATION AND INTEGRATION SUBSYSTEM WITH VARIABLE QUALITY EXOGENOUS INPUTS

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SUMMARY

This study develops a methodology for designing an information subsystem to process data concerning events exogenous to the organization. The design method is based on defined framework concepts which are a synthesis of Gerald Nadler's IDEALS design philosophy and Sherman Blumenthal's organizational concepts of information-decision-action, programmed and nonprogrammed decisions and the hierarchy of organizational planning and control. The design method is applicable to original, corrective, or improvement design for an information subsystem.

This study includes an example information subsystem development. This example serves to illustrate the practical interpretations of the framework concepts and the use of the design method in a subsystem corrective design effort.

CHAPTER I

INTRODUCTION

Background

Despite the recent advances in information technology and the flood of available data, business and industrial managers still express the need for more complete and timely information which is directly useful in planning, operating, and controlling their organizations (1, p. 37; 2, p. 55). The mathematical techniques and scientific method derived from operations research, management sciences and systems engineering disciplines have partially alleviated some of the problems of information control within the organization. Internal information systems supporting operating level activities have proven effective and worthwhile.

Management has direct control over its internal functioning. It can collect, verify, process, and store information that it needs for planning and control. The firm can specify what information is needed, how and when it is to be collected, how it is to be processed, and to whom the information is to be distributed. At the present state of information technology, it is theoretically possible to develop an information system that will provide management with the necessary information to control the internal functioning of their organizations (3, p. 17).

A great deal of the current emphasis of information systems design concerns the total systems approach. This approach is based on the tenet that the total system is composed of interacting information subsystems which attempt to satisfy all data requirements for all echelons of management and for all operating needs. The various information subsystems in the firm may include sales, advertising, production, and finance. The total systems approach is an attempt to unite all information subsystems into a single integrated system.

The information subsystems supporting the internal activities are only a portion of the total systems concept. The information concerning the organization's environment constitutes the complement of internal information. Management has little or no power to alter environmental influences such as the economic, social, or political conditions, governmental regulations or the competing firm's activities, although these external events exert a great influence on the internal functioning of the organization. Because there is imperfect knowledge of external conditions, a great deal of uncertainty is introduced into the internal decision-making process.

If the manager can develop a better understanding of the environment in which his organization operates, his logic and rationality in dealing with that environment should improve. The organization's internal information subsystems do not provide this type of information.

Existing information subsystems can provide the manager with excellent operating statistics, but they cannot tell him of the impact of governmental, industrial, or corporate threats to his firm. The typical management information system with its operations-oriented data base is of low utility when the manager must make decisions about economic threats, opportunities, risks, and future resources requirements and sources.

The development and implementation of an information subsystem to collect, analyze, evaluate, and integrate data from external sources would relieve some of the manager's uncertainty in decision making. Pertinent data that had been evaluated and integrated with knowledge from all other available sources would possibly provide the manager with the capability to compare his position, plans and problems with those projected or forecasted for his competitors. This additional information would promote more realistic objectives, better competitive strategies, and more effective and timely management actions (1, p. 37).

The inputs to such a subsystem will vary in quality because not all information can be objectively evaluated. Quantifiable data is the symbolic representation of transactions or events; data can in most cases be equated to numerical figures or measurements. Data becomes information by the process of evaluation or manipulation. By isolating only those elements of data which are needed, the manager derives reduced data which will be referred to as information. A column of numbers represents data, whereas the mean and mode of the column of numbers represent information about the numbers.

Political, ideological, and sociological information cannot be quantified easily. Management's subjective opinions, experience, insight, and biases concerning these ideas constitute qualitative information. When qualitative judgments are evaluated and integrated in light of known quantitative information, the result is intelligence. Intelligence can be described as the result of the evaluation and integration of all available internal and external information which may be significant to planning, operating, and controlling the organization.

The effect of external events on the organization cannot be predicted; nor can the manager's utility for or judgment of qualitative information be predicted with any certainty. The flow of this information within the organization can and should be controlled and directed to those managers who need the information. Numerous authors have advocated the establishment of a formal information subsystem to accomplish this, but there is no design procedure available. This lack of a design methodology is a motivating factor for this study. By formalizing a design method for an information evaluation and integration subsystem, the objective of directing intelligence to the appropriate manager may be accomplished.

Purpose

The purpose of this research is to develop a methodology for designing an information evaluation and integration subsystem which will process only variable quality exogenous inputs. This research has the following specific objectives:

1. To develop a logical and systematic design method for the design of an information evaluation and integration subsystem;
2. To illustrate this design method with an example military intelligence subsystem.

Scope of the Study

This research is concerned only with how exogenous inputs are processed within the information subsystem. The boundaries for the research are at the one extreme the receipt of the exogenous data and at the other extreme, the transmission of intelligence to the decision maker or manager. The actual collection of external data is vital to the subsystem, but the environmental data base is available. However, the availability of the data base is of little import unless the subsystem can translate the data into usable intelligence for the decision maker at the other extreme of the subsystem.

Within the total systems concept, all information subsystems interact with each other. This research will not be concerned with the interfaces between subsystems. This is a limitation, although one that can be adequately handled by the proper coordination and cooperation during the planning for the total system implementation. This development of a design method will be conducted in the vacuum created by the boundaries specified above. Additional research would be required to include subsystem interactions in the design method.

Procedure

To accomplish the objectives outlined above, a logical and systematic structure must be developed for the design method. The next chapter outlines the pertinent descriptive literature about information systems design and design methodologies. Chapter III lays the groundwork for the development of a design method by ordering and classifying the integral components needed in an information subsystem design method.

The actual design method is developed and described in Chapter IV. Chapter V illustrates the design method with an example, that of a military intelligence subsystem. The example represents a military application, but the development in Chapters III and IV will be general so that the method can be applied to business and industrial design problems. There are distinct parallels between a military intelligence subsystem and a business information subsystem processing data concerning the organization's competitive environment. Some of these parallels will be described in Chapter III.

CHAPTER II

LITERATURE SURVEY

Introduction

The topic of information systems has been receiving increasing attention in recent years, although the terms used vary widely. Information systems are variously called the management information system, the business information system, the total system, or the unified approach. There does not exist any taxonomy or structure to this particular field of knowledge. Information systems are multidisciplinary and interdisciplinary, and this may be a reason for the confusion and misunderstanding in the definition and meaning of terms. This literature survey will outline only those areas of the information sciences and design methodology which are of particular importance in this research.

Information Systems

Although the need for information in any management situation is more than obvious, its importance should be underscored. "Information flows are as important to the life and health of a business as the flow of blood is to the life and health of an individual (4, p. 475)." "Information is the catalyst of management and the ingredient that coalesces the managerial functions of planning, operating, and controlling (5, p. 106)."

Much of the semantic confusion existing today centers on the lack of a standard definition of what an information system is. Gosden et al. define an information system as a data management system devoted to the handling of data for management (6, p. 5). Duffy and Ganter define it as a system to satisfy the changing and unique needs of management at the moment in time when the information is required (7, p. 339). Orlicky states that an information system is a system that makes any information in the data base immediately available to the user to satisfy his planned, as well as unplanned, information requirements (8, p. 53). Murrish states that an information system provides for the collection of internal and external information in a form accessible to all management levels to assist in planning and control decisions (9, p. 2).

The common thread running through these definitions is the fact that information is provided to management to assist in decision making. The management decision-making functions are to use all available information to: establish organizational objectives, allocate resources to achieve the objectives according to a predetermined plan, and to react to deviations between the predicted and actual results to forestall the development of an unfavorable situation (10, p. 16).

If the system can provide the necessary information to create an operating plan and to detect deviations between the plan and the actual events, then it is possible for the system to:

1. Deliver information when it is needed so that situations requiring immediate decisions can be controlled, and situations that are not so pressing can be deferred, but not delayed to the point of loss of control.
2. Provide for simultaneous horizontal and vertical dissemination of necessary information so that management and every operating department will be adequately informed.
3. Provide for immediate random access to all information in the system so as to support management decisions in unpredictable situations.
4. Reduce reams of information to meaningful facts for management to use in planning the future operations (10, p. 17).

Much of the research concerning information systems deals with computer based systems. This is natural because of the power of the computer to accomplish repetitive computational activities. However, the availability of a computer should not be the overriding consideration in its inclusion in the information system. The objectives and requirements of the system should determine the type of processing.

Manual systems are preferable under certain conditions. When the criteria for decision making are not well defined, when the volume of data is small, or when the rules for decision making change frequently, manual information processing is preferable. A manual system may be superior when the quality of data entering the system is variable and standards of consistency cannot be maintained or when the inputs to the system are random or erratic (11, p. 92).

Design Methodology

Design is the specification of the desirable precise conditions for each of the system's elements (12, p. 43). The designer seeks a specific set of conditions. Designing is a creative activity that seeks to obtain useful results from the theory, laws, and experience derived from research. In the broadest sense, design is deductive in that it attempts to derive a specific solution that will logically follow from known laws and theories.

The objective of any methodology is the improvement of the procedures and criteria employed in the effort (13, p. 6). Design methodology is therefore the study of ways to improve the creative act of designing. Any final product, device, or system is a result of the synthesis of the designer's creative capabilities, the structure he can interject into the problem, and his methodology for solving the problem.

Several authors state that the design method consists of analysis, synthesis, and evaluation (14, p. 346). Other authors define the design method as: determining the problem, analyzing the system, suggesting solutions to the problem, selecting and detailing the solution, reviewing the solution, and drawing conclusions. These two views are essentially equivalent and can be summarized as:

1. Identify the problem for which a system is required.
2. Subdivide the problem into its component parts.
3. Analyze the components to uncover any new elements of the problem which would change the design specification.
4. Recombine the components into the desired system.

This approach to design is based on research methods. Research and design are different endeavors with different purposes. Research is used to establish general theories and laws and is inductive. Design is used to create useful products or systems based on theories and laws and is deductive in nature. Despite these differences, the same methodology has been used in both efforts.

The method summarized above is the basis of many of the texts and articles concerning engineering design, operations research, management sciences, and information system design (10, 11, 13, 15, 16, 17). There are numerous assumptions inherent in the above method. A full explanation of these assumptions is found in reference 12. The impact of these assumptions on the problem solution becomes critical when the method is used for design projects.

Only one design philosophy has been found that differentiates between the purposes of research and design. Gerald Nadler proposed a design philosophy based on research results from psychologists, sociologists, organizational theorists, and his own research with leading professional designers in the fields of engineering, law, medicine, architecture, and commercial art (12, 18).

Nadler's IDEALS (Ideal Design of Effective and Logical Systems) concept is a philosophy, not a technique. It is a way of thinking, not a rigid list of activities. This design philosophy essentially eliminates the restrictive assumptions inherent in the research-based design methods. The IDEALS concept frees the designer of all except the minimum restrictions so that he may use his imagination and ingenuity in developing the best possible system or product under a given set of circumstances.

The IDEALS philosophy is a way of designing with only minimum reference to the existing system, if one exists. This philosophy is summarized below.

1. Function determination - the mission of the system, and the higher level systems of which the project system is a part, are identified to select the highest level function.
2. Ideal system development - several high level and advanced ideal systems are actually developed - not just discussed in the abstract.
3. Information gathering - collect only the necessary information concerning design of the system, manner of implementation and basic organizational data.
4. Alternative systems suggestions - the information gathered will show that some of the components of the ideal system will not be feasible, therefore develop alternatives which will conform as closely as possible to the ideal system.
5. Select the feasible solution - basic evaluation factors are used to select the recommended system.
6. Formulate the system - the exact details of the system are prescribed.
7. Review the system design - to correct details and move closer to the ideal system.
8. Test the system design - to insure components function as designed.
9. Install the system - final changes made, personnel trained and activities debugged.
10. Performance measures established - determine if systems objectives are met and establish operating expectations (18, p. B 647-648).

The full detailed description of Nadler's IDEALS concept is included in Part IV of Work Design, A Systems Concept (12). Nadler admits that his concept still needs research and refining, but it has been tested extensively with impressive results.

Variations of the IDEALS concept have been used extensively. The "4D" version is widely used in applications in several industrial corporations. This is perhaps the simplest adaptation of IDEALS and is merely a conversion of Nadler's ten steps into four steps (12, p. 522). This version is:

1. Define the system.
2. Design the ideal.
3. Develop the optimum.
4. Deliver savings (12, p. 522).

Regardless of the variation of the IDEALS concept or the number of steps involved, the hallmark of the method is to free the designer's imagination to develop the best possible system under the known minimum restrictions without reference to previous systems.

Information System Design

The amount of literature concerning the analysis and design of information systems is overwhelming. Since 1959 in excess of 1,600 articles, books, or anthologies concerning some aspect of information systems have been published (19, p. 299). Much of the available literature is superficial. Some of it advocates suggested changes in design but offers no method of implementing these suggestions.

The design and implementation of an information evaluation and integration system is one particular area that has received superficial treatment in the past. William R. Fair (20) predicted the design and development of a new corporate activity whose mission would be the detailed analysis of competing firms with the view of discovering weaknesses that could be exploited. Fair realized that efforts in gathering information about competing firms were in progress at that time, but that the collection and processing system had not been formalized.

Carroll and Zannetos (21) proposed some redirection in the efforts of information systems designers so that management would not merely receive increased amounts of operational data but would also receive additional evaluated information about the organization's environment. This improved information would allow the manager to react more intelligently to the environment and changes in it.

Smith and Levitz (1) proposed the establishment of a commercial intelligence system. They defined commercial intelligence as describing the external business environment in which the company operates (1, p. 37). They described what this type system is to accomplish and gave a superficial outline of how to establish it.

Two other references available advocate the establishment of an information evaluation and integration system. Johnson and Derman (2) describe the type of data being presented to management for planning purposes as "operations oriented," and claim that this type of data is not what is needed. They propose that an information system designed to "collect data, process them into information, and convert them into intelligence" is what is required (2, p. 55). The method of designing this system is the purpose of the present research.

A second reference addresses the improper use of operating data for use in organizational planning. Symonds' (22) approach to a business intelligence system is basically from an economic standpoint. By obtaining the proper financial information, management can translate this into a form of intelligence for use in planning.

The above-cited authors have advocated the conversion of the present operations-oriented systems into systems that will provide the manager with intelligence rather than increased data. This concept is excellent, except that there is no design method available to accomplish this objective.

Numerous excellent volumes are available for use in information systems design. The approaches taken by Hartman, Matthes, and Proeme (23), Blumenthal (24), and Lee (16) are particularly well detailed. Each of these references is founded on research-based design methods, and each concerns only the organization's internal information systems.

Sherman Blumenthal (24) rigorously defined several information systems concepts. His definitions are clear, complete, and flexible. On the basis of these definitions, he developed a design methodology for information systems. His method was based on a research methodology, and it incorporates the implicit assumptions of research methods. However, some of his definitions and concepts will be adapted for use. These will be examined in detail as they are required.

CHAPTER III

BASIS FOR DEVELOPMENT

Introduction

This chapter will order and classify the concepts upon which the development in succeeding chapters is based. Terms which are casually used in the information sciences will be formally and explicitly defined. These definitions will serve to structure the transformation of data into intelligence, the tasks to be performed if the system mission is to be accomplished, and the organizational units which will perform these tasks. The developed vocabulary will be the basis for the information system design method developed in Chapter IV.

Information Characteristics

The problem here is to specify the detailed internal workings of the "processing black box" shown in Figure 1.

Definition 1: Processing is the totality of activities involved in transforming data into intelligence.

Definition 2: Data is the symbolic representation of transactions or events.

Definition 3: Information is data which has been evaluated.

Definition 4: Evaluation is the appraisal of data or information relative to a standard compatible with the objectives and goals of the organization (25, p. 146).

Evaluation is not a discrete event. It is continuous because the value of data or information to different individuals will vary. What is important to a line manager may be of no consequence to top management. This implies that data and information are evaluated and reevaluated in light of the goals of each echelon in the organization's hierarchy.

The data considered for this research is from sources exogenous to the organization. This data, when evaluated in light of organizational goals and objectives, becomes information. Information generated from exogenous sources may be classified according to its message-carrying function. These functional classifications are basic descriptive information, current estimate information, and speculative information (26, pp. 11-68). These information classifications are not mutually exclusive. Each classification is highly interrelated to each of the others.

Basic descriptive information describes the environment in which the organization has been operating. This information is of the type that can be verified or confirmed from open sources in the environmental data base. Basic descriptive information may describe the position of competing firms in the market, governmental regulations, restraints, or policies. This basic information is the groundwork upon which changes in the other two classifications of information can be gauged.

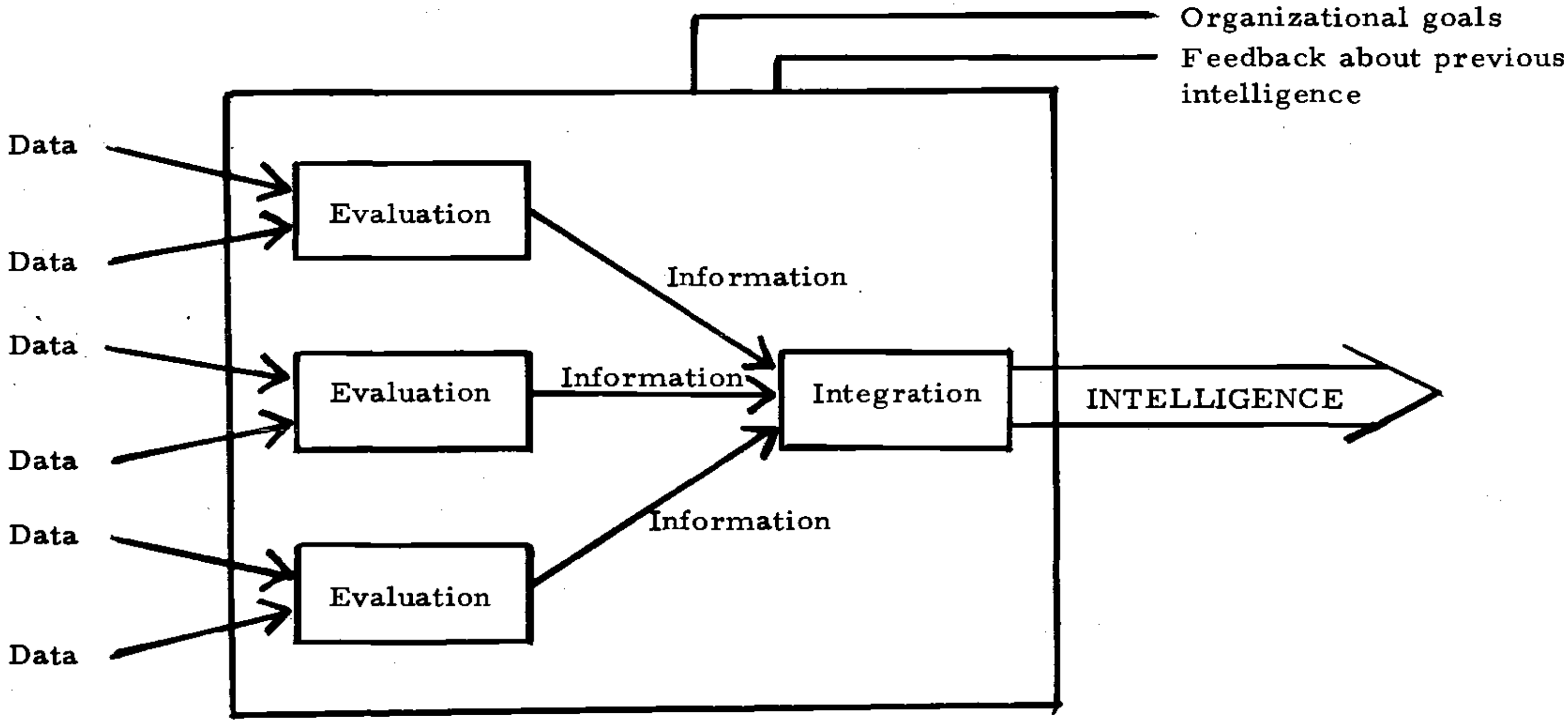


Figure 1. Transformation of Data into Intelligence

An example may serve to illustrate this type of information. The position of a competing firm can be obtained by knowledge of the competitor's economic objectives in the market, his authorized organizational manning level, description and specifications of his products or services, percentage of the market that he serves, amount and types of equipment owned, rented, or leased, number of buildings occupied or under construction, and bibliographic descriptions of the competitor's top management personnel. This list could be expanded and made more detailed. This type of information can be obtained from open sources such as the competitor's advertising brochures, prospectus, and financial reporting services.

Current estimate information describes not only the present situation of exogenous influences on the organization but also the ongoing activities of competitors, planned changes in product lines or prices, major policy or personnel changes within the competing organizations, new technological breakthroughs, and the status of proposed regulatory legislation. This information is basically a bridge from the past to the present. It serves to update basic descriptive information in light of changes and serves to alert the organization about matters which may eventually affect it. Current estimate information may be of such a nature that it cannot be verified by independent sources.

Speculative information is that functional classification of information which embodies the future. A clear, precise forecast of the future environmental influences on the organization is desirable. Speculative information about the future is perhaps the most important classification, but it is the most difficult to assess. Speculative information is available from both overt and covert sources such as information on financial trends, news announcements and analyses, employees of competing firms, and business espionage efforts (27, p. 118).

These functional classifications of information are by no means discrete. They are inextricably interrelated. Individually, or in pairs, their usefulness may be limited, but the union of the three sets of information is the input to information integration (see Figure 2).

Definition 5: Integration of information is the melding or synthesis of all available information to derive sets of indicators.

Definition 6: An indicator is a set of elements of information leading to an inference about the future course of events exogenous to the organization.

A set of indicators derived from information may infer that a competitor will take a particular course of action. A different integration of the same information may produce another set of indicators signifying that the competitor will take a different course of action. This results in multiple hypotheses about the future actions of the competitors. The apparent dilemma of multiple sets of indicators derived from the same set of information may be helpful in the long run. This dichotomy will widen the manager's perspective of the environment's influence on

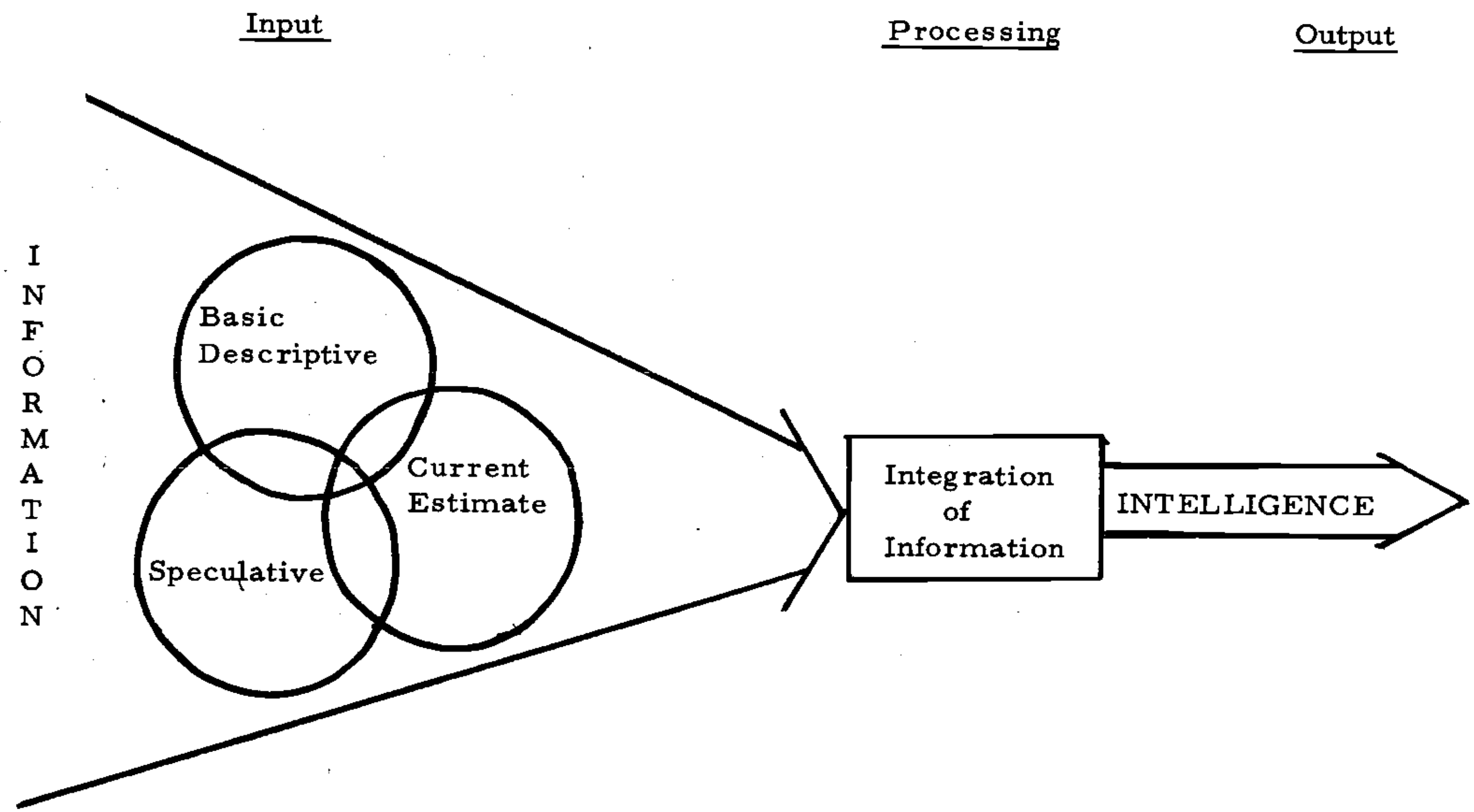


Figure 2. Integration of Information

his organization.

Definition 7: Intelligence is the result of the evaluation and integration of all available information significant to a decision at a point in time.

The union of all sets of indicators is the processed intelligence. Not all sets of indicators are necessary for all decisions. In consonance with definition 7, only those sets of indicators which are relevant to a decision in time need to be presented to the decision maker. A set of indicators may simultaneously be relevant to several decisions. For a particular decision, the relevant set of indicators is intelligence.

Definition 8: An intelligence estimate is the set of indicators which management judges to be the expected course of events.

The intelligence estimate is a judgmental decision on the part of the manager. The manager or decision maker must weigh the facts as he comprehends them, the sets of indicators presented to him and his own subjective evaluations of them, to determine which of the sets of indicators portrays the future course of events. If the decision maker had perfect knowledge, his decision-making process would be a mere academic exercise. Unfortunately, these conditions of perfect knowledge rarely occur.

The intelligence presented to a decision maker has some desirable qualities. These qualities are: timely, in that the intelligence is available when needed; reliable, in that independent observers view it in the same way; clear, in that the intelligence is understandable to the decision maker; valid, implying that the intelligence is in congruence with established facts; and adequate, in that the available intelligence gives a full account of the needed detail.

These desirable qualities are difficult to achieve simultaneously. Some of the qualities are working at cross purposes. For example, for intelligence to be timely for a decision, adequacy and reliability may need to be foregone. Although in practice the simultaneous achievement of all the desired qualities is not frequently accomplished, these qualities provide the description of the desired output illustrated in Figures 1 and 2.

Organizational Considerations

The organizational hierarchy exerts a pronounced effect on the type, quantity, and quality of data which is processed through the information system. At the various echelons of the organization, there are marked differences in the value and use of information. At the lower echelons information processing and usage are highly specialized and confined in interest, whereas at higher echelons these specialties are drawn together and have a greater breadth of interest.

Data may enter the system from exogenous sources at any echelon or it may be funneled through one particular echelon. If it can enter at any level, then the higher the level at which it enters, the less likely it will become distorted in processing and being communicated through the system. The shape as well as the number of echelons conditions the flow of information. Sociological research in information processing has indicated that the optimal shape of an intelligence hierarchy would be relatively flat with a large number of processing specialists in the middle management levels (28, p. 45). Fewer ranks in the hierarchy would permit speedier diffusion of more accurate information. More specialists at the middle levels would provide better information to more potential managers.

Assumption 1: Data can enter the information system at any echelon of the organizational hierarchy.

Assumption 2: Data entering the information system is processed distortion free.

Centralization of information also presents a dilemma to the information specialists. If information is centralized at one management level, too few managers with little accurate or relevant information are too far out of touch with the organization to function effectively. On the other hand, if information is scattered throughout many subordinate units, too many managers with too much specialized information may engage in dysfunctional competition, may delay decisions while consulting with each other, or may distort information as they pass it through the hierarchy (28, p. 58).

This research does not advocate either centralized or decentralized information processing. This decision is dependent on the type of organization and the philosophy of the management in that organization. However, several important results should be noted. First, there is a need for information evaluation and integration at every echelon of an organization where exogenous factors directly influence the internal decision-making process. This is necessary because the information processed at different echelons will be of variable value to the decision maker. Secondly, where information flows between like-minded specialists at the various echelons of the organization, much of the distortion of communications is eliminated (28, p. 59). Thirdly, distortion is also minimized in a single-purpose organization where the conditions at each of the operating echelons is uniform (28, p. 59).

Assumption 3: There are sufficient information specialists at each echelon to permit evaluation and integration at every echelon.

Assumption 4: Operating conditions at each echelon of the organization are uniform.

Framework Concepts

Sherman Blumenthal (24) presented a framework for information systems development based on the synthesis of the concepts of information-decision-action, programmed and nonprogrammed decisions, and the hierarchy of planning and control. Definitions 9 through 19 contained in this section are adapted freely from the concepts he introduced in *Management Information Systems, A Framework for Planning and*

Development (24, pp. 17-38).

Definition 9: A level is a file of information or intelligence.

Definition 10: An activity center is an organizational entity under the supervision of a manager, which regulates and/or transforms the flow between levels.

Definition 11: An action is a prescribed (or programmed) regulative or transformative response of an activity center to information or intelligence with which it is concerned.

Definition 12: A decision center is one or more management people with their staffs who (1) prescribe the decision rules which govern the actions of one or more activity centers and (2) make decisions for activity centers to execute as actions in situations where the established decision rules are exceeded or are nonexistent, or where the prescribed action was not properly responsive or needs to be adjusted.

Definitions 9 through 12 specify that the activity centers concerned with a level execute all programmed actions concerned with that level. The decision center intercedes in all actions which are nonprogrammed or when the prescribed action taken by the activity center does not cause the proper response.

Definition 13: A functional unit is an organizational entity consisting of an activity center and its decision center.

The general structure and components of a functional unit are depicted in Figure 3. It should be noted that the functional unit incorpor-

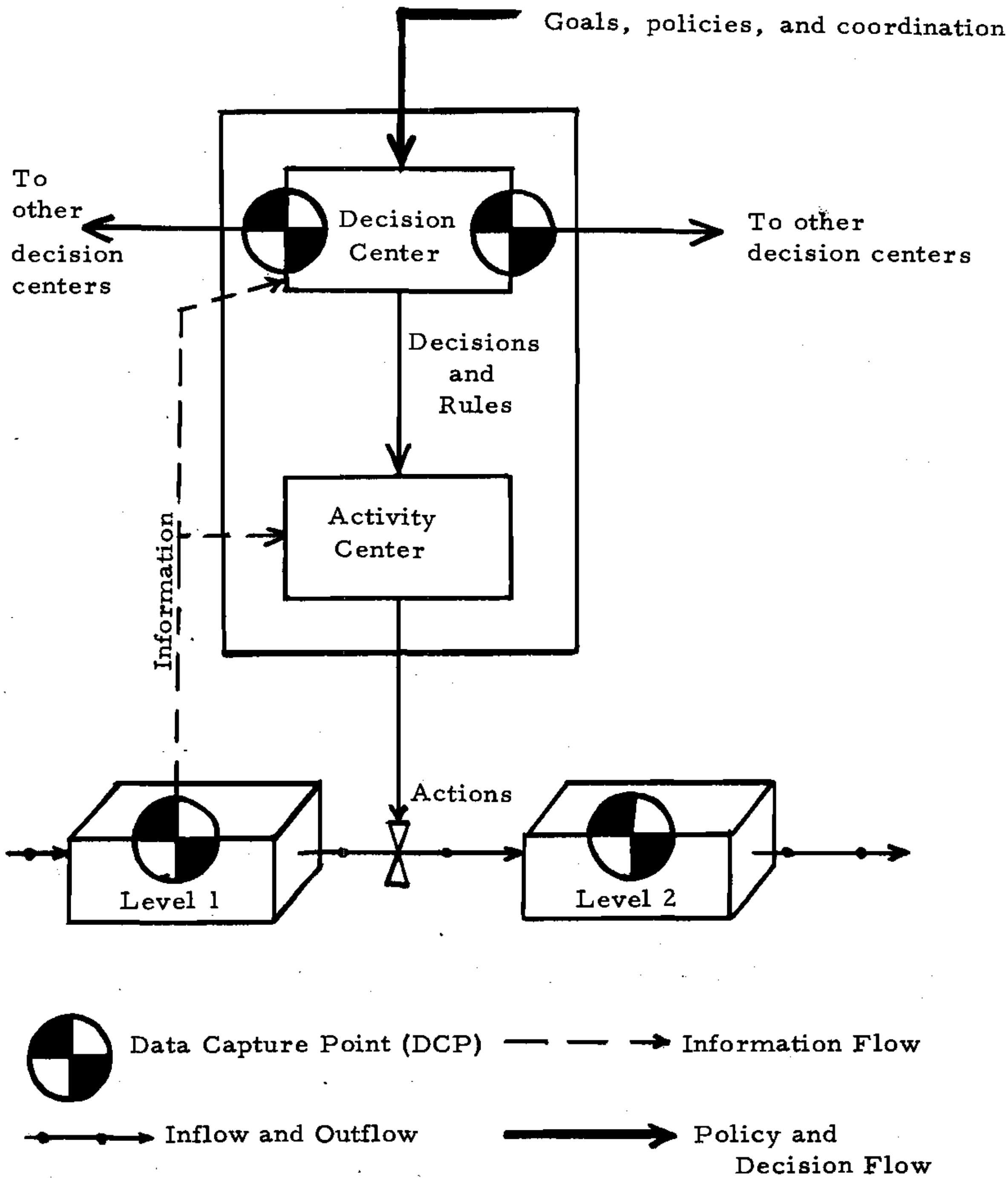


Figure 3. A Functional Unit (24, p. 32)

ates both horizontal and vertical linkage with other organizational entities. The decision center is linked horizontally with other decision centers and vertically to a policy-setting echelon. Information or intelligence from other levels links the functional unit with other functional units.

Definition 14: A management control center is one or more management people with their staffs, which acts as a decision center for one or more functional units or for one or more subordinate management control centers.

Definition 15: An operational function is a set of any one or more classes of actions carried on by one or more different functional units, which regulates or transforms the inflow to or the outflow from a sequence of levels as a group.

An operational function is a set whose elements are classes of action. Each class of action consists of a set of sequences of related action-decision steps in response to a type of information from a level.

Definition 16: An action subsystem is a group of activity centers involved in an operational function.

Definition 17: A decision subsystem is a group of decision centers and management control centers involved in an operational function.

Definition 18: An information subsystem is one or more functional units involved in an operational function and whose levels and flows consist of information and/or intelligence generated and used in the action and decision subsystems of other operational functions.

An action subsystem may consist of several different functional units. Figure 4 illustrates that each functional unit in the action subsystem executes an action which regulates or transforms the flow between levels. A management control center may also routinely execute actions which regulate or transform the flow of information between levels.

Definition 19: A management information system is an operational function whose parts are information subsystems of other operational functions.

The management information system of each echelon of an organization consists of numerous information subsystems (see Figure 4). Each information subsystem performs an operational function. In an organization separate information subsystems may be operated for major functional areas such as personnel administration, advertising, manufacturing, and finance. These particular areas are designated as operational functions, and each is a set of classes of actions dealing with that area. The information or intelligence generated by these subsystems is used by other information subsystems in the management information system and by other management information systems.

The three-dimensional view of levels in Figure 4 depicts the continuous nature of information flow with respect to time. As one sequence of information-decision-action is taking place, additional infor-

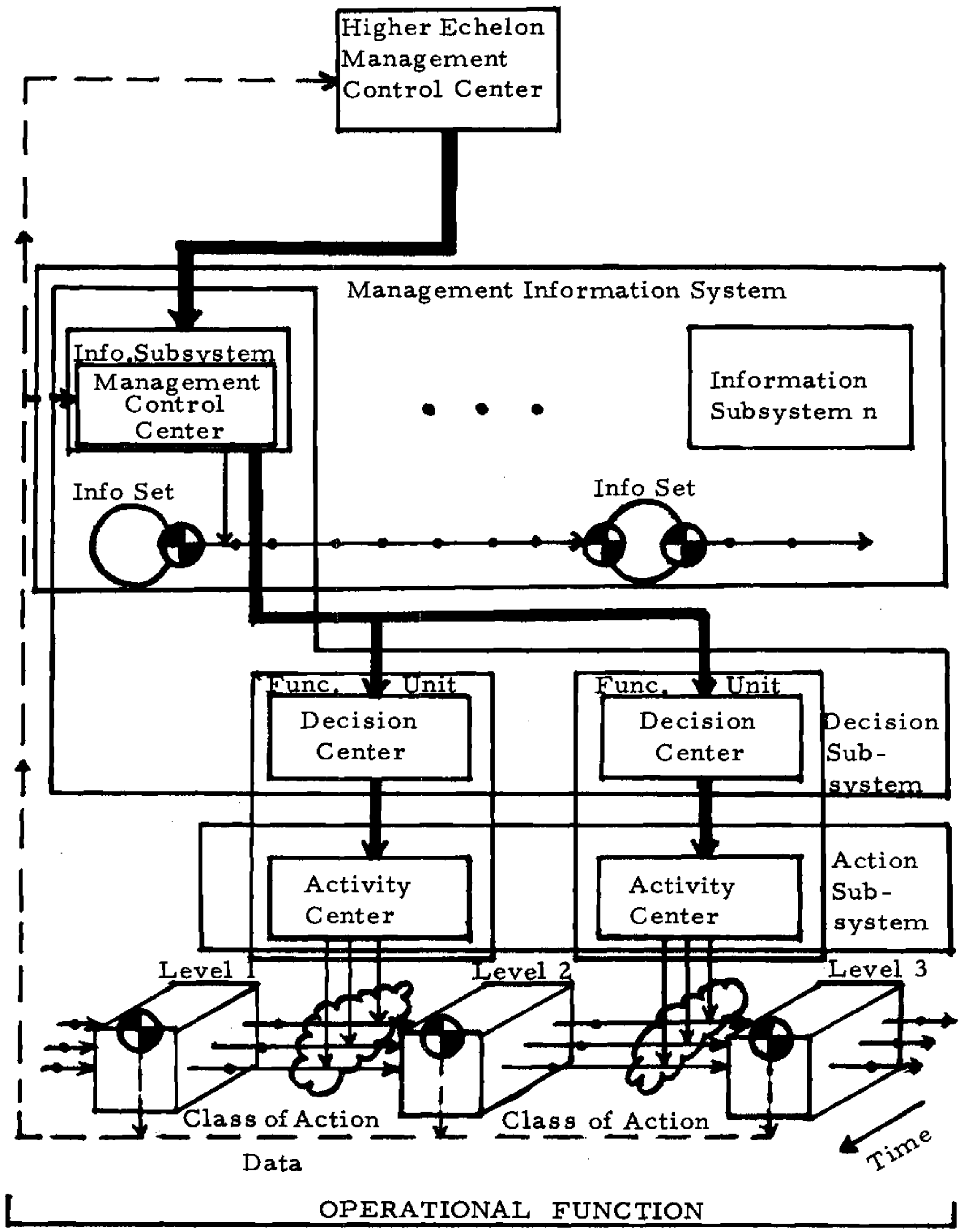


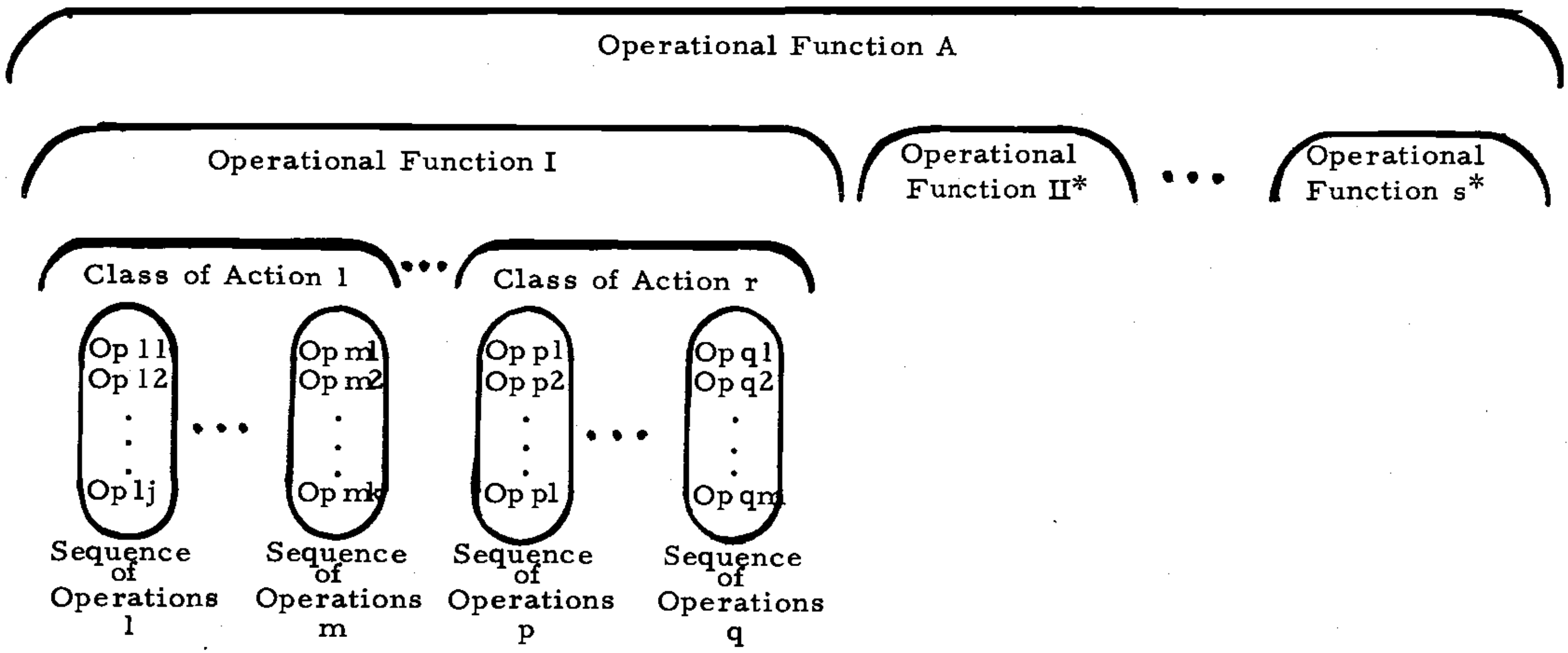
Figure 4. Management Information System

mation may become available which would nullify, change, or perhaps reinforce previously specified actions. With this continuous process, there must be some type of priority classification for the flow of information so that important information could be handled in a timely manner and less important information could be delayed.

Figure 4 depicts the management information system at only one echelon of an organization. There is a hierarchy within the organization, and there exists an information subsystem at each echelon of the organization for each operational function. Information subsystems performing the same operational function at the various echelons are closely related with information, decision, and policy flows, although not all subsystems need to be formalized.

These framework concepts describe a structure for the information-decision-action tasks to be performed by the information subsystem and an anatomical framework for the organizational units at each echelon. This task structure is illustrated in Figure 5.

Operational function A is a set of operational functions (i.e., OP A $= \{$OP I, OP II, ... , OP s$\}$). Operational function A is the set of tasks to be performed by the management information system. The elements of this set represent the actions to be performed by the s information subsystems of the management information system. Operational function I is a set of classes of action (i.e., OP I = $\{$CA I, CA 2, ... , CA r$\}$). The elements of this set represent the tasks per-



*Structure is similar to the operational function shown in detail.

Figure 5. Task Structure

formed by the combined efforts of all of the functional units in the information subsystem. Each class of action represents a set of sequences of operations to be performed by a particular functional unit in response to the flow of a type of information.

For a particular operational function, the number of classes of action may vary according to the designer's appraisal of the subsystem goals and the manner in which he defines them. Similarly, the number of sequences of operations in a class of action may also vary. There is no minimum, maximum, or recommended number. The designer has the following variables under his control: classes of action, sequences of operations, functional units, and levels. These are the decision variables.

Summary

This chapter has ordered or classified the concepts which will be used in the subsequent development of a design method. Definitions 1 through 8 specify the actions required to transform data into intelligence. Definitions 11 and 15 and their components define a structure for the tasks to be performed by the information subsystem. Definitions 10, 12, 13, 14, 16, and 17 define the organizational units necessary to perform these tasks. These definitions and concepts represent the problem structuring which is used in the design method for an information evaluation and integration subsystem.

CHAPTER IV

DEVELOPMENT OF A DESIGN METHOD

Information Subsystem Design Method

This section will develop a methodology for designing an information subsystem. The general scheme is to design the subsystem using the definitions and concepts of the previous chapter and the design philosophy proposed by Gerald Nadler. The method is a synthesis of ideas presented by Blumenthal, Nadler, and this author.

The method presented is flexible in that it can be adapted for use regardless of the subsystem state. If there is no existing subsystem, the method can be used in an original design effort. If there is an existing satisfactory subsystem, the method can be used for improvement design. If there is an existing unsatisfactory subsystem, the method can be used for corrective design. The developed method is discussed below and is summarized on pages 52-56.

Step 1: Define the Subsystem

The purpose in defining the subsystem is to enumerate explicitly the functions which it must accomplish. These functions include the mission, purpose, or primary concern of the subsystem in relation to the organization goals. The mission is the reason for the existence of the subsystem. The subsystem goals can be equated to measures of performance. The goals describe the desired ideal or target subsystem and provide a basis of comparison for the actual and desired outcomes from the testing to be conducted in Step 3.

The performance function is multidimensional, and its value is dependent upon the decision variables and the uncontrollable variables of the system (e.g., $P = f(X, Y)$ where the decision variable $X = g(x_1, x_2, \ldots, x_m)$ and the uncontrollable variable $Y = h(y_1, y_2, \ldots, y_n)$). The decision variables are the variables over which the designer has control and include the resolution of the classes of action and their included sets of sequences of operations, the number of functional units and the levels. Some decision variables are controlled by management and may extend over a range of values. These management decision variables are incorporated in the subsystem goals or measures of performance. The uncontrollable variables are those over which there is no control, such as the information-loading characteristics.

In the simple case of one decision variable (e.g., manning levels for the system) and one uncontrollable variable (e.g., information input volume), the performance function (e.g., processing time) may be viewed as the response surface as illustrated in Figure 6. The subsystem goal may be set as a minimum performance level (e.g., BB') or as a range (e.g., BB' to AA'). Situations in which a range of performance values might be appropriate will be pointed out later.

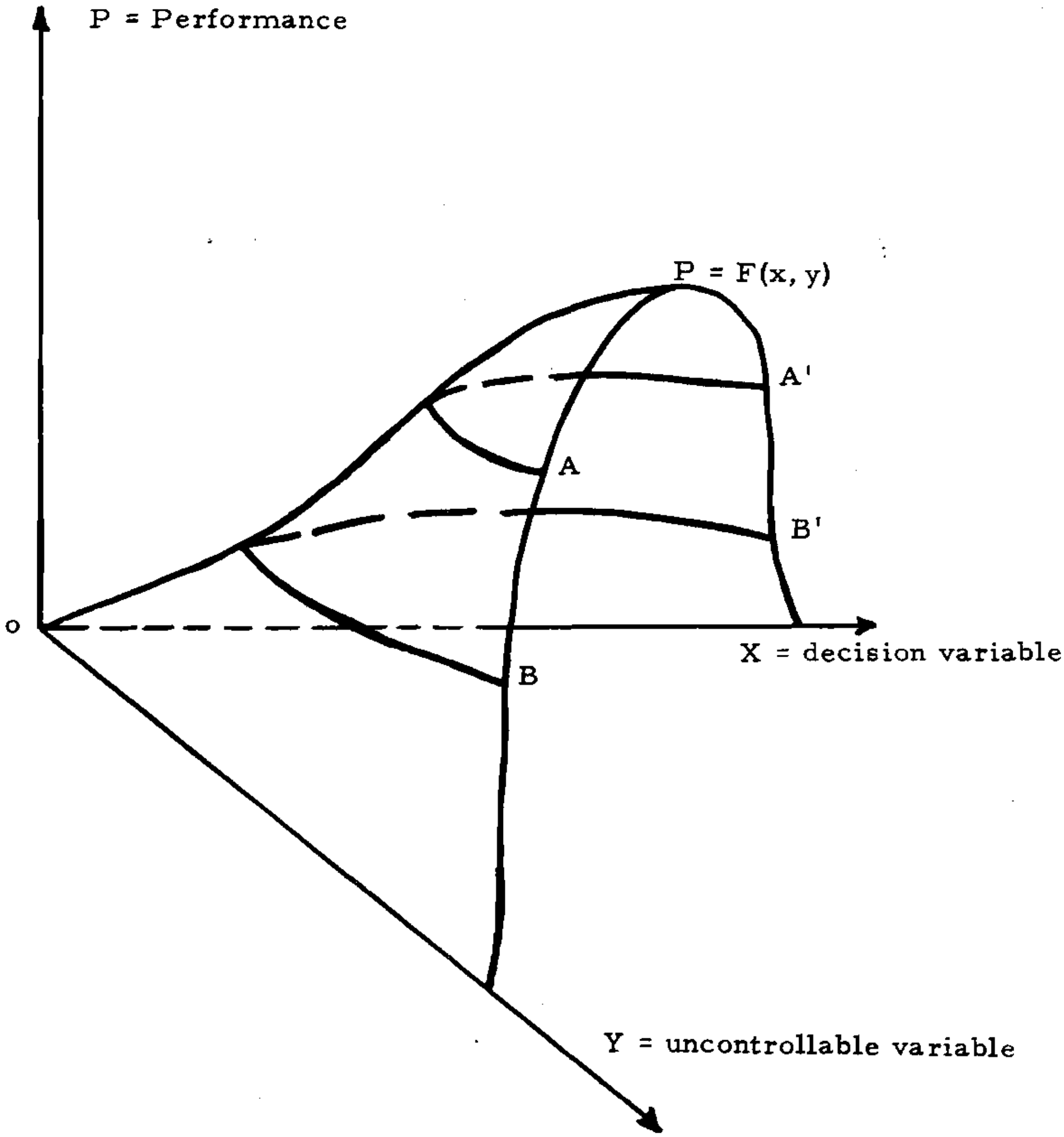


Figure 6. Performance Function

The information subsystem encompasses the various echelons of the organization. The mission and goals of these echelons do not necessarily correspond when examined in detail. The missions and goals of the subsystem at each echelon must be explicitly stated and examined to determine the interrelationships to be maintained in the accomplishment of each of their missions.

The optimal size and shape of information systems from an organizational viewpoint have been discussed previously. The organization for which the subsystem is being designed probably cannot be changed to meet these optimal conditions, but the designer can approach these conditions by the proper use of centralization or decentralization of the system.

An important portion of the subsystem definition is the resolution of the operational function into classes of action. In effect, this consists of partitioning the total set of tasks to be performed into a set of classes of action. Each class of action consists of a set of sequences of operations. Each sequence of operations consists of a series of specified decision-action steps. Classes of action and their respective sequences of operations are decision variables under the designer's control.

The minimum limitations or restrictions on the subsystem must be specified. The purpose is to eliminate all possible restrictions which would limit the designer in proposing new or unique ideas for incorporation into the subsystem. Some constraints will remain, but these must be the bare essentials. These remaining restrictions might be considered as the nonarbitratable constraints on the subsystem design.

The minimum constraints will vary in form. Some will be qualitative restrictions on the designer (e.g., manual processing system rather than a computer based system). Other constraints will be quantifiable in explicit terms. For example, an accounting annual total cost constraint may be imposed on the subsystem operation. The total cost, TC, is a function of its component fixed and variable cost factors (e.g., $TC = f(x_1, x_2, x_3, x_4, x_5, \ldots.)$ where x_1 = cost of training and salaries for managerial personnel, x_2 = cost of training and salaries for operational personnel, x_3 = cost of office space, x_4 = operating cost (equipment maintenance, supplies, etc.), and x_5 = initial cost of equipment).

In a simple two-dimensional case as shown in Figure 7, the subsystem goals specify the desired performance level, and the constraint specifies the maximum amount of scarce resource available. During the first pass through the design method, the constrained resource may not be completely used. By iteration through the design steps, the performance response of the subsystem under full utilization of the resource will be determined. This requires the subsystem response to lie on the constraint line CC'.

In Figure 7, region I indicates the set of feasible solutions and

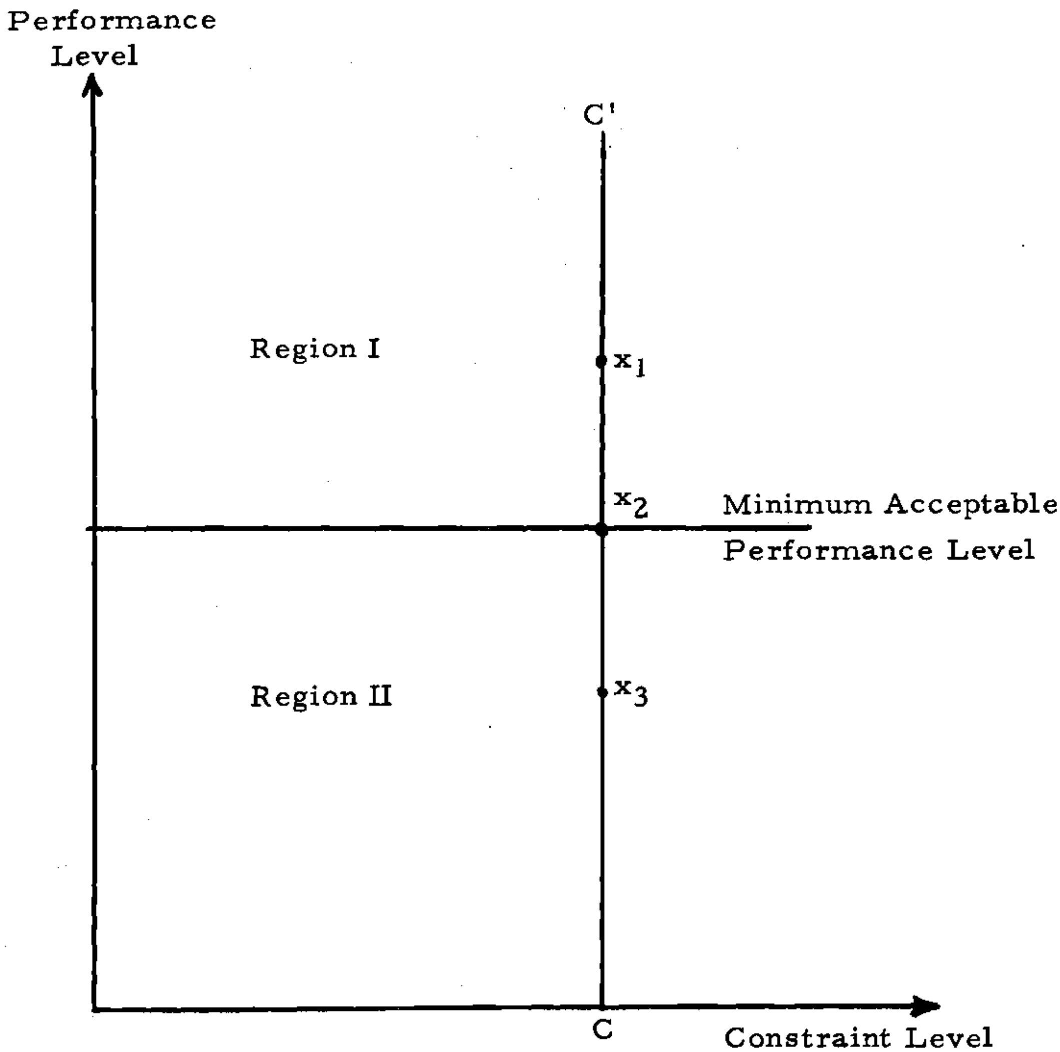


Figure 7. Performance Levels Versus Constraint Levels

region II indicates infeasibility because the minimum performance level is not attained. Any point to the right of line CC' is also infeasible since those responses would violate the constraint. The subsystem performance response may be above, on, or below the minimum acceptable performance level. Points x_1, x_2, and x_3 indicate that the desired performance level is exceeded, equaled, and not met, respectively. Only one of these conditions would occur for any particular situation, and the point x_i indicates only one point on the performance curve for a particular combination of constraint and performance.

Step 1A: Redefine the Subsystem

The design method commences with Step 1 on the first iteration for original design efforts but starts with this step for corrective or improvement design projects. When the method obtains an infeasible solution in Step 3, the process recycles to this step. The purpose of this step is to redefine the subsystem missions, goals, and restrictions imposed on earlier iterations. The missions and goals for each echelon of the subsystem must be considered in conjunction with management to determine which of them can be eliminated or relaxed. If the missions, goals, or restrictions cannot be modified, then the design of the subsystem is infeasible and the design process terminates. If the missions, goals, and restrictions can be modified, then Step 1A parallels Step 1 in its substeps and then proceeds to Step 2. The result of this step is the reformulation of the missions, goals, and restrictions on the subsystem design.

Step 2: Design the Ideal Subsystem

This step encompasses the creative aspect of the development of an information subsystem. The success of this step is directly dependent upon a clear statement and understanding of the subsystem missions, goals, classes of action, and sequences of operations. The subsystem design on each iteration through the method is a function of the designer's creative capability and his ability to restructure the subsystem based on the knowledge gained from previous iterations.

For each echelon and for each class of action, determine what functional units and levels are necessary to accomplish that class of action. This determination must be under the minimum restrictions derived in Step 1 or 1A. The designer should attempt to minimize the number of functional units necessary to accomplish each class of action. The purpose of this is to eliminate redundant sequences of operations by combining similar sequences. This minimization is accomplished by determining and isolating the commonalities in sequences of operations and by combining these sequences.

Determine the interrelationships between each of the functional units involved in each class of action at each echelon. This is a problem in logic to determine the flows of information between levels. It is a tedious, time-consuming process, but the end result will be the specification of the flows between all functional units. In conjunction with this, the responsibilities and boundaries of each functional unit need to be determined.

The next substep is to determine the relationship and placement of management control centers to act as decision centers for each of the functional units. The determination of the boundaries and responsibilities of the management control centers parallels the development for the functional units. Its delineation will specify the flow of information in response to situations in which decision rules for the functional units are exceeded or nonexistent, or in which the actions of activity centers or action subsystems need adjustment.

Upon completion of the above steps for each echelon, the echelons must be interconnected with flows of information between levels and the flows of policies, guidance and decision rules. This substep completes the design of the subsystem for the organization.

This step is time-consuming to complete. At this point the complete design must be reviewed. The logic for each substep should be scrutinized objectively to insure that the developed subsystem will accomplish the mission for which it was designed. The result of this step is the best possible subsystem under the minimum restrictions imposed in Step 1 or Step 1A.

Step 3: Ideal Subsystem Degradation

The purpose of this step is to degrade the subsystem by applying the constraints under which it will operate. To accomplish this, the designer must determine the actual conditions for operation. This may involve more detailed investigation of the organization. All internal elements must be considered. The economics, managerial policies, and the psychological effects of the subsystem on the organization may levy restrictions on the design.

The designer should collect data which will describe the subsystem operation. This data should reflect only sufficient information to represent statistically the operating conditions. The purpose is not to define the conditions completely but only to answer pertinent questions or to gather absolutely necessary data.

With the collected data, the additional constraints and the developed subsystem, construct a model of the information subsystem. This model should portray the operating conditions as realistically as possible. Through the use of this model and either manual or computer simulation, the feasibility of the subsystem can be determined by comparison to the stated goals.

During the initial simulation runs, the performance response must be to the left of or on line C_1C' in Figure 8 in order to satisfy the constraints. If the response is on the constraint line, then the scarce resource is being fully utilized. If the response is to the left of C_1C', then the resource is not being fully utilized. When this occurs, additional simulations should be conducted to determine the response at full utilization. These responses will sketch a portion of the performance curve for the subsystem.

Three cases may occur as indicated in Figure 8. In Cases I and II the subsystem is feasible because the performance response exceeds or equals the minimum acceptable level at full utilization of the resources. Case I is feasible over a range of constraint values (i.e., C_2 to C_1). The performance curve for Case I can be determined by additional simulation with the model. Case II represents a limit point of the feasible set. Case III is infeasible since the performance level is below the minimum acceptable at full utilization. If Case III occurs, the subsystem can become feasible by relaxing the constraint to any level equal to or greater than C_3 as shown in Figure 8.

Case I presents a situation in which a trade-off between performance and constraint levels must be made by management. The designer should prepare for this contingency by simulating at sufficient levels to sketch the shape of the performance curve in the feasible region. This additional information would assist the manager in making his decision.

If the subsystem is feasible, the designer should proceed to review the design in Step 4. If the subsystem is not feasible, determine which constraint is causing the infeasibility. This may require additional simulation under varying conditions. The end result may indicate that none of the constraints alone is causing the problem. This will require recycling the design process back to Step 1A to reconsider the

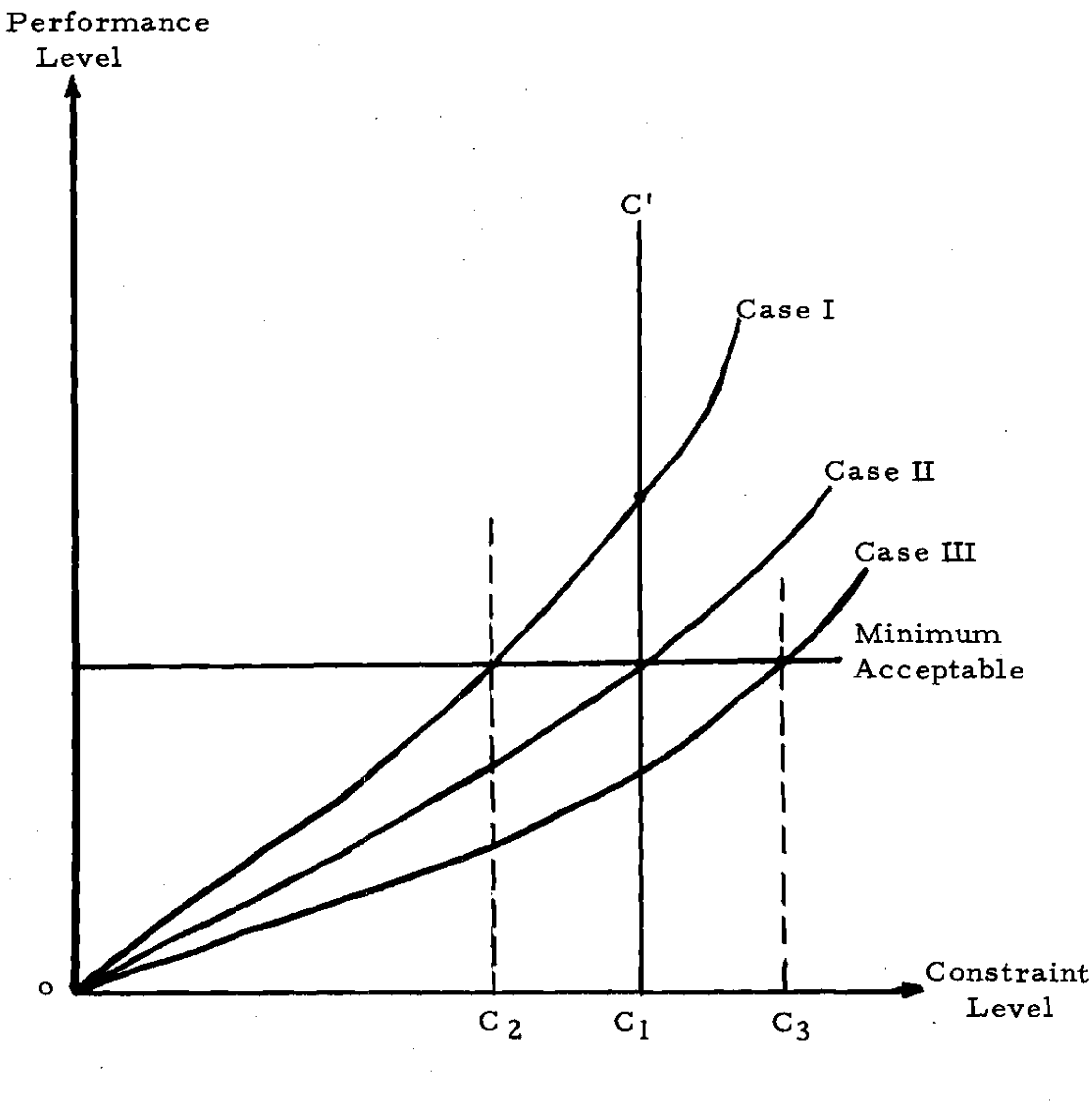


Figure 8. Performance Curves

specified subsystem missions and goals.

If the dominant constraint causing infeasibility was added during Step 3, it may be possible to eliminate or relax that constraint to the point at which the subsystem will again become feasible without recycling to Step 1A. This would require the consent of the management level that levied the constraint. If this case occurs and the constraint can be eliminated or relaxed, reconstruct the model and test for feasibility under all conditions. The end result of this step is a subsystem design that is both practical and feasible.

Step 4: Review the Subsystem Design

The purpose of this step is to review the originally stated missions and goals to insure that the subsystem achieves these. This requires a detailed check of each mission under all expected operating conditions. Additional simulation runs may be required to insure accomplishment under all extremes.

A complete check of the logic may illustrate any substitutions or omissions in the design. If any errors are located, they must be corrected, and the performance of the subsystem must be checked. If the subsystem functions as desired, present the proposed design to management. If the subsystem fails to operate as desired, then go back to Step 1A.

This step represents one of the design method's major interfaces with the organizational management. Once this step is completed and presented to management, the process is temporarily out of the designer's control. The proposed design will be returned from management as approved, disapproved, or modified. If approved, then the design method proceeds to Step 5. If it is disapproved, then the process terminates at this point. If the proposed design is modified by management, the designer should recycle the method to the appropriate step (Step 1A or Step 3c) and continue.

Step 5: Implement the Subsystem

This step consists of three broad categories of action. The first is thoroughly planning for the installation and implementation of the information subsystem. This area incorporates activities such as the development of time tables for installation, plans for hiring and training personnel to assume duties in the subsystem or retraining present organizational personnel, planning time schedules for subsystem equipment procurement and installation and the method and timing by which the subsystem becomes operational. These planning activities are conducted in conjunction with the organizational management.

The second major area of consideration is preparation for installation. This consists of actions carrying out the previously developed plans. Many of these activities will be executed simultaneously. The organization must prepare for installation in numerous ways. Prior to installing the subsystem, it must be documented. Depending on the size and complexity, this could be a major task. This documentation must detail how the subsystem will operate, how each functional unit and management control center are related, and what the subsystem mission and operating procedures are to be. This documentation might include manuals or texts to assist in training operators. Operators must be trained; equipment and materials necessary for operation must be prepared and installed; and the organization must be educated in the use of the subsystem and psychologically prepared for its installation. This last consideration may have a major bearing on the success of the subsystem in operation. Proper planning and preparation will facilitate an easy transition to the new subsystem with minimum confusion.

Upon completion of the preceding activities, the subsystem can be installed. It may be installed at one time or time phased. Management may require pilot subsystems prior to full implementation. After the subsystem is installed and is working, the designer's efforts must not terminate. Problems and inconsistencies must be eliminated, and improvements to the subsystem may be considered and tested. Design is a continuous iterative learning process, and improvements on the old subsystem can be made based on the experience and knowledge gained from previous iterations.

Design Method Limitations

This design method is for an information subsystem operating within a management information system. The methodology is complete for the internal specification of the subsystem but does not consider the interfaces and interactions with other subsystems in the management information system. This is a design limitation, although one that can be handled adequately in the planning for and implementation of the total system.

The designer's creative ability is a limiting factor in the use of this method. The ability to create useful results from an unstructured problem area cannot be fully systematized. Ingenuity and creativity in accomplishing Step 2 are within the designer's domain. His ability to enumerate and evaluate possible subsystem solutions in that step may produce quick satisfactory results to the design problem or may result in an unproductive effort.

The designer's relationship to the organization may also be a limiting factor. An outside consultant may not fully understand the importance of the subsystem missions and goals at the outset. Thus, he would require a longer time to develop a subsystem solution. A system designer within the organization may be too intimately involved with the system to suppress his own subjective opinions of how the system should be developed and operated. This inability to evaluate objectively the subsystem may detract from the use of the method.

Perhaps the greatest limitation of this method is the assumption that management can enumerate explicitly all subsystem missions, goals, and constraints. If management could fully specify these, the methodology would move quickly to a solution. However, it is felt that the exact missions and goals of the subsystem would be developed through reconsideration and modification of the originally stated missions and goals.

Design Summary

This design method provides guidelines for designing an information subsystem. These guidelines are internally consistent and can be applied to any information subsystem ranging from trivial to complex. This method was originally developed to design a specific information subsystem for the evaluation and integration of information. However, the generality of the concepts and definitions and the resultant method allows for its adaptation to the design of any type of information subsystem. These basic concepts and definitions could be expanded into a methodology for developing the full management information system.

The design method is an iterative learning process. It is highly unlikely that the first iteration would produce a feasible subsystem design solution. Several iterations through the process would insure that all performance goals were met or exceeded and that the best possible design under the restrictions would be developed.

For original design projects with no existing system, the method commences at Step 1. For corrective or improvement design projects, the method commences at Step 1A and considers the existing subsystem as an infeasible project solution from Step 3. By starting the design method at Step 1A, the full power of the method can be applied to the problem.

Step 1 or Step 1A provides the basis for the subsystem in the statement of missions and goals. Step 2 develops the ideal subsystem based on Step 1 or Step 1A. Step 3 models the constrained subsystem and tests it for feasibility. Step 4 reviews the complete design process and presents it to management. Step 5 implements the subsystem design. The developed method is summarized below and in Figure 9.

Step 1: Define the Subsystem

a. Specify the subsystem to be developed.

b. Enumerate the missions and goals of the subsystem and each echelon.

c. Determine the impact of the organizational hierarchy on the accomplishment of the subsystem missions.

d. Ascertain the set of classes of action necessary to accomplish the subsystem missions.

e. Determine the set of sequences of operations for each class of action.

f. Determine the minimum restrictions on the subsystem.

g. Go to Step 2.

Step 1A: Redefine the Subsystem

a. In conjunction with management, reevaluate each originally stated mission, goal, and restriction to determine which can be eliminated, reduced, or modified. If the missions and goals can be reformulated, continue; otherwise, terminate the project.

b. Determine the impact of the organizational hierarchy on the accomplishment of the revised subsystem missions.

c. Ascertain the set of classes of actions necessary to accomplish the revised subsystem missions.

d. Determine the set of sequences of operations for each class of action.

e. Restate all restrictions on the subsystem for this iteration; go to Step 2.

Step 2: Design the Ideal Subsystem

a. For each echelon and for each class of action, designate the functional units and levels necessary to accomplish the mission at that echelon under the minimum restrictions of Step 1 for the first iteration and Step 1A for subsequent iterations.

b. Specify the responsibilities and boundaries of each of the functional units.

c. Define the interrelationships between each of the functional units.

d. Determine the relationship and placement of management control centers for each echelon.

e. Specify the flows of information and policies between the echelons.

f. Review the logic and consequences of each of the preceding substeps; complete design; go to Step 3.

Step 3: Ideal Subsystem Degradation

a. Determine the constraints under which the subsystem will operate.

b. Collect data to describe the subsystem operating conditions.

c. Construct a simulation model of the constrained subsystem.

d. Through model simulation, determine whether the subsystem is feasible. If feasible, go to Step 3e; otherwise, go to Step 3f.

e. If feasibility is Case I, determine the feasibility range in terms of performance and constraint levels and then go to Step 4. If feasibility is Case II, go to Step 4.

f. Experiment with the model to determine whether there is a single dominant constraint causing the infeasibility. If there is, go to Step 3g; otherwise, to Step 1A.

g. If the dominant constraint was added in Step 1f or in Step 1Ae, go to Step 1A; otherwise, to Step 3h.

h. Determine whether the dominant constraint can be relaxed or eliminated. If so, relax to the maximum allowable and go to Step 3c; otherwise, go to Step 1A.

Step 4: Review Subsystem Design

a. Insure that the subsystem accomplishes the missions as stated in Step 1 or Step 1A.

b. Review complete design with detailed logic checks for substitutions or omissions in the design; correct errors; verify results.

c. If the subsystem functions as desired, prepare and present the proposed design to management. If it fails to function as desired, go to Step 1A.

Step 5: Implement the Subsystem

a. Plan for the installation of the subsystem.

b. Prepare for the installation of the subsystem.

c. Install the subsystem.

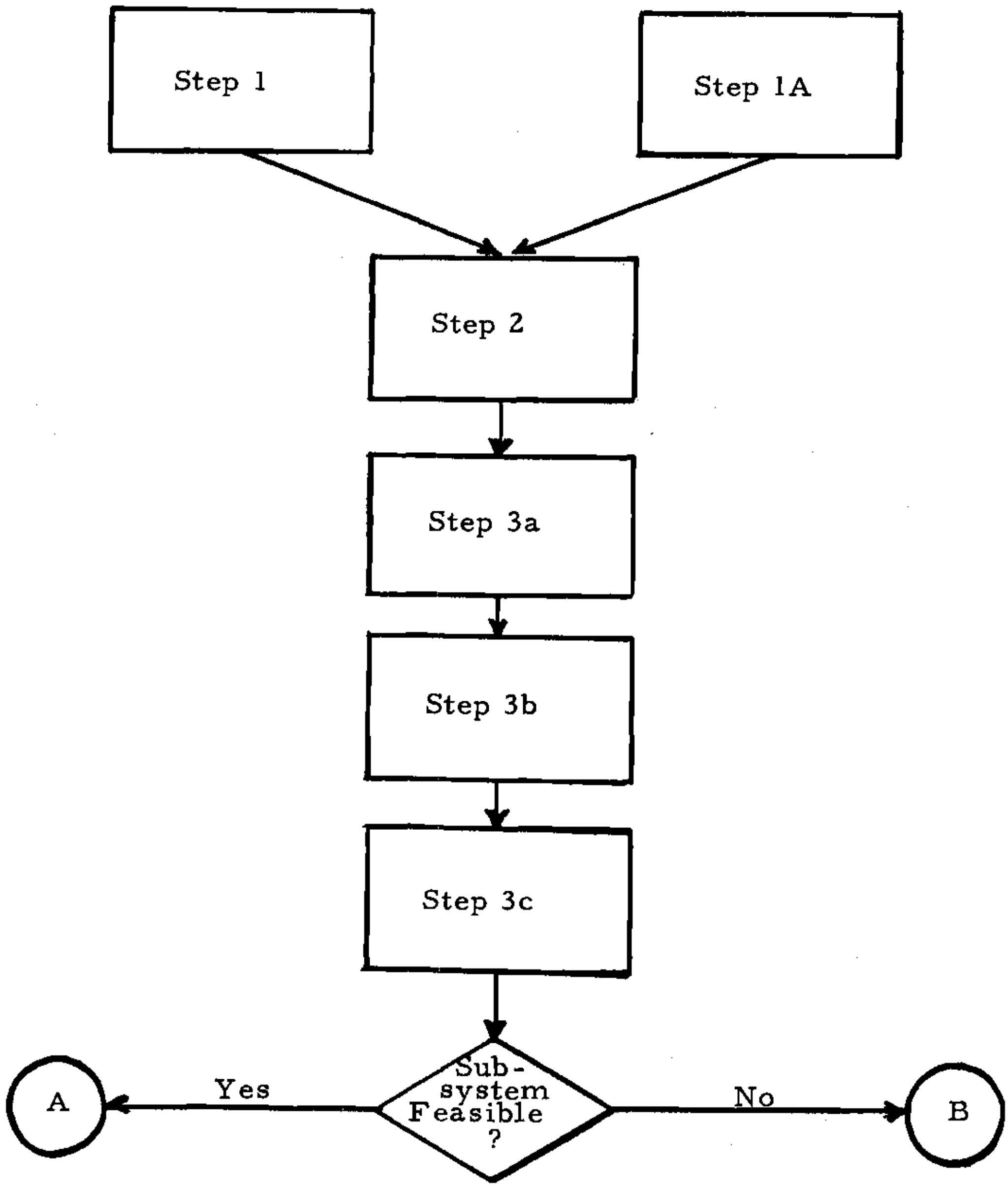


Figure 9. Design Summary

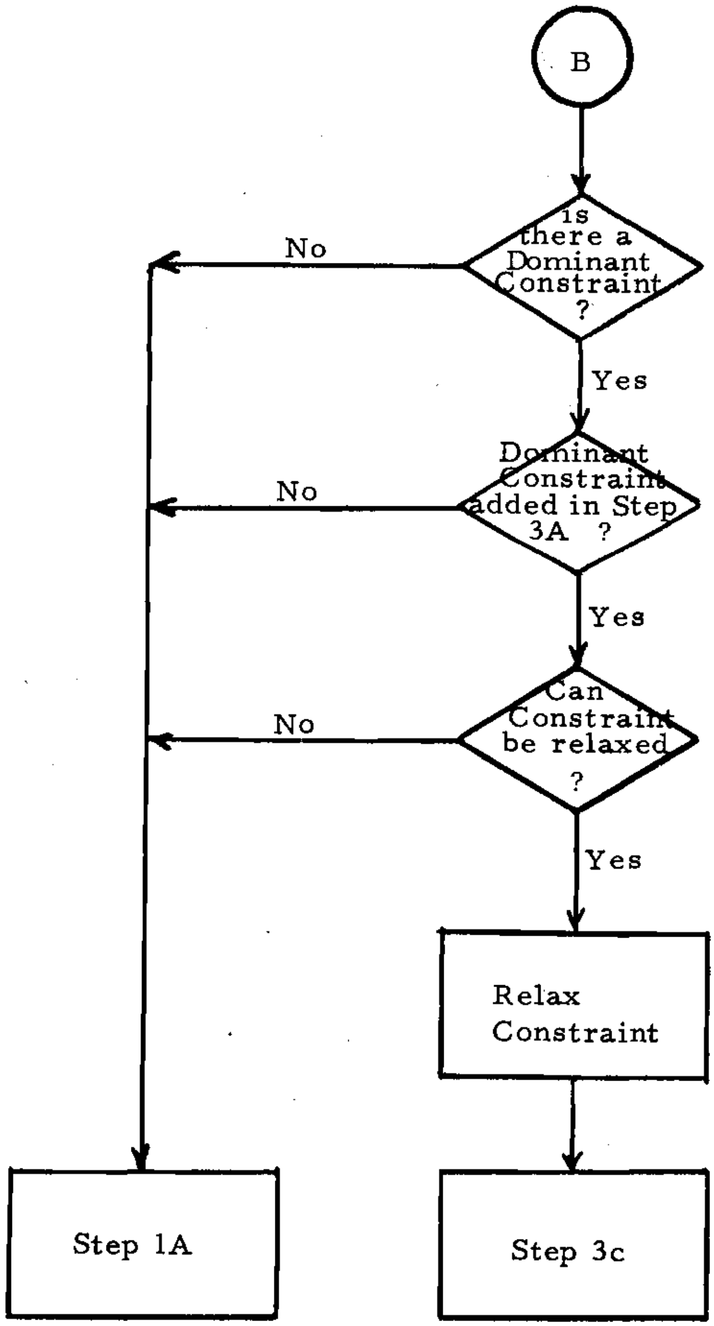


Figure 9. Design Summary (Continued)

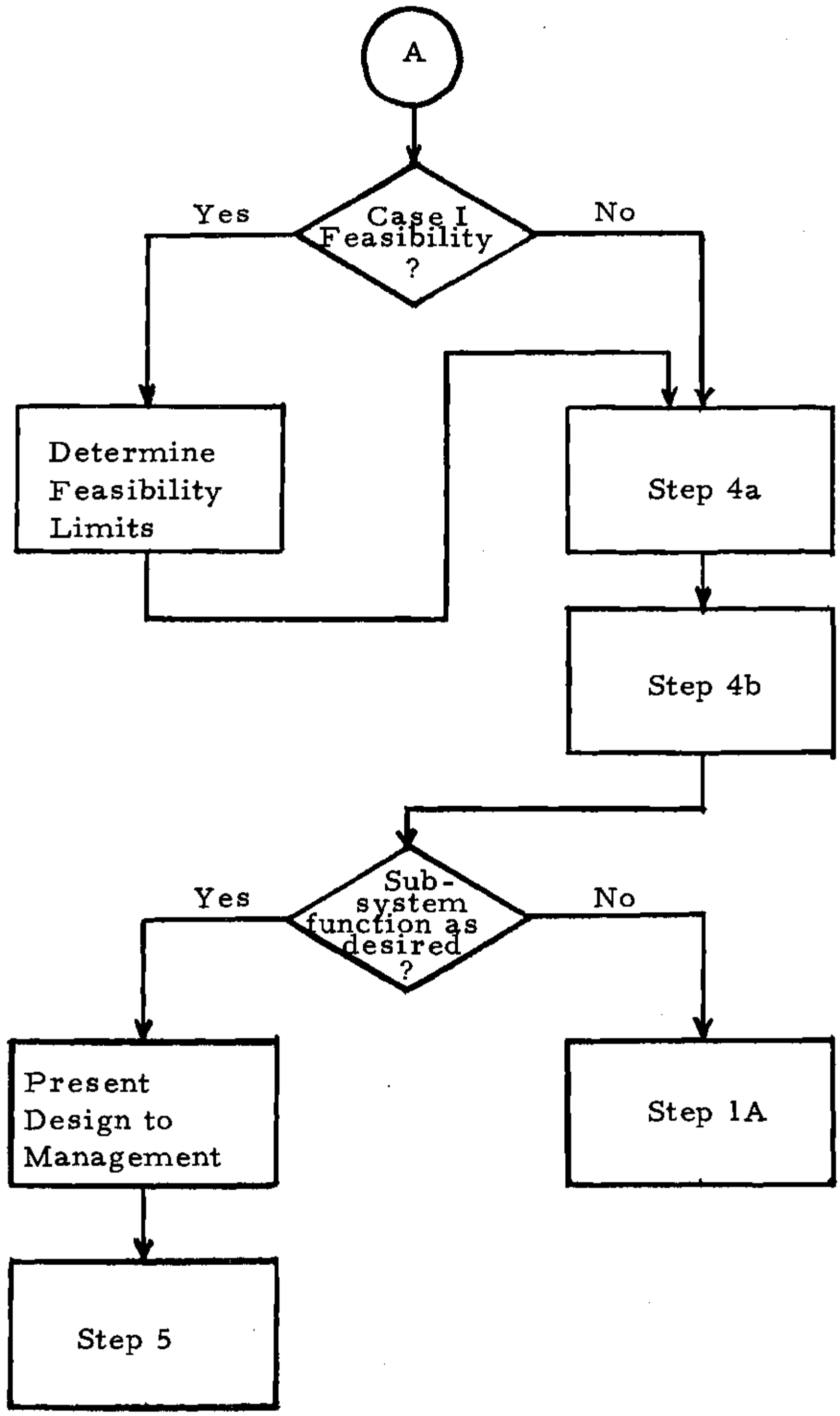


Figure 9. Design Summary (Concluded)

CHAPTER V

ILLUSTRATIVE EXAMPLE

Background Information

The use or misuse of data concerning exogenous events can spell success or resounding defeat for military organizations engaged in combat operations against an active enemy force. The importance of good intelligence has generally been recognized by military commanders since biblical times, but few commanders have had this fortunate resource.

In recent years significant efforts have been made in the area of increasing the capabilities of information collection devices such as radar, television, photography and image interpretation, and automatic recording and reporting sensors (29, p. 313). Despite these hardware advances, the field commander still labored under an "intelligence gap" because the organizational structure and governing doctrines of the supporting military intelligence units were not responsive to the information needs of the combat commander (30, p. 1-2).

Combat intelligence is that knowledge of the enemy, weather, and geographical features required by a commander in the planning and conduct of tactical operations (31, p. 5). The objective of combat intelligence is to minimize the uncertainties of the effects of enemy capabilities, weather, and terrain on the accomplishment of the friendly unit mission. The commander employs combat intelligence to determine the best use of his available resources and to accomplish his mission and maintain the security of his command (31, p. 5).

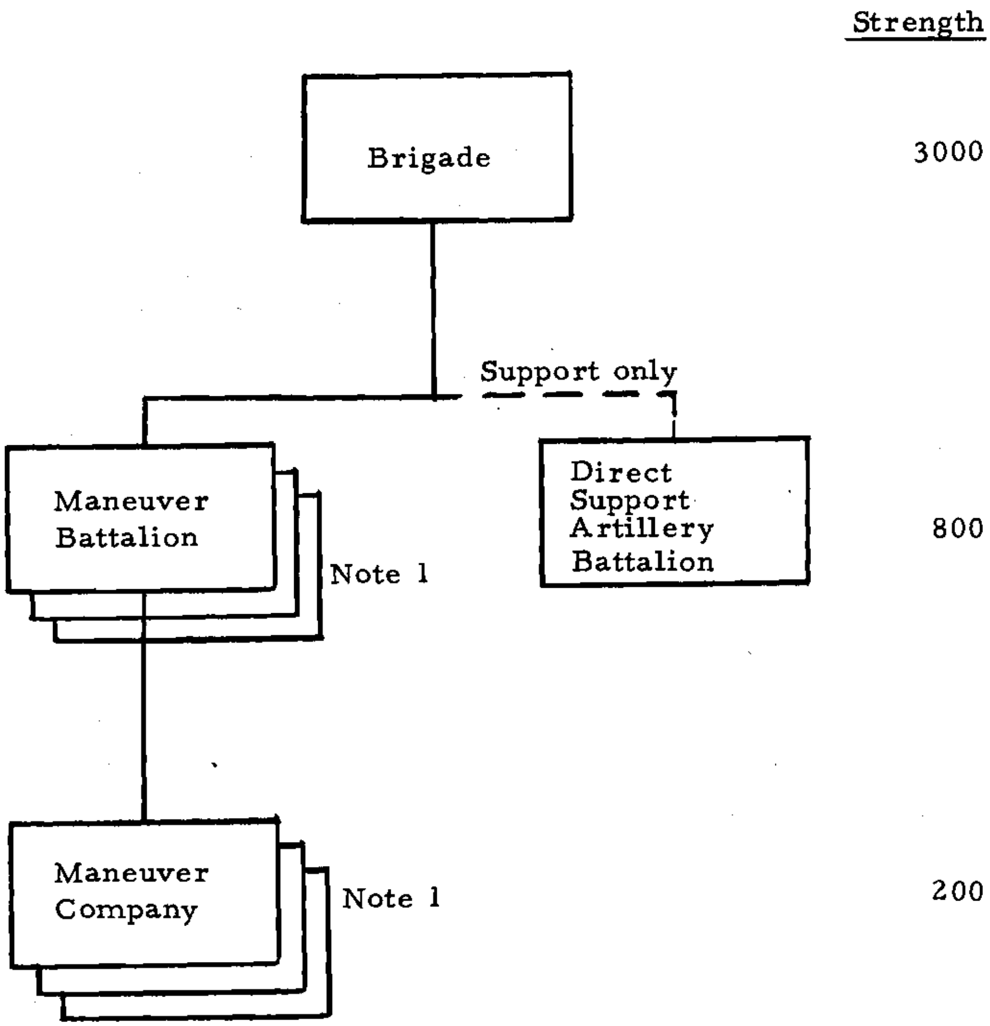
Sources which furnish data about the enemy, weather, and terrain are numerous, and the availability of new, more sophisticated devices is growing constantly. A partial list of these sources may include: friendly and allied combat units; captured enemy prisoners, documents, and equipment; ground and aerial reconnaissance and surveillance; electrical, mechanical, acoustical, and seismic detection devices employed by collection agencies; and espionage and counterespionage agents. This list of sources could be expanded further by enumerating the different devices in each of these categories.

Despite the diversity of collection sources and means, these sources have several common characteristics. First, they furnish the military organization with one or more of the classifications of information as discussed in Chapter III (e.g., basic descriptive, current estimate, or speculative). Secondly, the data which is furnished is of variable quality. The five desirable characteristics of intelligence rarely occur simultaneously.

The intelligence system to be discussed here will deal with a brigade-sized force. The organization of this combat force is illustrated in Figure 10. The approximate manning strengths of each element of each echelon is indicated to give the reader a feeling for the size of each element. It might also be noted that the composition of a brigade is variable in that it may control from two to five separate maneuver battalions. The normal configuration of three battalions will be used here.

The type of organization depicted uses numerous information subsystems. The brigade echelon operates a management information system consisting of information subsystems for major functions such as personnel/administration, operations, logistics, and intelligence. The battalion echelon operates similar information subsystems within its organic management information system. The battalion and brigade echelons have a staff section which handles each one of the information subsystems. The intelligence officer and his section at the battalion and brigade echelons are responsible for processing data into intelligence for use by the commander in his decision-making process. The company echelon does not have an intelligence officer. The system at company level is operated as required by the commander. The company echelon handles only a low volume of traffic about the environment, and the spectrum of interest is extremely limited. Any information concerning exogenous events that would affect the organization are transmitted through the operations information subsystem to the intelligence officer at the battalion echelon.

U. S. Army doctrinal material (31, 32) contains general guid-



Note 1: Same as the unit shown in detail.

Figure 10. Type Brigade Organization

ance on the processing methods to be used. However, in practice the methods have been left almost completely to the ingenuity of the intelligence officer. An attempt at rectifying this situation was conducted by the U. S. Army Combat Developments Command in 1967 (33). This study attempted to determine the essential battlefield information required by the combat commander, the optimum operational and organizational concepts for collecting, processing, and disseminating information and intelligence (32, p. 1-2). The study synthesized an intelligence system which would overcome the known existing weaknesses in the system. The new intelligence system was named the Battlefield Information Control Center (BICC).

The BICC system was field tested in Vietnam during 1968 with one of the units operating in that low intensity conflict situation.* The field test indicated that the BICC functioned as designed and was considered successful. This field test's success raised the question of the viability of the concept in the more demanding mid- and high-intensity conflict situations.**

Major Edward Maddox (34) conducted a computer simulation of a brigade-sized force operating with a BICC system under mid- and high-intensity situations. He concluded that under those conditions the BICC system became overloaded and was incapable of handling the ex-

*Low intensity refers to a counter-insurgency conflict.

**Mid and high intensity refer respectively to a mobile, conventional war and nuclear war.

pected information-processing load.

The information subsystem subsequently developed will use the method developed in the preceding chapter and the same mission and functions upon which the BICC system was based. No further reference will be made to the BICC. For a full description of its operations, see Maddox's thesis (34).

Intelligence Subsystem Development

The design problem is to develop an intelligence subsystem using the method of the preceding chapter. This example will serve to illustrate the practical meanings of the definitions used in the method and will serve to illustrate the use of the method in the solution of a corrective design problem. This example will not complete the cycle through the design method but will terminate when the concepts and method have been illustrated adequately.

Step 1Aa

The subsystem to be developed is a combat intelligence subsystem to operate within the type of brigade organization shown in Figure 10. This intelligence subsystem performs the tasks involved in an operational function called combat intelligence production.

The mission of the subsystem at the battalion echelon is "to produce timely and valid combat intelligence for use as a basis for command decisions (30, p. 4-17)." The mission of the subsystem at the brigade echelon is "to collect, process, and disseminate timely and valid combat intelligence for use as a basis for command decisions (31, p. 4-3)." Despite the differences in wording, the missions of both echelons are essentially identical. The only difference will be that the scope of interest of the brigade subsystem will be wider. This difference will become apparent in the discussion of the classes of action and sequences of operations necessary to accomplish the respective missions.

The company echelon does not have a stated intelligence mission. Therefore, further consideration will be directed only at the battalion and brigade echelons.

The goals common to the battalion and brigade echelons are that those subsystems must:

a. Be capable of operating under low-, mid-, and high-intensity conflict situations;

b. Process messages of the four standard military precedence designations;

c. Be capable of processing the estimated daily message volume according to the general time guidance contained in doctrinal literature.

An additional goal is included for the brigade echelon since it is the apex of the intelligence subsystem within the brigade organization. The brigade subsystem must produce target development information in accordance with the general time guidance contained in doctrinal literature.

These four goals are the framework for the measures of performance to be used in determining the feasibility of the subsystem in Step 3. The following comments will serve to quantify these goals. Under all conflict intensities, the message interarrival times are exponentially distributed with a mean calculated to yield the message volumes in Table 1. When testing in Step 3, each intensity and echelon must be tested to insure that the developed subsystem is capable of processing the mean number of messages for those conditions.

The second goal indicates precedences for messages. These precedences are explained in Table 2. This message structure imposes a priority service discipline on the subsystem. Precedence 4 messages constitute 15 per cent of the total message volume; Precedence 3, 5 per cent; Precedence 2, 10 per cent; and Precedence 1, 70 per cent (34, p. 64).

The third goal prescribes a time limitation on the subsystem. These time limitations are illustrated in Table 3. The transit time indicates the time interval from data receipt to intelligence transmission to users. The processing time indicates the time interval in which data is transformed into intelligence. The last goal, which is applicable to brigade only, is due to the brigade's position of superiority in the organizational hierarchy. This target development is also subject to the

Table 1

Estimated Daily Message Volumes (32, p. B-II-2)

Echelon	Intensity	Mean
Brigade	Low	606
Battalion	Low	282
Brigade	Mid	895
Battalion	Mid	444
Brigade	High	1021
Battalion	High	504

Table 2

Precedence Designations (35, p. 42)

Precedence	Procedure Number	Description
FLASH	4	Operational combat message of extreme urgency. This message will be transmitted ahead of all other messages. Messages of lower precedence will be interrupted.
IMMEDIATE	3	The precedence reserved for messages which relate to situations which gravely affect the security of national/allied forces or populace and which require immediate delivery to the addressee. This type of message is transmitted ahead of all other messages of lower precedence even to the extent of interrupting processing and transmission of lower precedence messages.
PRIORITY	2	The precedence reserved for messages which require expeditious action by the addressee and/or furnish essential information for the conduct of operations in progress. This type of message will be transmitted ahead of all other messages of lower precedence, except that routine messages being transmitted will not be interrupted unless they are long.
ROUTINE	1	This precedence is to be used for all types of messages which justify transmission by rapid means unless of sufficient urgency to require a higher precedence. This type of message will be transmitted after all messages of higher precedence.

Table 3

Transit and Processing Times (36)

Precedence	Precedence Number	Maximum Mean Processing Times	Maximum Mean Transit Times
FLASH	4	As fast as possible	As fast as possible
IMMEDIATE	3	30 minutes	Not more than 45 minutes
PRIORITY	2	2 hours and 30 minutes	Not more than 3 hours and 45 minutes
ROUTINE	1	5 hours and 30 minutes	Not more than 6 hours

same time-processing guidelines mentioned above.

Step 1Ab

The impact of the organizational hierarchy for this example is minimal since the subsystem is small, the organization is single purposed, relatively flat, and has only three echelons. The major impact derives from the fact that the company echelon will not possess a formal intelligence subsystem. This may affect the timeliness and adequacy of the subsystem accomplishing its stated goals.

Step 1Ac

To produce intelligence useful to the commander, raw data must be obtained from the sources available to the subsystem and the plans for additional data collection must be generated; this data must be transformed into intelligence; periodic reports and event-triggered reports must be prepared; these reports and plans must be distributed to the appropriate units or commanders for use in decision making. This logical expansion of the "intelligence production operational function" illustrates the nature of this substep.

The number of classes of action is rather dependent on the way these classes of action have been defined above. If the last two classes above had been defined differently, only three classes of action would result. However, this author will consider four classes of action on this iteration. These will be designated as: data collection, processing, reporting, and dissemination. These classes of action are the same for battalion and brigade.

Step 1Ad

In this substep each class of action for each echelon defined in Step 1Ac must be expanded to indicate the different sequences of operations inherent in each. At this point there is a transition from a purely general classification of tasks down to specifics. The designer's knowledge of the organization and requirements will affect the explicitness of this substep.

There are two echelons and four classes of action per echelon. Therefore, this step includes the expansion of eight classes of action. Classes of action at the two echelons need not necessarily be the same because of increased number of sources, requirements, or capabilities. The sequences of operations for each class of action are summarized in Tables 4 through 7. These tables indicate that there are more sequences at the brigade because of the wider scope of interest at that echelon. The process of deriving one of these sets of sequences of operations will be illustrated. The others are similarly derived, but will only be summarized in the tables previously indicated.

The response to types of data as they pass through the information subsystem may include transformative or regulative actions in one or more classes of action. As data passes through one of these classes of action, a series of operations will transform or regulate its flow out of this class of action and into another or out of the subsystem. Different types of data will elicit different sequences of operations to transform or regulate this flow. Thus, this step requires the designer to develop an understanding of the types of data entering each class of action. If the response to two types of data are the same or similar sequences of operations, then the two sequences should be combined into one.

The processing class of action at battalion will illustrate the division into sequences of operations. Data received by the subsystem must be evaluated and/or integrated with other known data, information, and intelligence. Some types of data will need both types of actions whereas other types of data will require only one or the other types of actions.

A brief description of the types of data entering the processing class of action will be useful at this point. The battalion periodically (either every 12 or 24 hours) receives an intelligence summary (INTSUM) from brigade. This is a document summarizing all of the detected enemy activities during the reporting period. Spot reports are event-triggered reports which are received randomly. These include such items as enemy sightings, enemy contacts, and detection devices sensings. Situation reports indicate the status of the battalion's companies. These are periodic verbal reports. Order of battle data is received randomly and provides information about enemy personalities. Intelligence estimates (Definition 8) are random reports indicating the brigade's judgment of future enemy activities. These are normally issued only when a change occurs.

In response to these types of information, the sequences of operations can be designated (see Figure 11). The processing class of action consists of a set of eight sequences of operations. Each of these sequences is a series of operations. For example, the sequence of operations entitled "evaluate spot reports" may consist of the following operations: (a) record report in log, (b) check situation map to determine accuracy and urgency of information, (c) if urgent, disseminate immediately, and (d) if not urgent, apply rating and post information in appropriate file. A particular sequence of operations may be used also for several types of information. For example, the same sequence is used to transform or regulate the flow of enemy observations, aerial R & S reports, and enemy bombing, mortaring, or shelling reports.

The set of eight sequences of operations constitute the tasks inherent in the accomplishment of the processing class of action. If all of the elements of this set can be performed, the class of action then can be realized. This initial set may be found inadequate during testing and thereby may require alteration on later iterations.

Step 1Ae

The minimum or nonarbitratable restrictions on this subsystem are:

a. The subsystem must be capable of sustained 24-hour-a-day

Sequence of Operations

Processing Class of Action

1. Evaluate Spot Reports
2. Evaluate Situation Reports
3. Evaluate Order of Battle Information
4. Integrate Spot Reports
5. Integrate Situation Reports
6. Integrate Order of Battle Information
7. Integrate Brigade Intelligence Estimate
8. Integrate Brigade Intelligence Summary (INTSUM)

Sequences of Operations

Figure 11. Sequences of Operations of the Processing Class of Action

operation.

b. The resulting organizational units of the subsystem must be capable of dividing into two smaller units and operating separately without loss of subsystem-operating characteristics for time periods not to exceed 12 hours.

c. The company echelon will not possess an intelligence subsystem.

d. The subsystem is to be designed for manual operation.

Steps 2a, 2b, and 2c

Up to this point, we have considered only a structuring of tasks needed to accomplish the subsystem missions and goals. At this point, we begin considering what functional units and levels are required to accomplish each class of action. These functional units and levels are decision variables. Once these are designated, then the flows of information between levels are fixed.

For this example we must consider eight combinations of echelon and class of action. One of these will be developed in detail, and the others will be summarized in later illustrations. All eight combinations are developed in a similar manner.

For a particular type of data, information or intelligence which must be processed through a class of action, a particular sequence of operations will transform or regulate the flow of this type of data. The way the sequences are defined will indicate the data in-

Table 4

Sequences of Operations of the Collection Class of Action

Number	Sequences of Operations Battalion	Brigade
1	Receive all incoming data, information and intelligence from adjacent units, and higher and lower units	Identical
2	Receive request for information called essential elements of information (EEI) and other intelligence requirements (OIR)	Identical
3	Plan the collection effort	Identical
4	Plan the ground surveillance coverage	Identical
5	Plan for ground reconnaissance and patrols	Identical
6	Request aerial R & S coverage	Identical
7	No requirement	Request image interpretation reports
8	No requirement	Receive request for aerial R & S

Table 5

Sequences of Operations of the Processing Class of Action

Number	Sequence of Operations Battalion	 Brigade
1	Evaluate all incoming spot reports	Identical
2	Evaluate all incoming situation reports	Identical
3	Evaluate order of battle information received	Identical
4	Integrate spot reports into data base	Identical
5	Integrate situation reports into data base	Identical
6	Integrate order of battle information into data base	Identical
7	Integrate brigade intelligence summary into data base	Integrate division and adjacent brigade intelligence summaries into data base
8	Integrate brigade intelligence estimate into data base	Integrate division and adjacent brigade intelligence estimates into data base
9	No requirement	Evaluate all counterintelligence reports
10	No requirement	Integrate all counterintelligence reports into data base
11	No requirement	Evaluate all aerial R & S reports
12	No requirement	Integrate all aerial R & S reports into data base
13	No requirement	Evaluate all target development information
14	No requirement	Integrate all target development information into data base

Table 6

Sequences of Operations of the Reporting Class of Action

Number	Sequence of Operations Battalion	Brigade
1	Prepare spot reports of intelligence resulting from processing incoming data	Identical
2	Prepare reports of circumstances of capture of enemy material	Identical
3	No requirement	Prepare INTSUM
4	No requirement	Prepare intelligence estimate
5	No requirement	Prepare spot reports of intelligence resulting from aerial R & S
6	No requirement	Prepare spot reports of intelligence resulting from counterintelligence efforts

Table 7

Sequences of Operations of the Dissemination Class of Action

Number	Sequence of Operations Battalion	Brigade
1	Disseminate intelligence resulting from processing all incoming data	Identical
2	Disseminate the ground reconnaissance and patrol plan	Identical
3	Disseminate the collection plan	Identical
4	Disseminate the ground surveillance plan	Identical
5	Disseminate request for aerial R & S	Identical
6	Disseminate capture reports	Identical
7	No requirement	Disseminate results of aerial R & S
8	No requirement	Disseminate counterintelligence reports
9	No requirement	Disseminate INTSUM
10	No requirement	Disseminate intelligence estimate

volved. The battalion collection class of action will be considered in detail.

Five types of data require actions of the type performed by the collection class of action. These types of data are: spot reports, situation reports, intelligence summaries (INTSUM), intelligence estimates, and order of battle. From the set of six sequences of operations of this class of action (Table 4), three major tasks can be inferred. These are receiving data, planning collection, and requesting information. Sequences 1 and 2 concern data reception; Sequences 3, 4, and 5 concern planning; and Sequence 6 concerns a request for information. These facts imply that three functional units are needed to perform this class of action. These will be designated: receipt, planning, and requesting.

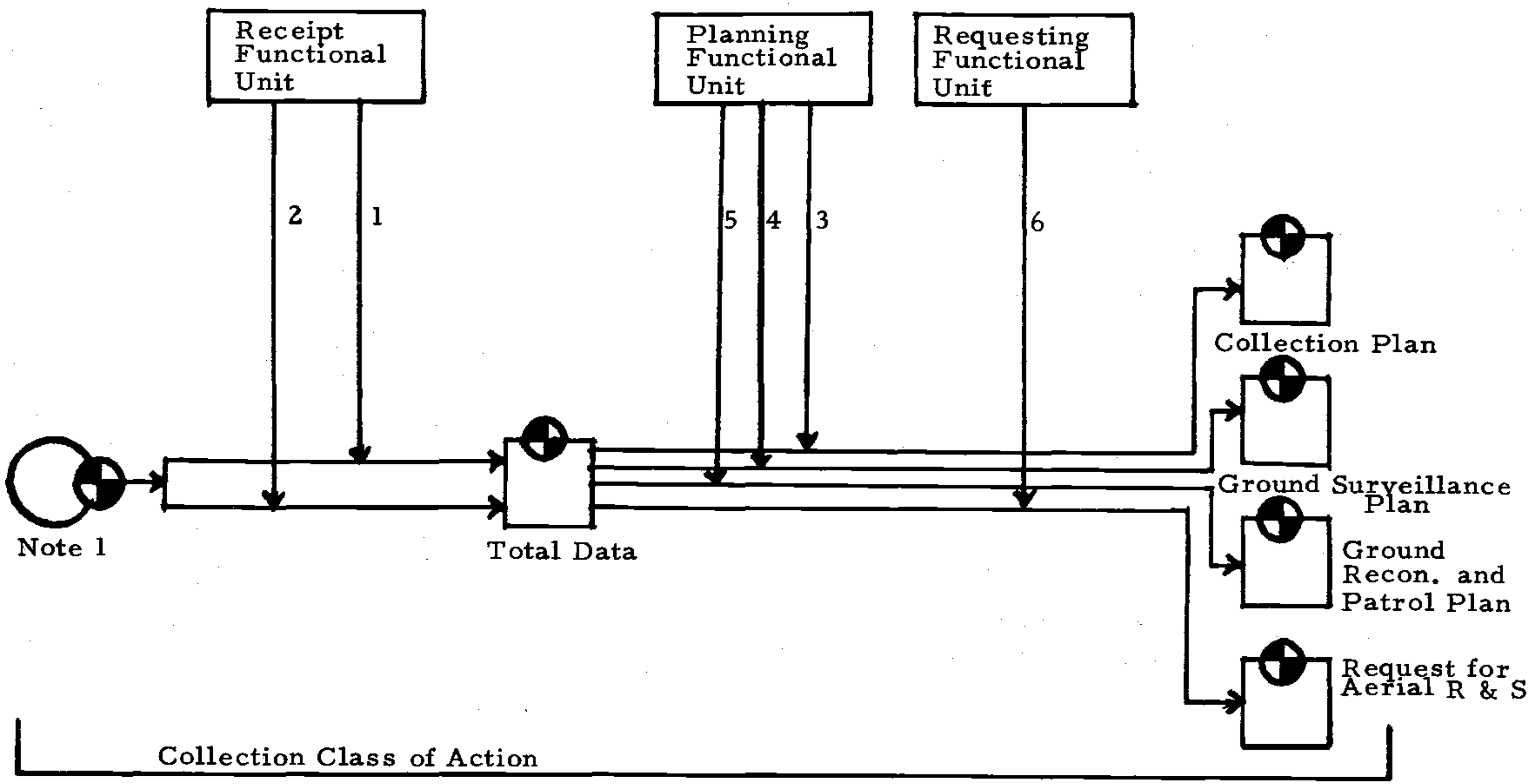
The receipt functional unit regulates the flow of incoming data between the levels of all external sources and a level of this intelligence subsystem which will be called total data. This total data level is the first in the subsystem. It may be considered as a record of all data which has entered the subsystem.

Data in the total data level is tapped by other functional units in the subsystem which need particular types of data. One of these is the planning functional unit. This unit regulates the flow of information between the total data level and the levels it maintains. In planning for the collection of additional information, three levels must be developed. These three levels are derived from the definition of the sequences of operations in the class of action. These three levels are: the collection plan, the ground surveillance plan, and the ground reconnaissance and patrol plan. Information in these levels is the result of the actions performed in transforming data into a plan.

One type of information is transformed from data into a request for aerial R & S by the requesting functional unit. This transformation is carried out by sequence of operations 6. Figure 12 illustrates these results.

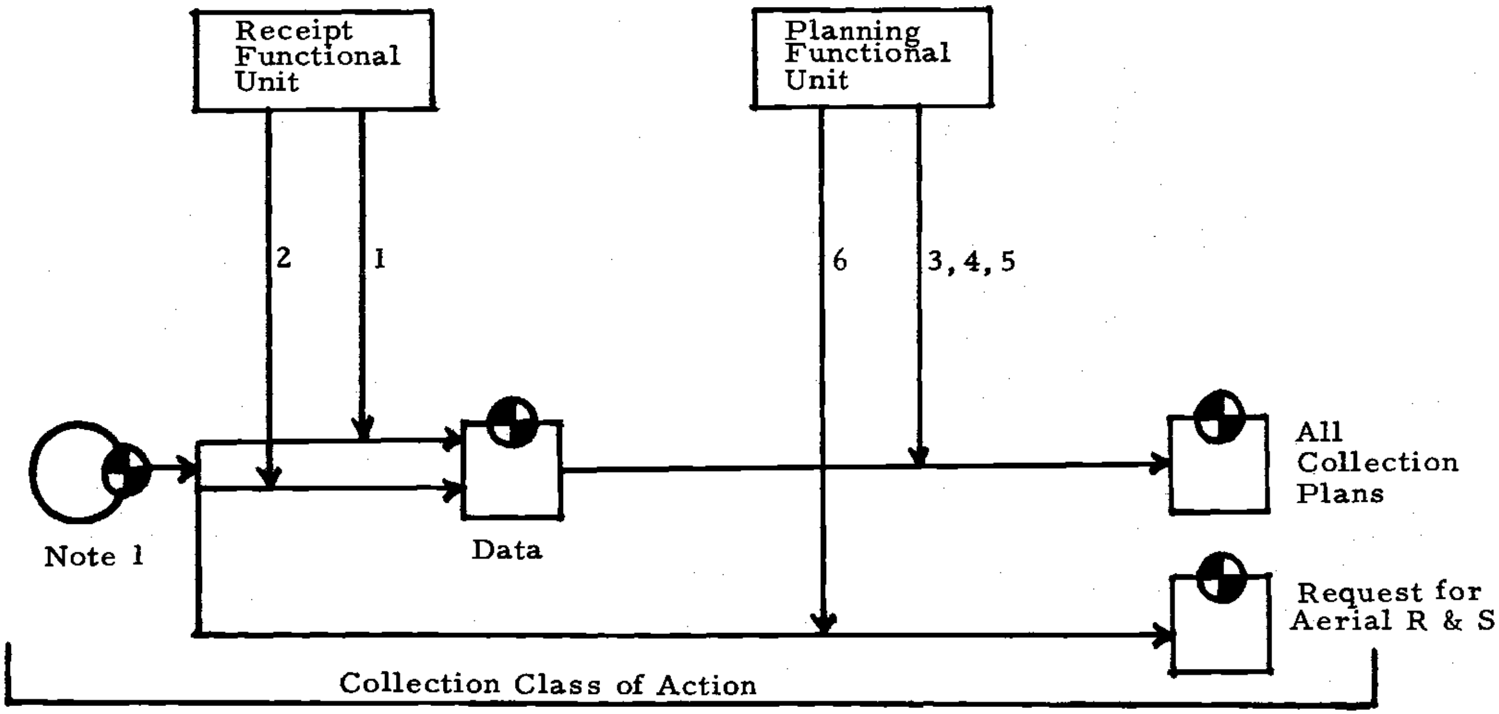
The reader should not infer that this is the only possible arrangement or even the correct one. This is a creative step based on the information developed in Step 1A. Two other possible ways of performing this class of action are shown in Figures 13 and 14. Either of these arrangements could be equally well justified on the basis of sequences of operations.

On the basis of Figure 12, the receipt functional unit regulates the flow of information from external sources to the total data level by taking actions in accordance with either sequence of operations 1 or 2 depending on the type of data entering the subsystem. This functional unit also maintains the total data level. The planning functional unit transforms the information flow from the total data level to one of the three levels that it maintains by taking actions in accordance with sequence of operations 3, 4, or 5 depending on the type of data being trans-



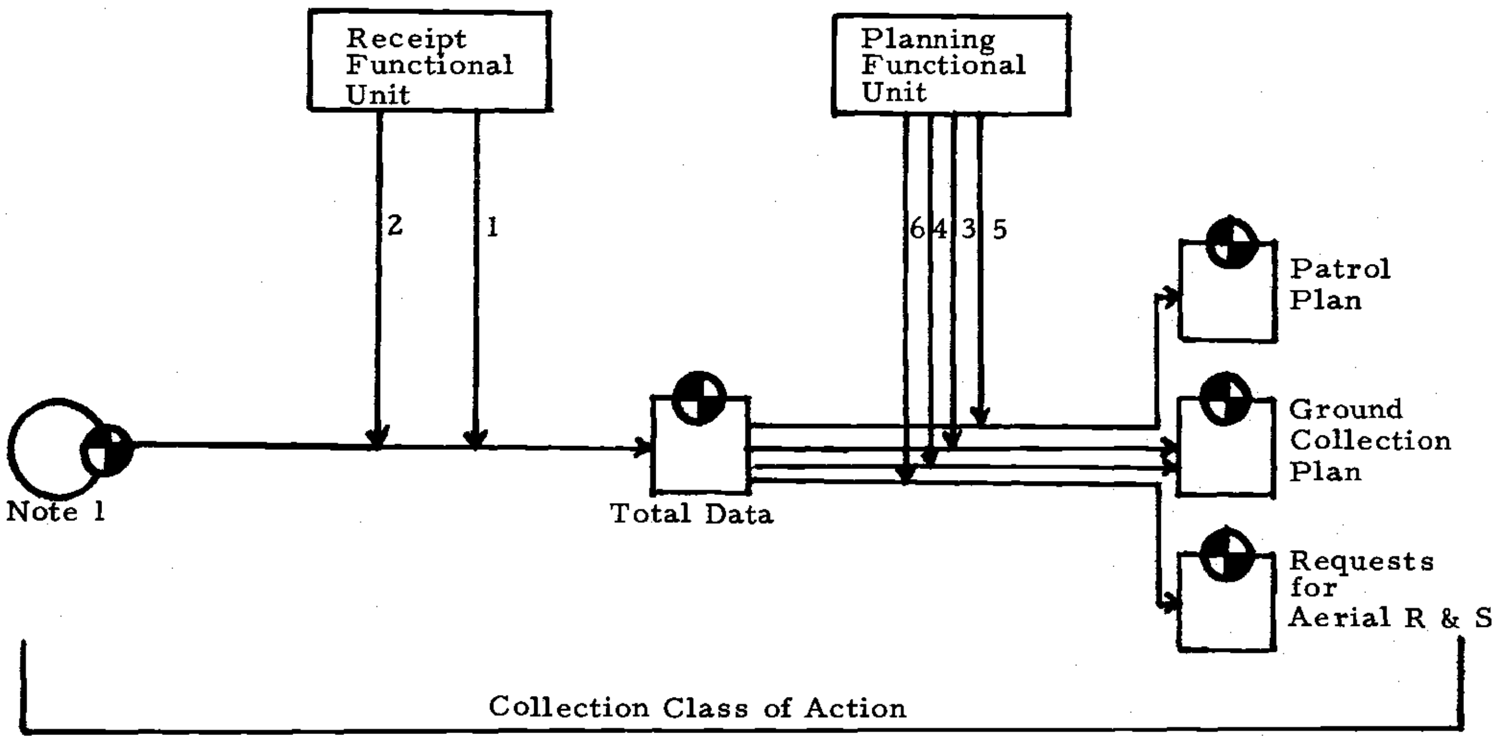
Note 1: Data, information or intelligence from sources external to the subsystem.

Figure 12. Functional Units Performing the Collection Class of Action



Note 1: Data, information or intelligence from sources external to the subsystem.

Figure 13. Alternate 1: Functional Units Performing the Collection Class of Action



Note 1: Data, information or intelligence from sources external to the subsystem.

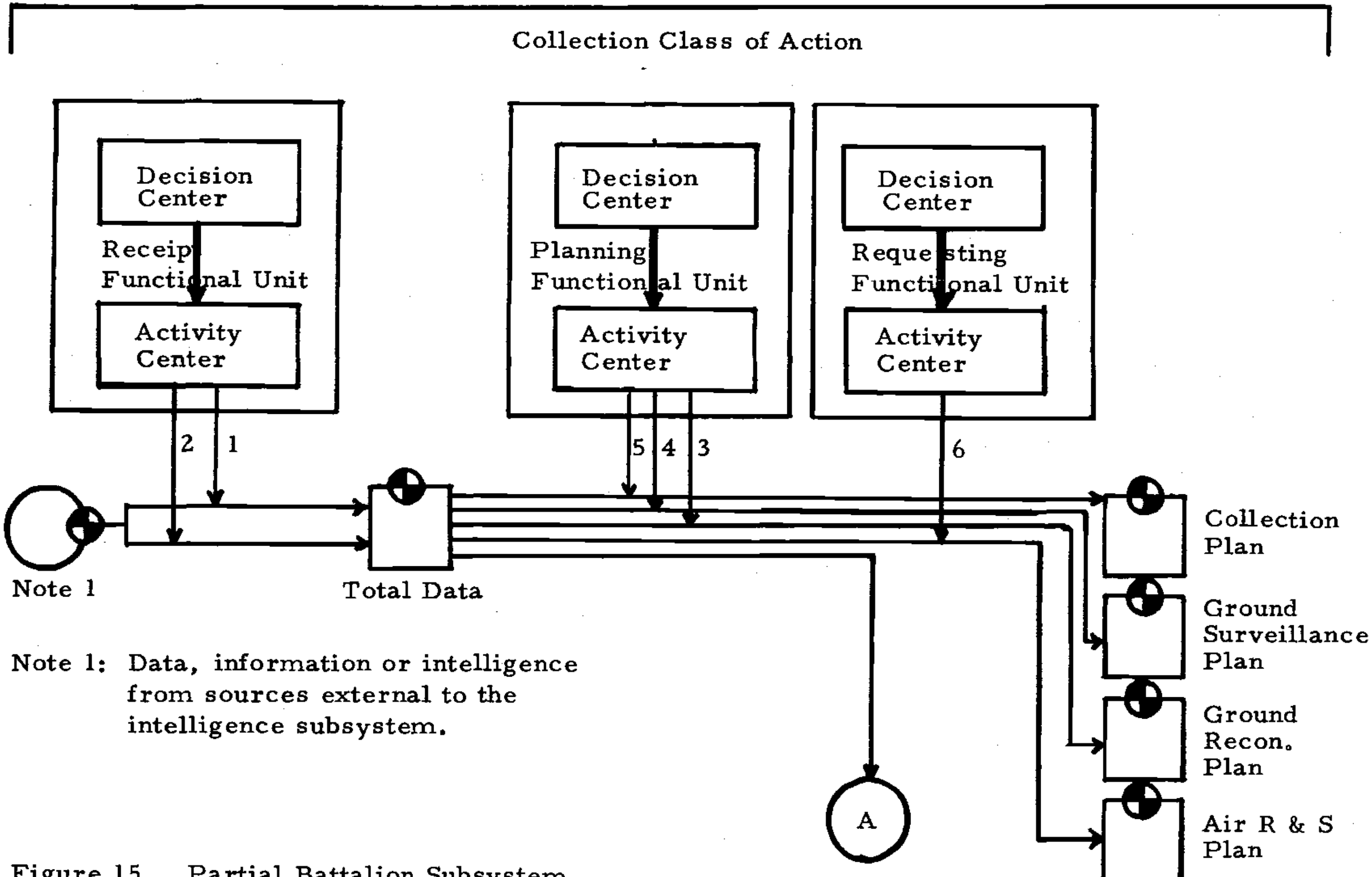
Figure 14. Alternate 2: Functional Units Performing the Collection Class of Action

formed. The requesting functional unit transforms the flow in information from the total data level to a request for aerial R & S by taking actions in accordance with sequence of operations 6. These descriptions of functional units and levels and Figure 12 complete Steps 2a, 2b, and 2c for the battalion collection class of action only. The same procedure is used for the other seven combinations of echelon and class of action. These other combinations are illustrated in Figure 15 for the battalion echelon.

Steps 2d and 2e

Step 2d places one or more management control centers to make decisions for its subordinate functional units when the prescribed decision rules are inadequate or nonexistent. The result of Step 2d will be a schematic model of the intelligence subsystem at battalion echelon and a schematic model of the intelligence subsystem at the brigade echelon. Step 2e connects these two subsystems with flows of information, policy, decision rules, and decisions.

Figures 16 and 17 show the complete intelligence subsystems for battalion and brigade, respectively. These two echelons are connected with the appropriate flows. For specificity the following data capture point (DCP) designation system is adopted. Each DCP of a level is indicated by a five digit sequence, ijklm. The first digit, i, indicates the echelon (1 = brigade; 2 = battalion). The second digit, j, indicates the unit number at echelon i. The brigade is numbered 1



Note 1: Data, information or intelligence from sources external to the intelligence subsystem.

Figure 15. Partial Battalion Subsystem

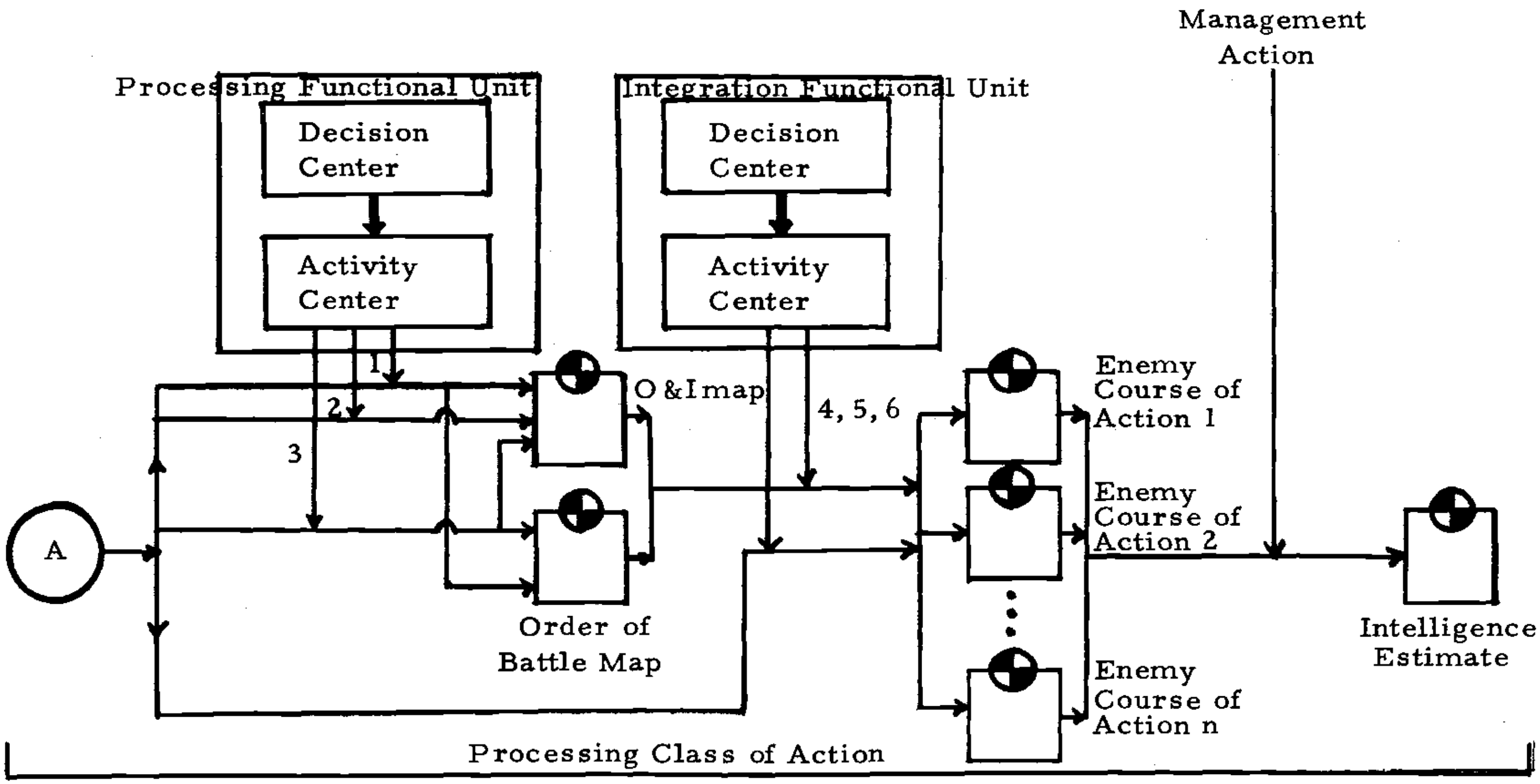
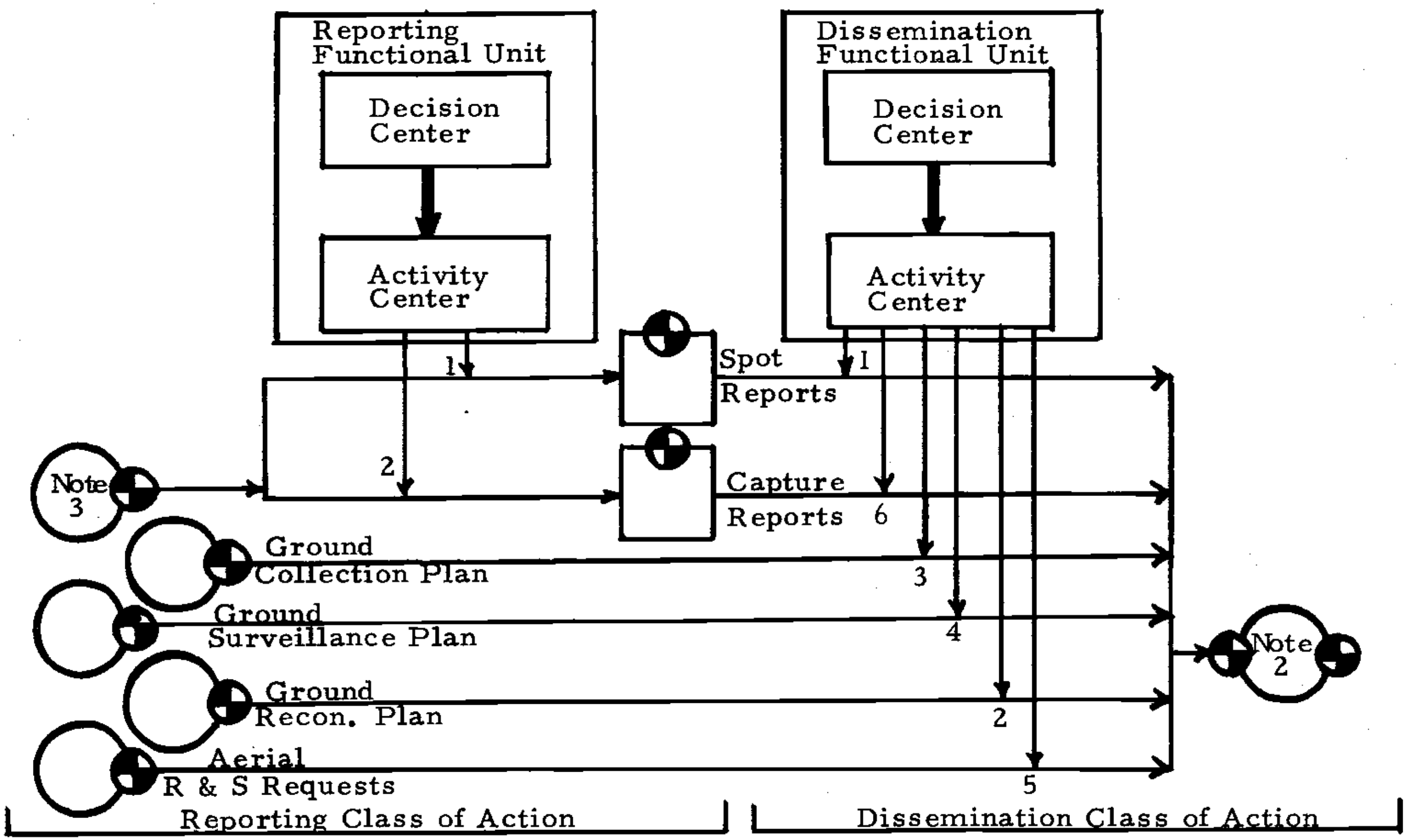
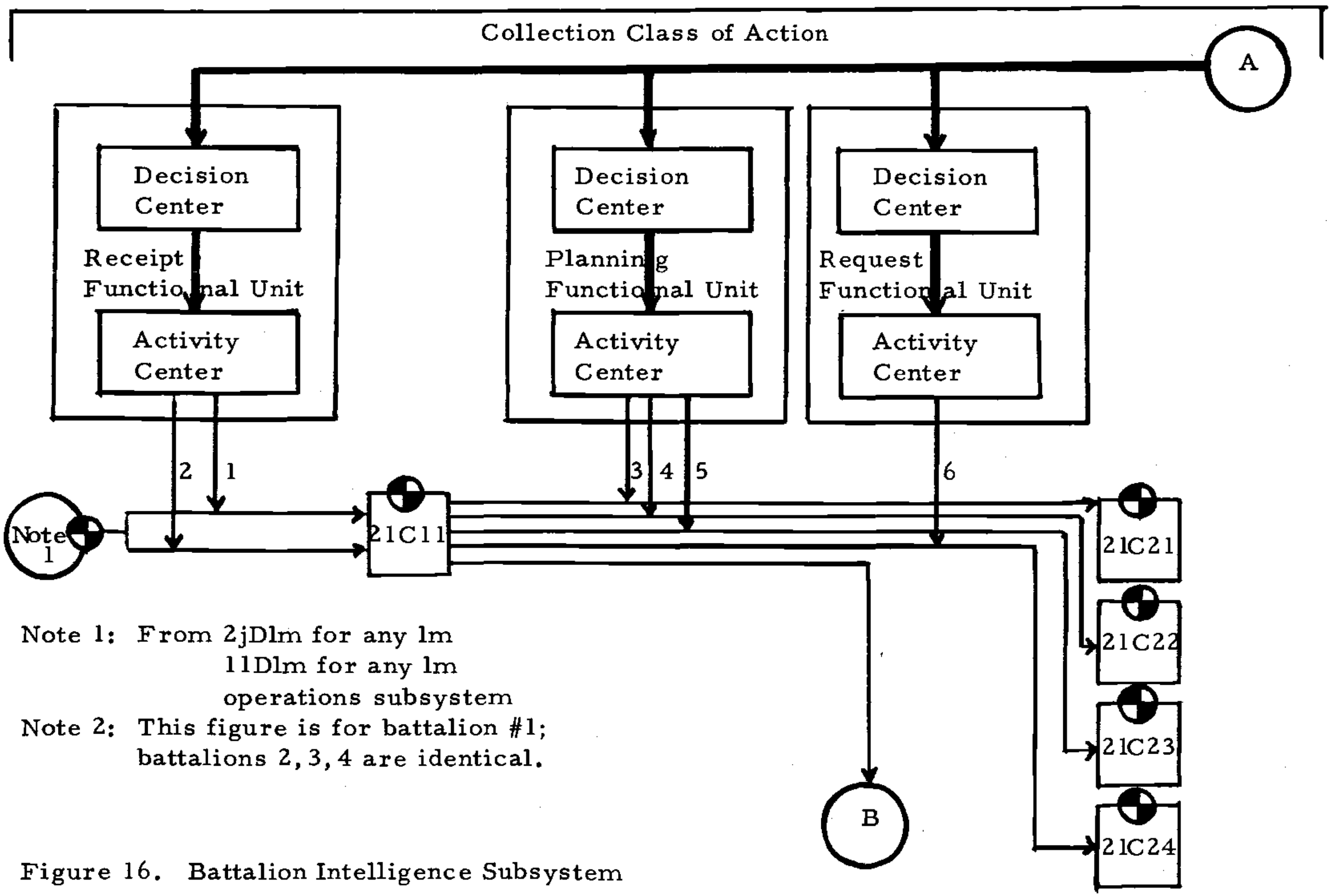


Figure 15. Partial Battalion Subsystem (Continued)



Note 2: To levels of other information subsystems or other management information systems.
Note 3: Intelligence can be obtained at any DCP in the collection class of action.

Figure 15. Partial Battalion Subsystem (Concluded)



Note 1: From 2jDlm for any lm
11Dlm for any lm
operations subsystem

Note 2: This figure is for battalion #1; battalions 2, 3, 4 are identical.

Figure 16. Battalion Intelligence Subsystem

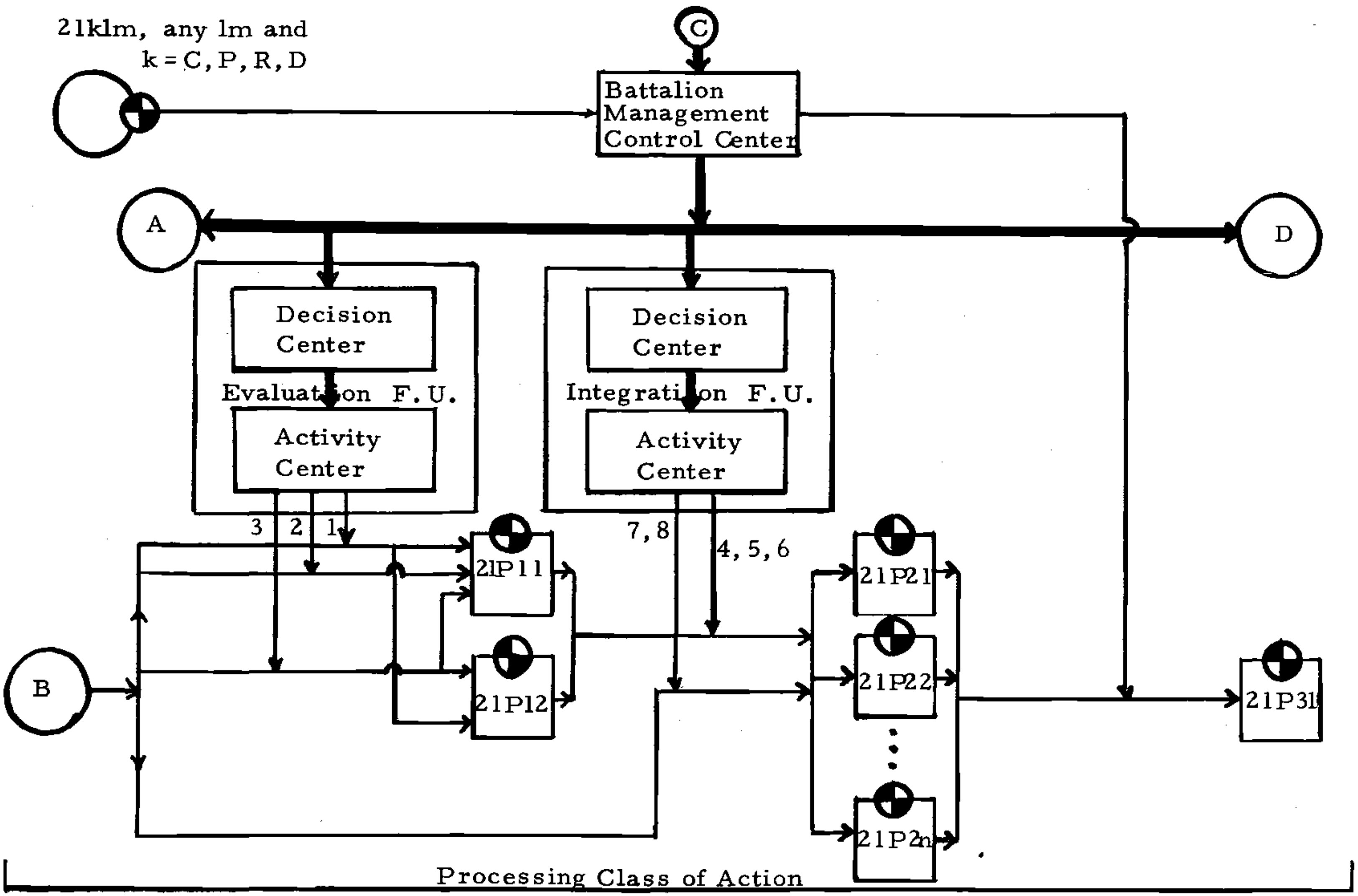


Figure 16. Battalion Intelligence Subsystem (Continued)

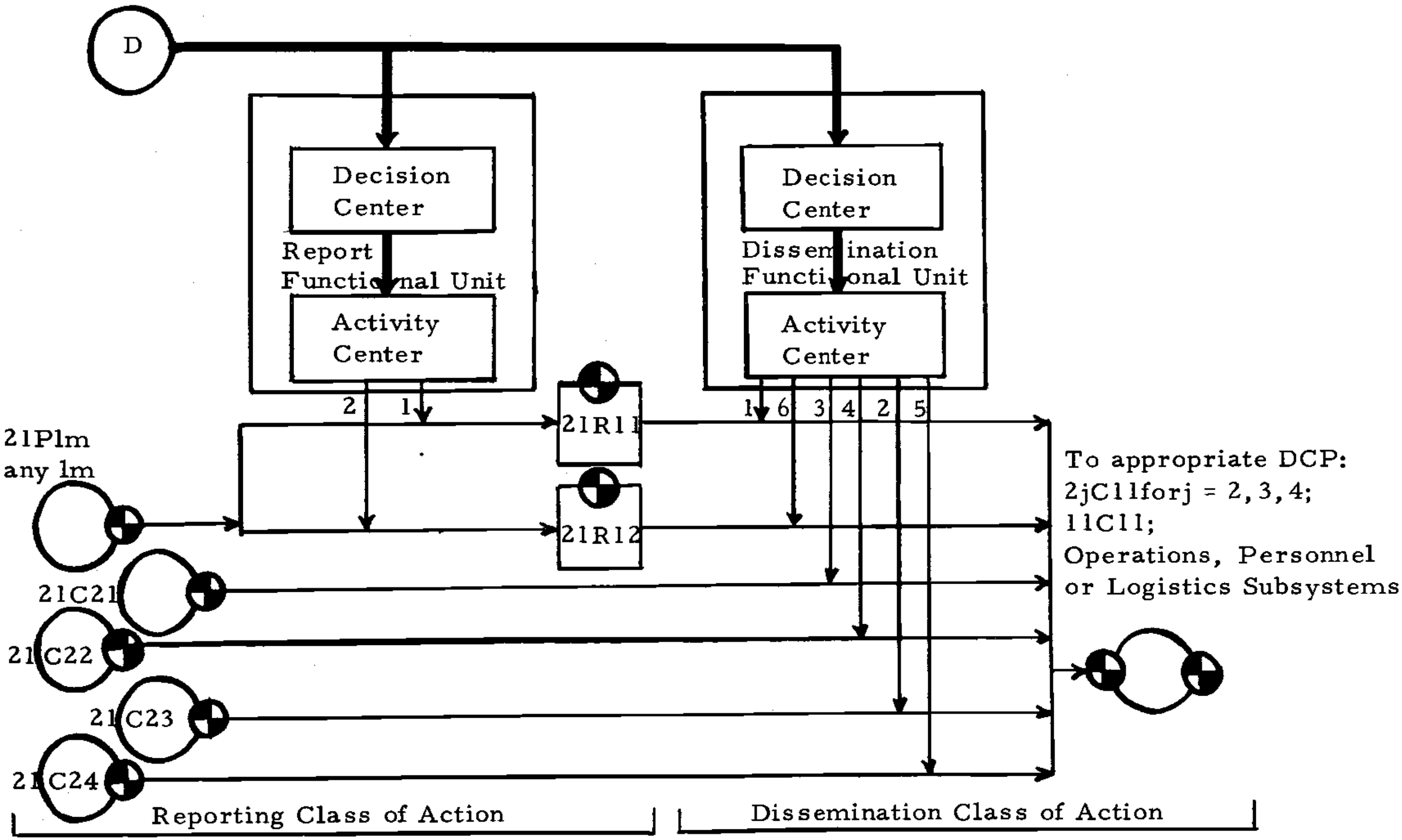
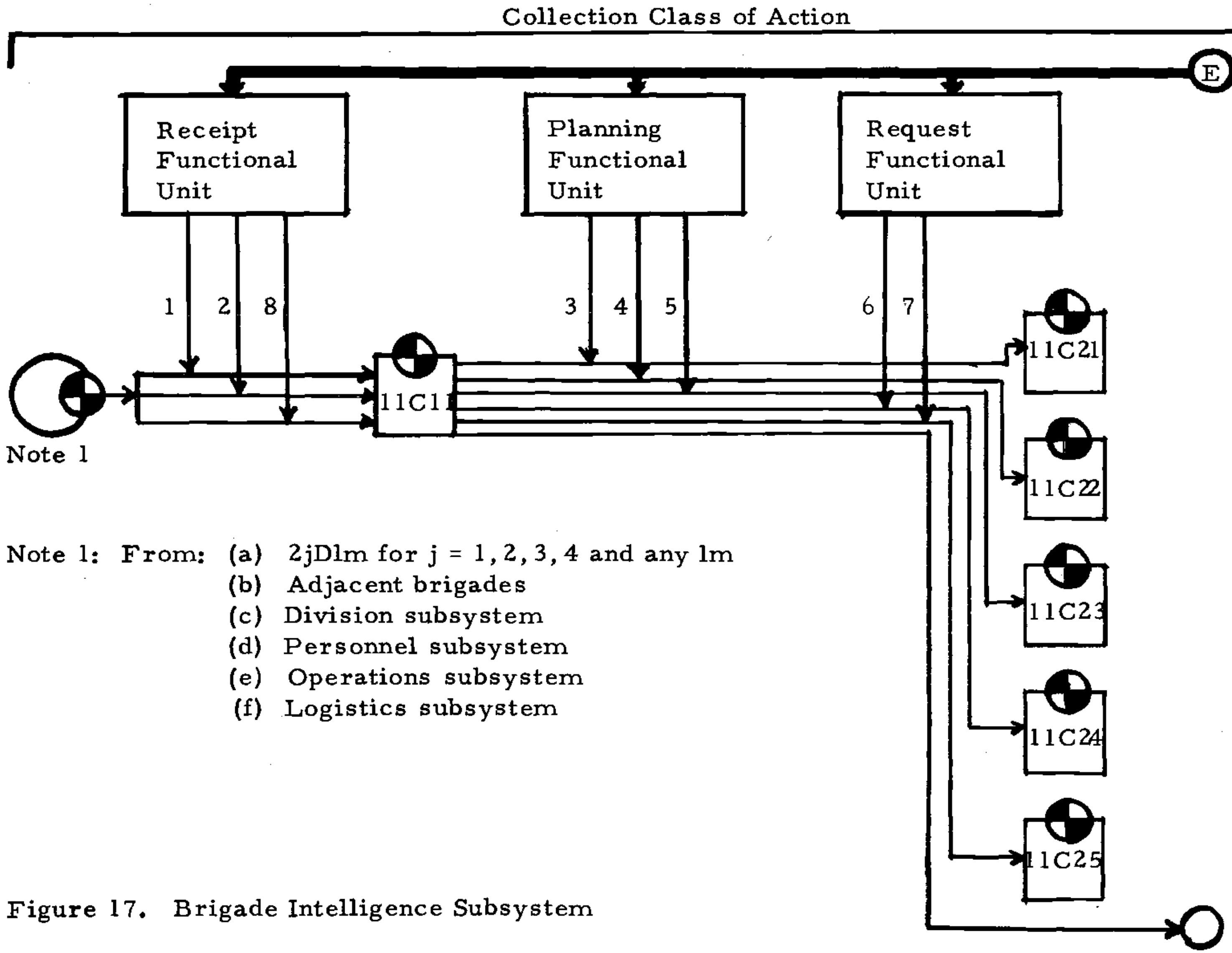


Figure 16. Battalion Intelligence Subsystem (Concluded)



Note 1: From: (a) 2jDlm for j = 1, 2, 3, 4 and any lm
(b) Adjacent brigades
(c) Division subsystem
(d) Personnel subsystem
(e) Operations subsystem
(f) Logistics subsystem

Figure 17. Brigade Intelligence Subsystem

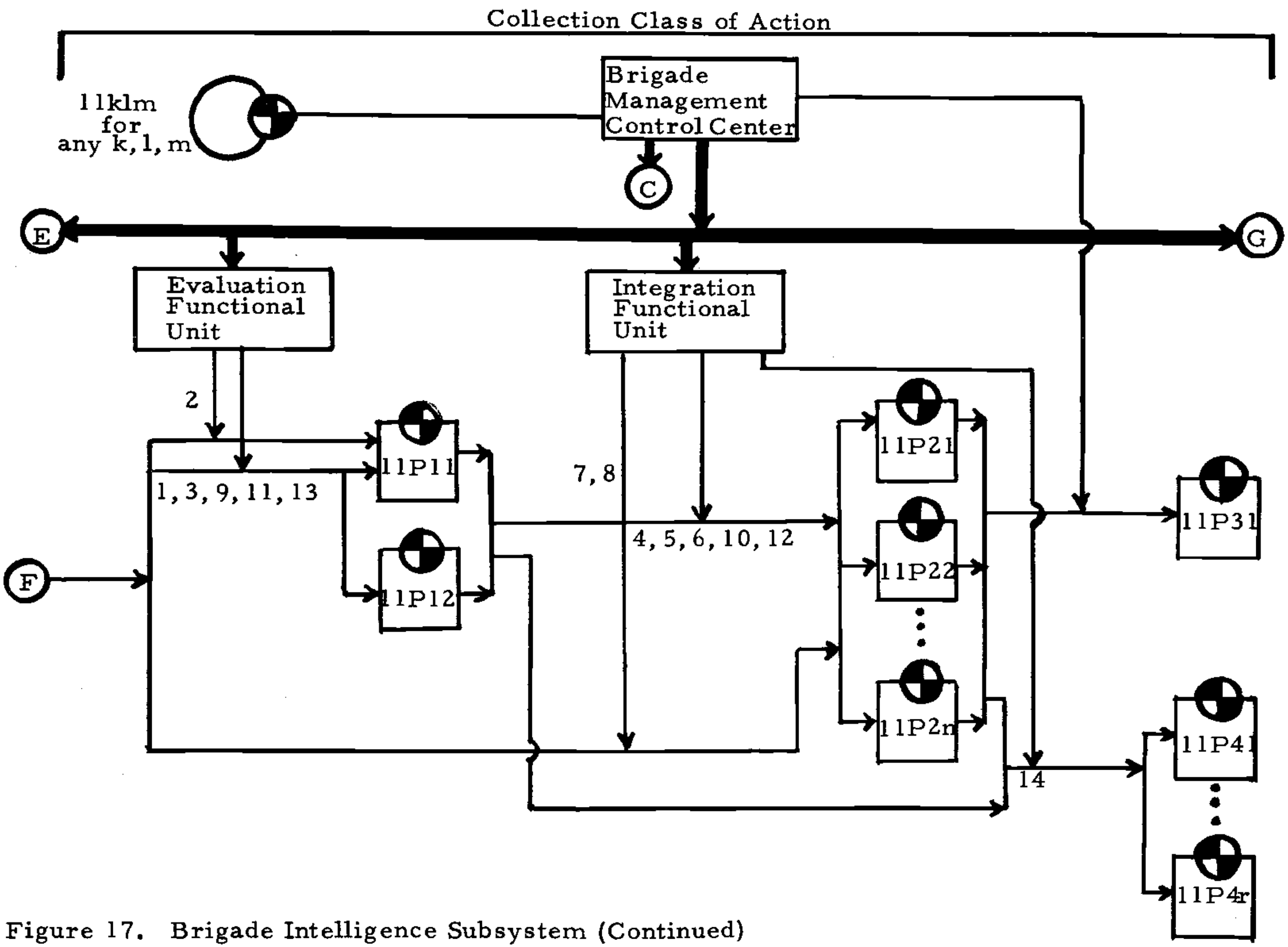


Figure 17. Brigade Intelligence Subsystem (Continued)

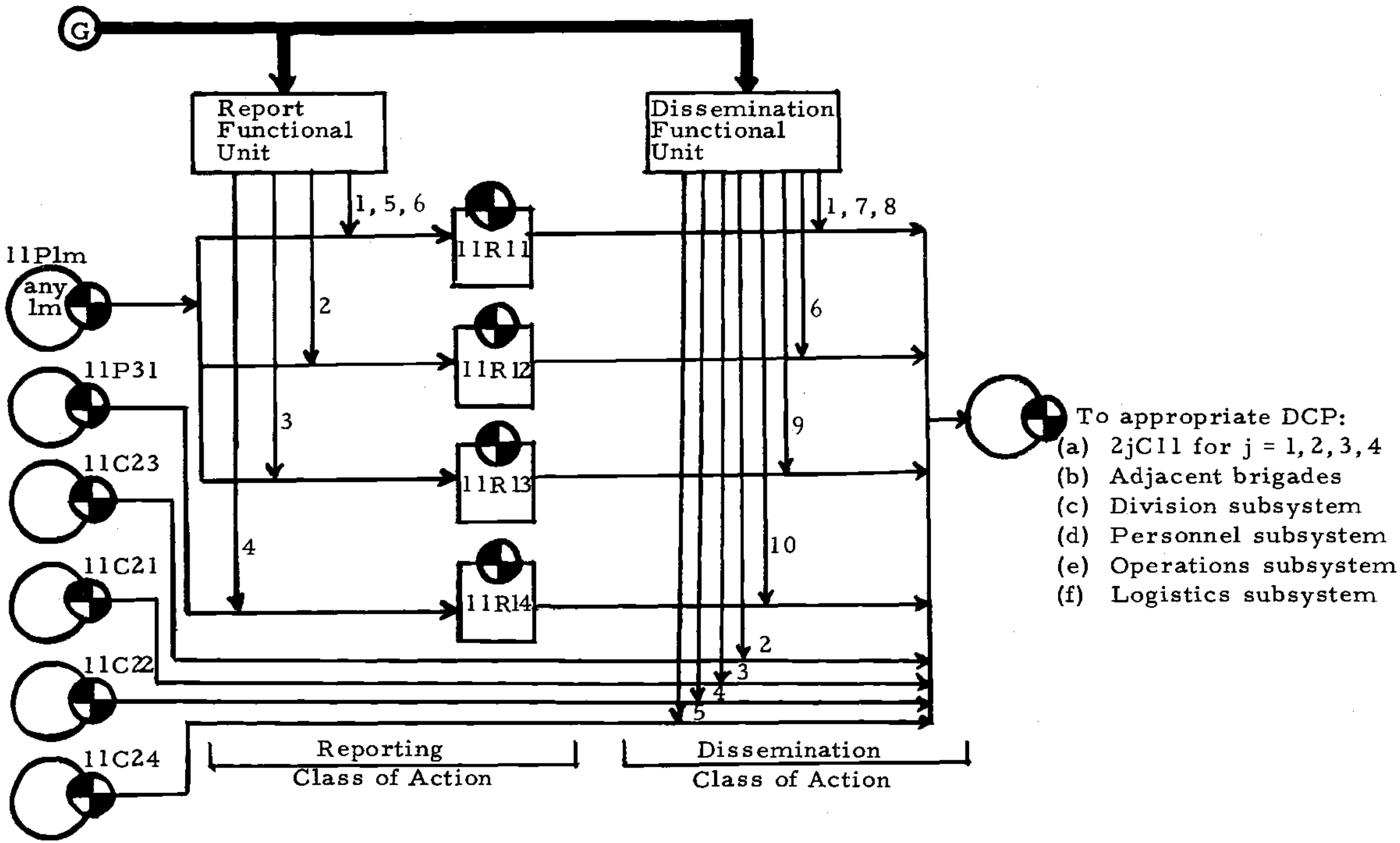


Figure 17. Brigade Intelligence Subsystem (Concluded)

since there is only one brigade under consideration. The battalions are numbered 1, 2, 3, and 4 indicating the three maneuver battalions and the direct support artillery battalion. The third digit, k, indicates the class of action (C = collection; P = processing; D = dissemination; and R = reporting). The fourth and fifth digits, lm, indicate the DCP level. For example, 23P21 indicates level 21 of the processing class of action at battalion number 3. Table 8 summarizes the battalion and brigade levels.

The subsystems at each of the four battalions are the same under Assumption 4. If this assumption were relaxed, then the entire preceding development would be needed to develop the subsystem for each different organization.

Step 2f

This step requires a complete reevaluation of each of the preceding steps. When this is complete, the result is a schematic of the ideal subsystem of the brigade intelligence subsystem. The next step will degrade this ideal subsystem.

Step 3a

At this point additional subsystem constraints are determined. Only one is evident for this example, and that is a personnel manning level constraint for each echelon. The battalion subsystem is to be manned by not more than one officer and nine enlisted men, and the brigade subsystem is to be manned by not more than one officer and 16

Table 8

Battalion and Brigade Levels

Echelon	Level	Designation
Battalion for j = 1, 2, 3, 4	2jC11	Total Data
	2jC21	Collection Plan
	2jC22	Ground Surveillance Plan
	2jC23	Ground Recon. and Patrol Plan
	2jC24	Air R & S Request
	2jP11	Operations and Intelligence Map
	2jP12	Order of Battle Map
	2jP2m	Enemy Course of Action m for m = 1, 2, ..., n
	2jP31	Intelligence Estimate
	2jR11	Spot Reports
	2jR12	Capture Reports
Brigade	11C11	Total Data
	11C21	Collection Plan
	11C22	Ground Surveillance Plan
	11C23	Ground Recon. and Patrol Plan
	11C24	Air R & S Requests
	11C25	Image Interpretation Requests
	11P11	Operations and Intelligence Map
	11P12	Order of Battle Map
	11P2m	Enemy Course of Action m for m = 1, 2, ..., n
	11P31	Intelligence Estimate
	11P4m	Target Information File m for m = 1, 2, ..., r
	11R11	Spot Reports
	11R12	Capture Reports
	11R13	INTSUM
	11R14	Intelligence Estimate

enlisted men. These personnel constraints will evidence themselves in the computer simulation model in the form of capacity constraints on the facilities.

Steps 3b and 3c

The methods and techniques of data collection, model construction and validation, and computer simulation will not be pursued here since they are discussed adequately in numerous references. However, there are several points concerning data collection and modeling which may serve to illustrate further the use of the design method.

The use of the schematic ideal subsystem (Figures 16 and 17), will assist in determining what data is needed to construct the simulation model. If a subsystem has previously existed, data collection will be greatly simplified. Statistically, representative data can be extracted from appropriate operations of the old system. This data can be used in simulating the new subsystem. However, if there was no previous subsystem, frequency distributions and service times will need to be estimated through limited experimentation with pilot components, other simulations, or PERT-time estimates.

The subsystem simulation must portray the flow of information into the subsystem, between levels and out of the subsystem in relation to time. The actions of the functional units can be treated as services on the information as it flows through the subsystem. The model may be constructed in any of a number of computer languages such as FORTRAN, ALGOL, BASIC, or in a special simulation language such as GPSS, SIMSCRIPT, or SIMPAC. In determining the language to be used, the characteristics of the various languages must be considered in relation to the purposes of the simulation. An excellent comparison of simulation languages was presented by Krasnow and Merikallio (37).

The response variables for the simulation are: (a) the processing times, (b) the transit times, and (c) the target development times. Full testing would require three simulated conditions. This number can be lessened since the only difference between low, mid, and high intensities is that the message mean is different. If the subsystem can operate at high intensity, it can operate at low and mid intensities. This would require the assumption that the subsystem personnel operate at a constant efficiency independent of time and state of the subsystem. By testing only under high-intensity conditions, only one simulation condition need be run. The measures of performance or goals for these conditions are shown in Figure 18. The indicated times are in minutes. These goals are tabulations of the goals specified in Step 1Ab.

The initial simulation runs should be conducted using the maximum manning levels allowed under Step 3a. This will cause the performance response for each set of conditions to be on the line C_1C' in Figure 8. The design method allows for relaxation of this constraint under

Subsystem	Intensity	High							
	Hours of Operation	24				12			
	Precedence / Response	4	3	2	1	4	3	2	1
Brigade	Processing	<30	30	150	330	-	-	-	-
	Transit	<45	45	225	360	-	-	-	-
	Target Development	<30	30	150	330	-	-	-	-
Brigade (Split Section)	Processing	-	-	-	-	<30	30	150	330
	Transit	-	-	-	-	<45	45	225	360
	Target Development	-	-	-	-	<30	30	150	330
Battalion	Processing	<30	30	150	330	-	-	-	-
	Transit	<45	45	225	360	-	-	-	-
Battalion (Split Section)	Processing	-	-	-	-	<30	30	150	330
	Transit	-	-	-	-	<45	45	225	360

Note: Response times are in minutes.

Figure 18. Performance Goals

Case I feasibility.

This example will be terminated at this step since the construction, validation, and experimentation with the subsystem model will serve no further purpose in illustrating the design framework or the design method.

The results of the simulation runs may cause several iterations through Steps 3, 1A, 2, and 3. The design method is complete and internally consistent, and specifies the actions for each contingency. The end result of these iterations will be a complete, practical, feasible solution if one exists. Additionally, it will be the best available under the given constraints. The method would then move to Steps 4 and 5 for completion of the design project.

Summary

This combat intelligence subsystem has served to illustrate the use of the definitions and the design method for a corrective design effort. It should be evident that the crux of the design is the proper detailed execution of Steps 1 and 2. Errors or omissions in these steps will carry throughout the remainder of the design.

The use of this design method is dependent on management sciences and computer sciences techniques. This example did not consider all the ramifications that other disciplines would have on the design. However, in a multidisciplinary team effort, these other peripheral areas could be considered.

The solution developed on this first iteration would probably not be a feasible solution. However, by iteration through Steps 3, 1A, 2, and 3, a feasible solution could be developed. These iterations would require management decisions about which missions, goals, or restrictions could be modified. By incorporating these changes and by manipulating the decision variables, the designer may develop an acceptable solution.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

General Comments

The two-fold objectives of this study as stated in Chapter I have been completed. Objective 1 was to develop a logical and systematic design method for the design of an information evaluation and integration subsystem. This objective was accomplished in the development of the design methodology in Chapter IV. This method is summarized on pages 52-58.

Objective 2 was to illustrate the design method using a military intelligence subsystem as an example. This was accomplished in Chapter V. The example served only to illustrate the meanings of the definitions and the use of the method in a corrective design effort.

It is felt that the developed design methodology is complete, internally consistent, and is applicable to any subsystem ranging from trivial to complex. The method is adaptable to original, corrective, or improvement design. The method is a synthesis of the framework concepts developed by Sherman Blumenthal, the philosophy presented by Gerald Nadler, and the ideas of this author.

Advances in information system design depend on advances in several rather than in a single technology. This research has only considered a part of design methdology. Only when the knowledge from all relevant technologies is "integrated" can a complete information system be developed.

Conclusions

The major conclusions derived from this study are:

1. The use of Nadler's design philosophy or a variation of it allows the designer the maximum freedom in developing solutions to design problems.
2. Definitions 1 through 19 provide a comprehensive framework upon which to base the development of an information subsystem design method.
3. The design method developed in Chapter IV and summarized on pages 52-58 is a logical and systematic method for designing an information evaluation and integration subsystem.
4. The design method can be adapted for use in original, corrective, or improvement design efforts.

Recommendations

The following areas or topics are suggested for further research to improve or expand the proposed design methodology.

1. The proposed design method should be expanded to develop a methodology for the design of a management information

system.

2. The example in Chapter V should be completed by model construction, validation, and testing to develop a feasible subsystem solution. This subsystem's performance could then be compared to the simulated BICC performance described in reference 34.

3. A procedure for formulating the subsystem missions, goals, and restrictions from management must be developed. This was indicated as a method limitation since these specifications are normally not available from organizational management personnel.

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