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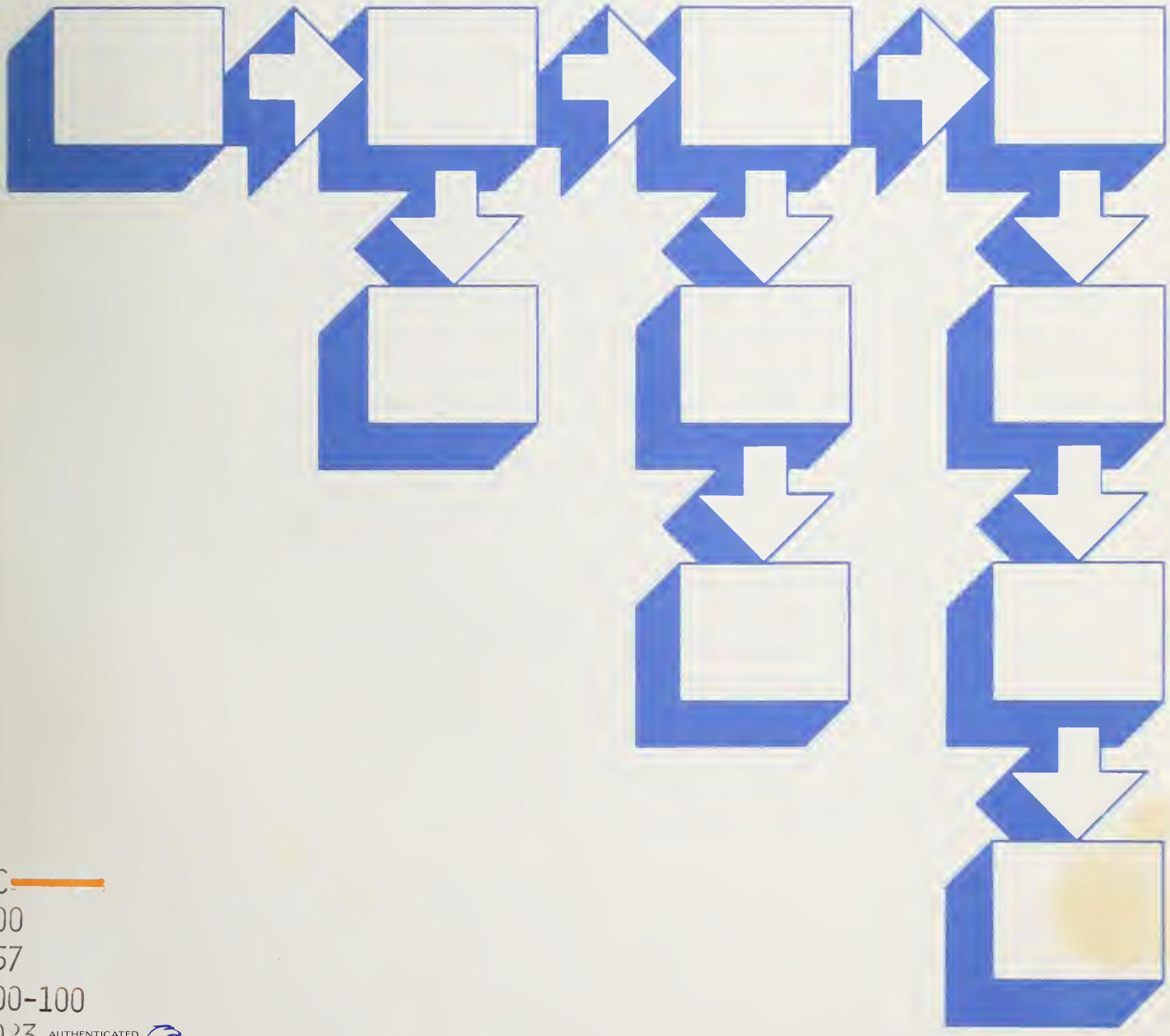
Computer Science and Technology

NBS Special Publication 500-100

Toward an Improved FIPS Cost-Benefit Methodology, Phase I: Descriptive Models—Data Processing Operations



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Foreword

The Information Processes Group (IPG) of the Institute for Computer Sciences and Technology (ICST) was created in 1981 and is responsible for, among other things, the development of methodologies for assessing the costs and benefits of Federal Information Processing Standards (FIPS). Almost immediately, it became apparent that existing cost benefit methodologies were inadequate to the purpose--partly because they were based on "rhetorical", or idealized, models of the Federal ADP environment* and did not take into account the multiplicity of operational variations among the agencies, the complex interactions among the components of data processing system management and operations (see Figure I-1), or the sometimes extreme difference between the way things are and the way things ought to be. In other words, existing methodologies are sufficient for "ball park" estimates, but--particularly in cases where anticipated costs and benefits are less than enormous--the expected margin-of-error is unacceptably large.

In order to reduce the margin-of-error, the IPG embarked on a program to describe more accurately the Federal ADP environment. Using functional flow diagrams as the basic tool for description, we hope eventually to have a realistic model of the Federal ADP environment. This report on Data Processing Operations marks the completion of Phase I of the program. Phase II, which covers Software Applications Development, is currently underway.

The bulk of the work on this project was done by Dr. Marco Fiorello and Mr. Peter Eirich of Fiorello, Shaw and Associates, working with Aurora Associates, Inc. The methodological framework was developed by Peg Kay of ICST. Like most of the IPG projects, results were obtained and validated through considerable interaction with personnel from other Federal agencies. In this case, the comments and suggestions from the other agencies led to a complete rethinking and revision of the report before the final draft was completed. We are particularly grateful to personnel from the Department of Energy, HUD, the Department of Justice, the FCC, the Federal Mediation and Conciliation Service, the FTC, and NASA for helping to shape the product.

Simultaneously with this attempt to improve the qualitative descriptions, the IPG looked for ways to improve the analysis of statistics concerning the Federal ADP inventory. The first product of that effort was the automation of the General Services Administration (GSA) data base. The first compilation and analysis based on the automated data base was completed in June 1982. As segments of the qualitative descriptive models are completed, it is our intention to apply the quantitative analyses to them and gradually to improve the accuracy of our cost benefit projections.

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* Another serious barrier to accurate cost-benefit projections is the absence of reliable base-line data. This series of reports does not address that issue.

While this program is primarily directed toward the improvement of ICST's products, it is clear that the descriptive models being developed are useful tools for ADP managers throughout the Federal Government--and probably for ADP managers in sub-Federal jurisdictions and in industry. Their usefulness is not confined to cost benefit related studies, but is applicable to a host of management concerns (e.g., reorganization, workload forecasting, functional specifications for procurement, and so on). We are therefore making these reports widely available in the NBS Special Publications series.

Questions or suggestions related to the program are welcome and should be addressed to Peg Kay, Institute for Computer Sciences and Technology, Building 225, Room B248, National Bureau of Standards, Washington, DC 20234.

ABSTRACT

This report presents a set of functional-flow descriptive models that can be used to categorize the operational activities of Federal data processing users. Data processing applications may be conceptually represented in descriptive model form by combining one or more of the basic models. The comprehensive framework for data processing operations provided by these descriptive models can be used in the identification of impacts from standards and guidelines and in the preparation of cost-benefit impact assessments. The framework provides both macro and micro levels of detail in order to link the descriptive models to additional data processing issues, such as computer security issues.

Key words: computer security; computer standards; cost-benefit analysis; data processing management; data processing operations; data processing standards; descriptive models; impact assessment; information systems.

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I. INTRODUCTION

A. General

The objective of this Phase I report is to present and describe a structure for a "descriptive model" of Federal data processing (DP) activities. By a descriptive model we mean a qualitative and pictorial (flowchart) portrayal of types of DP activities and how they interrelate. In simple terms, the descriptive model presented in this report describes "who does what" as Federal DP operations are accomplished by computer users. In order to place this effort in perspective, the role of descriptive models in the development and assessment of computer-related standards is discussed in the next section.

B. Background: Evaluation of Standards

Before ICST develops a standard or guideline, an assessment of the expected costs and benefits is performed. In such an assessment, the analyst identifies a specific set of changes that are expected to occur in the existing and projected Federal DP environment as a result of issuing a standard. The dollar consequences of those changes are then accumulated. If dollar amounts for projected changes cannot be estimated or imputed, then a qualitative description of the likely impacts is provided, along with a commentary on the relative desirability or undesirability of the results. At present, these assessments are performed in accordance with a 1978 set of preliminary guidelines [FIOR-78]. Appendix A summarizes the major steps in the assessment procedure.

Implicit in the analyst's identification of projected changes is a conceptual model of DP procedures, an expectation of how government agencies would act to comply with the standard, and an idea of how these actions would ultimately affect DP systems and procedures in those agencies. Similar conceptual models are implicit when standards are proposed and designed. While portions of these conceptual models are sometimes made explicit in assessment reports or standards design documents, there is no uniform vocabulary or framework in use to evaluate standards. Without a framework, it is difficult either to compare the impacts of different standards or to be confident that supporting data have been employed consistently from one assessment to the next.

A recent review of six impact assessments [FIOR-81], each completed in accordance with the 1978 preliminary guidelines, made several points relevant to the above discussion.

- The analyses tended to focus exclusively on the components or parts of the ADP system or process, and not mention the relevant procedures and management actions that must occur to achieve the impact modeled. (p. 9)

- The interpretation of the nature of impacts was inconsistent across the studies. (p. 10)

The review recommended that the impact assessment guidelines, when revised, should:

- o Improve the discussion of the formulation of the base case and impact process. The explicit use of scenario constructs and a descriptive model (functional diagrams with unifying flows) should be introduced. (p. 12)

An important benefit of this modeling effort will be to replace the analyst's implicit mental models with an explicit, documented, and commonly understood representation of Federal DP activities. This, in turn, will help to insure consistency among the different impact assessments of standards performed for ICST. It will also permit comparisons among the expectations of standards developers, the benefits projected in the impact assessment, and the actual benefits that may be computed after a standard has been implemented.

C. Project Goals

The end-product of the overall descriptive model effort will be a set of functional-flow descriptive models providing a comprehensive representation of Federal DP activities. Using this framework, it will be possible to specify the impacts of different standards, collect data organized so as to aid impact assessments, and define points of measurement for evaluating a standard's actual benefits.

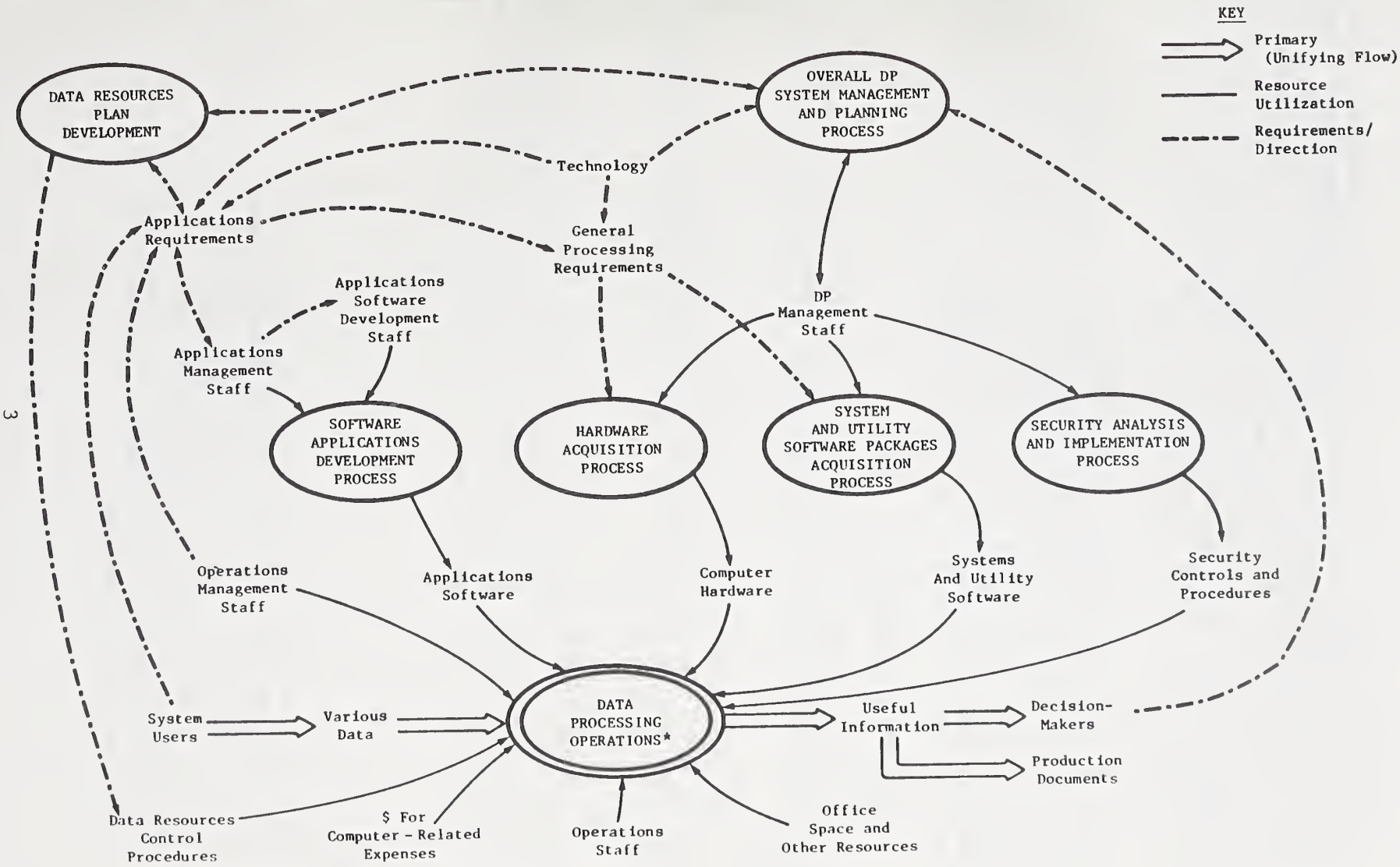
The Phase I descriptive model developed in this report can be applied immediately to the development of a cost-effective set of computer-related standards and guidelines. For example, it can improve planning for ICST products by identifying the types of personnel to be affected by a proposed standard or guideline. Improved standards will, in turn, assist computer system and application managers to do a better job of developing and monitoring DP systems.

D. Scope of the Phase I Effort

The descriptive model is intended to encompass the breadth of DP system management and operation represented in Figure I-1. The scope of this Phase I effort is limited to the "Data Processing Operations" portion of the Figure. The existence of hardware, system software, and applications software is taken for granted, and we do not develop descriptive models for how those resources came to exist in the right place, at the right time. The same is true for staff and management personnel, security controls, data resources controls, office space, etc.

This Phase I model is only a first step toward a comprehensive set of Federal DP descriptive models. Later study phases will develop models comparable to this one for the other areas shown in Figure I-1. Also, this Phase I model will be further refined as it is used for cost-benefit studies and as it serves as a basis for statistical data collection.

Figure I-1. MAJOR COMPONENTS OF DP SYSTEM MANAGEMENT AND OPERATION



*See Appendix B for detail descriptions.

The Phase I effort has identified and defined a generic set of independent functional flow modules, or "building blocks", for DP operations. For each module, the descriptive model of DP operations specifies functional flows for the activities comprising operations. These modules can be assembled in different combinations to represent consistently the variety of general-purpose DP applications in the Federal Government.[1] The "unifying flow" for our description is the transformation of data items into both useful information and output products in the course of DP processing operations. (The concept of a unifying flow is discussed in Chapter II.)

The accuracy and completeness of representation was verified by a process of review by a number of Federal data processing managers -- a process that will be repeated during the development of comparable descriptive models for the acquisition and development of hardware, systems software, and applications software. Later phases of this study effort will also treat broader concerns such as the selection and implementation of security procedures, data resources planning, and overall DP system management. The software applications development process will be the topic of the Phase II effort.

E. Overview of this Report

Chapter II presents the concept of a descriptive model composed of modular, functional-flow building blocks, or subsystems. It identifies the set of subsystems employed in the model and describes their interrelationships.

Chapter III describes each subsystem and introduces the subsystem flow diagrams. Chapter IV discusses how the subsystems may be combined to represent different complete DP applications, and compares the subsystem operational characteristics.

The subsystem concept is expanded in several ways in Chapter V. First, the use of subsystem functional flows to organize more macro and more micro levels of detail is described. Second, security considerations are related to these levels of detail. Third, the use of subsystem flows to organize data for planning and assessing standards is discussed. Finally, the use of the flow diagrams as a presentation medium is illustrated.

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[1] Our objective is to adequately cover the broad range of general-purpose DP activities, while keeping the total number of modules small and manageable. Accordingly, we do not include embedded weapons systems computers in the scope of this descriptive model, nor do we intend to cover relatively unique special-purpose applications not typical of the federal government as a whole. For example, the magnetic ink character recognition (MICR) equipment used the Federal Reserve for sorting checks is not covered by any of the modules.

Chapter VI summarizes the work covered in this report, and describes the steps to be undertaken in Phase II. Appendix A, as mentioned earlier, summarizes the basic steps in performing a standards impact assessment as described in the 1978 preliminary guidelines [FIOR-78]. Appendix B contains the flow diagrams for the different subsystems.

II. DESCRIPTIVE MODEL CONCEPT

A. General

This chapter explains the principle on which the descriptive model of DP operations is based and how the subsystem approach to categorizing DP activities was chosen. The 13 subsystems and their interactions are introduced.

B. The Unifying Flow Principle

A descriptive model, as the term is used here, traces a sequence of events or processing steps in a system or organization. The key to preparing a descriptive model that captures the essence of a system or organization, and portrays it in a straightforward manner, is to identify the proper "unifying flow" for the model [NAKA-82].

The basis for a unifying flow is some item or characteristic that can be traced throughout the system or organization to be modeled. The unifying flow, specifically, is the path taken by the selected item or characteristic and is the basis for organizing the descriptive model. For the model of DP operations developed in this report, the unifying flow is the transformation of data into information in the course of DP activities. Information may take the form of outputs used for decision-making, or of specific output products (for instance, Social Security checks).

Our broad view of DP likens it to an information factory, where various types and amounts of raw data are pumped in, various things are done to them and various useful information comes out. One must know who uses the information, and why it is considered information instead of data, in order to understand the role of DP in an organization. One must also understand the nature of the data submitted for processing, as well as what is done to them, and by whom, to understand the functioning of DP operations. All these elements belong to the descriptive model and are keyed to the unifying flow of "data into information".

C. Overall Model Structure

The range of Federal DP activities is too broad to be represented in a useful way by any one integrated descriptive model. Accordingly, our approach was to develop a set of related descriptive models that could be combined in different ways to reflect the wide variety of Federal DP activities. To create a workable set of models it was necessary to categorize DP activities in such a way that, for each category, a single model could be developed which would apply reasonably well to the various activities within the category.

A number of likely categorization schemes had to be rejected for a variety of reasons. For instance, while there are many similarities in DP activities among different agencies, there are still too many differences to allow building a descriptive model for one agency and applying it (with only

minor variations) government-wide. As another example, models based on functions (personnel, accounting, supply) were not practical because there are too many possible variations for any one function to have only one model for each, and yet there are enough similarities between different functions to make the models repetitive in many cases.

Breakdowns based on any of the resources shown in Figure I-1 were rejected for similar reasons. These possibilities included breakdowns by:

- o computer hardware used
- o system software environment
- o application software characteristics
- o security requirements
- o staff/position characteristics of users
- o size of organization

Management-oriented breakdowns were also not satisfactory. In a study of 56 decision-oriented computer applications[2] Steven Alter found that few significant conclusions seemed to emerge from commonly-used labeling schemes such as:

- o functional area (marketing, production, finance, etc.)
- o decision perspective (operational control, management control, strategic planning)
- o problem type (structured vs. unstructured)
- o computer technology (interactive vs. batch)
- o modeling approach (simulation vs. optimization)

The breakdown ultimately selected for our descriptive model is an expansion of Alter's work [ALTE-75; ALTE-77]. Alter found that seven "system types" served as a useful classification scheme for the 56 applications he studied. In a broader context, Alter's "systems" may be viewed as subsystems of still larger DP applications, and 13 such subsystems are needed to represent the breadth of general-purpose DP activities in the Federal Government.

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2 Presumably, most or all of them were in the private sector. See [ALTE-77, pp. 40-41]. Labeling schemes for applications reprinted with permission (see references).

The set of data processing operations subsystems is as follows:

1. Transaction Data Capture
2. Transaction Data Aggregation
3. Recordkeeping
4. Transaction Disbursement
5. Technical Data Preparation
6. Automated Data Capture
7. Analysis and Reporting
8. Data Retrieval and Analysis
9. Data Combination, Analysis, and Reduction
10. Specialized-Data Model Execution
11. Integrated-Data Model Execution
12. Computer-Aided Task Performance
13. Software Development

Subsystems 7 through 11 cover the scope of systems studied in [ALTE-75; ALTE-77]. We have redefined his categories to reflect the structure of the DP operations involved rather than following Alter's definitions, which reflect system behavior and intent. While this regrouping of applications is more appropriate for the analysis of ongoing DP activities, the discussion of subsystems also refers to Alter's categories in order to benefit from his research results.

D. Subsystem Interactions

Different subsystems may be combined to form various DP applications. In general, some subsystems will typically perform input processing, while others will primarily prepare output products. This can never be completely true, of course, since the output of one DP system is often the input to the next.

Figure II-1 shows the manner in which subsystems are generally interconnected. Types of intermediate files that serve to transfer data from one subsystem to the next are also shown. Again, this is not the only pattern of interconnection possible,[3] but we believe it is the most typical.

Subsystem interconnections will be treated further in Chapter IV, where DP applications are discussed. First, a more detailed description of each subsystem will be presented in Chapter III.

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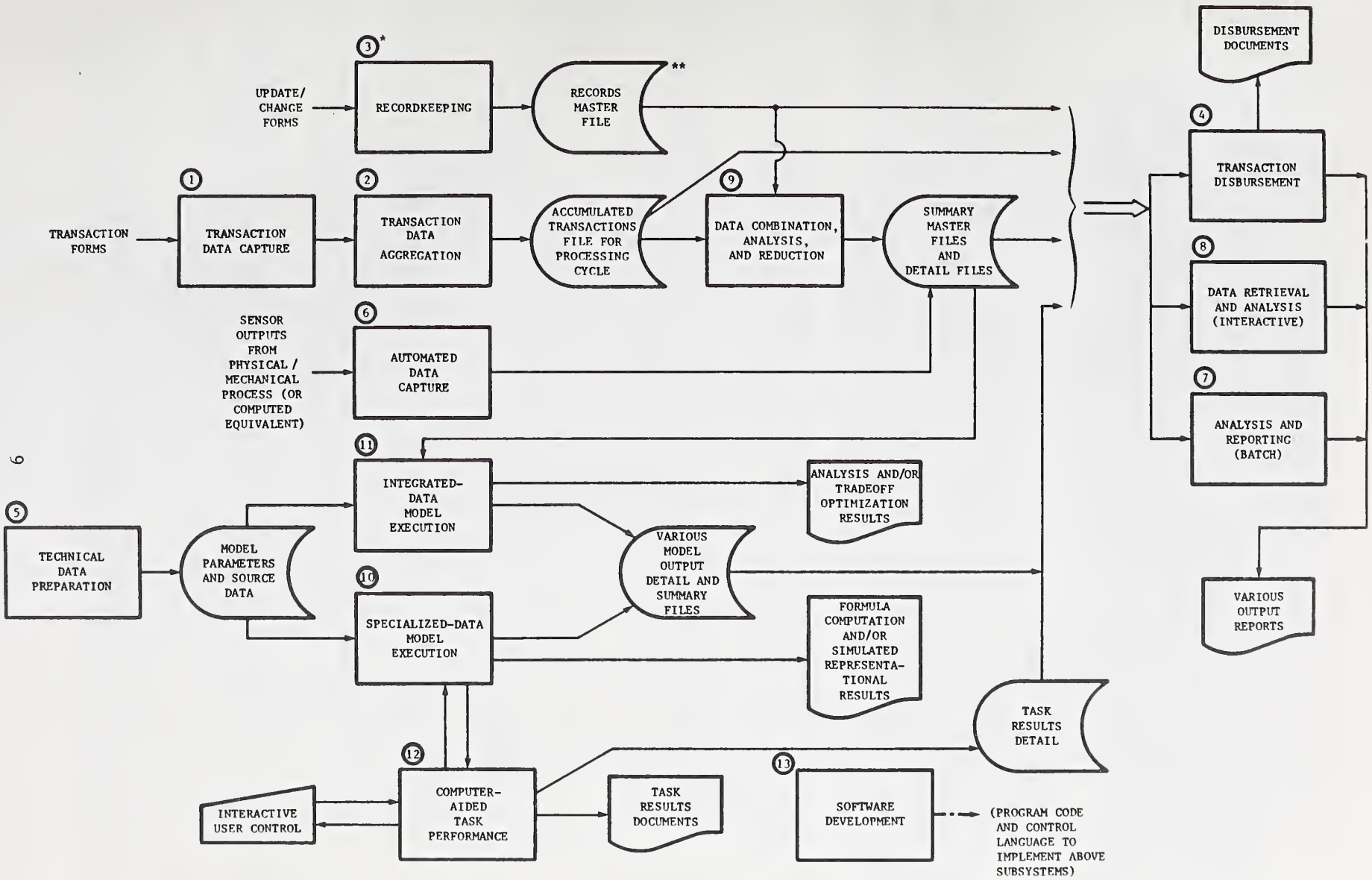
[3] Some additional types of interconnections are indicated in the subsystem flow diagrams in Appendix B.

Figure II-1. SUBSYSTEM INTERCONNECTIONS (Illustration)



*CIRCLED ○ NUMBERS ARE SUBSYSTEM NUMBERS KEYED TO DESCRIPTIONS IN CHAPTER III.

**ON-LINE STORAGE SYMBOL IS USED TO REPRESENT ANY DATA FILE (i.e., TAPE, DISK, OR OTHER PHYSICAL MEDIA MAY BE IMPLIED).

III. SUBSYSTEM DESCRIPTIONS

A. General

This chapter briefly defines and describes each of the 13 subsystems mentioned in Chapter II and introduces the subsystem models. These descriptions establish the role of each subsystem in the overall DP scheme to prepare for the explanation of DP applications and operational characteristics in Chapter IV.

B. Subsystem Descriptions

1. Transaction Data Capture: the entry of data from individual transaction documents such as accounting vouchers onto machine-readable media for further processing. The results of this procedure are a set of files, reflecting the relevant transaction data, residing on various processing media, and accompanied by physical documents and control totals (as necessary) to provide an audit trail. The resulting files are generally forwarded for processing under a subsystem 2 application (transaction data aggregation).

Examples include accounting, inventory, and timekeeping document entry, as well as the entry of corrections for errors detected in later stages of processing.

2. Transaction Data Aggregation: the collection of individual transaction records, when the data entered are essentially additive or cumulative in effect. The results of this collection are usually a set of master files updated for a given period and/or a set of merged transaction files for the period.

Besides various accounting vouchers where dollar amounts are cumulated, other examples of transaction aggregation are found in inventory control, where stock additions/withdrawals are tracked to adjust stock balances, and in employee timekeeping, where staff hours by project are accumulated.

3. Recordkeeping: the processing of transactions, which take the form of updates or changes to information in master files (3a--on-line, deferred update) and/or updates to an on-line data base (3b--on-line, immediate update). Note that maintenance of historical data in a file, such as previous position titles and past salaries for an employee in a personnel file, does not make these data cumulative in the sense of subsystem 2 (transaction data aggregation).

Examples may be found in payroll and personnel systems, where changes to employee status or salary and additions/deletions of employees are processed. Other examples are payment systems such as Social Security where transactions entered from field offices are used to change master files and thereby initiate, terminate, or change computed beneficiary payments.

4. Transaction Disbursement: the preparation of transaction documents to be distributed, as opposed to collected.

The most obvious example is the preparation of checks, which may be computed and prepared on the basis of transaction files, master files, or a combination of the two. Payroll systems are an example of a combination of both sources, since computation of the amount of each check for a pay period often depends on both the timekeeping data for the pay period (from a type 2 transaction data aggregation subsystem) and the employee master file (from a type 3 recordkeeping subsystem).

5. Technical Data Preparation: the maintenance of data files by technical personnel, typically for use as inputs to computer models. Unlike the previous four subsystems, which generally involve formal processing controls and audit trails, the integrity of the data in this subsystem relies upon the concern and attention to detail of the responsible analyst. Data maintenance will usually be accomplished with a generalized text editor, in contrast to the program-controlled or data base management system (DBMS)-controlled updates found in subsystem 3 (recordkeeping).

Examples are data preparation for all manner of engineering, scientific, and economic models. Maintenance procedures will usually be more formalized for either large-scale models or models where the results are widely publicized.

6. Automated Data Capture: the processing of a stream of real-time or recorded data samples to determine what events of interest have transpired and to report those events in a usable (or readable) format. This type of subsystem is typically found in manufacturing and engineering applications and represents only a "front-end" conversion step to provide inputs for other subsystem processing.

Examples include the processing of satellite transmissions and the analysis of recorded data from engineering field tests. The latter can include both environmental data such as underwater sound recordings and/or internal system information such as the outputs from electronic circuitry or micro-computers that implement decision logic.

7. Analysis and Reporting: primarily the preparation of routine, standard, periodic reports, using batch computer programs, on a wide variety of activities in the organization. (Often these are called "vanilla COBOL" applications when COBOL is the programming language.) They can also be sophisticated reporting systems utilizing a DBMS or other advanced technique.

The term "analysis" reflects limited manipulation of the data (in addition to straightforward summary) which may be performed to simplify use of the report's contents. When these manipulations take the form of evaluating simple decision rules, this subsystem can implement a "decision suggestion" function wherein specific managerial or operational actions are indicated by the results of a computer program. [1]

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[1] Suggestion models represent one decision support system type, as defined by Alter [ALTE-75; ALTE-77], that may be implemented by several of the operational subsystems (7, 10, 11) presented here.

Examples include summary reports of expenses and/or staff hours by project, employee, branch, division, etc. Such reports may be found in almost every sizeable organization. Examples of decision suggestion reports are: a list of employees due for a step increase on the basis of time-in-grade and an inventory list flagging items with stock-on-hand below the appropriate reorder point.

8. Data Retrieval and Analysis: the preparation of data listings and/or processed reports at the initiation of the end-user. This generally implies on-line, interactive access, although batch programs may be used in lieu of (or in addition to) on-line access. The two major usage modes for this subsystem, data item display and data analysis, are characterized below.

8.1 Data Item Display--the retrieval of status information or other data concerning specific items. The data may be stored in forms ranging from sequential files on off-line media to on-line data bases; the key here is that only a simple "file drawer" type of retrieval is done, with minimal (if any) aggregation of data. Inquiries can be either ad hoc, or operational and repetitive.

Examples include the retrieval of on-hand/on-order information for inventory items, status information on project expenditures, and employee data from a personnel database.

8.2 Data Analysis--the preparation of a variety of ad hoc or special-purpose reports by supplying input parameters to customized software or using user-oriented data manipulation languages. This includes both generalized data manipulation languages, such as the query langauges often incorporated into a DBMS, and specialized languages dealing with specific job or task. The data could be stored in various file structures or maintained under a DBMS.

While data item display involves the retrieval and display of individual records, data analysis typically presents aggregate data derived from sets of selected records. For instance, a data item display program might print all the outstanding orders for a specified vendor, while a data analysis program might provide the total amount of outstanding orders overdue by 30 days and a breakdown by vendor.

A variety of examples often may be found wherever a DBMS has been installed, depending only on the needs and skills of the DBMS users. Other examples include the use of customized software to provide tabular reports on research project expenditures. In this example the user supplies the variables to be summarized, and the tailored software determines the row and column headings, retrieves the appropriate data records, and produces the desired summary table.

9. Data Combination, Analysis, and Reduction: the preparation of intermediate data files and/or special-purpose reports requiring data from more than one operational DP system and/or management database. The software that makes this possible may be viewed as a collection of models and data utilities that can be applied by an analyst to gather data from

different systems and to perform planning calculations. Such systems often require cooperation between different software groups, different managers, and/or different organizations for successful operation and may be operated on a periodic or ad hoc basis.

One example is a system that extracts and integrates data from several logistics reporting systems, containing different types of information, and prepares a specialized database. This specialized database can then be used to provide summary reports for decision-making and also to generate data for computer models of the types listed below.

10. Specialized-Data Model Execution: the use of models that operate from "constructed" databases, such as the output files from either subsystem 5 (technical data preparation) or 9 (data combination, analysis, and reduction), that will usually be tailored to the needs of the particular model. These models will typically be used for planning, analysis, and problem-solving, and will often be set up for use by specialists on an as-needed basis. While any of the model types described in [ALTE-75; ALTE-77] could fall into this category, accounting models and representational models are (we believe) more commonly found here and will be characterized below, while optimization models and suggestion models are covered under subsystem 11 (integrated-data model execution).

10.1. Accounting Model Computation--the use of standardized formulas and relationships to prepare estimates for management planning and/or operations activity. These are frequently, but not exclusively, accounting/financial estimates.[2] As compared to type 8.2 subsystems (data analysis), the computations utilized involve more than simple accumulations or statistical summaries of stored data, and more than straightforward decision rules applied to such summaries, but are restricted to cases where the computational relationships are tightly defined or well-known, even though model parameters may vary. The "stable" algorithms involved make these models suitable for decision suggestion applications, and they may be utilized for this purpose as described under subsystem 11 (integrated-data model execution).

An example is the calculation of estimated retirement benefits for an employee, on the basis of salary and length-of-service data, using different date-of-retirement assumptions. Other examples would be the computation of project cost estimates based on estimated staff hours for different skill levels, project status reporting, and budget projections.

10.2 Representational Model Simulation--the use of mathematical models to represent more complex processes than might be handled by a simple accounting model, and to predict outcomes on the basis of either varying system inputs, or making different assumptions concerning the process modeled and/or the nature of relationships between variables. These models are often used for

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[2] We use the term "accounting-model" because it best exemplifies the type of computations performed. The term does not imply that subsystem 10.1 is found only in accounting applications.

engineering design decisions, and for other problems that cannot be treated by one or more definitional formulas like those covered by accounting model computation. In these problems the interactions between formulas and the amounts of computation are such that a computer is required, whereas, in an accounting model, it might be merely convenient.

An example is the computer simulation of the responses of a proposed weapon system in different operational environments, such as the performance of a sonar system at different depths and under different ocean temperature-gradient conditions. Another example is the simulation of the survivability of a ship under different forms of attack.

11. Integrated-Data Model Execution: the use of models that operate directly from operational data files or from slightly processed versions of those files, as opposed to tailored and/or highly aggregated data bases (such as those utilized for models in subsystem 10). While specialized-data models will often involve aggregate data inputs, integrated-data models will generally operate on detailed data and take the form of decision suggestion or trade-off optimization models.

11.1 Decision Suggestion: the use of a mathematical algorithm to indicate managerial or operational actions. The basis could be mathematical optimization, accounting model computations, or other decision rules. The expectation is that the computer-produced suggestions would be implemented, but only so long as the situation remains within the bounds of the circumstances for which the suggestion model was originally designed.

An example would be a student/class scheduling model for a military training school.

11.2 Trade-off Optimization--the use, for planning purposes, of mathematical models that find the combination(s) of resources or system parameters that maximize or minimize, within specified constraints, the value of some selected goal variable. These models can be used to evaluate design or management trade-offs as the constraints are varied. In contrast to a decision suggestion model, which may use optimization techniques to produce a specific answer, trade-off optimization implies that information about constraints, sensitivities, and input trade-offs is reviewed and analyzed in addition to the optimization results, and different scenarios may be evaluated.

An example is the determination of the mix of spare parts that provides the maximum expected aircraft availability for any specified level of additional investment in spare parts. The results of such a model enable managers to understand the effects of more or less investment in spare parts and to make better decisions concerning the trade-offs between the amounts invested in spare parts and other forms of investment such as new aircraft. Once the level of expenditure for spare parts has been determined, the optimization model can be used like a decision suggestion model in order

to specify which particular spare parts should be purchased.[3] Alternatively, when used to predict the availability rate that will result from a specified level of investment, the model is used as a representational model. (In the latter use, one assumption is that dollars will be spent optimally in terms of availability.)

12. Computer-Aided Task Performance: the use of a computer to enhance the ability of a person to perform a task by executing various operations under immediate and interactive control by that person. Included here are any applications where the computer acts to extend the capabilities of the user to perform some task in a real-time manner. Both printing and CRT terminals, with or without graphics capabilities, may be used.

An example is the use of computerized drafting systems where the computer constructs drawings on the basis of real-time instructions from a draftsman. Computer-aided design applications such as electronic circuit and mechanical component design can result from integrating this subsystem with a representational model simulation (subsystem 10.2). Word processing systems and office-of-the-future technology in general also belong under this subsystem.

13. Software Development: the use of text editors, compilers, and other system utilities to prepare either application programs, computer system software, or job control language. The result of this subsystem is the variety of programs and control statements necessary to implement instances of the previous 12 subsystems. We include in this subsystem only those activities that directly involve DP operations; other aspects of software development (e.g., planning, meetings, documentation) are covered under the Phase II descriptive model, which also encompasses the elements of this software development subsystem.

Examples include all types of programs given as examples under subsystems 1 through 12. These may be written in commonly used languages such as FORTRAN, COBOL, PL/1, and BASIC, or may be developed using special-purpose languages such as DBMS query commands.

C. Subsystem Models

Flow diagrams for the 13 subsystems may be found in Appendix B. Each is a fundamental building block of the DP operations descriptive model.

Each diagram follows the transformation of data to information within a subsystem. The figures show the different media and representations used for the data at different stages of processing, while still maintaining fairly general descriptions concerning the nature of the data. Each figure shows major steps in processing and the personnel that directly interact with the DP system or the data.

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[3] In practice, the suggested purchases are seldom followed exactly because of localized constraints and miscellaneous "real-world" factors that managers take into account when placing an order.

Decimal numbers are used for the figures in Appendix B. The numerical portion represents the subsystem number. A lower-case letter in the figure number indicates that the diagram is one of several common variations for the particular subsystem. Such variations occur when different computer technologies cause significant changes in the processing flow. Differences between batch and interactive processing, for example, are reflected within each figure as appropriate. When variations due to technology are minor, these are simply noted on the primary diagram.

Taken together, these subsystems represent the major variations of processing found in general-purpose DP activities in the Federal Government. They should be reviewed before proceeding to the next chapter, which illustrates how DP applications may be represented by combinations of the subsystems.

IV. DATA PROCESSING APPLICATIONS

A. General

This chapter begins by discussing the structural relationship between applications and the set of DP subsystems. The subsystems' operational characteristics are then compared. Our non-rigorous definition of an application is: a sequence of DP procedures that begins with some user data or computer files that exist independently (they are not simply intermediate by-products of a processing sequence) and ends with printed outputs or computer files that serve a definite organizational purpose.

B. Application Illustrations

In the descriptive model, applications are considered as combinations of subsystems linked by intermediate products of the processing sequence. For example, as illustrated in Figure IV-1, a minimal accounting voucher application usually consists of transaction data capture and aggregation subsystems to prepare a weekly transaction file, and an analysis and reporting subsystem to turn out weekly (or periodic) summary reports. There is little transformation of data into information -- the output reports are simply recapitulations, with totals, of the input documents. The subsystems are linked by a well-defined intermediate product -- a file containing the accumulated weekly transactions (typically grouped into batches of transactions, with batches in sequence according to an assigned control number). The intermediate file is shown as stored on tape, since we believe this to be the most common practice, but the application would not be affected if disk storage were used. [1]

As indicated in Figure IV-1, intermediate products can be shared among applications. As a result, drawing the boundaries between different applications can be somewhat arbitrary and can vary from organization to organization. As a general rule, the boundaries of applications will be drawn along lines of management responsibility (for the data and products) at some level in the organization. In this example, the accounting department "owns" (i.e., controls) both the input vouchers and output reports.

In general, application diagrams may be formed as subsets of the subsystem interactions diagram shown earlier as Figure II-1. For example, a basic personnel application would consist of subsystems 3 and 7 -- a record-keeping subsystem to maintain the employee master file and an analysis and reporting subsystem to prepare periodic staffing reports. However, other subsystems using the employee master file as input may also be found in personnel applications, as follows:

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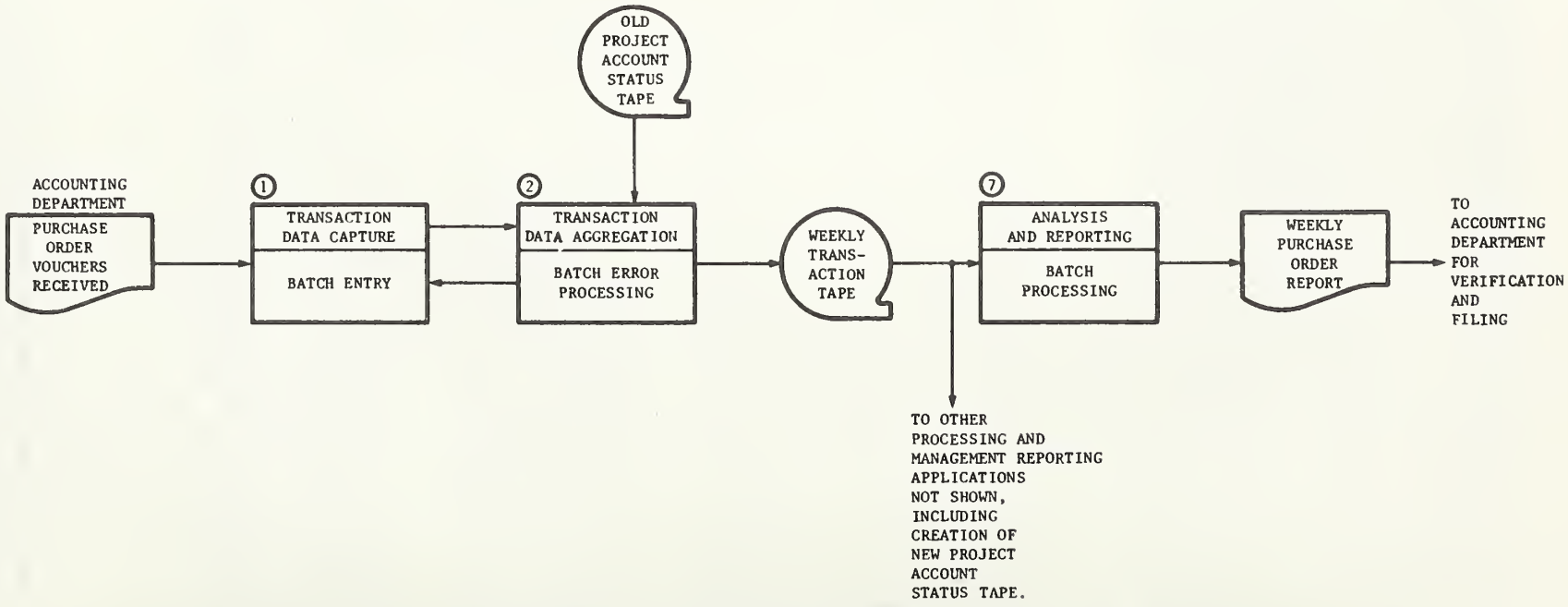
[1] Where the type of media is important to the nature of processing, such as the need for disk storage when random access is required, it will be specifically noted.

Figure IV-1. SAMPLE WEEKLY ACCOUNTING APPLICATION PURCHASE ORDER PROCESSING



- a transaction disbursement subsystem may be included to produce standard personnel action forms for filing in employee folders (as opposed to personnel systems that use these forms as input documents);

- a data retrieval and analysis subsystem may be used for simple on-line inquiries regarding employee status;

- a data retrieval and analysis subsystem may provide infrequent or ad hoc reports for a specific manager;

- a representational model in a specialized-data model subsystem can be included to simulate the effects of anticipated retirements and to project staffing needs.

The particular mix of such "advanced" features in an application will depend as much on the personality of the responsible manager as on organizational size and environment. As a result, while the functions of the personnel application will be comparable from site to site, the degree of automation and the provision of advanced analysis capabilities will vary.

More complex applications can vary from the typical pattern of interconnections shown in Figure II-1. For example, Figure IV-2 shows the subsystem structure of an advanced logistics planning model that processes data on all (expensive) repairable spare parts in the Air Force inventory. The difficulty of the problem forces a series of models to process data in sequence, with one model supplying inputs to the next. This is in contrast to the parallel organization in Figure II-1, where each model is implied to be optional and independent.

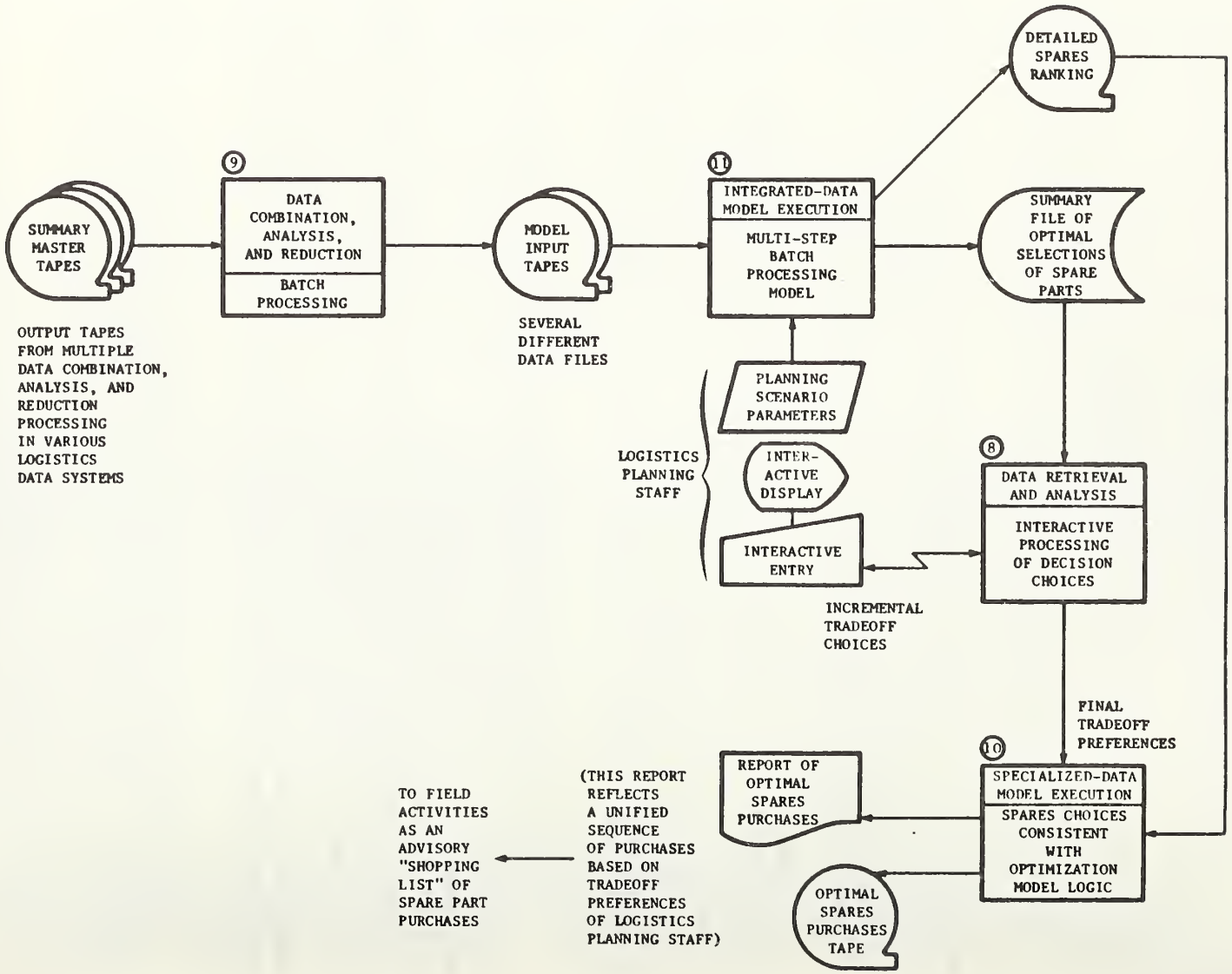
In the logistics planning model, there is extensive transformation of data into information. The data retrieval and analysis subsystem shown provides information to the planners -- it presents them with capability estimates in response to trial budget allocations and thereby allows them to make better budgeting decisions. The suggestion model shown provides information to logistics item managers concerning which parts to purchase. The original input tapes are simply not useful to logistics planners for budgeting purposes: without pre-processing, the mass of detail is impossible for a decision-maker to absorb. Until the data are transformed by the models, and presented in such a way that a decision-maker can make decisions and take actions, it cannot be said that those input tapes provide information -- only that the potential is there.

This section has introduced the concept of an application as comprising different DP subsystems, each serving as a module or building block for the application. Later phases of this effort may attempt to catalog the various ways subsystems are combined to form DP applications in the Federal Government.

C. Subsystem Operational Characteristics

The DP subsystems presented earlier can exhibit different operational characteristics because of both the types of applications in which they are

Figure IV-2. SAMPLE LOGISTICS PLANNING MODEL APPLICATION



included and the skill required to operate them and/or utilize their products. Master files are both an output from recordkeeping systems and an input to transaction disbursement systems, for instance. Transaction aggregation systems are typically used by clerical personnel, while representational models (in specialized-data model subsystems) are generally used either by economists or by technical, business, or policy analysts.

Table IV-A lists different operational characteristics for subsystems in several categories of variation. "Key Role" indicates the type of personnel most responsible for the successful operation of the subsystem. "Decision-Maker" indicates the type of personnel acting upon subsystem outputs. The other categories are self-explanatory.

For subsystems 8.1 through 11.2, the information on type of task, hands-on-user, decision maker, key role, and key usage problem comes from [ALTE-77].[2] The following definitions from Alter's 1975 work [ALTE-75, ch. 6] apply:[3]

- o Feeders are people who provide data for a system, but either do not use it directly for their own decisions or do not derive benefit from it for other reasons. This role is common in budgeting and planning systems in which people at various organizational levels are required to provide information which is later digested and consolidated by the system.

- o A user is a person who communicates directly with the system in either on-line mode or batch mode and receives and decodes its outputs.

- o A decision-maker is a person who makes decisions based on the outputs of the system. These outputs may have been filtered or interpreted by the user before the decision-maker receives them. In this case, the user is referred to as an intermediary.

And, in the context of subsystem 5,

- o A designer is the programmer/analyst and/or electronics engineer responsible for creating hardware and software linkages to sample and record the process data.

Other portions of the table are postulated from a general knowledge of DP applications.

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2 Alter covers some other categories as well, but these deal with system design and implementation and will be covered under the descriptive model for application software development. This portion of Table IV-A reprinted with permission (see references).

3 Reprinted with permission of the author.

TABLE IV-A

SUBSYSTEM OPERATIONAL CHARACTERISTICS [1]

Subsystem [2]	Type of Task	Inputs	Outputs	Hands-On User	Decision-Maker	Key Role	Key Usage Problem	Sample Functions
1. Transaction Data Capture	operational	source documents	transaction records	clerical key-entry operator	key-entry supervisor	hands-on user	source document accuracy and readability	accounting, inventory control, timekeeping
2. Transaction Data Aggregation	operational	transaction records	transaction or master filea	clerical, data technician operator	line manager	handa-on user	data error detection and correction	accounting, inventory control, timekeeping
3. Record-keeping	operational	source documents	master files and transaction filea	clerical or specialist	line manager	hands-on user	data error detection and correction	personnel, payroll
4. Transaction Disbursement	operational	transaction or master files	individual documents	DP operations group	line manager	hands-on user	data error detection and correction	social payments, invoice payments, payroll
5. Automated Data Capture	operational	electronic equipments	aampled data or summary data files	staff analyst or technical analyst	technical manager	designer	compensation for hardware malfunctions	R&D, production
6. Technical Data Preparation	operational or analysis	user-determined model parametera	model input files	technical analyst	technical manager	technical analyst	data accuracy and consistency	engineering economics
7. Analysis and Reporting	operational	master filea	printed reports	DP operations group	line manager	intermediary, feedera	timeliness and utility of reports	general management
8.1 Data Item Display	operational	on-line files	on-line display or printing	nonmanagerial line personnel	nonmanagerial line personnel	hands-on uaer	user motivation and training	inventory control, social payments
8.2 Data Analysis	operational or analysis	on-line data bases	on-line display or printing	nonmanagerial line personnel or staff analyst	nonmanagerial line personnel, manager, or planner	hands-on user	can people figure out what to do with the system	research management

[1] Intended aa a typical list, but not intended to be exclusive or exhaustive.

[2] Entries 8.1 and 8.2 represent Data Retrieval and Analysis (#8). Entries 10.1 and 10.2 represent Specialized-Data Model Execution (#10). Entries 11.1 and 11.2 represent Integrated-Data Model Execution (#11), although 11.1 implementations may also be found under Analysis and Reporting (#7).

TABLE IV-A

SUBSYSTEM OPERATIONAL CHARACTERISTICS [1]

Subsystem [2]	Type of Task	Inputs	Outputs	Hands-On User	Decision-Maker	Key Role	Key Usage Problem	Sample Functions
9. Data Combination, Analysis, and Reduction	analysis	various files from other data systems	summary data files	staff analyst	manager or planner	inter-mediary	how effective is the intermediary	planning, R&D, operations research, logistics studies
10.1 Accounting Model Computation	planning	summary data files	printed reports	staff analyst or manager	manager, planner, or line personnel	inter-mediary, feeders	integration into planning process	personnel, project management
10.2 Represen-tional-Model Simulation	planning	user-entered parameters	printed reports	staff analyst or technical analyst	manager	inter-mediary	understanding	engineering, R&D, operations research
11.1 Decision Suggestion	operational	on-line data bases	printed reports	nonmanagerial line personnel	nonmanagerial line personnel	hands-on user	user motivation and understand-ing	inventory, personnel
11.2 Trade-off Optimization	planning	summary data files, user para-meters	printed reports or summary data files	staff or non-managerial line personnel	manager or nonmanagerial line personnel	inter-mediary	understanding	logistics planning, R&D
12. Computer-Aided Task Performance	operational	real-time user inputs	real-time display, stored results	task performer group	task performer or supervisor	hands-on user	user training and motivation, user friend-liness of system, operational efficiency	secretarial, drafting, engineering
13. Software Development	operational	user-entered program statements	executable programs and control language	programmer/ analyst	as per subsystems 1 thru 12	programmer/ analyst	understanding user requirements, specification changes during development	any from subsystems 1 thru 12

[1] Intended as a typical list, but not intended to be exclusive or exhaustive.

[2] Entries 8.1 and 8.2 represent Data Retrieval and Analysis (#8). Entries 10.1 and 10.2 represent Specialized-Data Model Execution (#10). Entries 11.1 and 11.2 represent Integrated-Data Model Execution (#11), although 11.1 implementations may also be found under Analysis and Reporting (#7).

V. ADDITIONAL SUBSYSTEM CONCEPTS

A. General

The previous chapters have presented a descriptive model of DP operations. This chapter introduces some associated concepts which further develop the framework. It also describes some practical uses of the model made possible by combining those concepts with the earlier subsystem descriptions.

B. Micro Layers of Description

Each of the descriptive flow diagrams in Appendix B characterizes DP operational subsystems in terms of the interaction between employees, data processing steps, and various media containing data. The types of personnel, processing, and data are indicated. This level of detail is a process description: it shows what is done to data, by whom, and in what sequence, as well as what kinds of data (and, if desired, which data elements) are present.

While this level of detail is adequate for a descriptive model, much more information is necessary to evaluate a variety of computer-related standards and guidelines. For example, it could be important to the evaluation of certain standards to know what percentage of the data input terminals represented in Figure B-2 employed a standard ASCII character set. Later phases of the effort will, ultimately, expand the descriptive model to include such data.

This expansion will be accomplished by defining additional layers of detail within the constraints and patterns of interconnection established by the process descriptions. Comparable aspects of DP system activities will be grouped within the same layer. For example, plugging a cable into a terminal on one end and a modem on the other requires physical standards for pin configurations and connector dimensions. This, and all other mechanical interactions, would be included in descriptions of the "physical control" layer of the model. The subsystems represent the breadth of DP activities; the layers of detail represent the depth of description.

Much of the subsequent discussion of layers may not be familiar to the nontechnical reader. However, for the purposes of this report, it is only necessary to have a general understanding that information about DP activities can be meaningfully separated into layers of description.

The interactions (flows) between the blocks in each subsystem are the key to incorporating additional information into the descriptive model framework. The layers that will be used to relate the important characteristics of each flow are the seven layers of communication standards defined by the International Standards Organization (ISO). This structure was selected because it is compatible with existing standards and covers anticipated future standards.

A brief description for each layer is as follows:[1]

(7) process control - the high-level events and steps in a data processing procedure, including the personnel, DP equipment, software, and data involved.

(6) presentation control - functions relating to character sets, character encoding, and the presentation of character data.

(5) session control - procedures for establishing the rules for how a dialogue will take place between two elements (which machine will speak and in what sequence).

(4) transport end-to-end control - integrity controls for the flow of transactions between two user devices and/or computers, insuring completeness of transmission.

(3) network control - procedures for establishing a route for data through a shared network (a "virtual circuit") and for transmitting data through the network.

(2) link control - procedures for sending blocks of data over a physical transmission line.

(1) physical control - specifications for mechanical, electrical, or other physical interconnections that establish a transmission link between two devices.

Table V-A shows these layers, and lists some of the elements and processes found in each.[2] For example, in this breakdown, an ASCII character set is one of the character set options under layer 6 (presentation control), and the use of ASCII would be recorded as a layer 6 detail of the descriptive model. The subsystem descriptions presented earlier have involved only layer 7 (process control).

These layers apply to all system interfaces. For example, for the clerk in Figure B-2 to use a terminal to communicate with a computer, or for any of the flows in the subsystem description to exist, a "compatible" linkage must be established between terminal and computer at each of the seven layers. Compatibility means the specification, at each layer, of the procedures in use. For some of the layers, few, if any, of the procedures may be relevant to the interconnection. For example, layer 3 (network control) procedures do not apply to most timesharing computer users who dial the computer center directly.

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1 The level of the interface layer is indicated by the number in parentheses.

2 From [MART-80], but "character sets" and "data representations" have been added to clarify points for this descriptive model. Reprinted with permission (see references).

TABLE V-A
SEVEN ISO LAYERS [1]

7. PROCESS CONTROL

APPLICATION & APPLICATION SYSTEM
ACTIVITIES
DATA REPRESENTATIONS (ABBREVIATION & CODING)
OPERATOR FUNCTIONS
DISTRIBUTED FILE & DATABASE

6. PRESENTATION CONTROL

CHARACTER SETS
DATA FORMATS
DATA TRANSFORMATIONS
EDITING
COMPACTION
CRYPTOGRAPHY
VIRTUAL DISPLAY SPACE, ETC.

5. SESSION CONTROL

ACTIVATE AND DEACTIVATE SESSIONS
BIND
ENFORCE DIALOGUE CONTROL
CHECKPOINTING & RECOVERY

4. TRANSPORT END-TO-END CONTROL

DATA ASSURANCE
PACKETIZING, ADDRESSING,
FLOW CONTROL
NETWORK-INDEPENDENCE INTERFACE

3. NETWORK CONTROL

X.25 PACKET LEVEL
INTERFACE TO NETWORK

2. LINK CONTROL

HDLC, ADCCP

1. PHYSICAL CONTROL

V.24, V.25, EIA RS 232C, EIA RS 366
X.21, X.21 BIS

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[1] From [MART-80], but "character sets" and "data representations" have been added to clarify points for this descriptive model. Reprinted with permission (see references).

To adapt the ISO layers concept for this descriptive model, the concept must be broadened. For instance, ISO layer 3 (network control) covers the establishment of "virtual circuits" in computer networks. The descriptive model layer 3 includes much simpler cases such as a clerk's dialing the phone number of the computer center or an installer's connecting a hard-wired cable at one point in time. As another example, layer 1 (physical control) often implies the use of a standard 25-pin electrical connector. However, in the broader context of the descriptive model, it can mean <u>any</u> physical interface such as the sound waves carrying data between an acoustic coupler on a terminal and a telephone receiver (an energy linkage) or one employee handing a piece of paper to another (a physical, "touching" linkage).

Possible interfaces at the different descriptive layers could be described at great length, and a later phase of this effort may cross-reference the set of Federal Information Processing Standards to the descriptive model subsystems and produce some interface specifications. The present purpose is simply to show that the descriptive model concept is not limited to descriptions of DP procedures. All kinds of data about computer systems may be incorporated into the descriptive model, in an organized fashion, by employing the micro layers of description outlined above.

C. Macro Layers of Description

Certain broader questions of interest to Federal DP activities cannot be represented within the seven-layer framework, and an expansion to higher levels is needed. For example, subsystem 1 (transaction aggregation) indicates that transaction documents are received and keypunched but does not imply what kind of information contained in the transactions. In the application illustrated in Figure IV-1, purchase order processing, expense information is contained in the transactions. However, subsystem 1 transactions could contain other types of information such as stock level changes. As indicated in the Chapter IV examples, the information flowing through the system can change as additional processing is performed, depending on who interprets the data and in what context. For example, repair action information from an airbase, after much processing and aggregation, eventually becomes budget planning information. Layer 8 (information) will be designated for any discussion of the interpretation of the data items covered in the descriptive model.

The benefits of standards and guidelines that affect the accuracy and integrity of computer processing, most notably those related to computer security, will primarily depend on the actions taken, and the decisions made, based on the data. The value of the benefits will depend on the financial or other impacts of those actions and decisions. Discussion of such actions and decisions will be assigned to layer 9 (decisions).

Decisions are generally made in the context of one or more business or organizational functions, and layer 10 (organizational functions) is designated for information on organizational functions such as production, accounting, personnel, R&D, etc. Finally, layer 11 (organizational environment) is provided to describe the organizational environment that both constrains and motivates DP activities.

Table V-B shows the complete 11 layer hierarchy designed to organize DP information in the context of the descriptive model. While the higher numbered layers will not be utilized immediately, they are defined here to insure that a robust model structure will be available when needed. The next sections further elaborate the multi-layer concept.

D. Security Considerations

The descriptive model does not explicitly include computer security. However, combining the flow diagrams and the multi-layer hierarchy provides a different approach to categorizing and modeling security issues.

Figure V-1, [WARE-79], is a widely used representation of computer system vulnerabilities. It provides an overview of threat or "leakage" points for computer systems. These are areas where a system designer must provide protective features to safeguard information against both accidential and deliberate events. They may be classified into five major categories: physical surroundings, hardware, software, communication links, and organizational aspects (personnel and procedures).

In terms of the definitions given earlier, it is evident that Figure V-1 contains a mixture of elements from different descriptive layers. Categorizing both threats and system vulnerabilities in terms of the applicable descriptive layers makes a comprehensive and organized treatment of computer security possible. Heretofore, the literature has been characterized by a plethora of ad hoc, overlapping, and incomplete security categories, which have varied with the interests of the author. The combination of subsystem flow diagrams (covering the breadth of DP activity) and a multi-layer descriptive framework (covering the depth of DP activity) can both absorb the various existing security schema and provide a basis for analysis.

In any functioning DP subsystem, communication between layers occurs at many of the interfaces between data flows (the lines in the subsystem flow diagrams) and subsystem elements (the boxes in subsystem diagrams -- processing or action steps, and storage media). When a user enters data at a terminal by striking a key (layer 1), the terminal translates that action into a string of bits in accordance with the ASCII standard or some other defined character set (layer 6), other bits may be added if intermediate levels (2 through 5) are active, and the bit stream is translated into electrical impulses (layer 1). Between instances of communication between layers, activities or data flows in all active layers are considered to occur simultaneously and in parallel.

This conceptualization leads to several principles:

- To <u>compromise</u> a system, a perpetrator must be able to detect (and correctly interpret) data flows of interest at all layers between 1 and 8 that are in use at his point of system access.

- To <u>manipulate</u> a system, a perpetrator must be able to compromise the system and also influence or control at least one layer at one point in a subsystem.

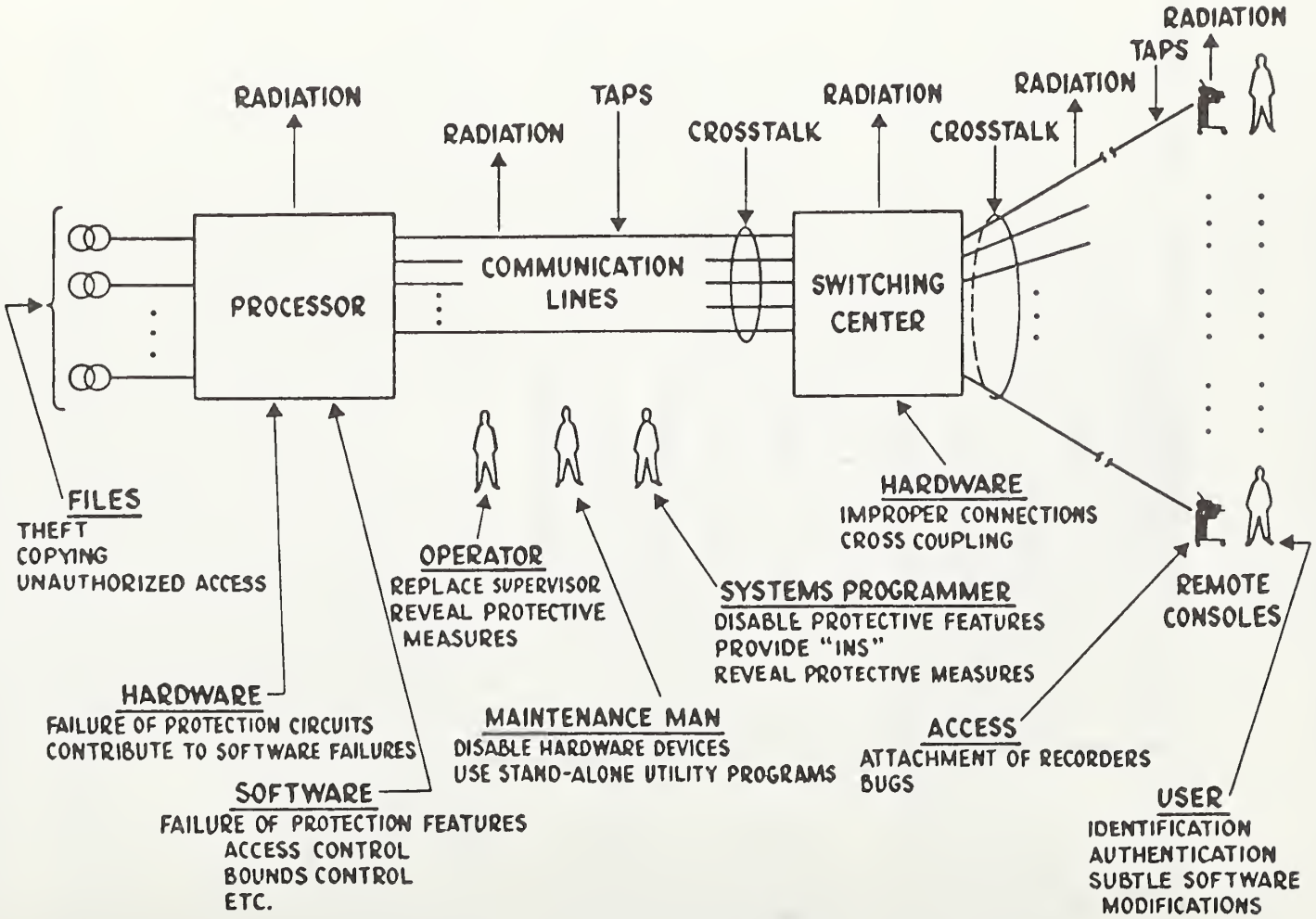
TABLE V-B

MACRO AND MICRO LAYERS OF DESCRIPTION

Layer #		Title
11		ORGANIZATIONAL ENVIRONMENT (GOALS, RESOURCES, CHARACTERISTICS)
10		ORGANIZATIONAL FUNCTIONS
9		DECISIONS
8	(MACRO)	INFORMATION
7	(PROCEDURAL)	PROCESS CONTROL [1]
6	(MICRO)	PRESENTATION CONTROL
5		SESSION CONTROL
4		TRANSPORT END-TO-END CONTROL
3		NETWORK CONTROL
2		LINK CONTROL
1		PHYSICAL CONTROL

[1] The subsystem descriptions in this report represent the process control layer.

Figure V-1. COMPUTER NETWORK VULNERABILITIES [1]



[1] From [WARE-79]

- To disrupt a system, a perpetrator needs only to disrupt any one layer, which may be accomplished by destroying data, inserting noise, or severing linkages. It is not necessary for the perpetrator to possess the in-depth knowledge of system processing that might be required to accomplish a compromise or manipulation.

- Errors and omissions need occur only at one level, like disruptions.

As an illustration, to compromise a system by wiretapping, a perpetrator must be able not only to detect the electrical impulses in the phone line (layer 1) but also correctly interpret those impulses as characters (layer 6) in order to gain information (layer 8). Secure encryption prevents the perpetrator from correctly interpreting any text (in layer 6) to get to the information desired (in layer 8). It is more difficult to manipulate a system by interrupting telephone communications. The perpetrator has to not only insert new signals but also have full knowledge of the higher layers if the new signals are to have the desired effects on, say, the data presentation (layer 6), while not affecting any intervening layers in a way that can be detected.

To disrupt a system communication, the perpetrator need only cut the telephone line or inject noise into it (layer 1); there is no need to manipulate or compromise the higher numbered layers. More extensive disruptions require either more extensive or more critical physical destruction, or an ability to manipulate the lower layers so as to disrupt the system at higher layers. An instance of the latter is the submission of a program that in fact "takes over" an operating system.

Detected errors or omissions are in general a form of disruption -- they cause additional work to be performed to straighten them out, and they slow down operations. Undetected errors and omissions are like manipulations -- they cause improper actions as they flow through a system.

In addressing security issues, layers 9 through 11 must be considered twice -- once for the perpetrator and once for the victim organization. The first instance involves the perpetrator point of view and addresses the costs and benefits of attacking the system; the second addresses both the costs of protecting the system from attack and the potential losses from not protecting the system, using the organization's point of view. Both sets of costs and benefits must be considered in the selection of security measures.

Both threats and protective measures can be cross-indexed in terms of subsystems and descriptive layers. This provides a powerful tool for security analysis, and is an illustration of how security issues may be incorporated into these descriptive models.

E. Presentation Methods

The set of descriptive flow diagrams presented in Appendix B can be used for more visually-oriented presentations of the impacts of standards.

Figure V-2 illustrates how the impacts of a hypothetical standard could be cross-referenced to points of impact in the descriptive model. This illustration shows only the aggregate totals for major impact areas, but other headings, such as detailed impact areas,[3] could be used if more space were available.

While the "Impact Areas" columns contain dollar impacts, the "Impact Descriptions" columns contain commentary text. The "Specific Impacts" column would show which system characteristics would be influenced by the standard in order to achieve the projected impacts. The "Measurements" column would list the data characteristics to be measured, the data to be collected, the methodology to be employed in data collection and analysis, and estimates of probable error.

Another use for this type of format would be to cross-reference impact categories and different standards and guidelines in a family or even different families. Such a presentation would highlight possible cross-impacts and indicate the need to explore whether the standards were complementary or in conflict. Standards could also be grouped by other criteria such as the descriptive layer affected or the specific points of impact in each subsystem.

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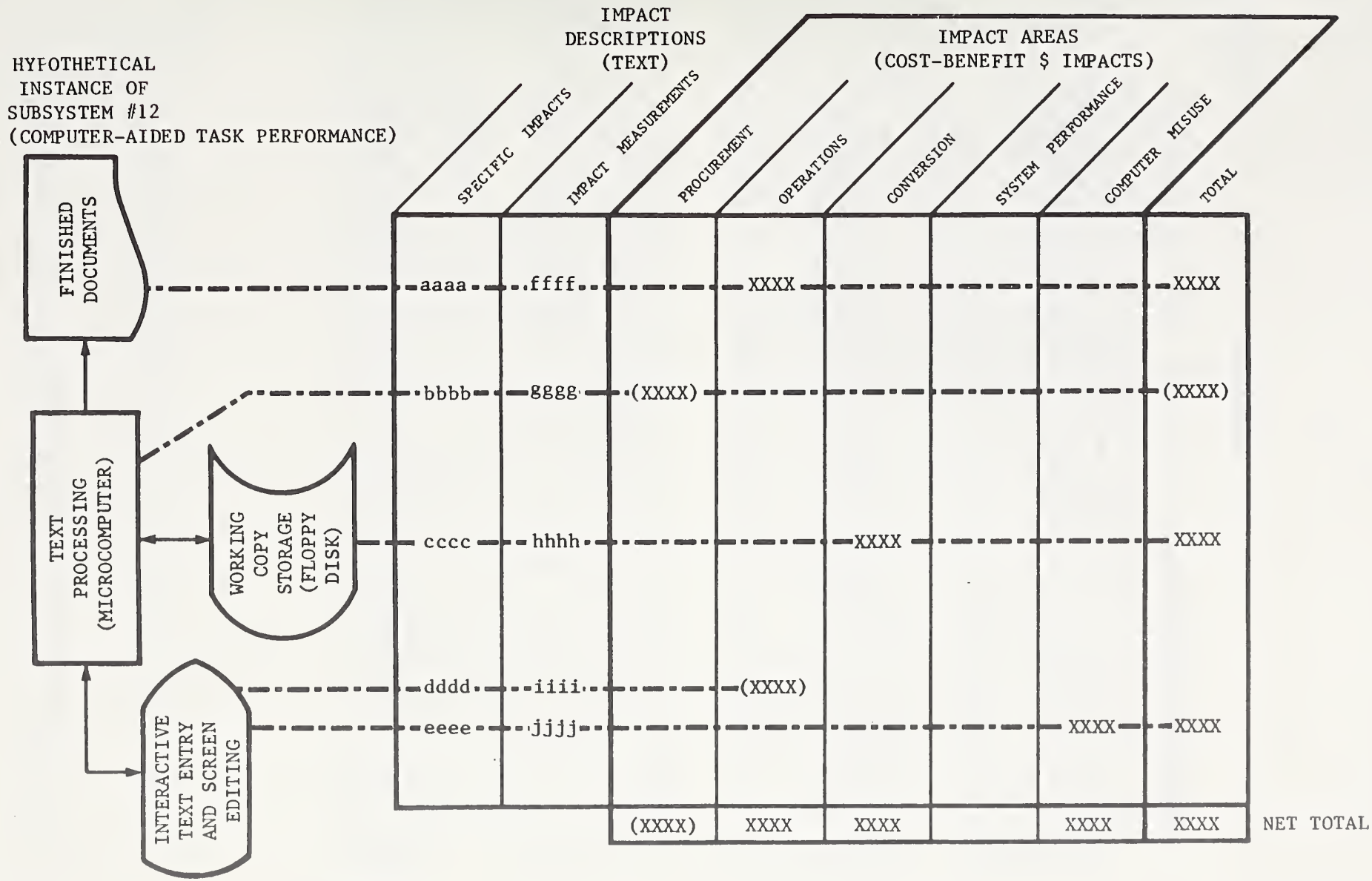
[3] Table A-1 in Appendix A lists impact areas.

Figure V-2. PRESENTATION FORMAT FOR SUBSYSTEM AND IMPACT AREA CROSS-REFERENCES[1]



KEY:

BENEFITS XXXX

COSTS (XXXX)

1 Based on a concept developed by Warren Frederick and Joe N. Nay for Performance Development Institute, Washington, D.C.

VI. CONCLUSION

A. Summary of Phase I Report

This report has presented flow-diagram descriptions for a set of DP operational subsystems. These diagrams and the specifications for the subsystems are the basic elements for a descriptive model of Federal DP operational activities. The subsystems serve as building blocks for computer applications. Different applications can comprise the same combinations of subsystems -- the processing can be similar even though the data items are different and serve different parts of an organization.

It will be useful for analytical purposes to associate information about system standards and guidelines and their impacts with the descriptive model. This may be accomplished through use of the multiple descriptive layers presented Chapter V. The layers characterize interfaces between elements in the descriptive flow diagrams. The concept is particularly useful for analyzing security issues, since security violators generally must access a system using the same types of interfaces as system users, and analysis by layers allows a more precise treatment of those interfaces. A brief overview was given of potential uses of the descriptive model for presenting interrelationships between DP systems and standards.

B. Future Work

During later study phases, the breadth of the Phase I descriptive models will be extended by the preparation of additional descriptive models for hardware acquisition, software acquisition, application software development, data resources planning, security, and overall DP management. Eventually, all secondary areas shown in Figure I-1 should be developed to a stage comparable to the model presented in this report for DP operations.

The focus of the Phase II effort is the development of descriptive models for applications software development. The Phase II model traces the unifying flow from initial problem to ultimate software solution, and intersects the Phase I model in subsystem 13, which in turn may intersect the remaining 12 subsystems at any point where in-house software is utilized. In addition, a parallel effort on a security-related descriptive model is now underway.

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[WARE-79] Ware, W.H., ed. Security Controls for Computer Systems, Report R-609-1, Rand Corporation, Santa Monica, California, October 1979

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[1] Labeling schemes (p.7), portions of Table IV-A (p. 21), and other [ALTE-77] excerpts, were reprinted from [ALTE-77] by permission of the publisher.

[2] Table V-A (p. 26) reprinted from [MART-80] by permission of the publisher.

APPENDIX A

BASIC COST-BENEFIT ANALYSIS METHODOLOGY

APPENDIX A

BASIC COST-BENEFIT ANALYSIS METHODOLOGY [1]

1. Specifying the Goals and Objectives for the Standard. Identifies which ICST goal(s) and objectives(s) the prospective standard is expected to contribute to and achieve, respectively.

2. Preparing the Standards Definition Statement. Summarizes all the essential information about the standard necessary to conduct the cost-benefit analysis. At a minimum this includes:

   - How the standard will be developed, used and supported.

   - Essential assumptions and information for the cost and benefit estimates submitted.

   - The historical data trail on the evolution of the standard's design and development and the corresponding impact and cost estimates from the beginning to the formal implementation of the standard. The trail is provided by the chronological sequence of updated definition statements.

   - A basis for a critical review of the standard's objectives and a discussion on how well the proposed design and development process will satisfy them.

   - Descriptions of the areas of high technological risk and cost-benefit uncertainty.

   The statement can also reference selected information in the backup material that documents the cost and benefit estimates. Each time a cost-benefit analysis is prepared, a Standards Definition Statement will also be prepared. In this way, the statement provides a readily available audit trail and a basis for critical review of the standard.

3. Defining the Base Case. Defines the status quo for those cost-benefit impact dimensions relevant to the standard. The base case can be defined for one or several FIPS that are under consideration. The several FIPS case would occur where the impacts from two or more alternatives tend to overlap, and the individual impacts are not readily distinguishable. It also provides a basis for the projection of future conditions if the standard is not developed and implemented.

---

[1] Based on the 1978 preliminary guidelines for impact assessments of standards [FIOR-78].

4. Selecting the Cost-Benefit Impact Areas. Specifies cost and benefit impact areas relevant to the standard. A standard will require certain costs for development, implementation, validation and maintenance. In addition, there are costs that can be incurred by the Federal ADP installations that utilize the standard. On the benefit side, a standard will typically tend to have its major economic impacts in one of three areas: procurement, operations, or conversion. These impact areas and elements further delineate how a standard contributes to the ICST goals and objectives concerned with achieving economies in ADP procurement, operations, and conversion. Table A-1 gives the list of impact areas.

5. Constructing the Cost-Benefit Analysis Model. Provides the appropriate model form to quantify the cost and benefit impacts expected of the standard. The model is used to estimate the flows of costs and benefits attributable to the standard over time. Adjustments for the time value of money can be incorporated in the model by using appropriate discount factors.

6. Obtaining Data. Collects the data to perform the analysis. In addition we expect to utilize the data and analyses from the cost-benefit analysis of selected, individual standards.

7. Estimating and Evaluating the Cost-Benefit. Represents the consolidation of the qualitative and quantitative analyses performed up to this point. The basis of the cost-benefit analysis will be the generation of the base case parameters and the computation, within specific confidence intervals, of the effect a new standard scenario will have on cost levels. The techniques used to generate the figures comprising the base case address the areas of: (1) level of expected resource consumption, (2) Federal ADP installation's unit cost for each resource, and (3) projected impact(s) of the proposed ADP standard. To aid in this process, cost element equations will be used. To determine the net cost-benefit impact of a FIPS, the costs to the Federal Government (specifically ICST) of developing and implementing the FIPS will be defined and incorporated into the analysis.

8. Presenting and Interpreting the Results. Translates the cost-benefits attributable to the FIPS in the context of the Federal agencies that are expected to be impacted by the standard. This step is crucial as it specifies whether actual budget dollars will be changed (such as in procurement impacts) or whether the impacts are productivity changes (such as when a resource is freed up for other activities).

TABLE A-1

COST-BENEFIT IMPACT ELEMENTS

100 PROCUREMENT
- 101 Hardware
- 102 Software
- 103 Testing
- 104 Planning & Analysis
- 105 Initial Training
- 106 Documentation
- 107 Installation

200 OPERATIONS
- 201 Operating
- 202 System Management
- 203 Maintenance
  - 203.1 Hardware Maintenance
  - 203.2 Software Maintenance
- 204 Programming
- 205 Ongoing Training
- 206 Facilities
- 207 Security Provisions

300 CONVERSION
- 301 Program Transfer
- 302 Retrofit

400 SYSTEM PERFORMANCE
- 401 Computer System
- 402 Applications Software
- 403 System Users

500 COMPUTER MISUSE
- 501 Errors and Omissions
- 502 Computer-Related Fraud and Embezzlement
- 503 Privacy Intrusion
- 504 Alteration of Computer Records
- 505 Theft of Computerized Information
- 506 Unauthorized Usage
- 507 Denial of Service
- 508 Equipment Damage

APPENDIX B

SUBSYSTEM DESCRIPTIVE MODELS

APPENDIX B

SUBSYSTEM DESCRIPTIVE MODELS

CONTENTS

APPENDIX B

SUBSYSTEM DESCRIPTIVE MODELS

Overview

This Appendix contains flow diagrams to illustrate representative processing procedures for the 13 operational subsystems defined in the text.

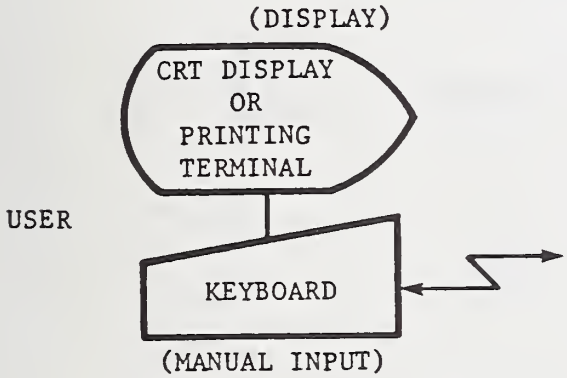
These flow diagrams are a breakdown of Data Processing Operations as represented in Figure I-1, and may be viewed as existing in that larger context. Technology variations and interactive vs. batch options are shown where appropriate within each flow diagram, with the exception of subsystem 3 (recordkeeping), where two separate flow diagrams were used to represent the differences between "standard" and DBMS processing. Exhibit B-1 introduces the symbols used in the flow diagrams and notes extensions to the standard symbols shown in Exhibit B-2.

Exhibit B-1. KEY TO ILLUSTRATIONS

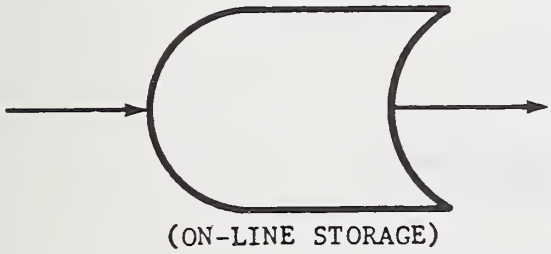
The subsystem flow diagrams in this Appendix have been prepared in accordance with FIPS PUB 24 [ICST-73], which adopts the flowchart symbols specified in [ANSI-71]. However, for the purposes of these flow diagrams, the extensions noted below were necessary to provide uniformity and clarity of representation. Please refer to Exhibit B-2 for a summary of the standard symbols.

(ANNOTATIONS) and COMMENTS

Interfaces between users and subsystems



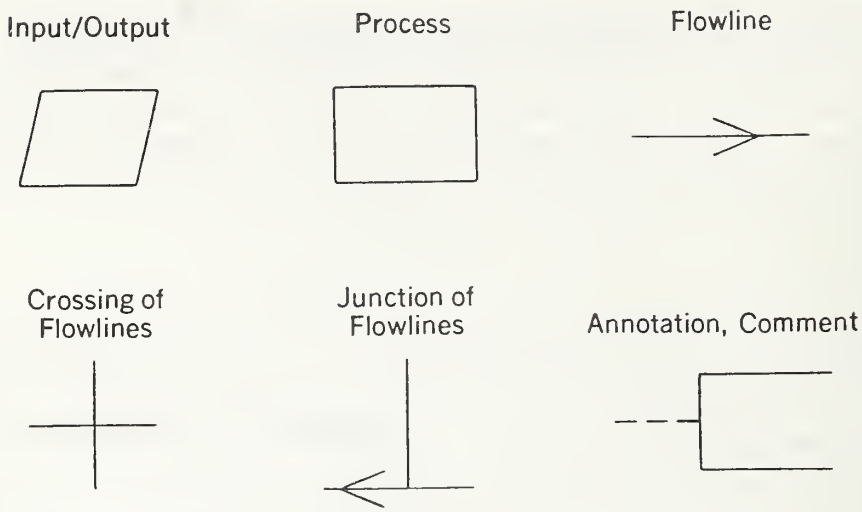
The combination of "manual input" and "display" shown here represents any user-interactive terminal, which may be a CRT, printing terminal, or CRT with attached printer. The symbol may have either a left- or right- orientation in order to face the illustration of a user in a flow diagram.



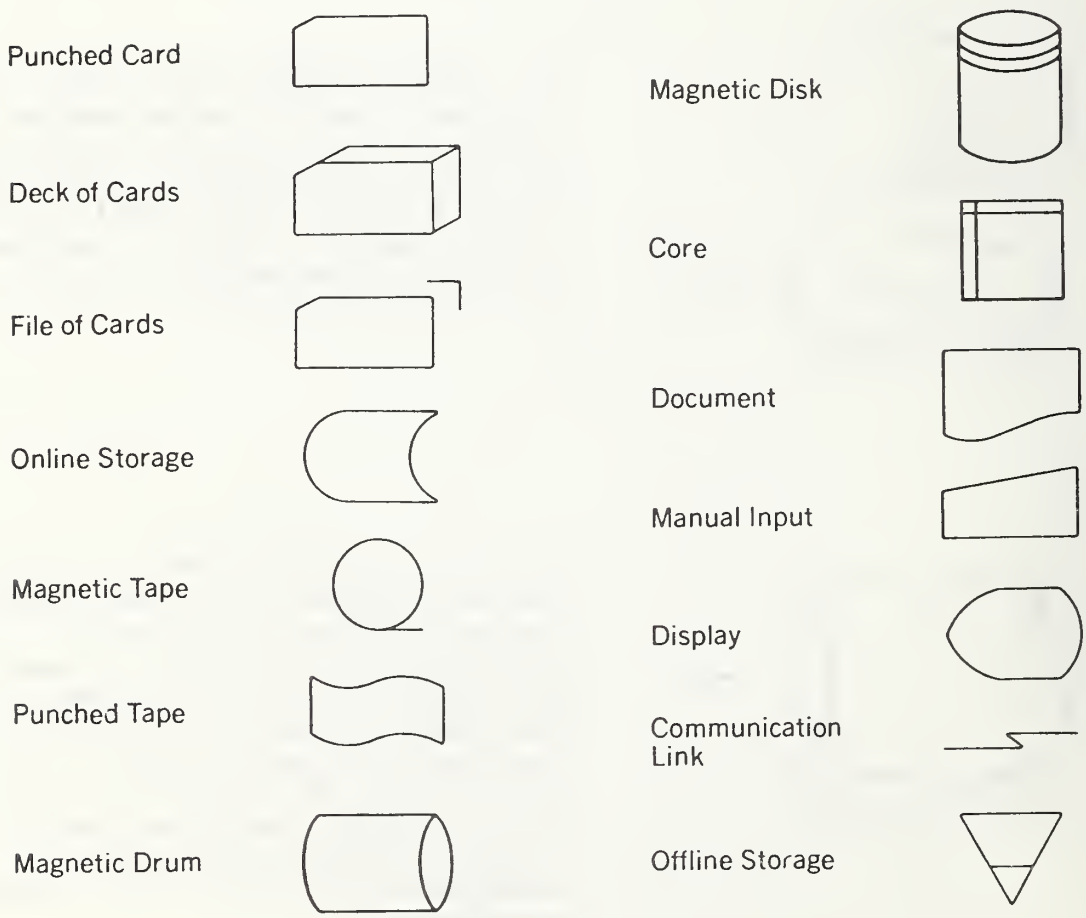
The on-line storage symbol is used to represent either tape, disk, or other storage media accessible on-line, in accordance with FIPS PUB 24. However, its usage includes instances where the more specific magnetic disk symbol would have been more correct. This was done in order to reserve the magnetic disk symbol for the emphasis of particular technology variations and/or database random access in the appropriate subsystems.

Exhibit B-2. Summary of Flowchart Symbols[1]

Basic Symbols



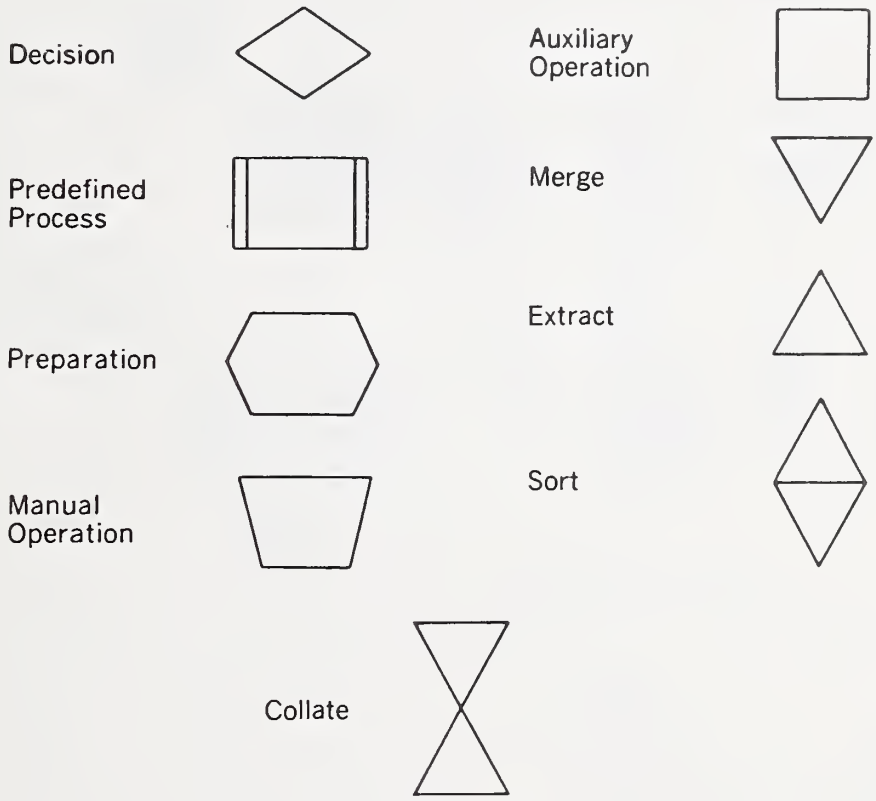
Specialized Input/Output Symbols



[1] From [ANSI-70]

Exhibit B-2. Summary of Flowchart Symbols (Continued)

Specialized Process Symbols



Additional Symbols

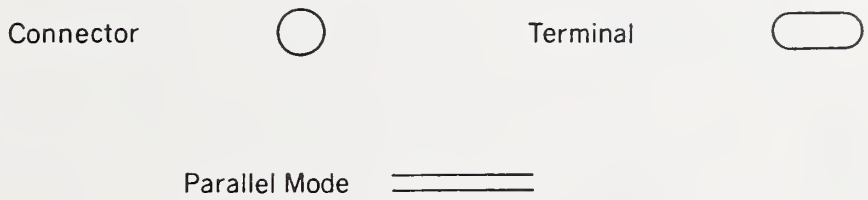


Figure B-1. TRANSACTION DATA CAPTURE

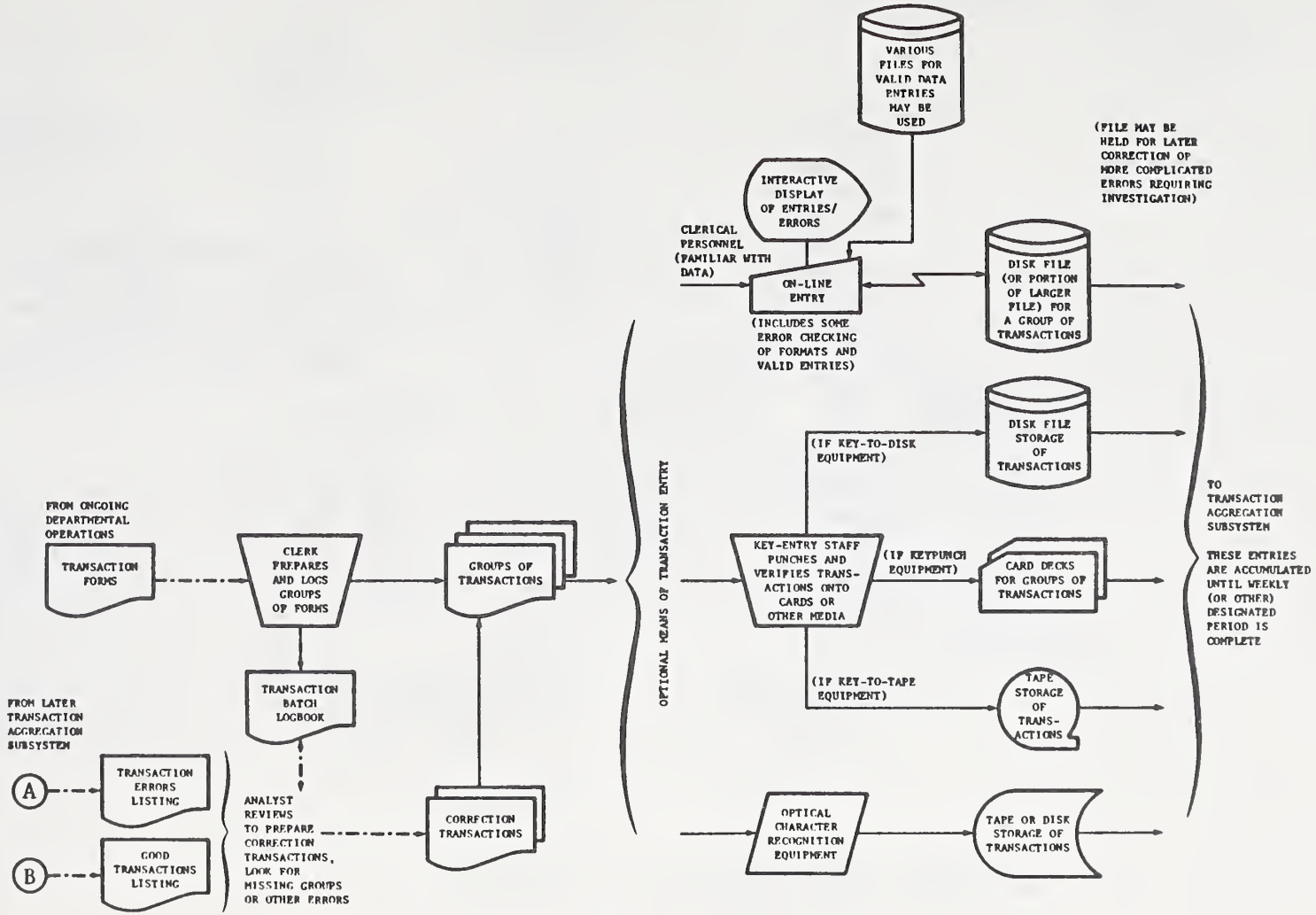


Figure B-2. TRANSACTION DATA AGGREGATION

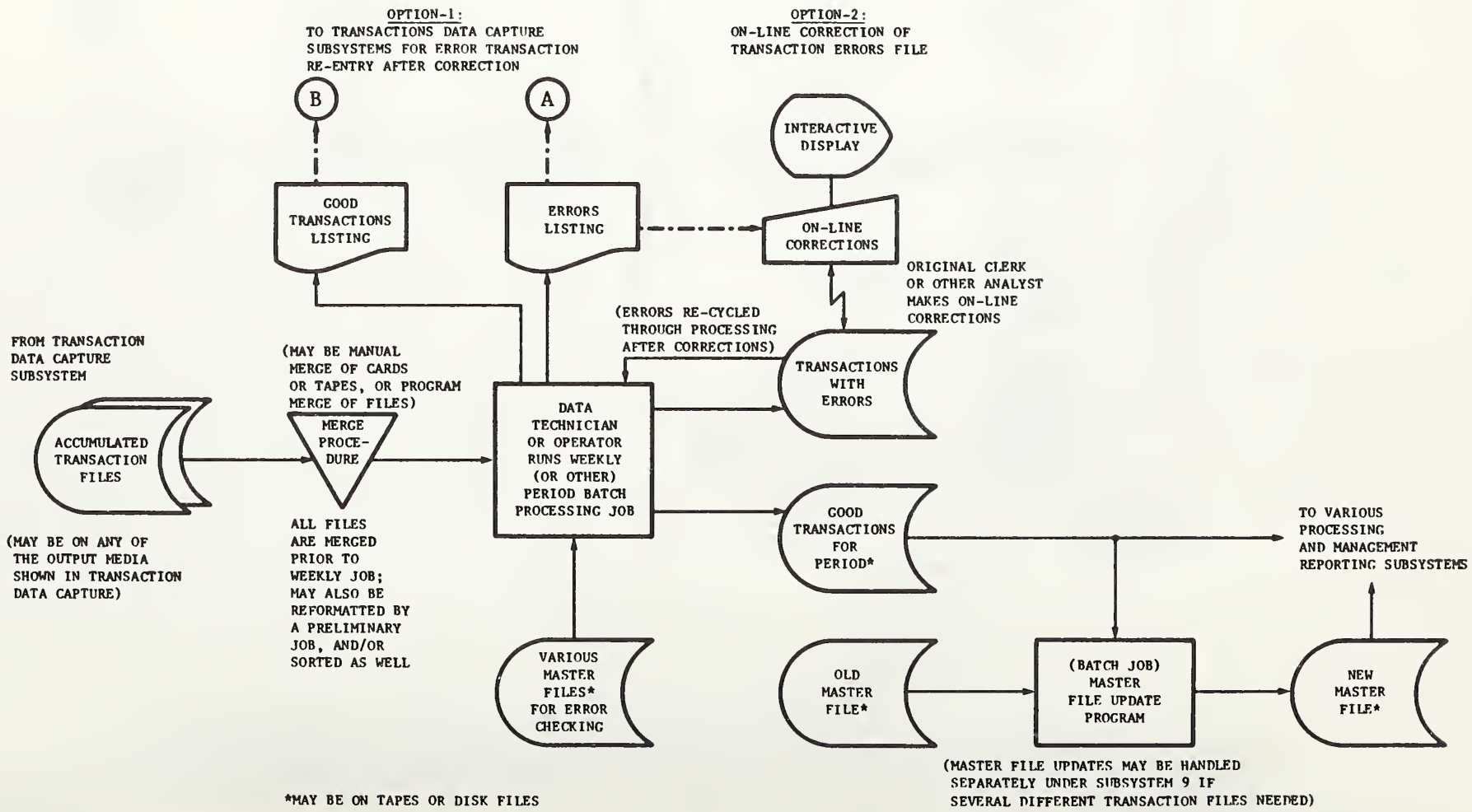


Figure B-3a. RECORDKEEPING (on-line, deferred update)

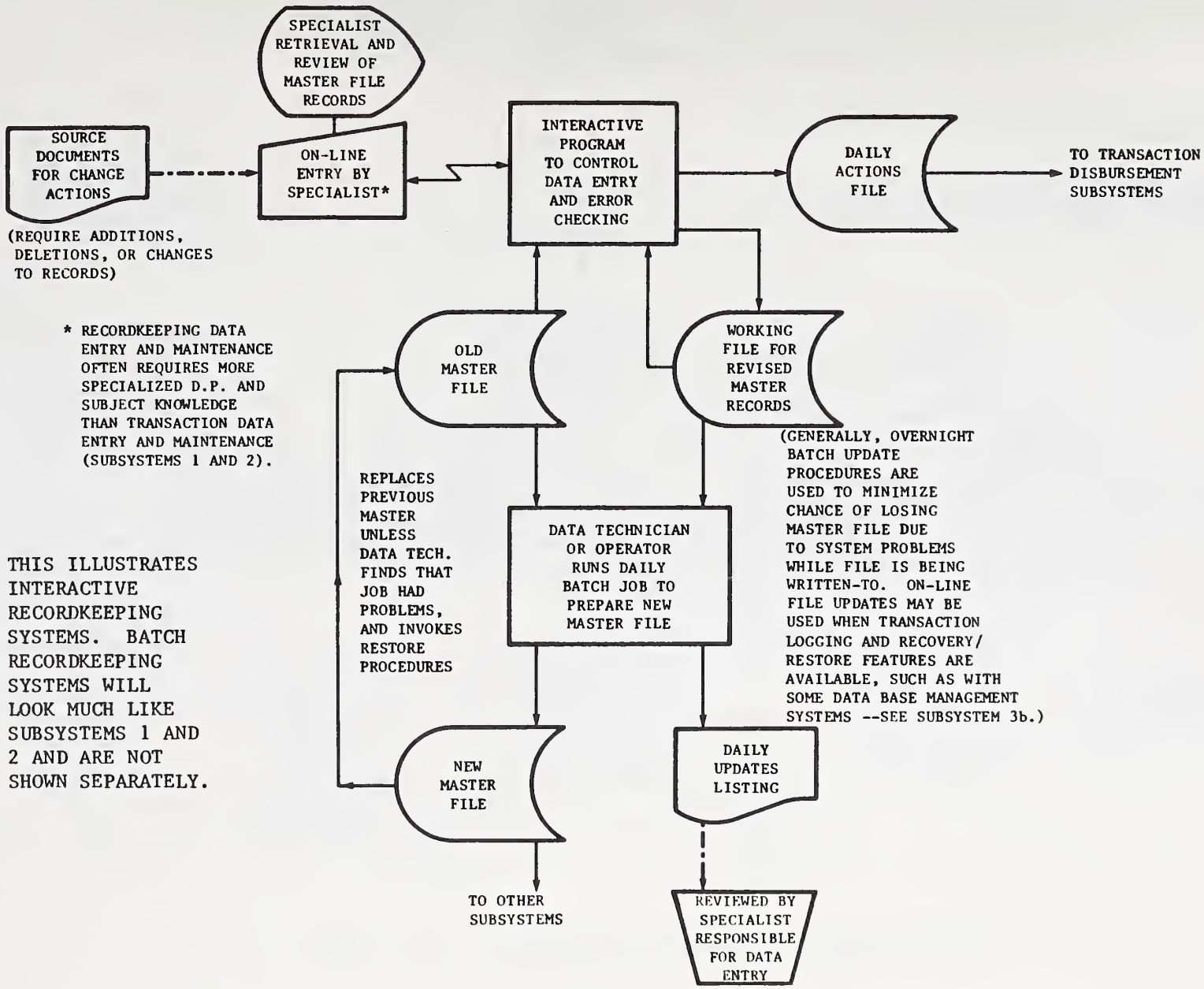


Figure B-3b. RECORDKEEPING (on-line, immediate update)

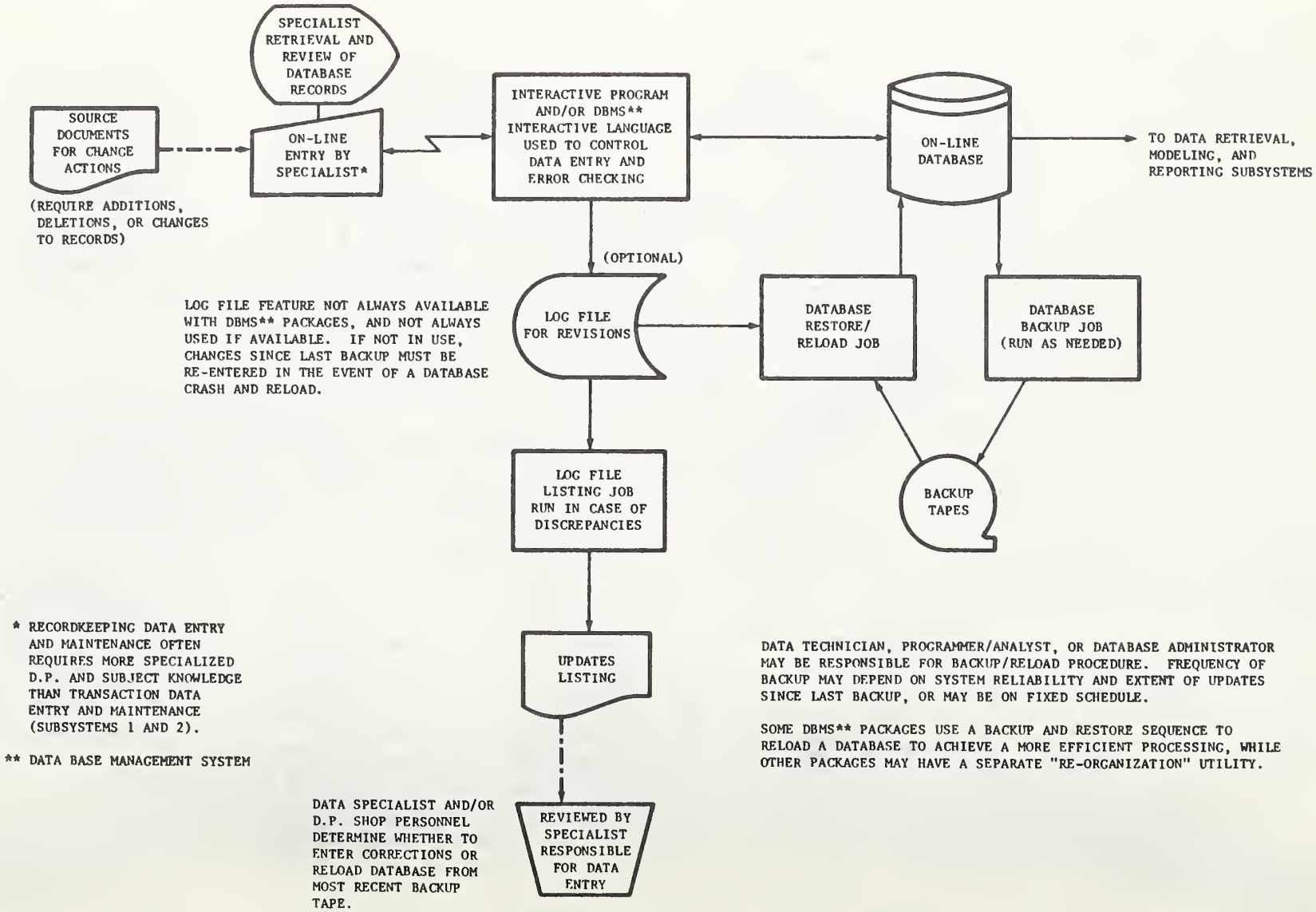


Figure B-4. TRANSACTION DISBURSEMENT

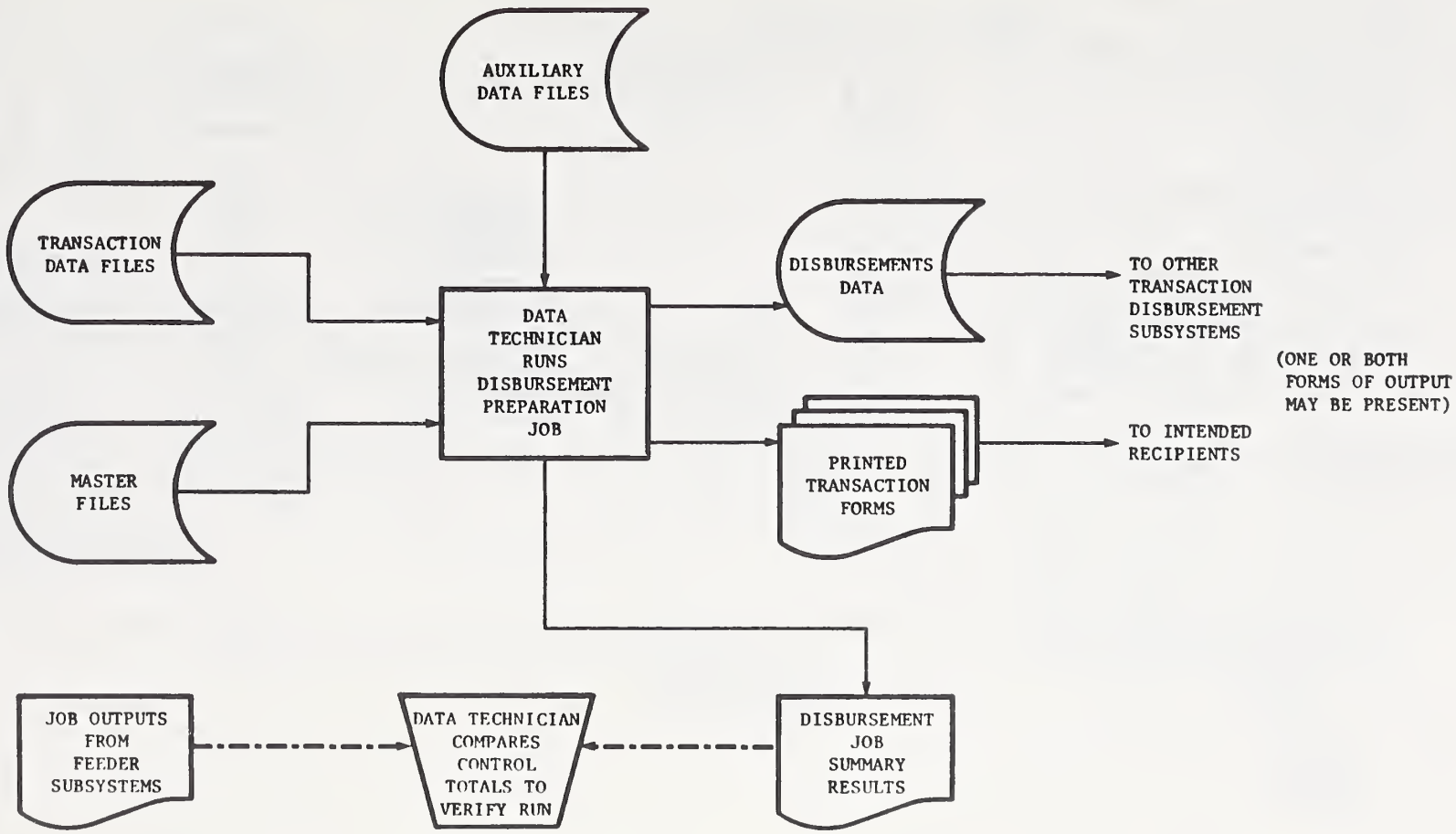
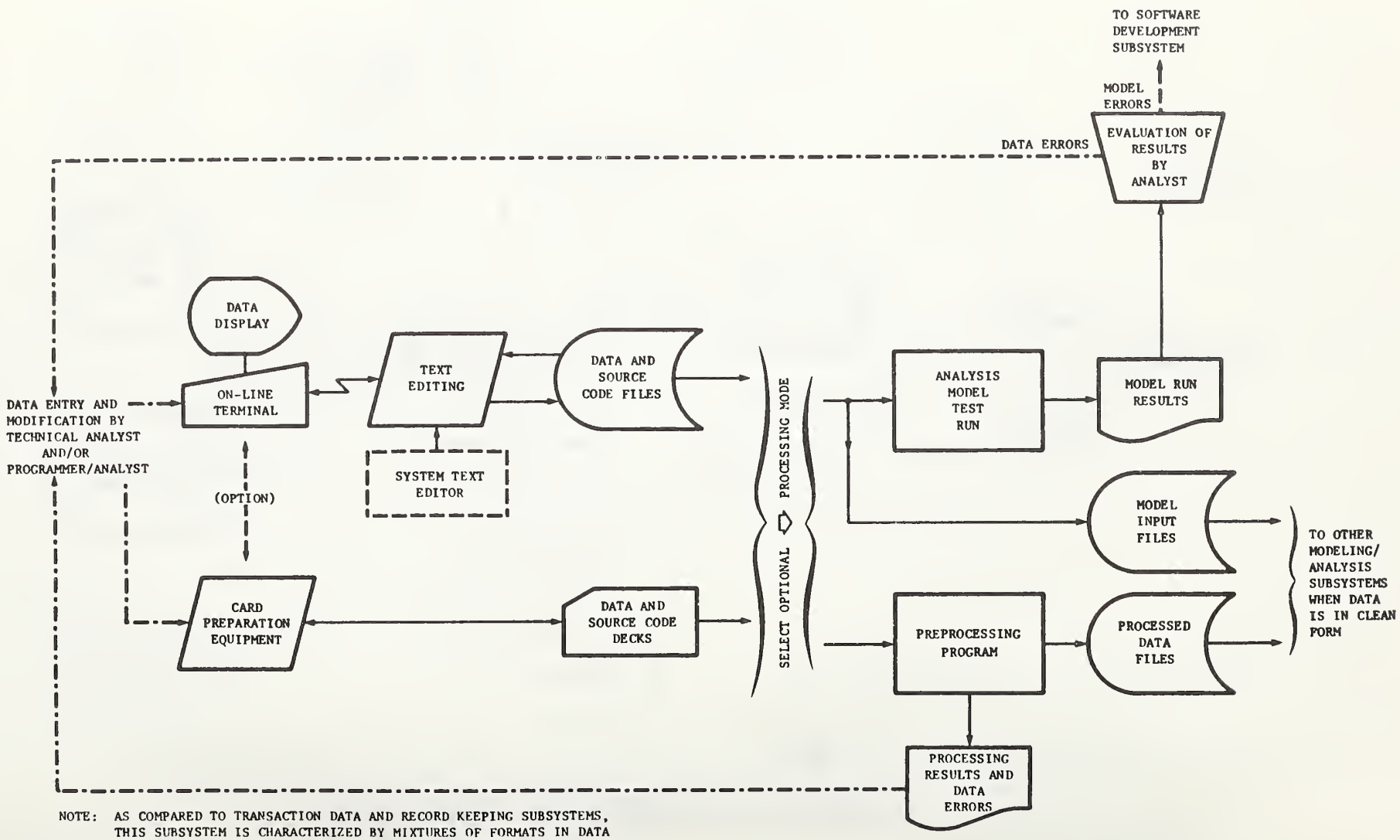


Figure B-5. TECHNICAL DATA PREPARATION



NOTE: AS COMPARED TO TRANSACTION DATA AND RECORD KEEPING SUBSYSTEMS, THIS SUBSYSTEM IS CHARACTERIZED BY MIXTURES OF FORMATS IN DATA FILES OF MODEL PARAMETERS, AND AD-HOC MAINTENANCE PROCEDURES WITH FEW FORMAL VALIDATION TESTS (IF ANY). DATA INTEGRITY DEPENDS ON THE CARE TAKEN BY THE ANALYST IN DATA ENTRY, AND ON SCRUTINY OF LATER MODEL RUNS OR COMPUTATIONAL RESULTS BY THE END-USER.

Figure B-6. AUTOMATED DATA CAPTURE

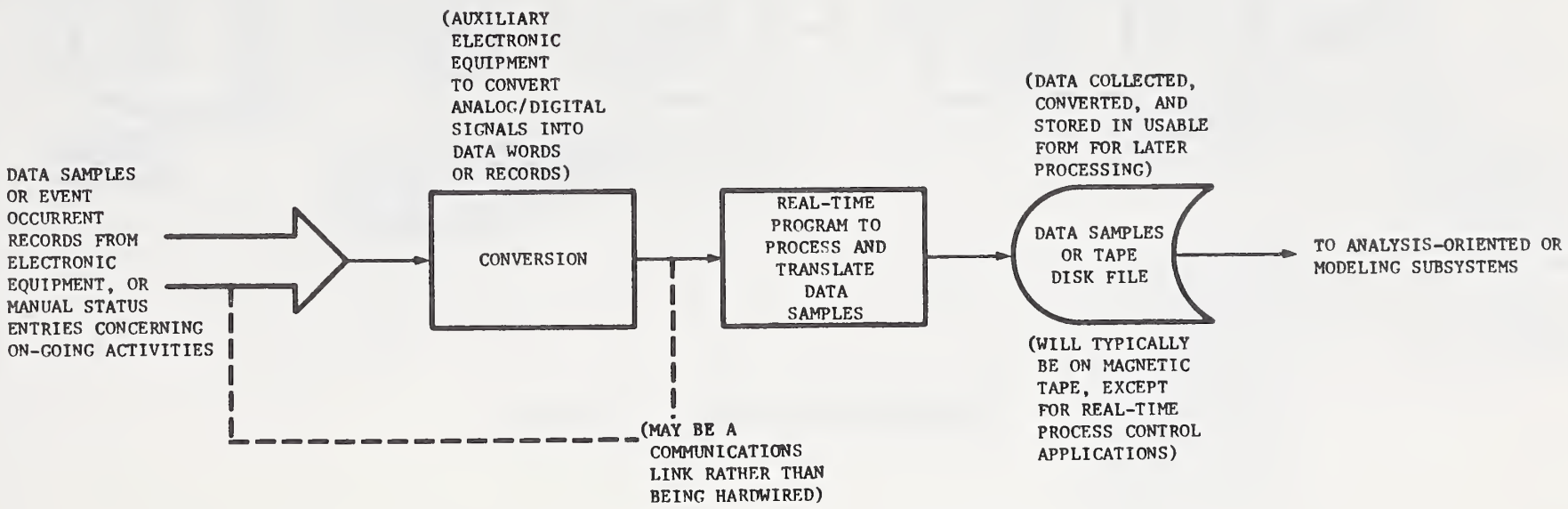


Figure B-7. ANALYSIS AND REPORTING

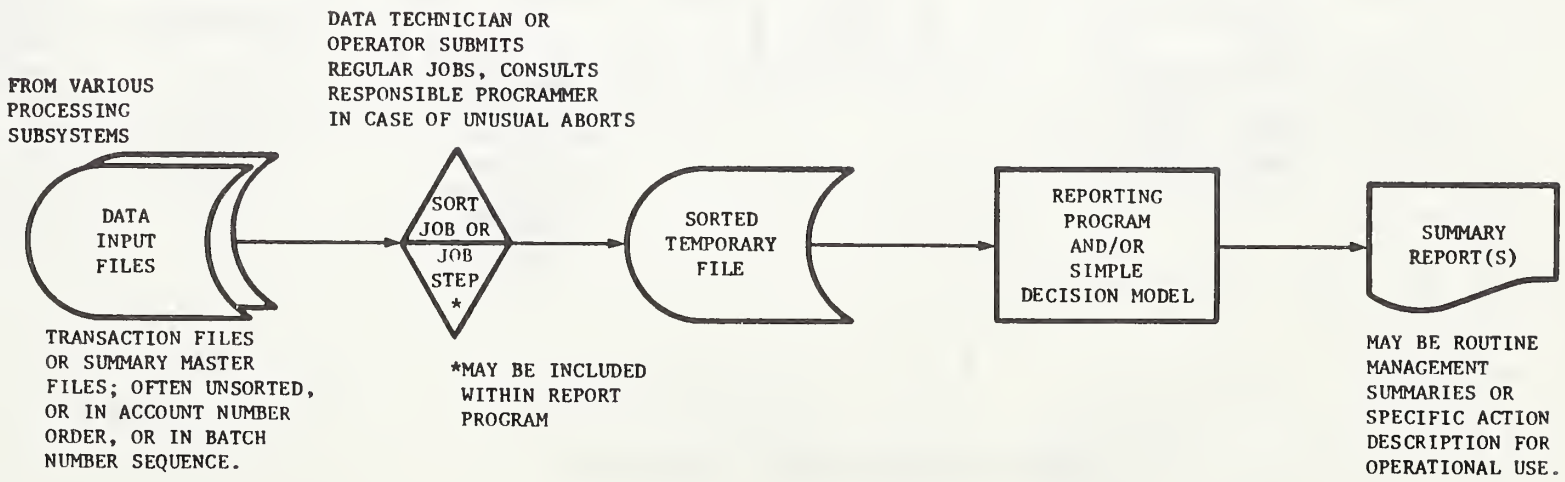


Figure B-8. DATA RETRIEVAL AND ANALYSIS

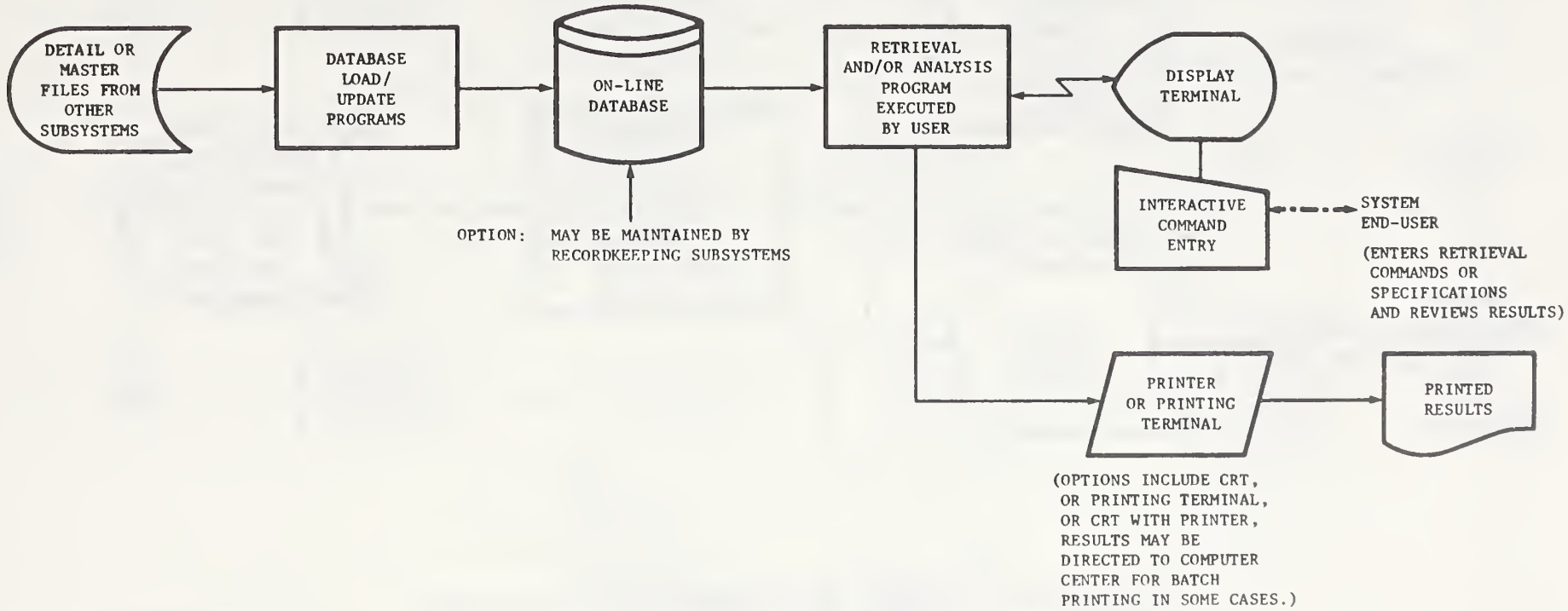


Figure B-9. DATA COMBINATION, ANALYSIS, AND REDUCTION

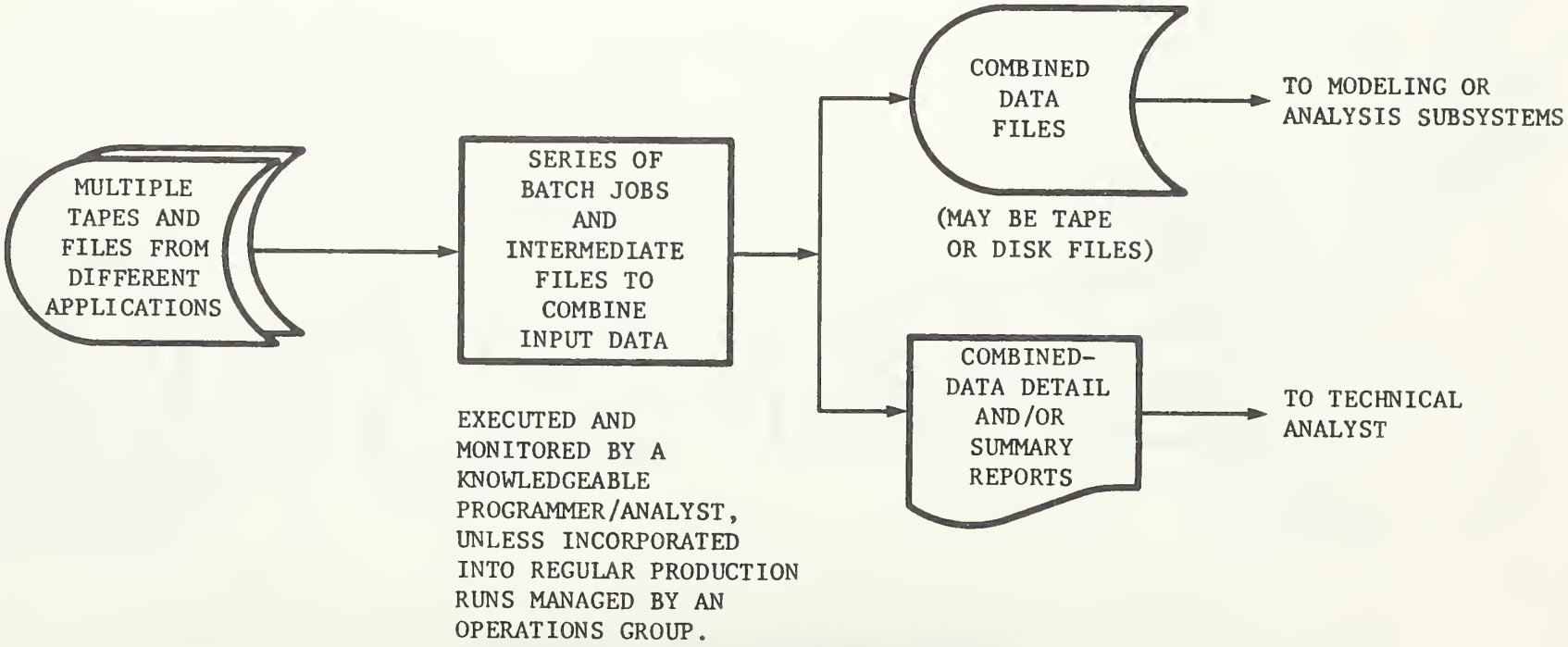


Figure B-10. SPECIALIZED-DATA MODEL EXECUTION

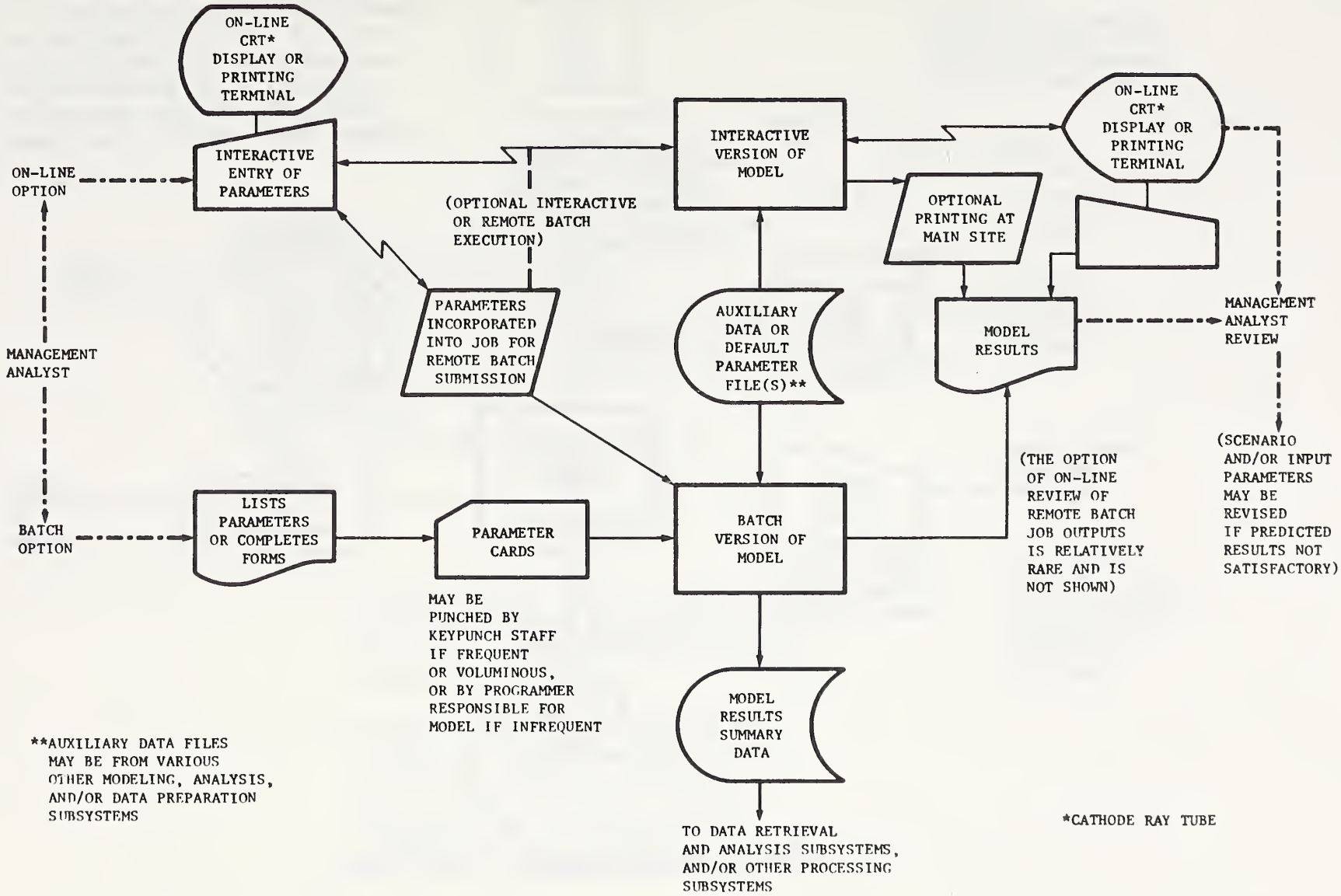
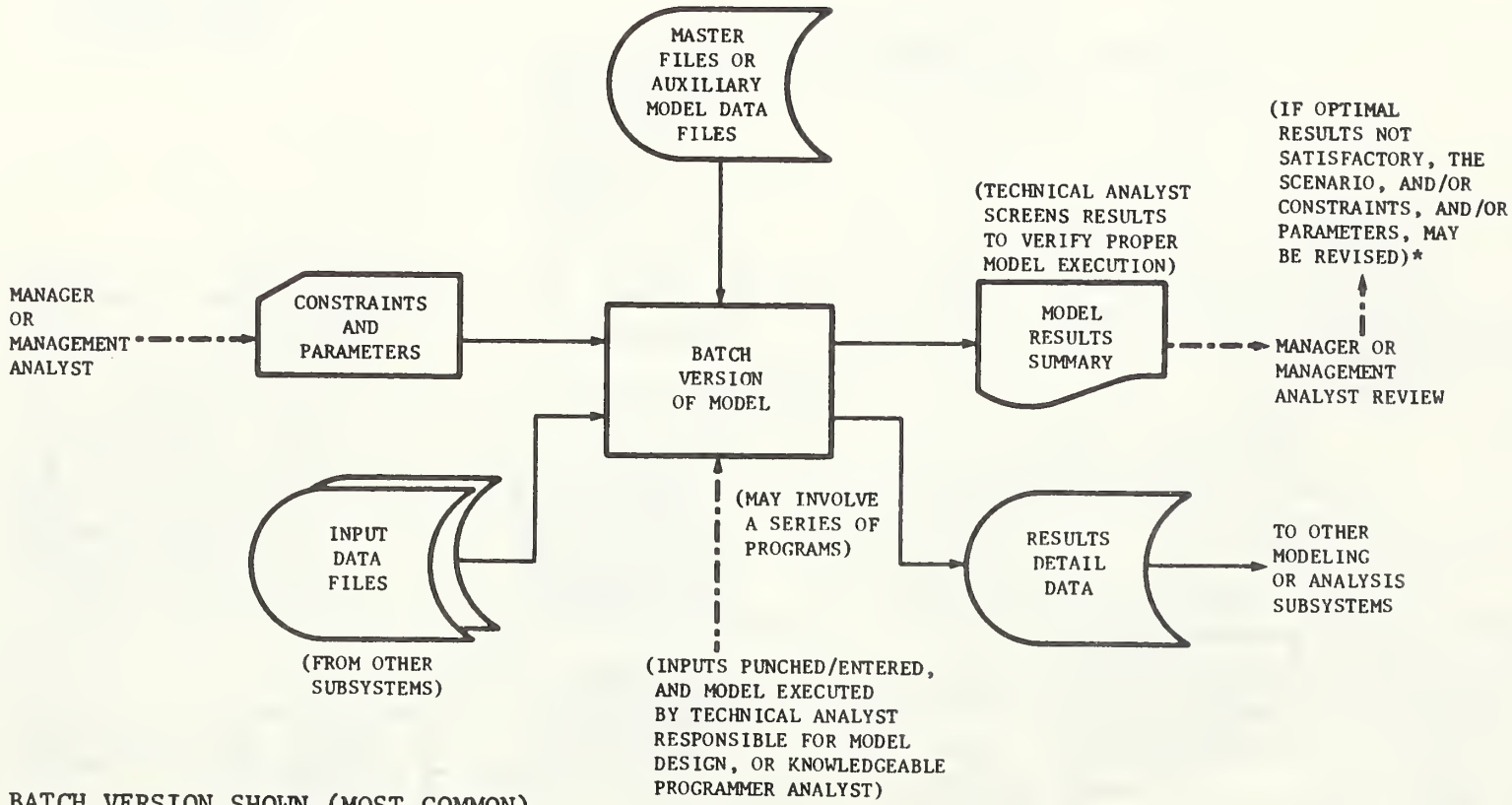


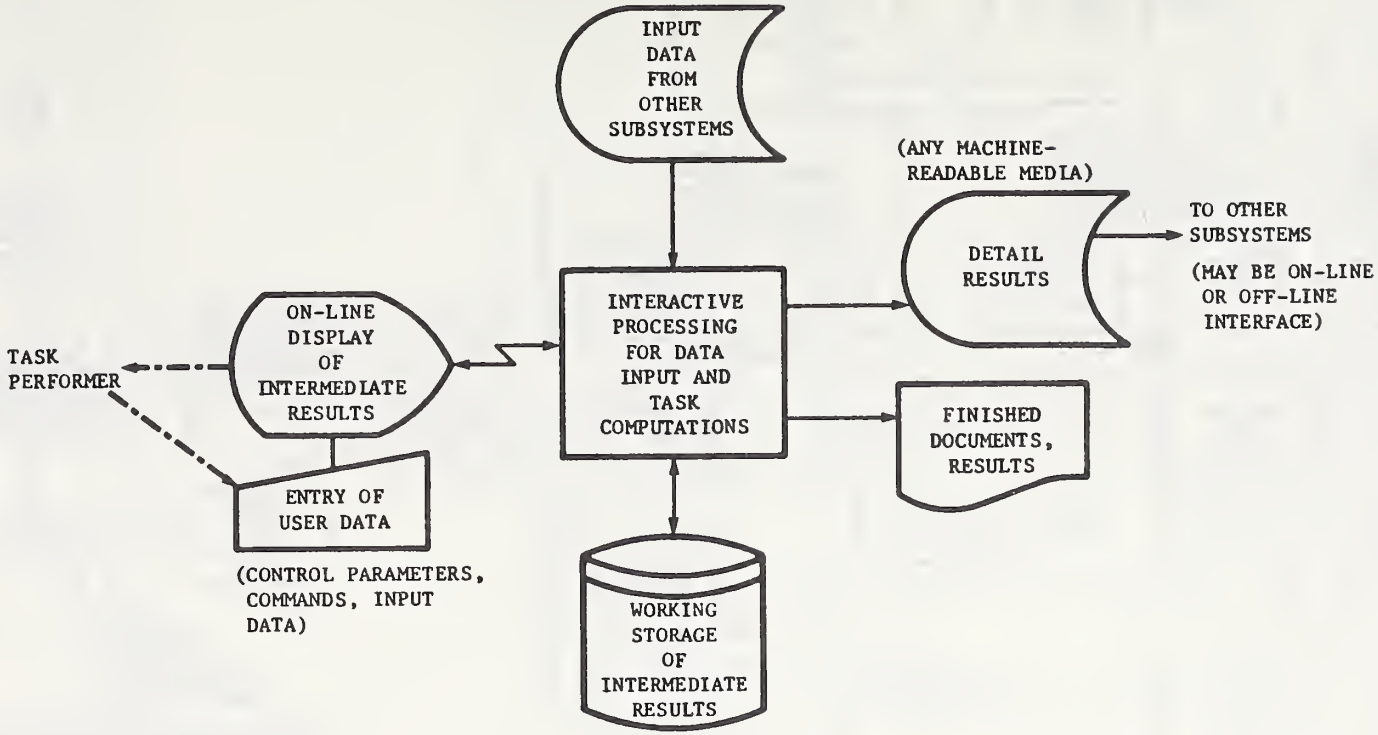
Figure B-11. INTEGRATED-DATA MODEL EXECUTION



BATCH VERSION SHOWN (MOST COMMON). INTERACTIVE VERSION EQUIVALENT, EXCEPT MANAGER MAY PERSONALLY ENTER CONSTRAINTS AND PARAMETERS VIA ON-LINE TERMINAL. NOTE THAT IF USED INTERACTIVELY, THEN RE-RUNS WILL BE FASTER AND MORE FREQUENT, AND MODEL SOFTWARE AND ALGORITHM MUST BE MORE RELIABLE.

*FOR EXAMPLE, THIS MAY CORRESPOND TO A MANAGEMENT DECISION TO CHANGE A POLICY OR PROVIDE A DIFFERENT MIX OF RESOURCES.

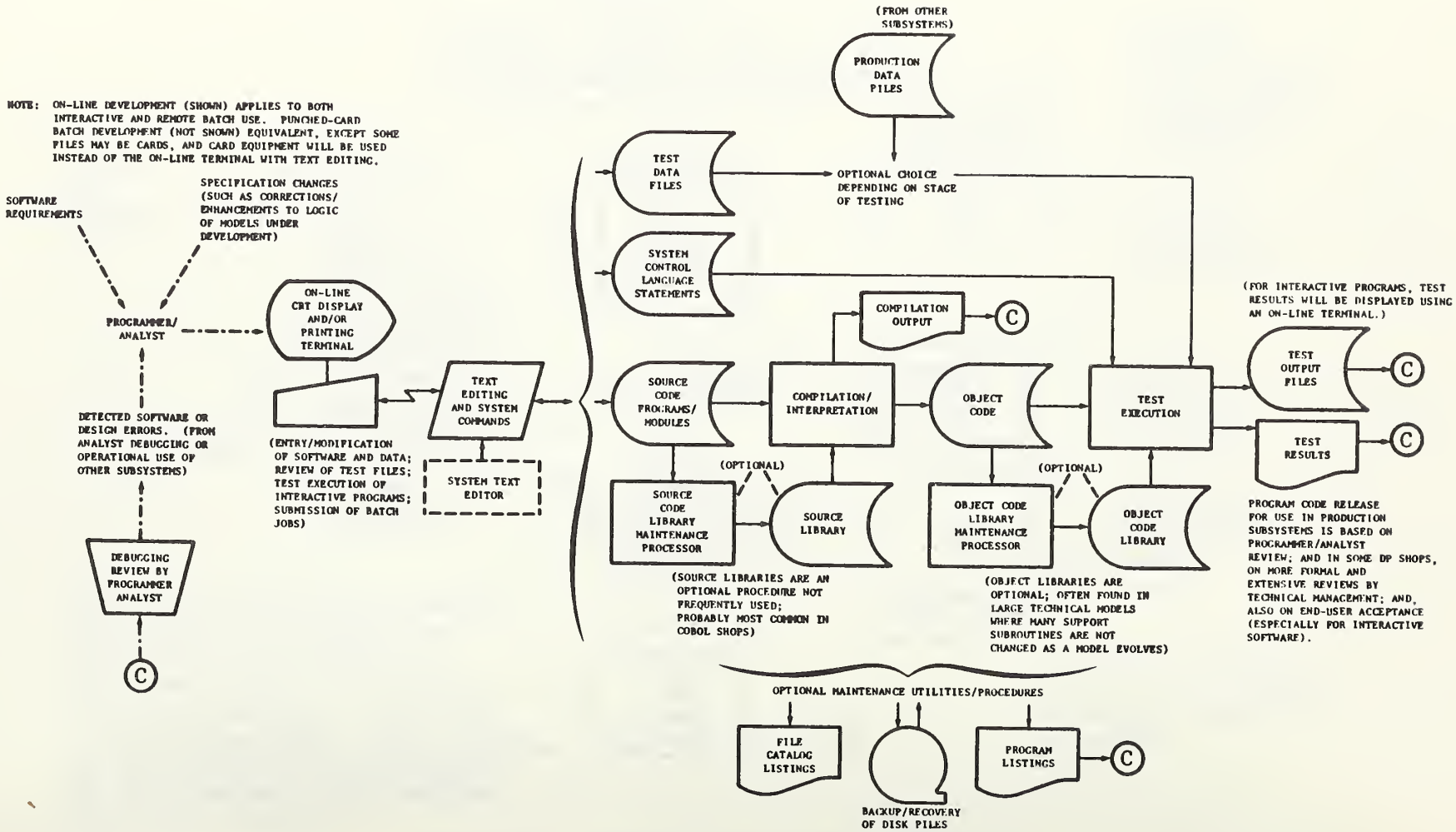
Figure B-12. COMPUTER-AIDED TASK PERFORMANCE



- TYPES OF TASKS PERFORMED CAN VARY FROM ROUTINE (WORD PROCESSING) TO HIGHLY CREATIVE (COMPUTER-AIDED DESIGN).

- NATURE OF PROBLEM CAN REQUIRE ONE OR MORE OF THE TYPES OF MODELS IN SUBSYSTEMS 10 AND 11. THESE MODELS MUST BE FULLY INTEGRATED INTO AN EFFICIENT, ON-LINE SYSTEM WITH INTERACTIVE, USER-FRIENDLY RESPONSES.

Figure B-13. SOFTWARE DEVELOPMENT (procedures that affect DP operations)



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5. AUTHOR(S) M. Fiorello and P. Eirich, Fiorello, Shaw and Associates; Peg Kay, Institute for Computer Sciences and Technology, NBS

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)*

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

This report presents a set of functional-flow descriptive models that can be used to categorize the operational activities of Federal data processing users. Data processing applications may be conceptually represented in descriptive model form by combining one or more of the basic models. The comprehensive framework for data processing operations provided by these descriptive models can be used in the identification of impacts from standards and guidelines and in the preparation of cost-benefit impact assessments. The framework provides both macro and micro levels of detail in order to link the descriptive models to additional data processing issues, such as computer security issues.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*
computer security; computer standards; cost-benefit analysis; data processing management; data processing operations; data processing standards; descriptive models; impact assessment; information systems.

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