DATA BASE MANAGEMENT SYSTEMS: AN EVALUATION OF THEIR POTENTIAL USE IN THE MANAGEMENT SYSTEMS OFFICE

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The only current attempt within The Management Systems Office at Goddard to use a data base management software system is the automated budget system currently under development which includes on-line update and query capability and uses the TOTAL data base management package.

A study was made of this automated budget system and all aspects of the current state of the Theory, Technology, and applications of data bases for the purpose of making recommendations for the future use of data base management in the data processing and management information systems at Goddard.

As a result of this study, a comparative evaluation was made of commercially available packages, a data base system was designed to provide complete information about the current data resource and allow better control. Recommendations were given for the use of this data base in the design of future applications.

I. APPROACH

A study was made of the automated budget system in order to determine how its features might be useful to other applications of the Management Systems Office (MSO) and to expose the investigator in depth to an application which makes use of a data base management system. The following strategies were used in this study:

1. Interviews were conducted with the personnel involved in the design and implementation of the budget system. These included Bob Boyer, John Schiavone, Burt Heacock, Moshe Abarbanel and Ahmed Nadeem. In addition, there were many valuable informal discussions with MSO personnel.

2. All reports and documentation pertinent to the automated budget system were read. See part D of the Bibliography for a complete list of items. In particular, the Project Workbook was valuable for giving a sense of the history of project and documentation of it current state.

3. Computer source code and sample outputs from the budget systems were examined. This included the data base definition and several of the major programs.

4. The TOTAL manual was carefully studied. Next a comparative study of some commerically available data base management software package was carried out. This was done by reading manuals for various systems and by a careful study of Data Base Management Systems: A Critical and Comparative Analysis by Performance Development Corporation. From this

study feature matrix was produced which compares four major data base management packages. Additional experience with these four systems was gained by designing the data base for the budget system as it would be appropriate for each of the packages.

Finally, a study was made of the state of the art of data base theory and technology by a search and study of the recent literature of the subject. This included reading sixty-six articles and eight books on the subject as listed in the Bibliography. Special study was made of the relational and CODASYL DBTG models for data bases and the budget system was designed around their specifications. This was all undertaken with an eye toward developments which might be of current or future use to MSO.

II. Review of the State of Data Base Management

Four data base management systems were studied in depth. These four systems were TOTAL, IMS, ADABAS and System 2000. These appear to be the most popular of the package which are commercially available. A feature matrix was constructed from the information gained by reading the Performance Development Corporation document and other pertinent information. This feature matrix is given in Appendix A. A brief summary of general impressions of important features of these four systems follows:

IMS. This system appears to be difficult to use both for the designer and for the application programmer. It completely lacks data independence, meaning a change to the data base almost always necessitates a change to all application programs. In addition, documentation is poor and overhead is significant.

TOTAL. TOTAL receives very good references from its users. It is simple to use, runs fast for update and reorganization and makes good use of disk space. It has good data independence properties. It appears somewhat restrictive in the way the data can be structured and lacks some of the feature found in other systems.

SYSTEM 2000. This package uses inverted files which results in fast retrieval but slow updates. It is by far the easi-

est of the four systems to use by both designer and programmer. It has its own query language which permits ad hoc queries to be generated by non-programmer users. Documentation is excellent and many extra features are included such as backup and recovery and report writer.

ADABAS. ADABAS also has inverted files. It is easy to use, although somewhat more difficult than System 2000. It has built-in data compression and queries are easy to form. It has good query flexibility in that the list of required records can be obtained without retrieving the records themselves.

In an overall evaluation of these systems, the investigator feels that System 2000 is superior because of the ease of use and overall flexibility of the system. ADABAS also rates very high, but appears to be slightly less adaptable to some applications. TOTAL is a good choice when on-line update requirements make the use of an inverted file structure impractical.

Two other data base management systems not included in this analysis warrant careful consideration. These are IDMS and INQUIRE. IDMS has the advantage of being the most popular implementation of the CODASYL recommendations. It also has a wide range of utilities to assist the data base administrator and a good report writer capability. INQUIRE is user-oriented and yet rated high on efficiency. A full range of

facilities including query language, report formatting, and data dictionary are available.

On the theoretical side of data base developments, the major debate is between two different models for data base representation. The first is the data structure-set model developed by the CODASYL Data Base Task Group in 1971. It's basic features are the existence of two views of the data: the schema and the subschema. The schema is the logical definition of the data base while the subschema is the subset of the schema in the form used by the applications program. The data consists of record types connected by sets which specify a logical relationship between two record types. The data manipulation language is an extension of COBOL.

The purpose of the DBTG proposed was to establish a standard for data base management. However, this has not happened in the five years following the release of this proposal. Implementations have been marketed by many major computer vendors. These include DBMS/10 by Digital Equipment Corporation, DMS/1100 by UNIVAC, EDMS by Xerox, and IDS by Honeywell. In addition. IDMS from Cullinane Corporation is marketed for IBM implementation. TOTAL contains many of the basic properties of the DBTG proposal, but lacks the terminology and precise organization.

Notably absent in the support of the DBTG proposal as a standard is IBM, who feels that the data manipulation language is

too procedural and the structure of the model is not powerful enough. Instead IBM seems to be pouring its research dollars into the relational model first proposed by E. F. Codd in a paper published in 1971.

The principle features of the relational model consist of a structure of relations which are sets of n-tuples of data elements and a data manipulation language based on the predicate calculus. Advantages of this model are the existence of normal forms which allow for the most convenient representation of the data, and a data manipulation language that is not procedural.

However, most of the work to date on relational systems has been done in research labs and universities. No widely marketed system is yet available based on this model completely. It could be that the state of hardware and software development is not yet to the point where such a model can be practically supported. It may take a machine with associative memory to permit such an implementation. In addition, its organization is so different from current implementations that conversion is a major problem.

There are several current technological developments which can have significant impact on the future data base management systems. One is the development of an extension to the CODASYL proposal which would introduce three levels of schema instead of two. This would make programs more independent of

changes in the data base. Associative memories and improved random access technologies can also have a profound effect on data base systems. Work is also taking place on data base hardware and software. Machines such as the Honeywell H60/64 include machine language instructions to perform data base functions and incorporation of the data base function within the operating system is becoming a common practice. The above developments also point to the possibility of processors devoted to data base management which communicate with general purpose central processors. A final development area is that of bridge processors which allow programs using one data base management system to make use of one with an improved technology by providing a bridge between the two.

III. Assessment of the Value of the Automated Budget System for Future Applications

As previously mentioned, one important aspect of the investigation being reported was a review of the automated budget system to determine which features of that system might be appropriate to future applications in MSO. The software basis for the automated budget system could be useful in future work. In fact, one such possible application is suggested in Part IV of this report. The applications part of the budget system, however, appears to provide little of value to future applications for the reasons to be outlined below.

The software combination of CIPS, INTERCOMM, and TOTAL constitutes a very useful package for on-line data base applications provided those applications are well suited to the structures of TOTAL and are carefully planned and implemented. This package should certainly be given careful consideration for future systems.

On the other hand, the application portion of the budget system provides more of a model of what to avoid than a pattern to be copied or a foundation for future work. The major weakness in the design of the system is that the data base management package did not fit the application. This could have been remedied in one or both of two ways. First, a more compatible

data base management system could have been chosen and second, the budget system could have been modified to make better use of the software.

In the investigator's exercise of designing the budget data base for each of the major packages, it was quite difficult to adapt the natural structure of the data to the TOTAL data base structure. The budget system data is very hierarchical, and therefore, hierarchical type packages such as System 2000 and IMS make design much more natural. A large number of files in the system exist only to overcome the structural limitations of TOTAL.

This is not to say that TOTAL is an inferior package. For appropriate applications it is definitely the best choice. An example is the very successful Mission Support Requirements System (MISURS) of the Mission and Data Operations Directorate at Goddard. That system, under the direction of Bob Hohl, is well designed to take full advantage of the capabilities of TOTAL.

In addition, the budget application itself could have been redesigned to take fuller advantage of the capabilities of TOTAL. Instead, the manual process was implemented directly with no improvements incorporated which might be made possible by the software.

For example, one of the major advantages of data base management technology is the elimination of redundancy in data. But the budget system, because of its design, is extremely

redundant in the storage of data, with the same data stored at each level of the hierarchy with a new level of summary. This redundancy, of course, represents a trade-off with retrieval time, but the cost in update, storage, and complexity is great compared to the attendant benefits.

Backup and recovery was largely neglected in the original implementation due to schedule constraints. Because of this, the final product will not be as well protected by backup and recovery features because these should be implemented as an integral part of the system and not as an add-on. This facility is a key one on any on-line system and any weakness invites tragedy. It should have been given higher priority in the design and implementation.

Another basic flaw in the design of the system that makes it unsuitable as a model, is that its design does not conveniently meet the users' needs. It is awkward for the user to carry out some of his common transactions, there is no convenient facility to examine all detail items in the system, and there is no way to satisfy ad hoc queries on-line, or even in a time-responsive manner in batch. All of the literature indicates that the first priority in the design of any data base system should be the convenience and needs of the user. The budget system has not done this.

The expansion of a data base system to include new applications can only be done effectively when the original system was

designed with extension taken into consideration. In other words, modular implementation of a data base system is feasible only when the total system is visualized for the initial design. The budget system was not designed from this perspective.

In addition, a sampling of the programs making up the application system shows those programs to be poorly constructed for future modification. This is the result of redundant code and uneven and sometimes incomplete documentation.

A final reservation concerning the design of the system is with respect to the on-line update capability. This seems to be a feature which adds much overhead to the system in terms of security, recovery, and data integrity. The investigator questions whether the benefits from this feature justify these costs.

In summary, because the budget system does not fit software to application well, is not sufficiently user-oriented, does not provide adequate recovery capability, and was not designed to accommodate extensions, it is not recommended as a basis for future development.

VI. Immediate Recommendation for the Application of Data Base Management

Although the use of a data base management system has greatly benefitted many computer centers, there appears to be more instances where the result of its use was tragic. The lesson to be learned from both of these types of experiences is that any move to data base management systems must be done on the basis of careful study and planning as to the data management needs of the organization.

There are many costs associated with the implementation of such systems, and these costs must be weighed carefully against the resulting benefits. These costs include the need for tighter security, the need for additional hardware, high conversion cost, and personnel to implement and maintain the system. For this reason, it is recommended that before MSO makes any costly move in the direction of a data base management system, that a careful inventory be made of the current data resource in order to establish which benefits might be most likely to accrue from the use of data base technology. The suggested vehicle for this analysis is a data resource data base system which will be described below.

The data resource data base (DRDB) system would be a data base management system making use of the CIPS, INTERCOMM, TOTAL software combination. It would consist of data related to the systems, programs, records, files, trans-

actions, reports, and data elements used in MSO processing. DRDB would have on-line query and batch report capabilities and would be regularly updated to reflect the current state of the data resource. A suggested design of such a system is given in Appendix B of this report.

A DRDB would accomplish three significant objectives. First, it would provide the information about the data resources which is necessary for making prudent decisions about the use of a data management system. Second, it would provide MSO some experience with the use of the CIPS, INTERCOMM, TOTAL software to allow a complete evaluation of its capabilities. Third, a DRDB would provide many facilities for the management of the total data resource, and could make the use of a data base management system unnecessary. Some such facilities would be the reduction of unplanned redundancy and inconsistency in the use of data, reduction in time and cost for the development of new systems and modification of old ones, and establishment of standards and security policies.

This system could be designed with relatively little expense and effort because the software package is already up and running and the data element file, the largest file of the data base, is currently under construction by the Data Management and Quality Control group of MSO. These efforts would form the foundation for the DRDB.

Once the DRDB system was operational, a comprehensive data base administration function could be instituted within MSO which would establish standards and controls, keep the DRDB up to date, and be a central information resource for the data bases.

V. General Suggestions for Future Use of Data Base Management Systems

As stated earlier, it is necessary that before any data base management system is implemented a careful study be made of the needs that it could satisfy. In this way realistic cost/benefit figures can be obtained. Such a study would include information obtained from the DRDB described in Part IV of this report. This information would specify the current use of data and determine areas where data sharing might be beneficial. Also a survey of future user needs and desires should be made with care taken to separate the needs from the desires. The results of such a study should indicate whether or not the organization should proceed in the area of data base management systems.

If the need appears great enough to warrant the use of a data base management system, the data base administrator should head a study team to determine which software is most appropriate for the task. It is important to realize that the best choice is dependent on the applications for which the system is intended. There are many good resources to assist in making this choice. The best is a recent publication, Selection and Acquisition of Data Base Management Systems, a report of the CODASYL Systems Committee. This report is available from ACM. Of particular interest is Chapter 6 which suggests some quantitative techniques for evaluation.

Although TOTAL is already available at MSO and may very well be the best choice on the market, it could also turn out to be a very costly choice if it is not well matched to the projects to which it will be applied. Therefore, a full range of possible alternatives should be investigated.

Once a decision has been made to go with a data base management system, there are two different approaches commonly recommended in the literature. One is the radical approach which recommends that a full-scale committment be made by management to convert all existing systems to data base management. This approach is based on the philosophy that only such a complete conversion can take full advantage of the system. The second approach is the cautious approach which recommends that the implementation decision be made one system at a time. This approach comes from the idea that it is better to build on earlier success by starting small, so that failures are less likely to occur and if they do, they are less likely to be tragedies.

It appears obvious that if a decision is made to proceed with data base management in MSO, the cautious approach should be used. In order to do this, a first project should be chosen from the earlier compiled list of possible projects. This project should be low profile and low risk. In addition, care should be taken to keep expectations from being too high. As experience is gained on projects such as this and success

builds the confidence of the user community, more ambitious projects could be attempted.

One author has made the point that data base management systems are like roses. The rose is widely recognized as one of the most beautiful of garden flowers. And yet the rose is not found in every garden. The reason for this is that the rose requires considerably more care than other flowers and the gardener who wishes to grow roses must be prepared to devote the time and resources necessary. Likewise, the data base management system can be a tremendous asset to an organization, but it will only be so if that organization has the time and resources to make it bloom. This the crucial input to any data base decision.

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APPENDIX A

A Feature Matrix for the Comparison of Data Base Management Systems Rated on a Scale of 1 to 10

	IMS	TOTAL	SYSTEM 2000	ADABAS
1. Data Manipulation				
1.1 Data entry, update and delete	5	3	8	6
1.2 Privacy, security and recovery	4	2	8	9
1.3 Data integrity	1	1	9	9
1.4 Format modification	1	1	7	8
1.5 File convertibility	3	5	3	9
1.6 Redundancy and consolidation	3	7	3	9
1.7 Growth	5	5	8	7
1.8 Data manipulation performance	3	3	6	8
2. Query capabilities				
2.1 Host and embedded languages	6	5	9	4
2.2 Specification of parameters	3	5	8	6
2.3 Conjunctions and disjunctions	5	3	8	8
2.4 Degrees of generality	8	5	8	5
2.5 Heuristic searches	4	1	9	1
2.6 Skill level required	4	2	8	7
3. Applications Programming				
3.1 Problem orientation	3	7	6	4
3.2 Application flexibility	5	5	7	7
3.3 Program/data independence	4	8	8	8
3.4 Specification of manipulations and retrieval operations	3	4	7	5
3.5 Construction of logical file organization	8	5	2	6
3.6 Data base description methods	3	5	6	6
3.7 Skill level required	5	4	6	7
3.8 Performance in manipulation and retrieval	3	6	5	8
4. Physical files				
4.1 Record types, flexibility and extensibility	3	5	7	8
4.2 Record distribution in the data base	5	4	6	8
4.3 Indexing methods	4	6	7	7
4.4. Physical file organization	4	7	6	6
4.5 Creating the logical record	4	8	4	7
4.6 Data space management	4	6	8	8

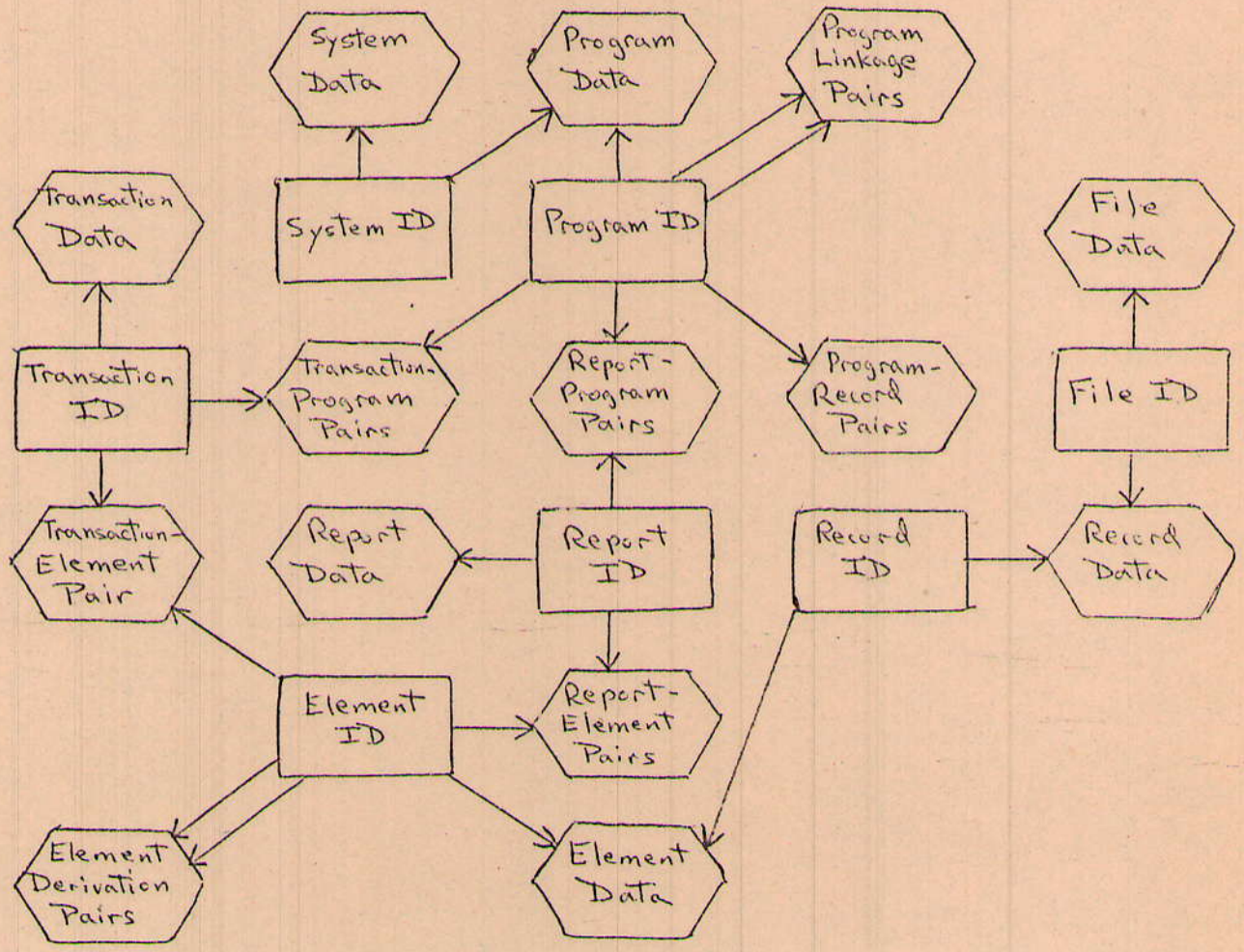
APPENDIX A (continued)

	IMS	TOTAL	SYSTEM 2000	ADABAS
5. Communications				
5.1 Line drivers	8	6	4	NO
5.2 Transaction orientation	5	4	8	INFORM-
5.3 Messages and commands	6	3	8	ATION
5.4 Single thread/multi-thread	7	8	4	AVAILABLE
5.5 Application program interface	6	7	1	
5.6 Distribution controls	8	7	2	
5.7 Security	7	5	8	
5.8 Recovery and restart	5	8	6	
6. System Installation				
6.1 File distribution control	3	6	8	8
6.2 Data base loading	4	4	7	9
6.3 System generation	3	6	9	9
6.4 Control software interfaces	7	7	5	7
6.5 System verification	4	7	7	7
6.6 Configuration requirements	3	8	5	6

APPENDIX B

Suggested Design for a Data Resource Data Base

The following is a schematic for the suggested TOTAL data base used in the data resource data base system.



Reports generated by the DRDB might include:

- Summary reports on data element usage
- All manner of cross-reference reports
- Keyword listing of elements containing the keyword in their description
- Alphabetic listing of all data elements

Suggested Contents of files in the DRDB system:

SYSTEM DATA FILE
System ID
Description

FILE DATA FILE
File ID
File Location
Organization
Security
File Description

REPORT PROGRAM-PAIRS
Report ID
Program ID

PROGRAM DATA FILE
Program ID
Description
System ID
Language
Frequency
Type

TRANSACTION DATA FILE
Transaction ID
Source
Frequency
Transaction Description

ELEMENT DERIVATION PAIRS
Element derived ID
Source element ID

ELEMENT DATA
Element ID
File ID
Element description
Data type and size
Source
Security
Edit rules

PROGRAM LINKAGE PAIRS
Calling Program ID
Called Program ID

TRANSACTION-ELEMENT PAIRS
Transaction ID
Element ID

PROGRAM-RECORD PAIRS
Program ID
Record ID of Record Used

TRANSACTION-PROGRAM PAIRS
Transaction ID
Program ID

RECORD DATA FILE
Record ID
Record size
Security information
File ID
Record description

REPORT DATA FILE
Report ID
Frequency
Description
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DATA BASE MANAGEMENT SYSTEMS: AN EVALUATION OF THEIR POTENTIAL USE IN THE MANAGEMENT SYSTEMS OFFICE

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