DOCUMENT RESUME

ED 039 889 LI 001 942

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TITLE	Developing the Common Data Base for Management Information Systems: VI. Designing a Data Base for Growth.
INSTITUTION	Leasco Systems and Research Corp., Bethesda, Md.
PUB DATE	69
NOTE	67p.; Paper given at American Management Assoc. Orientation Seminar #6207-06,July 23 - 25, 1969
EDRS PRICE	EDRS Price MF-$0.50 HC-$3.45
DESCRIPTORS	Computers, *Data Bases, Data Processing, Information Processing, Information Retrieval, Information Storage, *Information Systems, *Ma agement Systems
IDENTIFIERS	*Management Information Systems, MIS

ABSTRACT

A subset of data base management techniques for the hardware/software functions necessary to support a management information system are discussed. Seven basic dimensions of data base design are: (1) data base life span, (2) logical record growth, (3) record content growth, (4) data set organization, (5) linkages, (6) design criteria and (7) modeling and the data base. The approach utilized is to introduce the broad concepts concerned with data base design techniques and to focus on practical file management software examples. Data base examples are utilized from MARK IV, Informatics Inc. and Retrieval Analysis and Presentation System (RAPS), Leasco Systems and Research Corporation. Broader managerial implications are introduced as a determinant set of conditions that affect data base size and growth. Economies of technological scale are a function of various factors such as the selected file management software system, the data base size, and the computer processing/communication environment. Recognizing the tradition of gradually integrating files into the future common data base structure of tomorrow's management information systems, data base design technology is introduced at the individual file level. Common data base development consolidation and integration can be achieved by extending the basic concepts that are presented. (Author/MF)

ED039889

AMERICAN MANAGEMENT ASSOCIATION

AMA ORIENTATION SEMINAR #6207-06

July 23 - 25, 1969

DEVELOPING THE COMMON DATA BASE FOR MANAGEMENT INFORMATION SYSTEMS:

VI. DESIGNING A DATA BASE FOR GROWTH

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ACKNOWLEDGMENTS

This paper has been developed to meet the American Management Association outline for topic VI concerning data base design, and to present the reader with a meaningful appreciation of current data base design technology. Conceptual guidance concerning the "information systems approach" and the decision making process was furnished by Professor Charles R. Pack, Management Information and Reporting Systems, 55.660E, 1969, American University: Center for Technology and Administration.

Technical review concerning the RAPS (Retrieval Analysis and Presentation System) file management system was provided by Paul Kalbach, Systems Manager, Proprietary Software, Computer Systems Group, Leasco Systems and Research Corporation.

The opinions expressed in this paper are the author's, as are any errors.

Harold J. Podell
July 23, 1969

ABSTRACT

Designing a data base for growth as the normal mode is an essential feature for the successful management information system. Within the decision-making requirement domain for accurate and current data, seven basic dimensions of data base design are investigated:

A. The data base "life span."

B. Logical record growth.

C. Record content growth.

D. Data set organization.

E. Linkages.

F. Design criteria.

G. Modeling and the data base.

By pragmatic definition, current data base design technology requires that the vital growth and file maintenance operations be performed under summary level software control. The approach utilized in this paper is to introduce the broad concepts concerned with data base design techniques and to focus on practical file management software examples. Data base examples are utilized from MARK IV, Informatics Inc. and RAPS, Leasco Systems and Research Corporation.

Constraints in data base size and structure are discussed in terms of hardware/software limitations. Although a wide spectrum of data base design strategies are known, the cost and availability of custom/off-the-shelf file management software must be considered for the selected hardware/software configuration.

Broader managerial implications are introduced as a determinant set of conditions that affect data base size and growth. Economies of technological scale are a function of various factors such as the selected file management software system, the data base size, and the computer processing/communication environment.

Recognizing the tradition of gradually integrating files into the future common data base structure of tomorrow's management information systems, data base design technology is introduced in this paper at the individual file level. Common data base development consolidation and integration can be achieved by extending the basic concepts that are presented.

AMERICAN MANAGEMENT ASSOCIATION

The techniques discussed in this paper constitute a subset of data base management techniques for the hardware/software functions necessary to support a management information system.

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A. THE DATA BASE "LIFE SPAN"

The concept of a data base, as analyzed in this paper, is directed toward the effective processing and utilization of management information in a computer-based communications environment. Conceptually the data base in the management information system is considered as a set of interrelated data elements that are necessary for the decision-making process of the organization.

No distinction is made between business and scientific processing, since both capabilities are necessary in the modern decision-making processes. Examples in later parts of this paper from MARK IV, Informatics Inc. and RAPS, Leasco Systems and Research Corporation are generally directed toward the technology of data base growth. These two file management systems have provisions for business/scientific processing capabilities that are beyond the scope of the current data base discussion, but are vital for effective data base utilization (1,2).

There are numerous data base management systems, however, for simplicity only MARK IV and RAPS are utilized in the illustrations.

1. DATA BASE AS A SUBSET OF DATA BASE MANAGEMENT

A data base consists of the alphanumeric records pertaining to an organization that are stored in computer processable form. In the context of this discussion, data base is the set of data that is operated upon by a data base or file management system to assist in effective managerial decision-making.

The "life span" of data is therefore a direct function of the need for and application of current and projected records in a given data base or file management environment (3).

There are many aspects of data base management that exist and are not directly addressed in this paper. They are listed for reference purposes to indicate the relative position of the data base (Blumenthal, 4):

a. Data Base Management

(1) Input/output control.

(2) Systems control.

(3) Data base control.

The relationships between data base or file management and the data base are abstracted in Figure A.1.

Another viewpoint concerning the data base management set of functions is given below (Bachman, 6):

b. Data Base Management

(1) Input/output control (message management).

(2) Systems control (job management, computer program management).

(3) Data base control (media management).

A data base is therefore the centralized repository of machine readable data that is to be operated upon within the data base management system.

DATA BASE/DATA BASE MANAGEMENT SYSTEM RELATIONSHIPS (5)

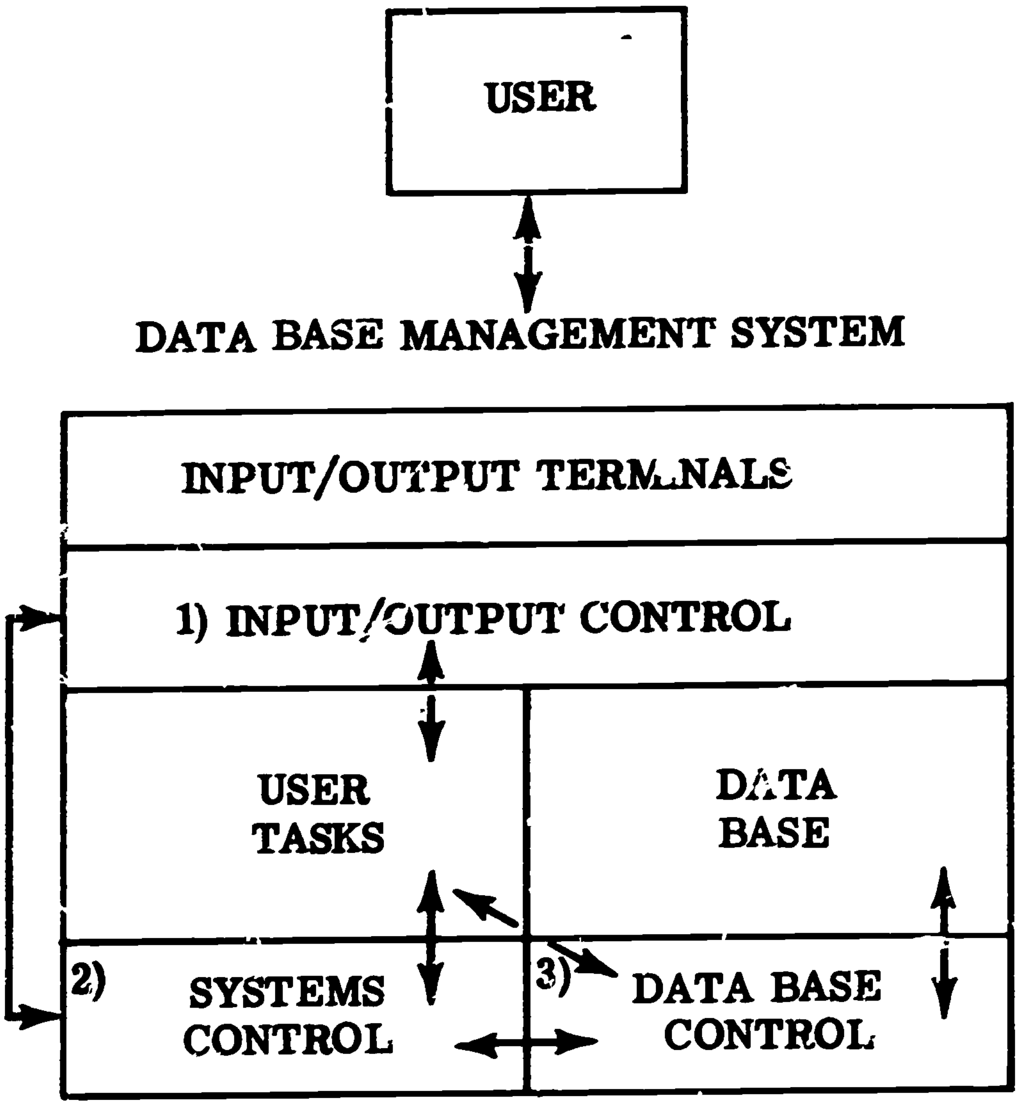


Figure A. 1

2. DATA BASE MANAGEMENT AND THE MANAGEMENT INFORMATION SYSTEM

In a general hi rarchical sense, the data base management system is one element of the management information system for a given organization (7):

a. Management Information System

(1) Hardware.

(2) Systems software (operating system, data base management system, user programs . . .).

(3) Application (to assist user decision making objectives).

In turn, the management information system is a representation of a subset of the organization decision making process. The management information system can consist of several independent and/or interrelated functions. A total information system is considered the total set of programmed/unprogrammed decision making functions for the organization (8).

For perspective, the management information system is shown below as it relates to information processing and the decision making process (9).

b. Management Information System

(1) Traditional information systems (closed), e.g. responsibility accounting systems.

(2) Production and operation information systems (partially open), e.g. inventory management information systems.

(3) Marketing information systems (open), e.g. sales analyses and credit control information systems.

In a broader perspective, the management information system is shown as a subset of the total information system, which includes the decision making process.

c. Total Information System

(1) Programmed decision making and unprogrammed decision making support functions in the computer, i.e. the management information system.

(2) Unprogrammed decision making functions external to the computer, i.e. management.

Conceptually, a total information system provides the programmed and unprogrammed decision making functions for the organization. The management information system design trend is to gradually extend beyond the programmed (traditional) into the unprogrammed (planning and innovation) domain of decision making operations.

Management is an art, therefore the concept of a total information system is bigger than the computer. A total information system is, by definition, a man-machine system.

In this context, the management information system can achieve programmed decision making and support some of the unprogrammed decisions in a total information system.

3. MANAGEMENT INFORMATION SYSTEM AND EXECUTIVE DECISION MAKING

In the hardware/software and the organizational perspectives, the management information system has been identified as essential for effective executive decision processing. This concept is summarized in Figure A.2.

MANAGEMENT INFORMATION SYSTEM AND EXECUTIVE DECISION MAKING

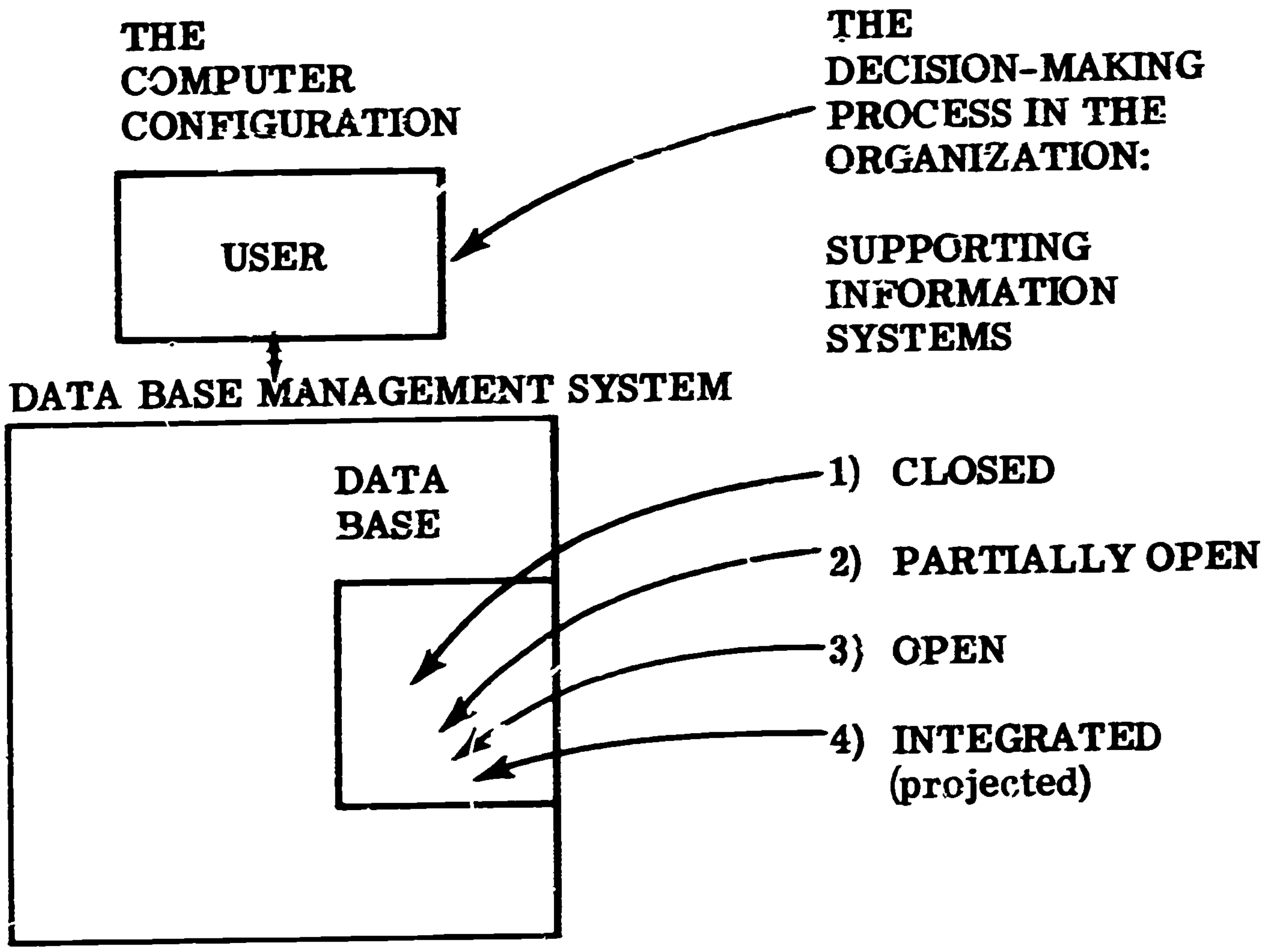


Figure A. 2

The data base is therefore a structured model of the applicable organization management information system set, e.g. (1) closed, (2) partially open, (3) open, and (4) integrated (projected). In effect, the data base development process consists of the mapping of the management information system record set and relationships into the machine stored data base. The trend is to consolidate the (1) closed, (2) partially open, and (3) open data base subsets into an (4) integrated or common data base.

Data base element "life span" is a function of the needs and constraints of a given organization's management information system and decision making process.

B. LOGICAL RECORD GROWTH

1. THE LOGICAL RECORD

In terms of the decision making process which has been identified, a logical record is the definition of a required structural information record in the computer. Logical refers to the design or specification of the record within a data base system; structural refers to the physical record in the computer based storage system (10).

The logical/structural relationships are illustrated in Figure B.1. Terminology varies from file management system to system, depending upon particular organization vocabulary.

In a conceptual sense, a given data base configuration (logical) can be equated with a computer hardware configuration (logical). Further, a file set (structural) can be equated with a computer hardware set (structural).

This logical/structural separation is a vital concept to achieve data base management flexibility. Within the computer, logical designs are stored in software dictionaries that are separate from the actual data. Changes in data base element design can be effected upon the logical software dictionaries rather than upon the structural data itself.

The nature of this logical/structural separation is illustrated in the next two sections with examples from MARK IV and RAPS, two file management systems.

Logical record growth is achieved as necessary to support the management information system and related decision making process.

MANAGERIAL DATA BASE
LOGICAL/STRUCTURAL RELATIONSHIPS (10)

- DECISION-MAKING FUNCTIONS (Logical)
  - DATA BASE CONFIGURATOR (Logical)
    - DATA BASE CONFIGURATION (Logical)
      - FILE SETS (Structural)
        - FILES (Structural)
          - RECORDS (Structural)
            - SEGMENTS (Structural)
              - FIELDS (Structural)

Figure B. 1

2. MARK IV TRANSACTION DEFINITION AND TEMPORARY FIELDS

Two types of MARK IV "runs" are described to illustrate the logical record growth process. Figure B.2 shows a dictionary maintenance run and Figure B.3, a processing run. RAPS dictionary building is virtually identical with MARK IV (Figure B.2). Selected details are given for the MARK IV processing phase in Figure B.4.

In Figure B.2, the key point is that the design of the logical record is defined separately in the dictionary. The user then can refer to the logical record in a short-hand manner, using a glossary.

User output is achieved, with the assistance of the MARK IV file management system, as illustrated in Figure B.3. The user requirements are expressed using the MARK IV language and the user's logical record definition set (glossary).

As indicated above, the data base (master/transaction/new master files) is separate from the dictionary. This relationship is implied in the figures.

In addition to processing temporary fields (14), MARK IV assists the growth of logical/structural records by providing for (15):

a. Creation/deletion of a master file record.

b. Insertion/deletion of a segment (within a record).

c. Addition/subtraction from the contents of a field (approximate hierarchy is record/segment/field).

d. Replacement of master file record fields.

MARK IV DICTIONARY MAINTENANCE RUN (11)

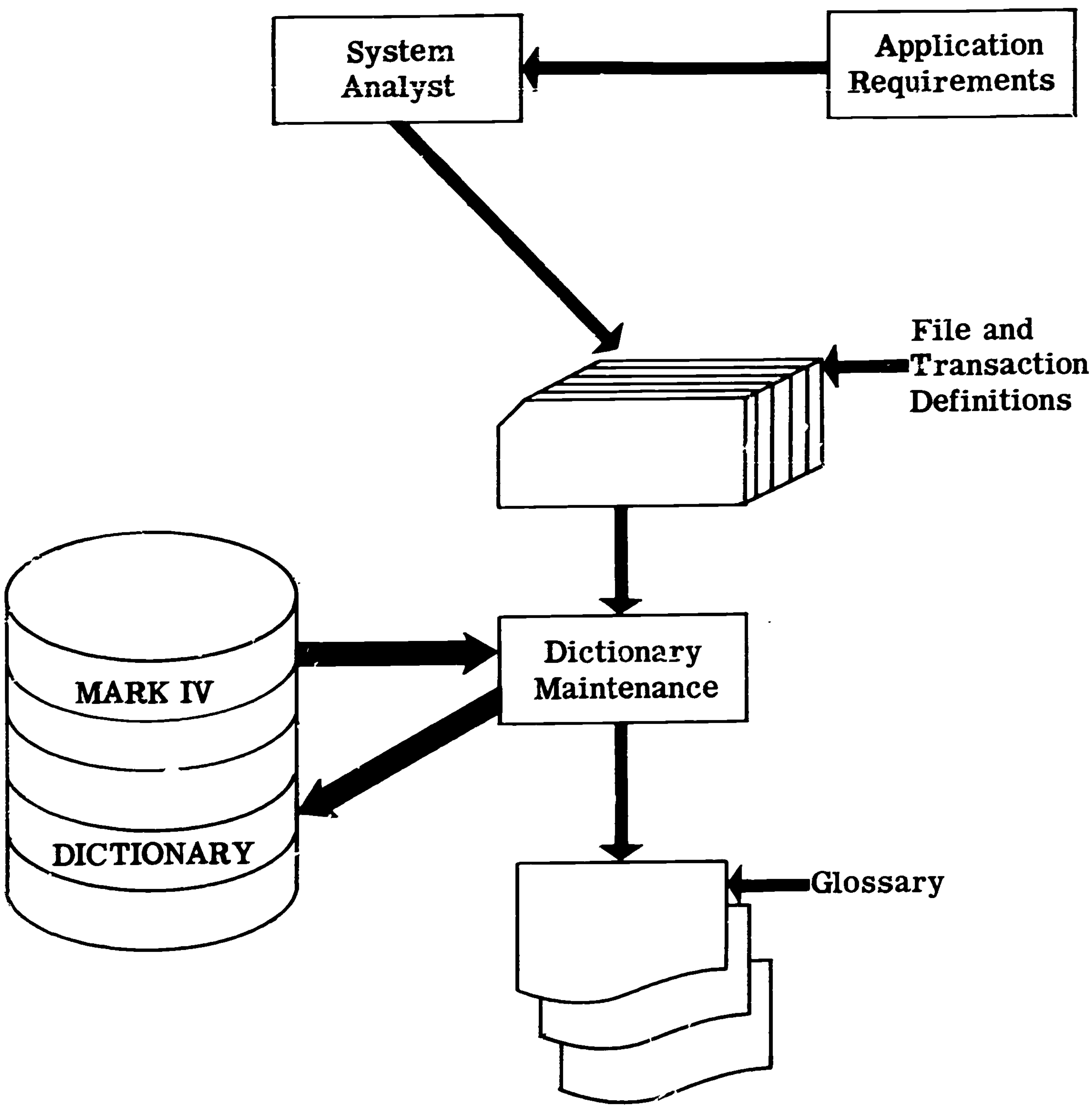


Figure B. 2

MARK IV PROCESSING RUN (12)

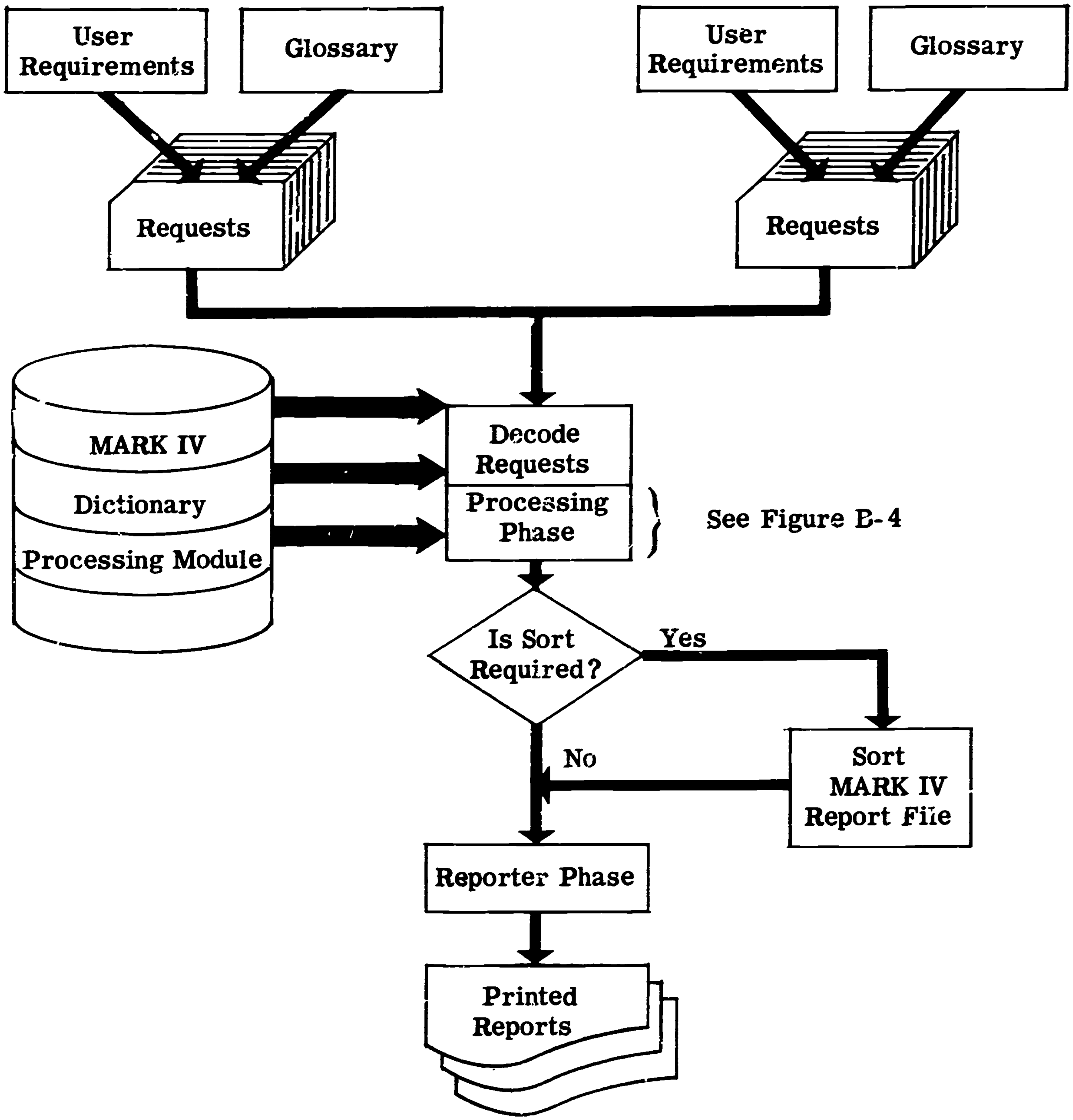


Figure B. 3

MARK IV PROCESSING PHASE (13)

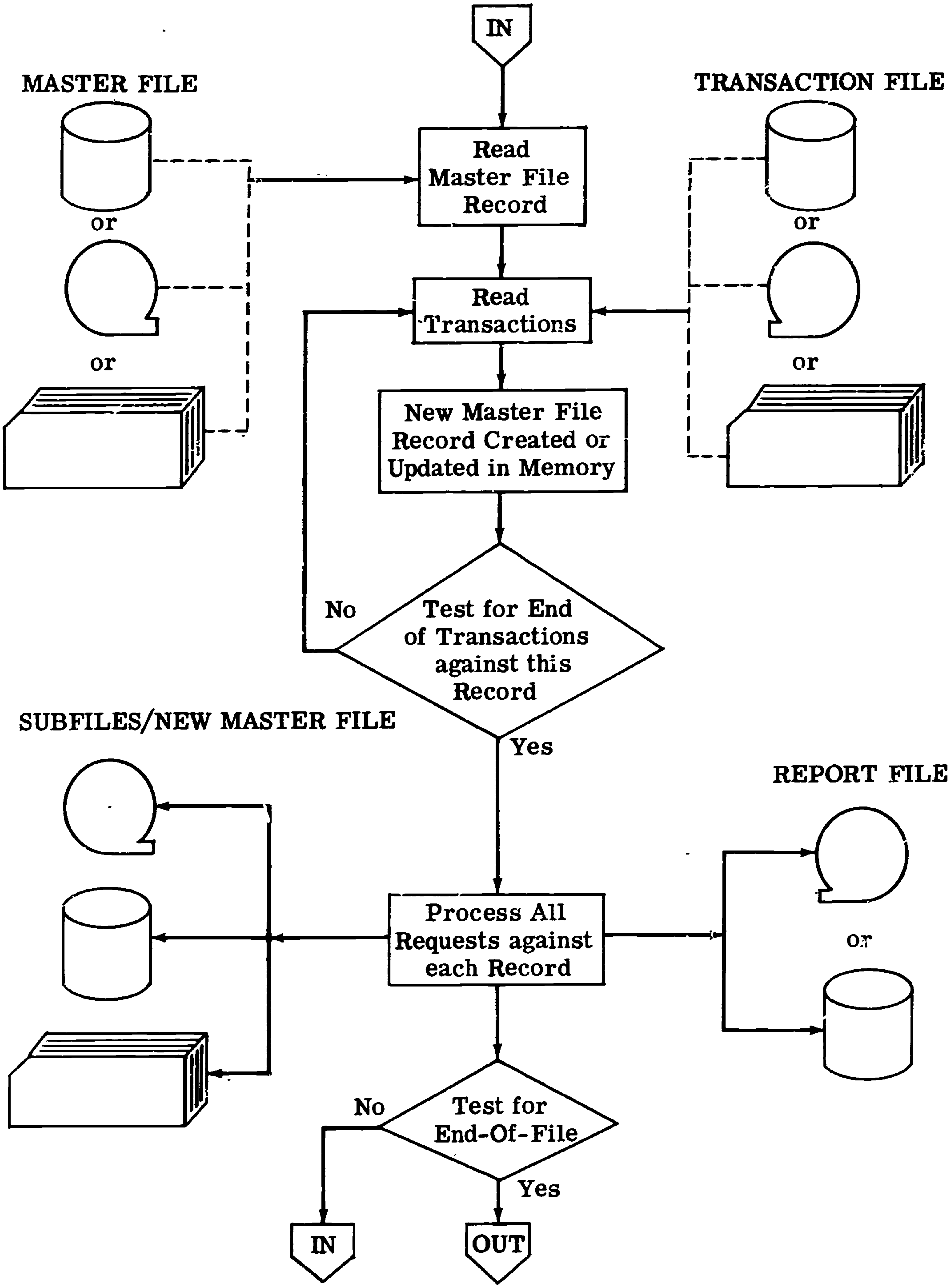


Figure B. 4

3. RAPS INPUT PROCESSING AND TEMPORARY FILE DEFINITIONS

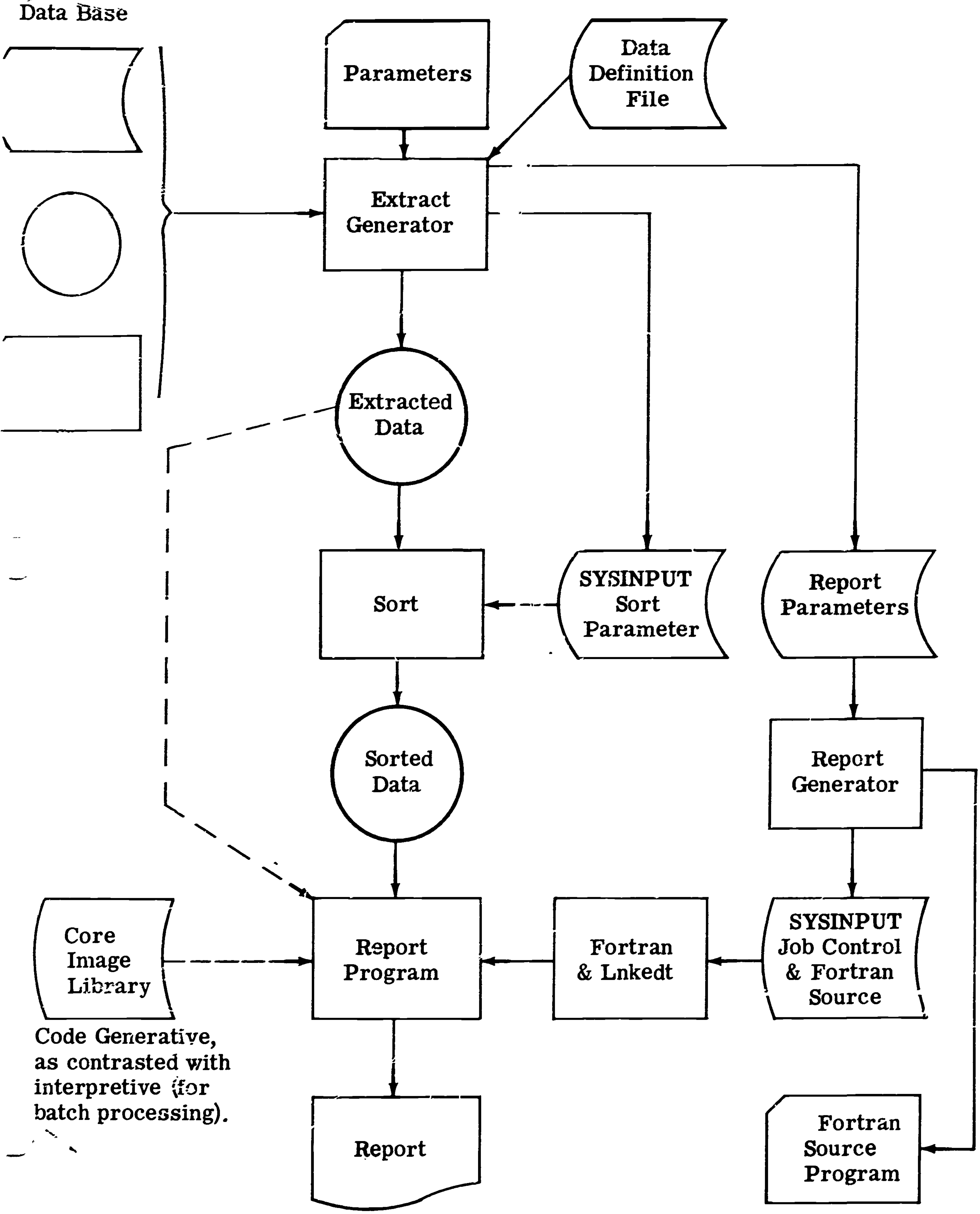
Logical record separation from the data base is achieved in RAPS as illustrated in Figure B.5. The dictionary in MARK IV is also referred to as a data definition file in RAPS. User requirements are identified in RAPS by parameter cards.

In a manner similar to MARK IV, RAPS provides for temporary file and data descriptions (17).

Input processing requires that the logical file definition be created for each file set (18). File maintenance functions (creation/deletion, addition/subtraction, replacement . . .) are performed in a manner compatible with but not identical to the MARK IV process, as described above.

The major point that has been illustrated by the MARK IV/RAPS examples is that logical record growth can be readily achieved within a controlled data base management environment.

RAPS SYSTEM FLOW (16)



Code Generative, as contrasted with interpretive (for batch processing).

Figure B. 5

C. RECORD CONTENT GROWTH

1. REPEATING DATA SETS

As a subset of record growth, record content growth is briefly addressed in this section. An example from MARK IV is given in Figure C.1, which shows the difference between a fixed length record format and a fixed length record format with repeated data groups.

Repeating data sets are one means of providing expansion within record content, e.g. in the MARK IV example, previous employer/ salary information.

The same repeating field or data set capability is illustrated for RAPS, in Figure C.2, e.g. in the RAPS example, up to 20 skills per employee number.

2. CHAINING

Chaining introduces the broader concept of data set organization which is discussed in the next section. In contrast with repeating data sets, chaining provides for a list of noncontiguous record extensions (21). For purposes of definition, several common terms are used to refer to a chain; they are: (1) simple list, (2) (2) string, (3) thread, and (4) chain.

A simple list is identified in Figure C.3. The list in this case pertains a set of data elements that are concerned with animals. The data elements are linked together by memory location and address pointers. Figure C.4 indicates the use of several simple lists. The example in C.4 illustrates two lists for "eye color," i.e. value 1 and value 2. Access times to any single data element in the list is relatively slow since the list is entered by a single entry point, e.g. "eye color."

MARK IV FIXED LENGTH RECORD/FIXED LENGTH RECORD FORMAT WITH REPEATED DATA GROUPS (19)

Emp. No.	Employee Name	Age	Hire Date
444	MARK IV	3	66 12 01

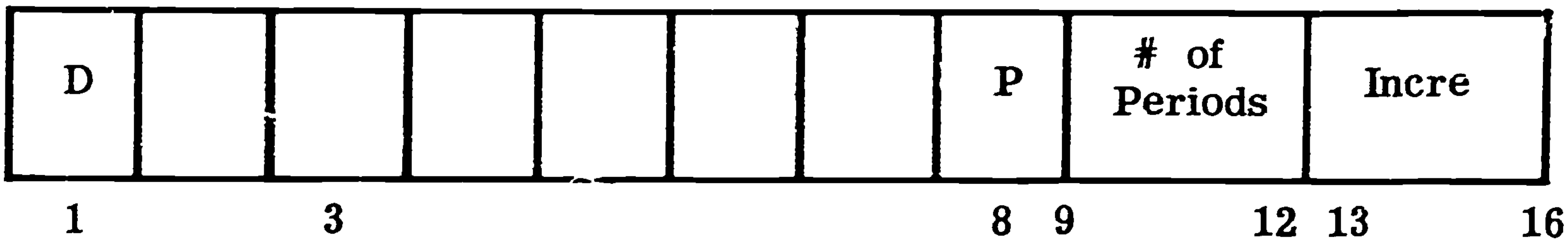
FIXED LENGTH RECORD

Emp. No.	Employee Name	Age	Hire Date	Previous Emp. 1	Salary 1	Previous Emp. 2	Salary 2	Previous Emp. 3	Salary 3
444	MARK IV	3	66 12 01	UNIVAC	10,000	PHILCO	14,000	INFORMATICS	18,000

FIXED LENGTH RECORD FORMAT WITH REPEATED DATA GROUPS

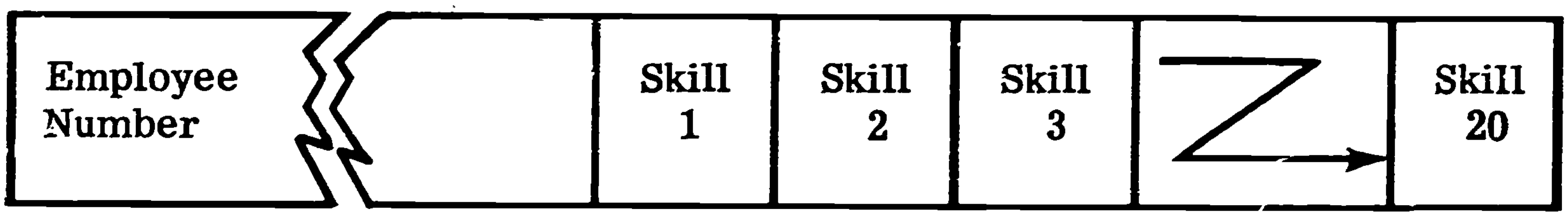
Figure C. 1

RAPS REPEATED FIELDS (20)



REPEATING CARD FORMAT FOR EXAMPLE BELOW:

1. Name = Skill
2. # of Periods = 20
3. Increment = 4 Characters/Skill Code



REPEATING FIELDS EXAMPLE: SKILL

Figure C. 2

A SIMPLE LIST (22)

	(Name) Memory Location	Contents	
		Data (Data Elements)	Address (Pointers)
Example Animals:	14	cat	18
	18	dog	11
	11	mouse	143
	143	pigeon	56
	56	END	

A SIMPLE LIST = STRING = THREAD = CHAIN

Figure C. 3

SEVERAL SIMPLE LISTS (23)

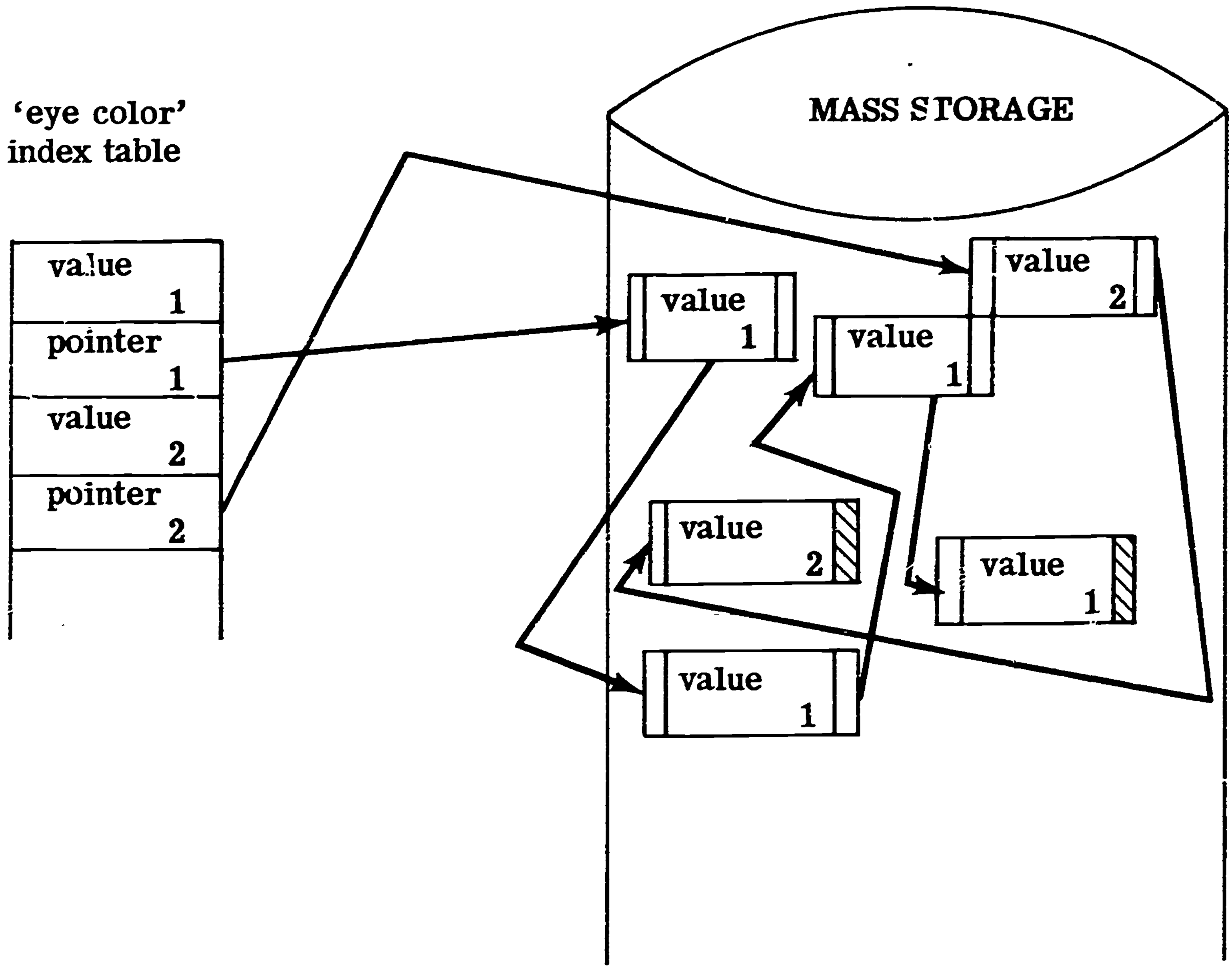


Figure C. 4

This discussion introduces the concept of pointers or linkage, which is more fully discussed in E. Linkages. The conceptual point that is being developed here is that linkage between noncontiguous records is necessary to achieve correlation between the separated logical/structural records in a data base management system.

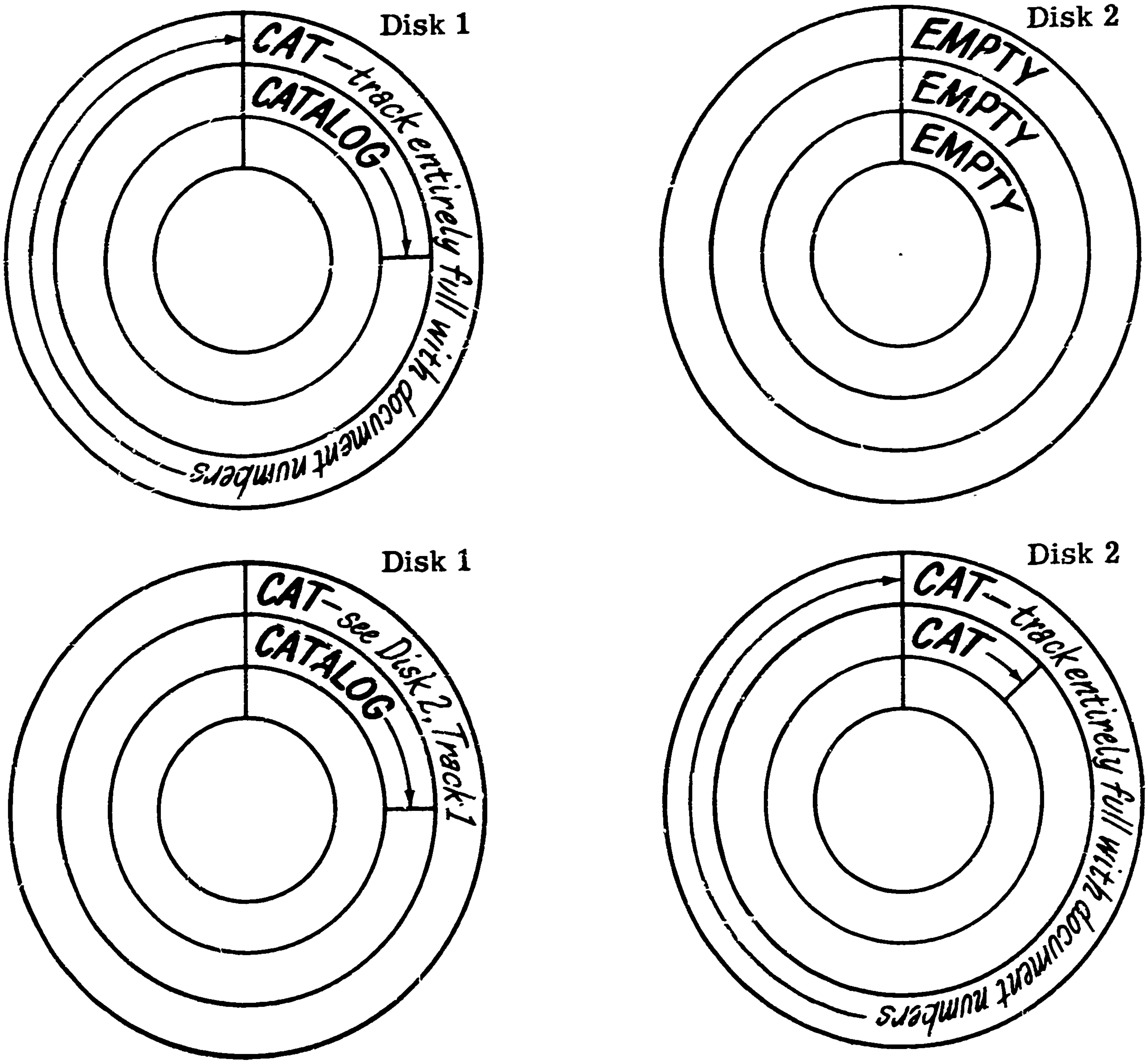
Several examples follow to illustrate the utility of chaining and pointers (linkage). A basic noncontiguous storage problem concerning disk storage is shown in Figure C.5.

The movement pictured in Figure C.5 of the record CAT is indicative of overflow processing that is internal to a data management system. This concept is chaining in an elementary sense. The chain consists of data elements related to CAT. After consolidating the chain on disk 2, in the example, a pointer is instituted on disk 1 to assist in the location of the set of data elements concerning CAT.

It is possible to expand the reasoning in the example to a set of chains as is done in Figure C.6. Disk 1 is in alphabetical order and each entry is the first of a chain of one or more data elements. The "x" indicates the terminator for each chain. Linkage facilitates overflow utilization of auxiliary disks. For example, the chain that concerns last names starting with "B" starts on disk 1, track 2. This sample chain utilizes an overflow pointer to disk 2, track 1 (2,1), where the chain ends.

Chaining constitutes the basis of a simple dictionary. Two variations of basic dictionaries are illustrated in Figure C.7. For example, AIRCRAFT, AIRPLANE, and PLANE are linked to code 01 or the equivalent word AIRPLANE. More complex dictionaries are utilized in data base management systems such as MARK IV and RAPS.

NONCONTIGUOUS RECORD STORAGE (24)



Noncontiguous record storage. Track 1 of Disk 1 is completely full when new information, to be filed under CAT arrives. In order to place this information in the next track, the data already there would have to be moved. To avoid this change, two contiguous empty tracks are sought and the overflowing record is moved over; a reference to the new location is left in the old location.

Figure C. 5

CHAINING (25)

Disk 1

Track	Name	Pointer
1	Abbey E. A.	
	Allen, J. B.	2. 2
2	Bacon, G. M.	
	Bradshaw, W. V.	2. 1
3	Cabel, W. P.	
	Crandall, W. C.	2. 3
4	Dale, A. C.	
	Donaldson, M. P.	2. 4
5	Earle, B. D.	
	Ewell, R. S.	X
6	Fabian, B. S.	
	Fulton, S. T.	2. 5

Disk 2

Track	Name	Pointer
1	Bradstreet, A. N.	
	Butler, N. J.	X
2	Allison, S. T.	
	Anthony, G. B	3. 1
3	Crawford, G. R.	
	Cyril, M. R.	X
4	Doyle, L. E.	
	DuPont, D. N.	3. 2
5	Funston, C. A.	
	Fyfe, T. I.	X

Disk 3

Track	Name	Pointer
1	Appleton, F. L.	
	Atwell, J. J.	4. 1
2	Durant, W. J.	
	Dyer, J.	X
3		

Figure C. 6

WORD-TO-CODE / WORD-TO-WORD DICTIONARIES (26)

Word	Code
AIRCRAFT	01
AIRPLANE	01
CALCULATOR	02
CANINE	03
COMPUTER	02
DOG	03
PLANE	01

WORD-TO-CODE DICTIONARY

Entry Word	Approved Equivalent
AIRCRAFT	AIRPLANE
AIRPLANE	AIRPLANE
CALCULATOR	COMPUTER
CANINE	CANINE
COMPUTER	COMPUTER
DOG	CANINE
PLANE	AIRPLANE

WORD-TO-WORD DICTIONARY

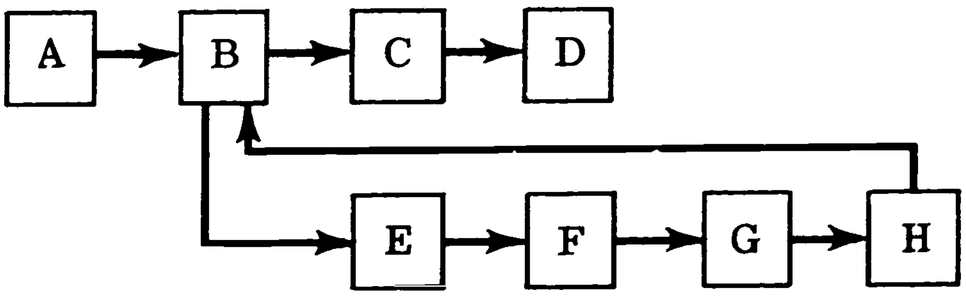
Figure C. 7

A list structure is shown in Figure C.8. The list structure is a list where one of the data elements is itself a list. The list element "B" is itself a list (E, F, G, H), therefore A, B, C, D is a list structure. This same principle applies to list element "78," which is itself a list (collie , retriever, setter, terrier).

LIST STRUCTURES (27)

Memory Location	Contents: Data	Contents: Address
14	cat	18
18	78	11
11	mouse	143
143	pigeon	56
56	END	
78	collie	79
79	retriever	2
2	setter	194
194	terrier	22
22	END	18

A LIST STRUCTURE



DIAGRAMMATIC REPRESENTATION OF A LIST STRUCTURE

Figure C. 8

D. DATA SET ORGANIZATION

The data set organization discussion, which follows this introduction, is technique and availability oriented. Data set organization is addressed from a practical performance viewpoint.

For the individual organization analysis and design of a data base for growth, managerial factors must also be considered. Managerial factors assist the analyst in focusing upon the specific set of requirements for a given management information system.

The managerial design criteria that affect selection of the data set organization methodology are discussed in F. DESIGN CRITERIA. Major decisions must also be made concerning hardware/software "brand" selection, since the availability of custom/off-the-shelf data base management systems is "brand" dependent to a significant degree.

Although the prime emphasis of this discussion is data set organization, an introduction is provided to some of the organization/access time tradeoffs for information retrieval.

1. BASIC TECHNIQUES

Some of the basic data set organization methods have been introduced:

a. Repeating Data Sets (C. RECORD CONTENT GROWTH).

b. Chaining (C. RECORD CONTENT GROWTH).

There are several data organization variations available. Some of these are discussed in the following sections. In order to preserve a practical orientation, the type of data set organization processed by MARK IV and RAPS is summarized (28).

c. MARK IV

(1) Fixed length and repeated data groups

(2) Variable length

(3) Undefined (fixed or variable)

(4) Indexed sequential access method (ISAM)

Within these four types of organization, blocking, and hierarchical variations are possible.

d. RAPS

(1) Fixed length and repeated data groups

(2) Variable length

(3) Indexed sequential access method (ISAM)

As in MARK IV, variations are possible in blocking and unblocking.

The techniques that are discussed in the following sections can exceed the offered options of many data base or file management systems. In general, the more general a software system the less likely it is going to be optimized for a given specialized function.

As a basic comparison point, it is more likely that a data base management system would have (1) basic techniques, (2) sequential access method (SAM), and (3) indexed sequential access method (ISAM). General file management systems would be associated with (4) hierarchy, e.g. MARK IV. The (5) inverted list capability is usually available in text processing systems that utilize Boolean search strategies.

2. SEQUENTIAL ACCESS METHOD (SAM)

The most common method of file processing is sequentially by key filed as illustrated in Figure D.1. Historically, sequential processing is associated with card/tape operations. Sort algorithms order a sequential file based upon the key field, e.g. alphabetical for a personnel list.

SEQUENTIAL ACCESS METHOD (SAM) (28)

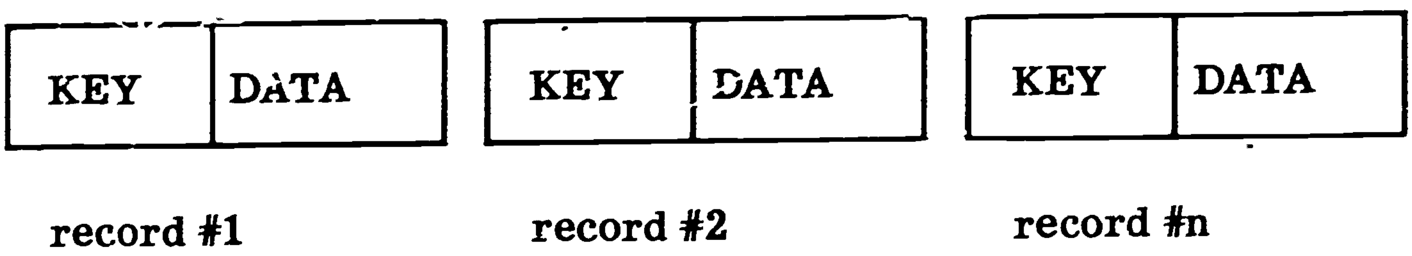


Figure D. 1

Search times are relatively long and a function of serial processing times, since each key field must be read serially until the desired field is identified. Various short-cuts are possible, such as blocking records and searching blocks of records.

3. INDEXED SEQUENTIAL ACCESS METHOD (ISAM)

This method of file structure is a relatively popular compromise method. It is available in MARK IV and RAPS and is usually associated with IBM (29).

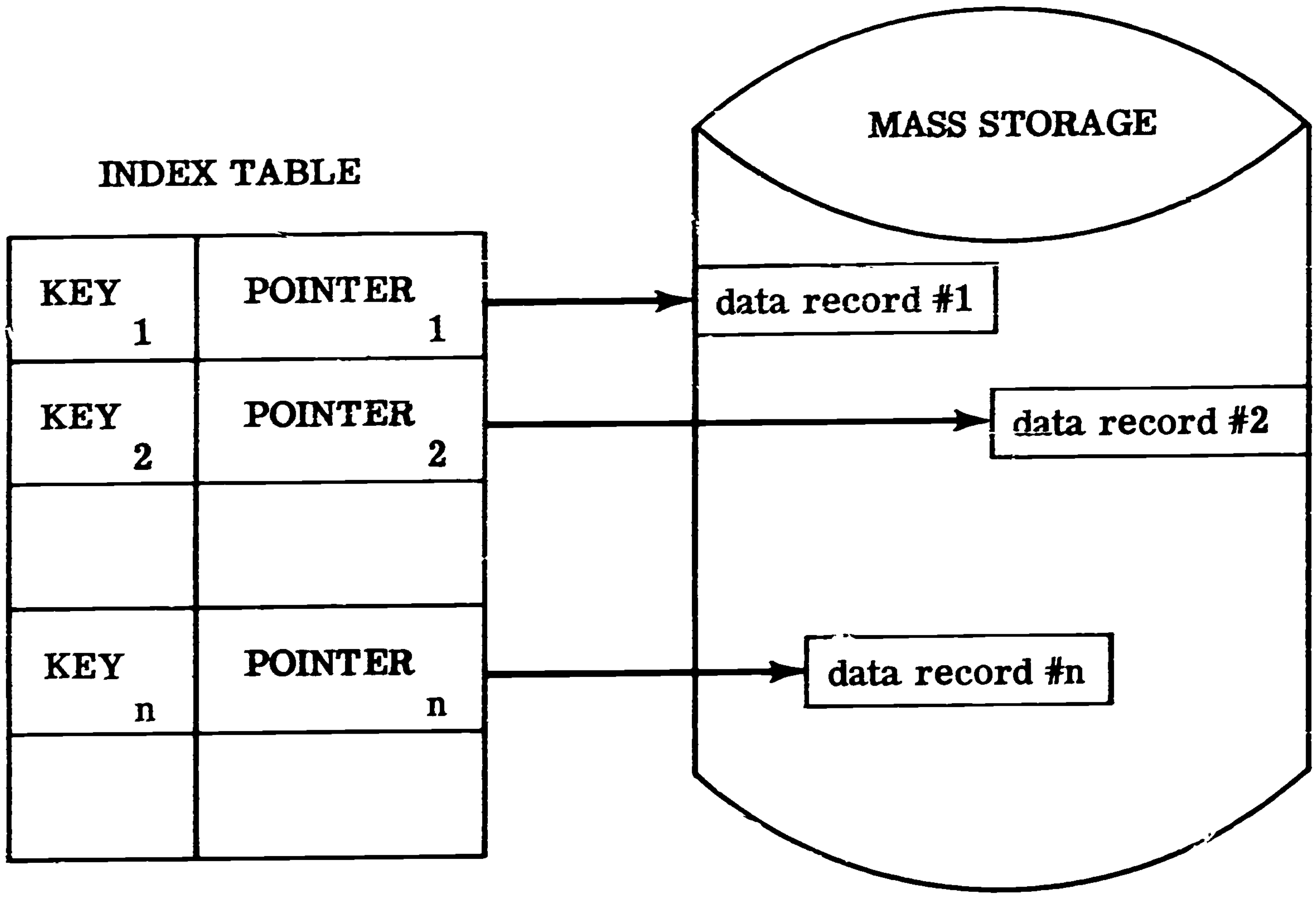
The most common ISAM application is on a direct access device, such as a disk file. Figure D.2 indicates a basic ISAM index table/direct access pointer approach.

In a basic sense, the ISAM uses a simple dictionary sorted by key field. Noncontiguous data record storage is achieved, since all data element locations are furnished by the ISAM pointers, e.g. POINTER 1, 2, . . . n.

There are costs associated with ISAM. These include the resident memory requirement for the index table and the sequential search mode within the dictionary on sort key, e.g. "eye color."

An extension of ISAM is given in Figure D.3. Conceptually, if the 2nd index table sort key field has entries for the value "blue eyes" only, then a search of this table provides rapid access time for records pertaining to blue-eyed personnel and their respective records. This type of extension can produce more rapid searches and operate independently of the main ISAM index table.

INDEXED SEQUENTIAL ACCESS METHOD (ISAM) (30)



Note: The Index Table is usually Main Memory Resident.

Figure D. 2

INDEXED SEQUENTIAL ACCESS METHOD
(ISAM): EXTENSION (31)

2nd INDEX TABLE

EYE COLOR 1	POINTER 1
EYE COLOR 2	POINTER 2
EYE COLOR D	POINTER D

Figure D. 3

4. HIERARCHY

As this type of structure becomes more complex, the complexity also increases for file maintenance. Several examples from MARK IV are utilized to indicate the progressive capability that evolves in a hierarchical structure.

Figure D.4 introduces a fixed length-two-level, hierarchical record structure. Hierarchy or "nesting" of up to nine levels is provided by MARK IV. In the Figure D.4 example, subordination on the second level applies to previous employment (PREVEMPL) and salary (SALARY). Null entries for record B indicate absence of a level 2 subordinate segment set.

Certain efficiencies can be gained by adopting a modification of Figure D.4 as illustrated in Figure D.5. In the Figure D.5 example, a variable count field (PREV. COUNT) identifies the number of segments, e.g. PREVEMPL.

Storage space is conserved in cases where PREV. COUNT is zero, e.g. for record B in Figure D.5, using a variably repeated segment.

A final hierarchical example from MARK IV is given in Figure D.6. The terminology begins to become more "brand dependent" as specialized structures are discussed. For the purposes of Figure D.6, a specialized MARK IV term is introduced. "Sibling" segments refers to different segment types at the same level that are not necessarily related.

For example in Figure D.6, SCHOOL and PREVIOUS EMPLOYER are "sibling" segments since they are both at level 2 and are essentially unrelated. SCHOOL is labeled as segment type 2; PREVIOUS EMPLOYER, segment type 4.

FIXED LENGTH-TWO-LEVEL, HIERARCHICAL RECORD STRUCTURE (32)

	RECORD A						RECORD B						
Type of Data	Level Number	Segment Number	EMP. NO.	EMPLOYEE NAME	AGE	HIRE DATE	Level Number	Segment Number	EMP. NO.	EMPLOYEE NAME	AGE	HIRE DATE	
Employee Identification	1	1	444	MARK IV	3	66 12 01	1	1	555	Zilch, Joe	21	67 12 01	Base Segment
			PREVEMPL	SALARY					PREVEMPL	SALARY			
Employment History	2	2	UNIVAC	10,000			2	2	(blank)	0			Subordinate Segments
	2	2	PHILCO	14,000			2	2	(blank)	0			
	2	2	INFORMATICS	18,000			2	2	(blank)	0			

[hatched box] = KEY FIELDS

Figure D. 4

TWO-LEVEL HIERARCHICAL RECORD STRUCTURE
SHOWING A VARIABLY REPEATED SEGMENT (33)

	Level	Segment	EMP. NO.	EMP. NAME	AGE	HIRE DATE	PREV. COUNT
RECORD A	1	1	444	MARK IV	3	66 12 01	3

	Level	Segment	PREVEMPL	SALARY
	2	2	UNIVAC	10, 000
	2	2	PHILCO	14, 000
	2	2	INFORMATICS	18, 000

	Level	Segment	EMP. NO.	EMP. NAME	AGE	HIRE DATE	PREV. COUNT
RECORD B	1	1	355	Zilch, Joe	21	62 12 01	0

[hatched box] = KEY FIELDS

Figure D. 5

EXAMPLE OF A THREE-LEVEL VARIABLE HIERARCHICAL RECORD (34)

EMPL. NO.	NAME	JOB TITLE	CLASS	DIVISION	DEPT.

GROUP	HIRE DATE	DEPEND.	SOC.SEC.#	COUNT FIELDS	
				School	Jobs
				2	1

Level 1 Segment Type 1

SCHOOL # 1	ADDRESS	YEARS	HONORS	DEGREE COUNT	REMARKS
				1	

Level 2 Segment Type 2

DEGREE	GPA	DATE

Level 3 Segment Type 3

SCHOOL # 2	ADDRESS	YEARS	HONORS	DEGREE COUNT	REMARKS
				0	

Level 2 Segment Type 2

PREVIOUS EMPLOYER # 1	ADDRESS	TITLE	REF COUNT	SALARY
			2	

TERM DATE	START DATE

Level 2 Segment Type 4

REFERENCE # 1	TITLE	YEARS KNOWN	EVALUATION

REFERENCE # 2	TITLE	YEARS KNOWN	EVALUATION

Level 3 Segment Type 5

(shaded) = SEGMENT KEYS

Figure D. 6

5. INVERTED LIST

A final type of data set organization is presented in Figure D.7. This organization method is titled inverted list and it is related to coordinate indexing techniques that utilize Boolean search algorithms (e.g. A + B means find all of the records that contain A or B key field entries).

This method is usually found, as indicated previously, in software processing systems with text search capability. In a general sense, more than one index table would be utilized. The example in Figure D.7 shows two index tables for the illustrated personnel data record.

The two index tables are (1)"eye color" and (2)"job title." In a broad conceptual sense, each index table correlates with a descriptor or term card in coordinate indexing systems.

For the sample Boolean search, all of the personnel records for blue-eyed people (value 1) who are systems analysts (value 11) can be retrieved rapidly from the mass storage system in Figure D.7.

The Boolean search could be stated:

Search answer = A "times" B

= value 1 "times" value 11.

= value 1 • value 11.

= "logical" intersection of value 1 and value 11.

= A • B.

= record 7, which contains both value 1 and value 11 entries for "eye color" and "job title," respectively.

INVERTED LIST (35)

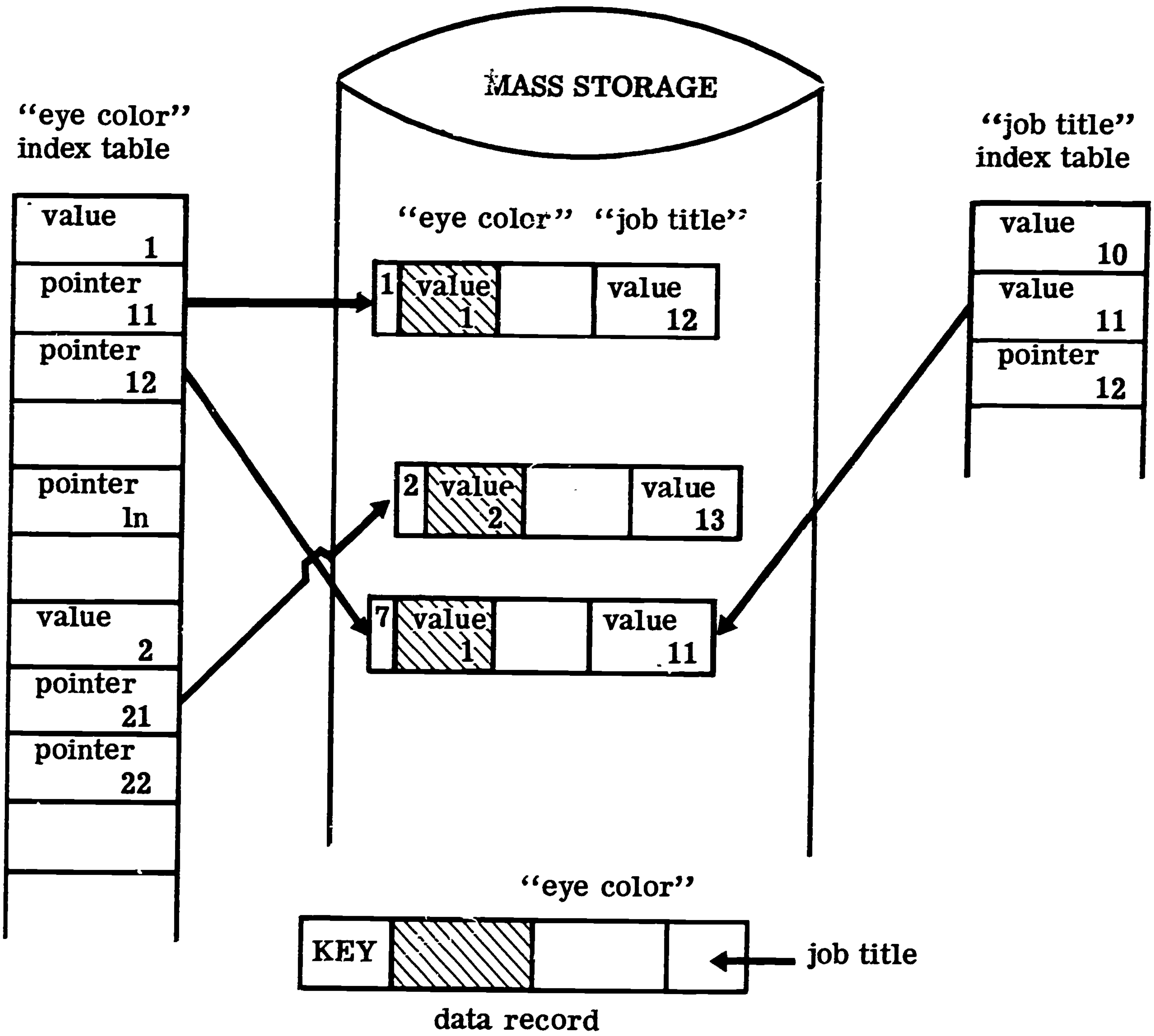
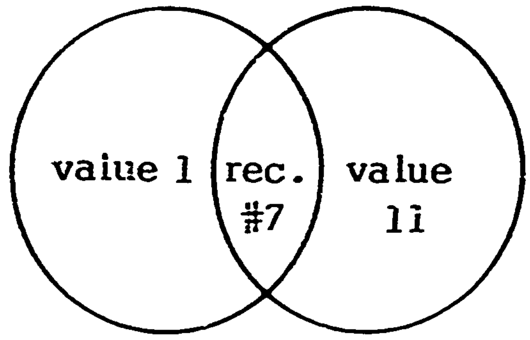


Figure D. 7

Search answer =



Inverted list is organized from the field level up, rather than relying upon record level keys. More rapid searches are possible. The cost is expressed in additional resident index requirements and more extensive file maintenance software investment.

E. LINKAGES

Linkages have been introduced as a necessary constituent of data base organization and maintenance flexibility. File management systems require extensive internal linkage systems to assist the user organization in the achievement of orderly and effective data base growth.

The user communicates with table defined terms that contain implicit linkages necessary for data base management.

Within this introductory scope of this paper, highlights concerning linkages are presented in the following sections.

1. SUMMARY OF LINKAGE RELATIONS

Four general categories have been identified by Minker and Sable as the basic linkage relations (36). The linkage techniques that have been introduced in this paper can imply one or more of the basic relations in Figure E.1. Each of the linkage relations is discussed in this section.

a. Sequencing: Ordered List

The basic ordered list type of relationship is called sequencing. Pointers conceptually connect noncontiguous data elements or "target" items.

b. Associative: Value List

This type of relationship is essentially a connection based upon a common "value for a given property." For example, a value list for animals could be (1) cat, (2) dog, (3) mouse, and (4) pigeon.

In contrast to an ordered list (sequencing), the value list (associative) does not imply a logical ordering of the list elements.

BASIC LINKAGE RELATIONS (36.1)

1. SEQUENCING: ORDERED LIST
2. ASSOCIATIVE: VALUE LIST
3. HIERARCHY
4. ADJOINING

Figure E.1

As introduced earlier, the following "list" synonyms are used in this paper:

A Simple List = String = Thread = Chain

c. Hierarchy

A generic-specific relationsnip is implied by hierarchical linkage. A MARK IV example presented a basic form of hierarchy (Figure D.4):

Level 1, Segment 1	EMPLOYEE NO.	(EMP. NO.)
Level 2, Segment 2	PREVIOUS EMPLOYER	(PREVEMPL)

In standard hierarchical representation, this example becomes:

EMP. NO.

    PREVEMPL

It is said that PREVEMPL is subordinated to EMP.NO. Several synonyms are used for the purpose of this paper:

Subordinated = Nested = Embedded

Hierarchy is a type of noncontiguous linkage, since no physical adjacency is implied.

A conceptual variation of hierarchy that applies to inverted list is presented briefly below for reference concerning thesaurus construction in text processing systems (37). The inverted list or coordinate indexing structure does not necessarily imply hierarchy, however, a vocabulary set or thesaurus for inverted list is usually constructed in a hierarchical manner.

To illustrate the inverted list application of a thesaurus, the following example is used (Figure D.7):

(1) Inverted list terms - "(1)" blue eye color, "(11)" systems analyst (job title).

(2) A thesaurus entry for the inverted list sample could be:

Eye color
  Blue (value 1)
  Green
  Hazel
Job Title
  Computer Programmer
  Manager
  Systems Analyst (value 11)

There are standard thesaurus conventions evolving (38). The basic relations expressing generic-specific relationships are (39):

(1)	Broader Term	BT
(2)	Narrower Term	NT

Other thesaurus relations are (40):

(3)	Use (synonym)	USE
(4)	Related Term	RT
(5)	Used For (cross-reference)	UF

In thesaurus format, an example is developed:

Color of Eyes
  USE Eye color
Employee
  NT Eye color

Eye Color

BT Employee

NT Blue (value 1)

Green

Hazel

UF Color of Eyes

Job Title

NT Computer Programmer

Manager

Systems Analyst (value 11)

RT Profession

Profession

RT Job Title

Note: The convention order used in this example is:

USE

BT

NT

RT

UF

d. Adjoining

This last type of linkage indicates that a continuation relationship is implied. For example, in repeated fields the variable information is a continuation of the fixed information.

The linkage necessary to identify PREVIOUS EMP. (PREVIOUS EMPLOYER) with EMPLOYEE NAME is adjoining linkage (Figure C.1):

EMP. NO.	EMPLOYEE NAME	PREVIOUS EMP. NO. 1	PREVIOUS EMP. NO. 2	PREVIOUS EMP. NO. 3
444	MARK IV	UNIVAC	Philco	Informatics

This adjoining linkage becomes more complex in a hierarchy where the record may be noncontiguous (Figure D.4):

Level 1, Segment 1	EMPLOYEE NO.	(EMP. NO.)
Level 2, Segment 2	PREVIOUS EMPLOYER	(PREVEMPL)

2. FILE MANAGEMENT SOFTWARE/HARDWARE IMPLICATIONS

Data set organization and linkages do have definite relationship with file management cost/benefit performance analysis. This concept was introduced in D. DATA SET ORGANIZATION.

The major point for linkage implications is that more complex linkage requires more complex file maintenance and more powerful hardware. These added costs must be weighed against time and investment considerations.

Some of the overall decision criteria are introduced in the next section.

F. DESIGN CRITERIA

The basic thesis of this presentation is designing a data base for growth. A corollary theme is that change should be the normal mode of operation. This is why modern file management systems provide for dynamic file structure and input/output processing.

Returning to the introductory discussion in this paper, data base is a subset of data base management (A. THE DATA BASE "LIFE SPAN," i. DATA BASE AS A SUBSET OF DATA BASE MANAGEMENT). Continuing the conceptual hierarchy introduced in topic A, the overall relationship is shown in Figure F.1.

In this broad perspective, data base design criteria are viewed. Consideration is given to efficiency of man/machine operation, but emphasis is upon the effectiveness of executive decision making.

1. PERFORMANCE REQUIREMENTS

As indicated in Figure F.1, there are several levels at which performance can be evaluated:

Level 1: o Executive decision making

Level 2: o Management information system

Level 3: o Data base or file management system

Level 4: o Input/output control

o Systems control

o Data base control

Level 5: o Data base

DATA BASE DESIGN CRITERIA HIERARCHY (41)

- EXECUTIVE DECISION MAKING
  - MANAGEMENT INFORMATION SYSTEM
    - DATA BASE OR FILE MANAGEMENT SYSTEM
      - INPUT/OUTPUT CONTROL
      - SYSTEMS CONTROL
      - DATA BASE CONTROL

        DATA BASE

Figure F. 1

Performance at any given level must ultimately be translated into more effective executive decision making at level 1 (42). The significance of this managerial requirement is that systems efficiency at levels 2-5 does not necessarily result in effectiveness at level 1: No management information system can insure effective decision making.

Effective decision making can be assisted by the computer, but the ultimate performance responsibility rests with the executive. Each organization has its unique measures of performance. For example, profit is the test of performance for business.

Within the realities of executive performance measures, data base design for growth must be subordinated to the requirements for effective decision making. The impact of this design criteria is that it is entirely feasible to design for suboptimum performance at the data base level so that the optimum can be achieved for the overall management information process.

Historically, data base design has possibly been restricted by technology and related constraints. New technology is being developed rapidly and it is management's responsibility to innovate so that tomorrow's deicision making will utilize the most advanced data base design criteria and strategies.

Competitive advantage can be achieved by distinquishing between today's uses for a data base and the managerial requirements that are not being satisfied (43). Concentrated efforts should focus upon a data base design that is capable of supporting changing information needs.

Performance measures must be developed for the individual organization and objectives within this framework, Some technological aspects of data base design criteria are discussed in the next section.

2. HARDWARE/SOFTWARE COST/BENEFIT ANALYSIS

A set of data base size/structure and input/processing/output current and projected performance specification requirements can be established for a given organization's management information system. These specifications should be functionally oriented toward the system input/processing/output needs, rather than oriented toward a specific hardware/software vendor.

Given a set of functionally oriented specifications, it is then a matter of cost/benefit analysis when evaluating available hardware/software solution sets. Traditional and advanced systems analysis can be aided by computer models such as SCERT from COMRESS (44).

The data base size/structure and growth criteria are constituent requirements that support the overall development of a management information system.

Economic and technological trends in hardware and software have a definite impact upon the availability of suitable hardware/software systems that can meet the desired performance specifications at a reasonable cost.

General trends are briefly indicated below:

a. Hardware/Software Control

(1) Lower cost mass storage, peripherals and hardware/software control.

(2) Improved multiprocessing, timesharing, and communication hardware/software capability.

b. User Software

(1) Standardized summary software to support off-line processing, e.g. MARK IV and RAPS.

(2) Interactive on-line summary languages to support hardware/software communication capability.

a. Standardized off-the-shelf summary software, e.g MARK IV/2 (projected).

b. Custom summary software.

NOTE: Many standardized software systems are hardware "brand" dependent, but usually to less of a degree than custom systems.

These future trends suggest lower unit costs for processing more data. This situation can result in an increased economy of technological scale for the management information system function. The implicit requirement upon data base design is to prepare now for the anticipated growth and innovation.

G. MODELING AND THE DATA BASE

Modeling in an organization has been traditionally limited by data storage and processing methods. With the advent of third/fourth generation hardware/software configurations, the nature of modeling application is changing rapidly.

There are broadly two types of modeling that can use a modern computer complex effectively. The first type concerns business games and is used primarily for training purposes (45). This present discussion emphasizes a second category of modeling, operational models.

Operational models are defined in this paper as those models that utilize or "operate" upon actual and projected data in the data base. The requirement is that the data is stored in a computer configuration.

The broad spectrum of operational models can be identified as a subset of operations research. These models utilize developed techniques such as mathematical programming, network analysis, queueing, and probability analysis.

There are special languages such as GPSS and Simscript that support model development requiring simulation techniques.

Within the scope of this paper, a brief indication of the role of the data base in relation to operational models is discussed.

1. FILE MANAGEMENT FUNCTIONS

The major contribution of data base or file management systems, in support of modeling, is to provide an accurate up-to-date data base. An increasing economy of scale is realized as the modeling algorithm "operates" on the data base. This situation occurs because a second use is being made of the data base, i.e. modeling.

In a broad sense, there are two purposes of a data base: (1) to support the management systems daily functions and (2) its analytical or modeling requirements.

Most file management systems concentrate upon (1) the MIS daily functions. There are exceptions. For example, RAPS provides for a FORTRAN analytical capability (46). Therefore a system like RAPS can support selected (2) analytical or modeling requirements, as well as (1) the MIS daily functions.

2. MODELING AND INFORMATION SYSTEMS

Information systems require modeling support and analysis in order to achieve optimum technological economies of scale.

There are distinct trends in modeling that reflect the data base management evolution. Historically, data base management has been identified as gradually evolving from separate data bases and subsystems or "islands of automation" (47). Modeling is developing in the same way.

To illustrate this point, "islands of modeling" are listed in the sample below:

a. Traditional Information Systems (closed)

   (1) Cost and budget models.

   (2) Basic variance analysis for budget vs actual.

   (3) CPM/PERT network models.

b. Production and Operation Information Systems (partially closed)

   (1) Inventory control models.

   (2) Production scheduling models.

   (3) Process control models.

c. Marketing Information Systems (open)

(1) Sales models.

(2) Credit models.

d. Total Information Systems (closed, partially open, and open)

(1) Executive decision making analysis.

(2) Management information system analysis.

(3) Data base or file management system analysis.

Progress in modeling is uneven and a function of organization requirements and capabilities. In certain areas pioneering work has been done, such as linear programming in the oil industry. In general, the trend toward complex models that utilize an expanding data base is on a "pay-as-you-go" basis.

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   MARK IV has special provisions for "Own Code" user instructions.

2. RETRIEVAL ANALYSIS & PRESENTATION SYSTEM: RAPS: TECHNICAL REFERENCE MANUAL (Bethesda, Maryland: Leasco Systems & Research Corporation, 1969; Doc. No. CS-RM-003.0), pp. 3-6, 7, 8.

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3. Prince, Thomas R., INFORMATION SYSTEMS FOR MANAGEMENT PLANNING AND CONTROL (Homewood, Illinois: Richard D. Irwin, Inc., 1966), pp. 17, 18.

4. Blumenthal, Sherman C., MANAGEMENT INFORMATION SYSTEMS: A Framework for Planning and Development (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1969), pp. 171-183, Figure 8-1.

5. IBID., Blumenthal, p. 174, Figure 8-1.

6. Bachman, Charles W., (G.E. Phoenix, Arizona) Data Base Management: The Keystone of Applied System Architecture, Fred Gruenberger, Editor, CRITICAL FACTORS IN DATA MANAGEMENT (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., To be published August, 1969), pp. 33-40.

7. IBID., Bachman, p. 34.

8. a. The concept of a total information system as defined is computer independent. As stated, a total information system exists in any and every organization in varying degrees of complexity and formality.

   At the margin, those organizations that are employing computers to increase their economies of technological scale will accrue productivity benefits.

   In the development of this view of a total information system, I have synthesized thoughts from several sources including Professors Charles R. Pack and Richard Hellman, American University; Herbert A. Simon, THE SHAPE OF AUTOMATION FOR MEN AND MANAGEMENT . . . Reference J.11; and Will Patee, Management Systems Group, Leasco Systems & Research Corporation, Bethesda, Maryland.

   b. It is virtually impossible to extrapolate prior work in management information systems (MIS) development and arrive at the concept of total information system as utilized in this paper.

Essentially, early pioneering work in MIS was directed toward independent information subsystems, and gradual systems integration was a secondary thought in the empirical design process.

Reference 8c below describes the independent or non-integrated systems approach.

c. Cross, Hershner, (VP & Group Executive, G.E.), Donald J. Lowry (Manager, P&G), A. R. Zipf (Exec, V.P., Bank of America), George Kozmetsky (Dean, College of BA, U. of Texas), and Robert N. Anthony (Asst. SECDEF - Comptroller); COMPUTERS AND MANAGEMENT: The 1967 Leatherbee Lectures (Boston: Harvard University, Graduate School of Business Administration, 1967); tradition of non-integrated systems, pp. 16, 17, 34, 35, 55, 56; tradition of a "pay-as-you-go" philosophy, pp. 47, 59; trend toward integrated interfaced business/scientific MIS, pp. 28, 29, 48, 49, 69-75, 118-121; and data base management trends, pp. 107-108.

d. Historically, organizations started with the parts and evolved an MIS plan which could facilitate integration of these parts.

If a total information system philosophy is utilized initially, a probable approach would be to design the MIS parts with integration in mind as well as the requirements of the applicable decision making process.

9. Op. Cit., Prince, INFORMATION SYSTEMS . . ., pp. 38-44ff.

10. a. Nilson, N. W., The Logical Data Base--Its Concepts, Development and Use, (Informal presentation at AMA Seminar No. 6207-2, July 9, 1968).

b. Podell, Harold J., Foundations of Constructing a Marketing Data Base (Informal presentation at AMA Briefing Session No. 6310-04, September 30, 1968), p. 18.

11. Op. Cit., MARK IV FILE MANAGEMENT. . ., p. 1-4, Figure 1-1.

12. IBID., MARK IV, p. 1-5, Figure 1-2.

13. IBID., MARK IV, pp. 1-6, 7, Figure 1-3.

14. IBID., MARK IV, pp. 5-1 through 5-8.

15. IBID., MARK IV, pp. 3-17 through 3-44.

16. Op. Cit., RETRIEVAL ANALYSIS & PRESENTATION SYSTEM: RAPS, p. G-1.

17. IBID., RAPS, p. 2-1.

18. IBID., RAPS, pp. 4-1 through 4-8.

19. Op. Cit., MARK IV, pp. 3-3, 3-4, Figures 3-2, 3-3.

20. Op. Cit., RAPS, p. 4-8.

21. a. Meadow, Charles T., THE ANALYSIS OF INFORMATION SYSTEMS: A Programmer's Introduction to Information Retrieval (New York: John Wiley & Sons, Inc., 1967; Information Science Series), pp. 38-45.

    b. Podell, Harold J., I. Environment for Change, IV. Developing a Common Data Base for MIS (Informal presentation at AMA Orientation Seminar No. 6207-02, July 8-10, 1968), pp. 71-79.

22. IBID., 21a, Meadow, Figure 6.9.

23. Data File Organization/Retrieval Concepts, THE DATA LETTER: CONTROL DATA CORPORATION (Rockville, Maryland: U.S. Army Marketing Program, CDC, Vol. 1, No. 4, December 1967), Attachment A, pp. 5-6.

24. Op. Cit., 21a, Meadow, Figure 6.4.

25. IBID., 21a, Meadow, Figure 6.5.

26. IBID., 21a, Meadow, Figures 8.2, 8.3.

27. IBID., 21a, Meadow, Figures 6.10, 6.11.

28. Op. Cit., Data File Organization/Retrieval Concepts . . ., p. 1.

29. Introduction to IBM System/360 Direct Access Storage Devices and Organization Methods (IBM Manual No. C20-1649).

30. Op. Cit., Data File Organization/Retrieval Concepts . . ., pp. 1-3.

31. IBID., Data File . . ., pp. 2-3.

32. Op. Cit., MARK IV, pp. 3-4, 3-5, 3-6, Figure 3-6.

33. IBID., MARK IV, pp. 3-6, 3-7, Figure 3-7.

34. IBID., MARK IV, pp. 3-7 through 3-10, Figure 3-8.

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    Sponsored by the American Documentation Institute, now the American Society for Information Science.

36.1 IBID., Jack Minker and Jerome Sable.

37. Taulbee, Orrin E., Content Analysis, Specification, and Control, Carlos A. Caudra, Editor, ANNUAL REVIEW OF INFORMATION SCIENCE AND TECHNOLOGY: VOLUME 3 (Chicago: Encyclopaedia Brittannica, Inc.; The American Society for Information Science, 1968), pp. 105-136.

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40. IBID., Thesaurus Rules. . .

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b. Op. Cit., Bachman, Data Base Management. . ., pp. 33-40.

42. a. 1954: Drucker, Peter F., THE PRACTICE OF MANAGEMENT (New York: Harper & Row, Publishers, 1954), pp. 34-48.

b. 1966, 1967: Drucker, Peter F., THE EFFECTIVE EXECUTIVE (New York: Harper & Row, Publishers, 1966, 1967), pp. 143-165; in particular, Decision Making and the Computer, pp. 159-165.

c. 1968, 1969: Drucker, Peter F., THE AGE OF DISCONTINUITY: Guidelines to our Changing Society (New York: Harper & Row, Publishers, 1968, 1969), pp. 11-41; in particular, p. 40 ". . . knowledge has become the central economic resource."

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44. SCERT: Modeling Technique for Computer System Hardware/Software Analysis.

This system was described by COMRESS, Washington, D. C. in a DATAMATION (Vol. 15, No. 2) advertisement, pp. 126-127.

The five functional phases of SCERT are:

(1) SCERT builds a model of present or planned system.
(2) SCERT models each candidate hardware configuration.
(3) SCERT merges the systems/hardware models.
(4) Full simulation is achieved for hardware/software interface and performance.
(5) Cost/performance data are produced from the simulation for hardware and software operations.

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