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DEFENSE INTEGRATED DATA SYSTEM (DIDS) COMPUTER SYSTEM ANALYSIS,(U)

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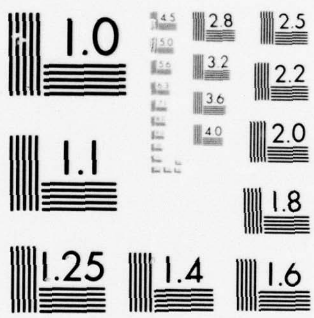

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DEFENSE INTEGRATED DATA SYSTEM (DIDS) COMPUTER SYSTEM ANALYSIS

Marco Fiorello

February 1977

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Defense Integrated Data System (DIDS) Computer System Analysis		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER LMI-Task-77-5
7. AUTHOR(s) Dr. Marco R. Fiorello		8. CONTRACT OR GRANT NUMBER(s) SD-321
9. PERFORMING ORGANIZATION NAME AND ADDRESS Logistics Management Institute 4701 Sangamore Road Washington, D. C. 20016		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics)		12. REPORT DATE May 1977
		13. NUMBER OF PAGES 93
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

"A" Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer System Analysis, Performance Measurement, Cost Analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Defense Integrated Data System (DIDS) at the Defense Logistics Services Center (DLSC) is designed to provide logistics data services for logistics managers in various functional areas. DIDS is designed to make the logistics management of defense items more effective through centralized processing of the workload, rapid response to inquiries, and exhaustive screening of logistics data to maximize the utilization of current inventory items and reduce the introduction of redundant items into the inventory. The DIDS computer system

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) is a large scale, centralized, multiprocessor system that utilizes a functionally integrated data base of some 8 billion characters, and processes about 2.5 million transactions monthly. It includes two Burroughs 6700 computer systems and one IBM 360/65J computer system

DIDS is experiencing difficulties meeting current workload requirements, and there is growing concern over its efficiency and capacity. In view of these difficulties, a request has been submitted to augment DIDS computer equipment to alleviate both current and near-term capacity limitations.

This study assesses whether the additional hardware requested would solve the alleged DIDS efficiency and/or capacity problem, or whether the present hardware is adequate, but must be utilized more effectively. The current DIDS computer configurations are described, their capacity to process the existing and projected workload determined, and the apparent causes of the processing limitations identified. Five options for eliminating these constraints are assessed for their feasibility, practicability, potential for relieving capacity constraints, and approximate costs.

PREFACE

The ability to assess complex computer-based information systems is critical to their management and review. The larger and more complex the EDP system and automated applications, the more difficult it is to assess their performance. The Defense Integrated Data System (DIDS) is a large-scale, functionally integrated data system with a direct access data base of about 8 billion characters.

The study was carried out under LMI's contract with the Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics), at the request of the Director for Supply Management Policy. Its purpose is to provide insights useful to the management review of DIDS. Because of time constraints, the study was carried out in one month. The nature of the analysis called for an eclectic set of skills in EDP performance analysis, management information system design and evaluation, and organization analysis. Few individuals are proficient in all these skills; indeed few organizations can field a team with such expertise. Our approach was to assemble a team from LMI, consultant and subcontractor personnel. The use of the team approach for this short and intensive effort proved to be very effective.

Even though the study focuses on a few selective questions, we feel that the nature of the task, the approach taken and the fact that we could successfully perform an intensive four-day EDP audit of a large-scale computer system should be of interest to managers and analysts concerned with such systems. These kinds of analyses, particularly for large-scale systems, are not straightforward efforts. They can and should be approached systematically. Their success, however, is dependent upon many qualitative ingredients, a tailored study, and real time adjustments to diagnose and carry out experiments to analyze the problems.

ACKNOWLEDGMENTS

In carrying out this analysis, we benefited from the direction and insights of Mr. Harrell B. Altizer, Mr. Robert Moore, and Mr. Paul Judge of the Directorate of Supply Management Policy, OASD(MRA&L). At the Defense Logistics Agency, Mr. Harold Inge and Mr. Merwin Liss, who participated in the on-site visit, provided particularly helpful descriptions of DIDS. At the Defense Logistics Services Center (DLSC), Captain desRoches, USN; Mr. Richard Edwards; and Commander George LeBlanc were most hospitable and successfully established the basis for open and cooperative discussions. Mr. Dean Erwin, Mr. Tom Donovan and Mr. Bob Knez of DLSC deserve special thanks for their energetic participation and many useful insights and recommendations. We also thank all the other DLSC staff that helped in this analysis. Within LMI, Mr. Perkins Pedrick and Dr. Margaret Grotte provided many useful comments and editorial improvements.

In addition to the author, the study team included three Peat, Marwick, Mitchell & Co. (PMM) personnel, Dr. Tom Bell, Mr. Michael Bealmear, and Mr. Bob November; and an LMI consultant, Mr. Bill Dickson. Each of these individuals contributed special skills and experiences that were essential to the successful conclusion of this analysis. Dr. Bell deserves particular mention, for he more than anyone represented the sine qua non of the study team. In preparing this report, I have incorporated the written comments from PMM and Mr. Dickson, and, with the above acknowledgments, assume full responsibility for its contents.

SUMMARY

The Defense Integrated Data System (DIDS) at the Defense Logistics Services Center (DLSC) is designed to provide logistics data services for logistics managers in various functional areas. DIDS is designed to make the logistics management of defense items more effective through centralized processing of the workload, rapid response to inquiries, and exhaustive screening of logistics data to maximize the utilization of current inventory items and reduce the introduction of redundant items into the inventory. The DIDS computer system is a large-scale, centralized, multiprocessor system that utilizes a functionally integrated data base of some 8 billion characters, and processes about 2.5 million transactions monthly. It includes two Burroughs 6700 computer systems and one IBM 360/65J computer system.

DIDS is experiencing difficulties meeting current workload requirements, and there is growing concern over its efficiency and capacity. In view of these difficulties, a request has been submitted to augment DIDS computer equipment to alleviate both current and near-term capacity limitations.

This study assesses whether the additional hardware requested would solve the alleged DIDS efficiency and/or capacity problem, or whether the present hardware is adequate, but must be utilized more effectively. We first describe the current DIDS computer configurations, determine their capacity to process the existing and projected workload, and identify the apparent causes of the processing limitations. We then discuss options for eliminating these constraints and assess their feasibility, practicability, potential for relieving capacity constraints, and approximate costs.

DIDS COMPUTER RESOURCES

Primary B6700

The critical DIDS resource is the Primary B6700. Only that system has direct access to the Total Information Record (TIR). As currently operated and configured, the

Primary B6700 is processor (CPU)-bound. It has the maximum number (three) of Central Processing Units (CPUs) for B6700's, and is near the limit on physical device addresses and physical I/O connections.

We estimated that the Burroughs Master Control Program (MCP) and Data Management System (DMS) consume between 25% to 40% of the CPU resources on the Primary B6700. In other words, on the average, almost one out of the three CPUs is not available for processing application programs. For other, typically smaller, B6700 applications, the MCP and DMS overhead requires about 20% of the CPU resources. The application programs on the Primary B6700 consume about 60% to 75% of the CPU resources.

The Primary B6700 presently has no peripheral memory or I/O contention. The usable peripheral mass storage capacity is estimated to be about 11 billion characters. The present DIDS data base is about 8 billion characters.

Secondary B6700

As currently configured, for testing application programs, the Secondary B6700 is core (memory)-bound. The two CPUs on this system are utilized about 50% of the time. In other words, one half of the time the CPUs are idle. We observed no I/O contention on the Secondary B6700.

The proposed hardware augmentation would double the current core (memory), and more than double the disk and tape storage devices. The number of CPUs would remain at 2.

IBM 360/65J

This computer was not closely examined because it did not have any apparent bottlenecks. The IBM 360/65J, with the Storage Technology Corporation (STC) high speed/capacity tape drives, has sufficient processing and storage capacity for the proposed Alternate Relocation Site (ARS) processing, although requirements for fourth quarter publication apparently cause temporary saturation or capacity deficits.

DIDS FILE DESIGN

The TIR file organization is effective. The National Item Identification Number (NIIN) is used as the physical address in the direct access memory. The cross-index (part number) file is not as effectively organized. Approximately 24% of the daily transactions for inquiries do not have a NIIN, and require access to this cross-index. That 24%, however, accounts for about 47% of the I/O time required to process all the daily transaction inquiries.

DIDS WORKLOAD

There are now processing backlogs for several DIDS functions. Additional functions have already been scheduled, but not implemented, thus intensifying the issue of workload saturation. This analysis assumes the DIDS workload projections prepared in December 1976 by DLSC and DLA.[1]

By December 1977, the overall DIDS workload volume is expected to have increased 10% over the January 1977 figure. Projected increases for each EDP system are shown in Table S-1.

TABLE S-1. WORKLOAD PROJECTIONS BY EDP SYSTEM

Computer System	Projected Workload Increase By 12/77 Over 1/77
Primary B6700	10%
Secondary B6700	2%
IBM 360/65J	19%

Source: DLSC DIDS Workload Projections based on wall clock hours, December 1976.[2]

[1]Since this study it has been pointed out by DLSC and DLA that their December 1976 workload projection was not complete because several workload areas were not quantifiable at that time. A discussion of the possible additional workload magnitudes and its implications for the study results is given in Appendix B of the report.

[2]The brevity of the study precluded the computation of DIDS workload and EDP capacity estimates in terms of CPU processor hours. Consequently, we used the DLSC estimates based on wall clock hours, which are not as appropriate as processor hours.

The DLSC DIDS December 1976 workload projection shows no increase in 1978 or 1979 over the projected levels for end of the year 1977. Assuming that the DLSC projections are accurate, if the 1977 year-end workload levels can be accommodated, the following two years can also be accommodated.

EDP CAPACITY VERSUS PROJECTED WORKLOAD

The estimated differences between the current (January 1977) DLSC EDP capacity and the projected DIDS workload requirements by year-end 1977 are tabulated in Table S-2. These projections are based on DLSC wall clock hour estimates.

TABLE S-2. DIFFERENCES BETWEEN CURRENT EDP CAPACITY AND PROJECTED WORKLOAD REQUIREMENTS

System	Current (1/77)	Projected (12/77)
Primary B6700	+ 0.2%	- 9.7%
Secondary B6700	- 3.6%	- 4.8%
IBM 360/65J	+11.3%	- 5.8%

Source: DLSC DIDS Workload Projections based on wall clock hours, December 1976.

The Primary B6700 is virtually saturated and will have a capacity deficit of about 10% by the end of 1977. The Secondary B6700 is now saturated. Its capacity deficit in January 1977 was about 4%, and it is expected to grow to about 5% by December 1977. The IBM 360/65J presently has a capacity surplus of about 11%, but is projected to have a deficit of about 6% by the end of the year. We did not analyze the IBM 360/65J workload projections carefully, but its end of the year deficit is apparently related more to the publications scheduled for the fourth quarter than to growth in the daily workload.

ESTIMATION OF WORKLOAD TRANSFERABLE FROM THE PRIMARY B6700 TO THE SECONDARY B6700

Based on two separate efforts, we estimate that about 85 hours of processor time per month could be transferred from the Primary B6700 to the Secondary B6700. This amounts approximately to an additional 5.8% to 7% of processor capacity that would be available per month for processing application programs on the Primary B6700.

WORKLOAD SCHEDULING AND APPLICATION PROGRAM PROCESSING

Considerable processing is required for the application programs to access the TIR, because of interface inefficiencies, limited asynchronous processing, and variable length fields/records not handled effectively by the B6700 software. Workload scheduling of transactions is now done manually, and the use of checkpoints for potential recoveries limits throughput, particularly on the Primary B6700. The preemptive introduction of high priority (levels 1 and 2) transactions in inefficient queue lengths into the workload stream disrupts the work flow and reduces the throughput volume.

OPTIONS FOR IMPROVING DIDS PROCESSING CAPACITY

We considered five options as candidate solutions to the current constraints on DIDS processing capacity. They were assessed for their feasibility (Is it possible?), practicability (Will it work well?), and relative cost. No detailed cost benefit analyses were performed, and no options entailing equipment incompatible with the current hardware were considered. The options and their assessment follow:

Option One - Maintenance of the Status Quo

The EDP systems could be left as they are, with little or no software and application program optimization. The current workload congestion would continue and probably worsen, because of the saturation of the Primary B6700. Maintenance of the status quo is feasible (DLSC is basically operating this way now), but it is not judged practicable by either DLSC or DIDS users. We concur in this judgment.

Option Two - Use of Off-Site Computer Facilities

This option would make use of EDP resources (only those that are compatible with the B6700) at installations where computer time could be purchased piecemeal. DLSC has tried this option; in 1976, some 556 hours were used on the State of Michigan Treasury Department's B6700 installation. We doubt that it is feasible to transport sufficient DIDS work to an off-site facility to affect the workload saturation on the Primary B6700 significantly. As DLSC has noted, the logistics are complex and costly. Use of off-site facilities only makes sense for emergency situations that require an alternate site for continuance of minimal DIDS processing. The practice is infeasible for the alleviation of daily workload saturation.

Option Three - Augmentation of the Primary B6700 with Larger Burroughs Computers

For this option, only Burroughs-compatible equipment has been considered.

As currently configured, the Primary B6700 has the maximum number (three) of CPUs, and is about at the maximum in memóry modules and physical connections to mass storage devices. Increasing the memory from the present 4.7 megabytes to the maximum 6 megabytes, or adding additional peripheral storage would not solve the processor bottleneck situation.

As a means of roughly sizing the potential costs of this option, we considered reconfiguring the DLSC existing and functionally separate B6700 computer systems into an integrated system via a Burroughs Global Memory with a B6800 single CPU computer. In this integrated configuration, all six CPUs (three on the Primary B6700, two on the Secondary B6700, and one on the B6800) can have access to the TIR. For the smallest B6800 processing system (the B6807) with the minimum Global Memory (~ 1.5 MB), and retaining both B6700 systems, this augmentation is estimated to cost $1,104,000 (in 1977 dollars). If the next larger B6800 system (the B6811) and the maximum Global Memory (~ 3 MB) are used the augmentation is estimated to cost $1,768,000 (in 1977 dollars). These augmentations would provide between two to four times the capacity of the current DLSC DIDS workload processing potential. Further, they are no more costly and an order of magnitude more effective than the augmentation of the Secondary B6700 proposed by DLSC. Both of these augmentations maintain full compatibility with the existing systems for minimal conversion and implementation costs and time, and incorporate the potential for additional, substantial growth. For either of these configurations, a 16-month lead time from order to installation is estimated.

This option does not offer short-term (3 to 6 months) relief for the Primary B6700 processor saturation problem. If the long-term prospects for the DIDS workload exceed the current projections and/or call for continued growth throughout the 1980-1990 period, then this option or its cost-effective equivalent will be required.

Option Four - Augmentation of the Secondary B6700 as Proposed and Offloading Work from the Primary B6700

This option reflects the pending DLSC proposal. Based on an unsolicited proposal from the Burroughs Corporation, the estimated cost for additional equipment (hardware) is $1,628,547 (in 1977 dollars), with an additional $56,710 for maintenance, installation and shipping costs.[3]

This augmentation would leave the Primary B6700 in essentially its current configuration and almost double the size of the Secondary B6700. A comparison between the current and proposed augmentation of the Secondary B6700 is given in Table S-3.

TABLE S-3. COMPARISON BETWEEN THE CURRENT AND PROPOSED AUGMENTATION OF SECONDARY B6700 HARDWARE

Current Configuration	Proposed Configuration After Augmentation	Approximate Impact
2 CPUs	2 CPUs	No Change
100 Megabytes of HPT Disk Storage	200 Megabytes of HPT Disk Storage	Double Capacity
~1 Megabyte of Core (Memory)	~ 2 Megabytes of Core (Memory)	Double Capacity
8 Disk Packs	21 Disk Packs	2½-Fold Increase in Capacity
10 1600 BPI Tape Drives	22 1600 BPI Tape Drives	Double Capacity
--	1 CRT TD830 Display/Adapter	New

[3] DSAH-LS, Funding Requirement for DLSC ADD B6700 Equipment Augmentation Request, November 18, 1976.

How much would the proposed augmentation of the Secondary B6700 relieve the CPU congestion on the Primary B6700? Two different efforts were made to estimate the likely workload volume that could be transferred from the current and projected Primary B6700 workload to the Secondary B6700. (See Chapter II.) Both efforts yielded estimates of about 85 hours of processor time per month as the likely workload that could be transferred. That 85 hours is equivalent to about 5.8% to 7% of the current monthly Primary B6700 processor time potentially available for application programs. This offloading of work would certainly contribute to the relief of the Primary B6700 processor bottleneck, but could not in itself solve the problem. Some other alternatives must be pursued, if the DIDS workload bottleneck is to be relieved.

We conclude that no amount of equipment augmentation on the Secondary B6700 will be adequate by itself to solve the congestion problem on the Primary B6700.

Option Five - Optimization and Limited Hardware Changes to Increase the Effectiveness of Current Machines

Given the current DIDS situation and assuming the DLSC DIDS workload projections of December 1976, we feel that this option is the most effective in the short term of the five considered and, even if higher projections materialize, is the most logical first course of action. Both DLSC and Burroughs personnel agree that it is feasible.

The effectiveness of the current machines could be increased by smoothing the DIDS workload, reducing the CPU congestion in the Primary B6700, and offloading a maximum of work from the Primary B6700 to both the Secondary B6700 and the IBM 360/65J. We also include limited hardware adjustments in this option.

We estimate that an additional 10-20% of Primary B6700 CPU capacity could be made available for application programs, and at least a 20% additional CPU utilization on the Secondary B6700. These improvements, plus a concerted strategy to offload work to the Secondary B6700 and IBM 360/65J, will relieve the current CPU congestion on the Primary B6700. Basically, we expect that optimization of the present machines will achieve everything Option Four does, plus yield additional opportunities to increase the Primary B6700 effectiveness, and at less cost.

We discuss 20 actions that can be taken to improve the EDP systems and their management. The first 17 actions are listed in Table S-4. That table also summarizes the actions by indicating, in terms of a relative three level subjective scale, their estimated impacts on the Primary B6700 CPU congestion, implementation times, and DLSC resource requirements.[4]

Some of these actions are dependent on other actions, while others are independent or mutually exclusive. We have tried to identify all such relationships. We have also tried to indicate those actions that DLSC either has considered or is presently considering.

Actions 15 and 16 are variations of the proposed DLSC ADP Augmentation Plan. We estimate that the combined costs for the additional hardware called for by Actions 15 and 16 are $350,000 to $400,000 (in 1977 dollars). This contrasts with the estimated $1.6 million for the proposed ADP augmentation. (See Option Four.)

Action 15 calls for changing the Primary B6700 hardware by adding the remote cathode ray tube (CRT) display console and removing the surplus 100 megabytes of Head Per Track (HPT) mass storage. The remote display console will aid in scheduling and can contribute to smoothing the workload. We do not include the additional 3 dual-drive disk packs called for in the ADP Augmentation Plan, because they will not help the CPU congestion problem, and the current Primary B6700 configuration's 11 billion characters of mass storage is adequate.

Action 16 involves adding 1 megabyte of core (memory), 100 megabytes of HPT mass storage (from the Primary B6700), and the remote console display device to the Secondary B6700. This action would modify the Secondary B6700 hardware differently than the ADP Augmentation Proposal. (See Option Four.) All the TIR data processing and updating would still have to be done on the Primary B6700. Based on our analysis, only 5.8

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[4] All those actions are discussed in Chapter III.

TABLE S-4. INCREASE EFFECTIVENESS OF CURRENT MACHINES THROUGH OPTIMIZATION AND LIMITED HARDWARE CHANGES: RECOMMENDED ACTIONS

	ACTIONS[1] / CRITERIA[2]	Impact On Primary B6700 Processing Congestions (H = High, M = Med, L = Low)	Time to Implement Action (S-M-L[3])	DLSC Resource (Personnel) Required (H = High, M = Med, L = Low)	Action Approval Or Dependency On Agencies Other Than DLSC
Primary B6700	**Software Improvements**				
	1. Identify the Cause of and Reduce the Excessive Volume of GEORGE Calls	H	M	-	Burroughs
	2. Remove MCP Inefficiencies in Processing Variable Length Data Records[4]	M	M	-	Burroughs
	3. Reduce the Periodic Peaking of Presence-Bit Overhead[4]	L	S	L	-
	4. Reduce Excessive DMS II Activity	L-M	M	-	Burroughs
	Application Program Improvements				
	5. Modify Trigger File Follow-Up Processing[4]	H	M	L	DLA/OSD/DIDS Customers
	6. Modify the COBOL Compiler to Handle Variable Length Records More Efficiently	M-H	M	M	Burroughs
	7. Use ALGOL For Selected DLSC Application Programs	M	S-L	-[5]	DLA/OSD
	8. Increase the Efficiency of Programs Processing the TIR File[4]	M	S-L	H	-
	9. Increase the Efficiency of TIR Accesses by AFARS	M	L	M	-
	10. Reduce the Number of Future Update Records Processed[4]	L	M	M	-
	Improvements in the DIDS Data Base				
	11. Reduce the Impact of Inquiries Without a NIIN[4]	M	M	L	DLA/OSD
	Increase the Efficiency of Workload Scheduling				
	12. Implement the DLSC Revised Queuing/Processing Concept with a Time Dependent Check Point[4]	H	M	M	DLA
	13. Utilize Automated Scheduling for B6700 Workloads[4]	M-H	M	M	-
	14. Process Only Full Batches[4]	M	S	M	-
	Hardware Changes				
	15. Modify Primary B6700 Hardware	M	S	M	OSD/DLA
Secondary B6700	16. Modify Secondary B6700 Hardware	M-H	S	M	OSD/DLA
	Job Shop Scheduling				
	17. Improve the Scheduling of Jobs on the Secondary B6700	L	M	M-H	-

1. Actions 18-20 dealing with Management Improvements are not listed because their impact on the Primary B6700 CPU congestion is indirect and long term.
2. These rankings are relative to the set of 17 actions considered and are based on subjective judgments.
3. S = short term, 1 to 3 months; M = mid term, 3 to 6 months; L = long term, 6 to 12-plus months.
4. DLSC has similar ideas under consideration as part of planned actions or future actions.
5. The negligible effort indicated is for new programs. For the conversion of old programs the resource requirements would be high (H).

to 7% of the Primary B6700 workload (in processor hours) could be transferred to the Secondary B6700, regardless of how big it is made.

The rationale for the augmentation recommended by Action 16 is as follows:

- Currently the Secondary B6700 is memory-bound. That bottleneck causes the CPUs to be idle about 50% of the time. Doubling the current 1 megabyte of core would allow for fuller utilization of the currently idle CPUs.
- The Secondary B6700 now has only one electronic unit (EU) for its 100 megabytes of HPT disk storage. The additional 100 megabytes of HPT would double the capacity of this mass storage medium and add one more EU. The additional EU will provide needed redundancy, and the extra 100 megabytes will provide additional useful storage space.
- The console/display device will enhance the ability to schedule the Secondary B6700 workload. However, given the nature of the work on this system, the real justification for adding a remote console is that it will provide a useful test bed for new scheduling concepts intended for the Primary B6700.

All the disk and tape mass storage devices are not included for two reasons. One, all the workload to be transferred will fit on the Secondary B6700 as currently configured. Two, the thrust of the Augmentation proposal is to have sufficient capacity on the Secondary B6700 for almost all the applications (both old and new) to reside concurrently in the system. Since most of the new workload to be transferred is to be processed on an "as required" basis, it should be processable on the current configuration with an improved scheduling procedure. More mounting and dismounting of disks and tapes will be necessary, but this is a standard procedure in job shop-type applications.

The last three actions (18, 19 and 20) deal with DIDS management improvements. They are not listed in Table S-4, because their impact on EDP processing effectiveness is indirect and mid- to long-term. Also, their focus is different. Actions 1 through 17 aim at achieving improved performance of the Primary B6700 and the Secondary B6700. Actions 18 through 20 focus on management procedures to sustain those improvements, and to improve workload planning. The program design reviews and quality assurance procedures would build upon the existing DLSC program optimization effort, and introduce steps to ensure that the improvements called for are in fact implemented.

CONCLUSIONS

We recommend Option 5 as the most cost effective short-term action to alleviate the current and near-term DIDS capacity limitations. The necessary optimization improvements are possible with the appropriate assignment of critical DLSC resources, and DLA and OSD support.

If the workload projections should be higher and/or reflect an increasing growth rate, then Option 5 is still the logical first course of action. In that event, after Option 5 is taken and appropriate workload projections carried out, Option 3, or its cost-effective equivalent, should also be pursued.

GLOSSARY OF TERMS AND ABBREVIATIONS

AFARS - Asynchronous File Access Routine System

ARS - Alternate Relocation Site

BPI - Bits per Inch

CMD - Catalog Management Data

DMS - Data Management System. Burroughs Corp. Software

EU - Electronic Unit

FIIG - Federal Item Identification Guide

HPT - Head Per Track. Burroughs Corp. Mass Storage Device

IIM - Item Intelligence Maintenance

IL - Identification List

IMC - Item Management Coding

INC - Item Name Code

I/O - Input/Output

I&S - Interchangeability and Substitutability

MB - Megabyte or 1 Million Bytes or Characters

MCP - Master Control Program. Burroughs Corp. Software

MIX - The number of programs or jobs resident in the computer at any one time

MRC - Master Requirement Code

NIIN - National Item Identification Number

NSN - National Stock Number

O.E. - Organization Entity. A file in DIDS that indicates the assignment of codes to manufacturers and non-manufacturers

PAC - Primary Address Code

P-BIT - Presence-BIT

RL - Reference List

Segment - A Part of a Record. The TIR for an item has 19 segments

SoS	- Source of Supply
SPARK	- Systems Performance Analysis Review Kit. Burroughs Corp. Software
SSR	- System Support Record. A series of cross reference files
STACK	- An area in memory in the Burroughs Computer that is assigned to a program
TIR	- Total Information Record. Currently about 8 billion characters
Transaction	- A unit of DIDS input workload. Typically a single message entailing a search, update or inquiry for the TIR
Trigger	- Temporary data in the file to indicate when an action or change is to become active or effective.

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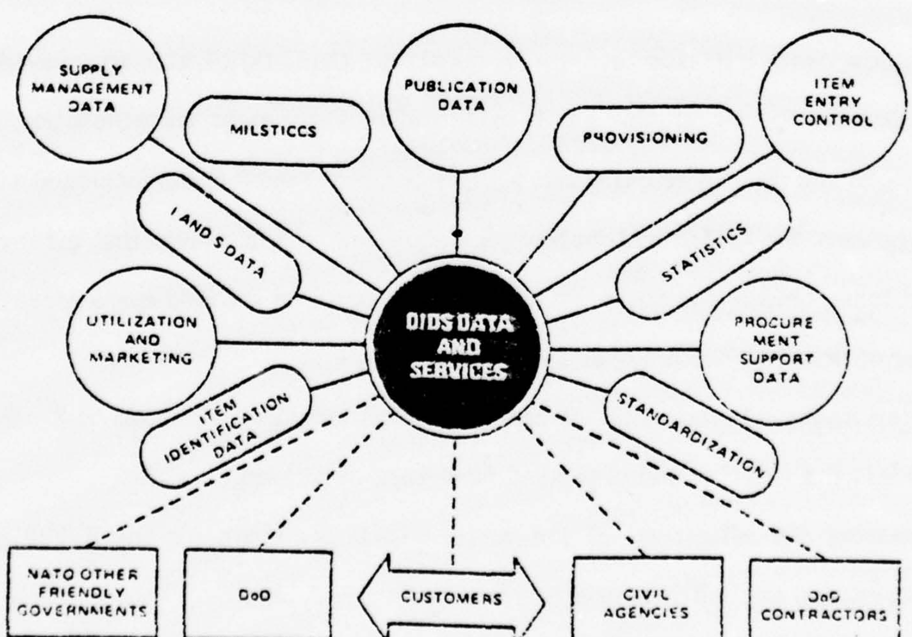
APPENDICES

I. INTRODUCTION

BACKGROUND

The Defense Integrated Data System (DIDS) is a large-scale, centralized, multiprocessor system that utilizes a functionally integrated, direct-access data base of some 8 billion characters, and processes about 2.5 million transactions monthly. The hardware and software design and development of DIDS were initiated in 1966. DIDS is designed to provide data services for logistics managers in nine functional areas: cataloging, item utilization and marketing, interchangeability and substitutability, supply management, Military Standard Item Characteristics Coding Structure (MILSTICCS), publications, provisioning, item entry control and screening, and statistics. Figure 1 shows the interactions among these functions and the DIDS data base.

FIGURE 1. DEFENSE INTEGRATED DATA SYSTEM (DIDS)



Source: DSA, Defense Logistics Services Center.

Overall responsibility for DIDS resides in the Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics), where both policy and guidance are developed and issued. Authority for the development and implementation of DIDS has been delegated to the Defense Logistics Agency,[1] which in turn has made the Defense Logistics Services Center (DLSC) responsible for the development and design of DIDS, and the development, coordination and maintenance of its operating procedures. Close ties with the Military Departments, General Services Administration, and Department of Transportation are also maintained.

Over the past 18 months, attempts have been made to improve DIDS processing capability by augmenting hardware and refining software. Notwithstanding these efforts, DIDS is still experiencing difficulties meeting current workload requirements, and concern has been growing over its efficiency and capacity, particularly in view of future requirements. DLSC has therefore submitted a request to augment DIDS computer equipment to alleviate both current and near-term capacity limitations.

OBJECTIVE

This study was initiated at the request of OASD(MRA&L) to provide useful information for its review of the DLSC ADP B6700 Equipment Augmentation Request. Specifically, LMI was tasked to carry out a DIDS computer system performance evaluation to assess whether the additional hardware requested would solve the efficiency and capacity problems, or whether the present hardware could be utilized more effectively.

In order of priority, the analysis focused on:

- Determining whether the current hardware configuration has the capacity to process the existing and projected near-term workload
- Assessing the efficiency of the current software (both for the B6700 operating systems and applications programs) and the file design

[1] Formerly the Defense Supply Agency.

- Outlining the basics of an implementation plan to correct the deficiencies in the hardware and software
- Assessing the cost effectiveness of optimizing the existing data processing system versus expanding the hardware configuration.

ASSUMPTIONS AND QUALIFICATIONS

We did not analyze the cost benefits of DIDS, the workload demand or the DLSC organization; the constraints of both time and the task order place them outside the scope of the study. By taking the DIDS workload as a given, we may have overlooked a fruitful area in which to seek relief from the current DIDS workload congestion. Also, the task order did not call for a review of all the DLSC on-going analyses, programming, and DIDS-related activities (e.g., testing practices).

Our conclusions and observations must be taken in the context of our treatment of the DLSC DIDS workload projection and DLSC organization as givens. Their omission from explicit consideration in this analysis does not imply that they are unimportant, or irrelevant to the overall effectiveness of DIDS. Since this study was carried out, it has been pointed out by DLSC that their December 1976 DIDS Workload Projection was not complete because certain workload areas were not quantifiable at that time. A discussion of the possible additional workload magnitudes and its implication for the study results is provided in Appendix B.

METHODOLOGY

The approach taken in this analysis consisted of the following steps:

Formulation of the Study Objectives and Plan

The specific information required by the DIDS review decision was identified, and the time constraints determined. From this information, the focus and plan of the study were decided.

Selection of the Team

The analysis depended upon the availability of skills in the following areas: EDP system performance analysis, B6700 system architecture, design and evaluation of large–scale, direct–access data files, and MIS design and analysis. Few individuals and few organizations could meet all these requirements. Furthermore, the study plan indicated a short and intensive on-site visit requiring multiple and concurrent interviews. A carefully selected team having appropriate eclectic skills and experiences was therefore deemed necessary. We also expected the team approach to enhance the quality of the diagnosis and interpretation of the findings.

Pre-On-Site Visit Preparation

The success of a short study of this nature is heavily dependent upon the availability of relevant data. Our plan called for the collection and review of data, prior to the on–site visit, that described:

- History and current configuration of the DIDS hardware
- DIDS software and application programs
- Current and anticipated DIDS workload and its content[2]
- DLSC DIDS organization and resources
- Availability and content of past and current DLSC DIDS system and optimization analyses
- The key DLSC personnel relevant to the study

On-Site Visit and Analysis

The study plan called for a short and intensive on-site visit to:

- Interview key DLSC personnel to utilize their DIDS experience
- Review existing DIDS computer system monitor reports
- Collect additional data
- Execute special jobs on the DIDS computers to identify processing bottlenecks
- Assess the existing hardware capacity

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[2]For this analysis we utilized the latest DLSC DIDS workload projections prepared in December 1976. For a discussion of potential growth and workloads not included in the December 1976 projection, see Appendix B.

- Analyze the DLSC ADP B6700 Equipment Augmentation Request
- Formulate options to improve DIDS effectiveness.

For a study of this nature, an on-site visit is essential to ensure that the actual conditions are reflected and incorporated in the analysis, and that the analysis is relevant and the recommendations practicable.

Interpreting and Presenting the Study Findings

This last step entails the synthesis of the different observations into a set of conclusions directed at answering the study objectives, and presenting the findings.

OVERVIEW

The rest of this report is presented in two chapters. Chapter II begins with a brief account of the current DIDS, its status and situation, which represents the base case for the analysis. Topics covered include: hardware and software configurations; the data base; and the DIDS workload, current volume, distribution, backlogs and projections. Next, the current capacity of the DIDS EDP systems is described and related to projected workloads. Finally, current DIDS limitations are analyzed to identify specific capacity limitation problems and their causes.

Chapter III describes and assesses five options for dealing with the constraints on DIDS processing capacity. One option, Increasing the Effectiveness of Current Machines through Optimization and Limited Hardware Changes, is selected as the preferred alternative, and broken down into 20 actions that would contribute to increased effectiveness of the DIDS EDP systems.

II. DIDS: CURRENT CONFIGURATION, CAPABILITIES, LIMITATIONS

DIDS HARDWARE CONFIGURATION

In order to understand the study findings and to place them in perspective, a description of the current DIDS EDP design and workload is needed. The current system constitutes the base case for this analysis. Because the focus of this study is very specific, we have omitted any discussion of how DIDS started, what the initial plan and cost estimates were, and so on.[3]

Currently the DIDS hardware consists of two Burroughs B6700s and one IBM 360/65J. The specific configurations are listed in Tables 1, 2 and 3. The larger B6700[4] is the primary DIDS processing system and has the maximum number (three) of central processor units, and nearly the maximum amount of memory modules and physical connections installable. (See Table 1.)

The smaller B6700[5] is primarily used for program development and testing, and the processing of some overflow work from the Primary B6700. The Secondary B6700 was initially sized for testing requirements and is much smaller than the Primary B6700. (See Table 2.)

Both B6700's currently utilize the Master Control Program (MCP) version II.7 field release 1, and the Data Management System (DMS II) version II.7 available from the Burroughs Corporation.

The IBM 360/65J (Table 3) processes a variety of applications (e.g., the Defense Property Disposal Service Integrated Disposal Management System, Simplified File

[3]Some of that information can be found in References 2-5.

[4]Hithertofore this system will be referred to as the Primary B6700.

[5]Hithertofore this system will be referred to as the Secondary B6700.

TABLE 1. DLSC PRIMARY B6700 CONFIGURATION

Model Number	Qty	Description
B6724	1	Basic System
	2	Central Processing Unit
	1	Input/Output Processor
	1	Console Display Terminal
	1	Optional PTR/Keyboard
	1	Console Display Control
	1	Adapter for Print Key
B6710	1	Central Processing Unit
B6780	2	Input/Output Processor
B6730-1	16	Data Switching Channel
B6006-1	24	Memory (500 NS, 2,359,296 bytes)
B6005-4	3	Memory (1.6 US, 1,179,648 bytes)
B6005-5	3	Memory (1.6 US, 1,179,648 bytes) (Total - 4,718,592 bytes)
B9111	2	800 CPM Card Reader
B6110	2	Card Reader Control
B9213	2	300 CPM Card Punch
B6212	2	Card Punch Control
B9243-1	5	1100 LPM Printer
B6240	6	Printer Control
B9940	5	High Speed SLEW
B9941	5	Additional 12 Print Pos
B9943	5	Printer Memory
M407B	1	Macro OCR Printer
B9394-2	2	96 KB Mag Tape Unit
B6393-3	2	Magnetic Tape Control
B6492	2	4 x 16 Tape Exchange
B9394-1	4	7-Channel Mag Tape Unit
B6391-4	3	MTU Control
B9393-3	34	9-Channel Mag Tape Unit
B6393-2	10	MTU Control
B6493-2	5	2 x 8 Exchange
B9375-10	5	23 M.S. Disc File (500,000,000 bytes)
B6373	4	Disk File Control
B6471	2	DF Exchange
B9350-41	1	Typewriter Inquiry Station
B9350-4	1	Optional Printer Keyboard
B6650-1	1	Line Adapter
B6471-5	4	Control Adapter
B6471-6	8	Electronics Unit Adapter
B9485-4	18	Dual Drive Disc Pack
B9486-4	48	Dual Drive Increment
B9974-4	132	Disk Packs
B6383-2	9	Dual Control
B9342-1	2	Console Display Terminal
B9371-8	2	DF Electronics Unit
B9371-2	1	Optical PTR/Keyboard
B6340	2	Console Display Control
B6340-1	3	Adapter for Print Key
B6350	2	Data Comm. Processor
B6350-5	2	Data Comm. Processor Memory
B9350	6	Typewriter Inquiry Station
B6350-1	2	Adapter Cluster
B6650-1	10	Line Adapter
B6790	1	Optional MDL Processor

Source: DLSC

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TABLE 2. DLSC SECONDARY B6700 CONFIGURATION

Model Number	Qty	Description
B6750	1	Basic System
	2	CPU's (5/10 clock), 1 I/O Processor with 12 Data Switching Channels, 1 MDL Processor, 1 Operator Console with Dual-6340 Displays, 1 Peripheral Control Cabinet and 1 Power Control Cabinet
B6780	1	Additional I/O Processor w/12 Data Switching Channels
B6005-4	2	Memory (1.6 US, 786,432 bytes)
B6005-5	1	Memory (1.6 US, 393,216 bytes) (Total - 1,179,648 bytes)
B9111	1	800 CPM Reader
B6110	1	Card Reader Control for B9111
B9213	1	300 CPM Punch
B6212	1	Card Punch Control
B6610	1	BCL-BCL Code Translator for B6212
B9243-1	3	1100 LPM Printer, 120 Print Positions
B9941	3	Additional 12 Print Positions for B9243-1
B6240	3	Printer Control for B9243-1
B9940	3	High Speed SLEW for B9243-1
B9943	3	Printer Memory
B9393-3	6	240 KB MT Unit (9-Channel 1600 BPI)
B6493-2	1	2 x 8 Common Elec. Exch. for B9393-3
B6393-2	2	240 KB Unit Control
B9394-1	1	24-66-96 KC MT Unit (7-Channel 200/556/800 BPI)
B6490	2	2 x 10 Tape Exchange for B9394-1 & 2
B6391-4	1	96 KC Unit Control
B9375-10	1	23 MS Disk (100,000,000 bytes, includes 1 EU and 5SU's)
B6373	1	Disk File Control
B9383-8	1	Disk Storage/Dual Controller-872 MB (10 Spindles)
B9486-4	3	Dual Drive Increment (6 Spindles)
B6304-1	2	Disk Pack Drive Control for B9383-8
B9495-5	5	400 KB MT Unit (9-Channel 1600 BPI)
B9499-12	1	2 x 8 Master Elec. Exch. for B9495-6
B6395-7	2	400 KB Unit Control
B9394-2	1	96 KB MT Unit (9-Channel 800 BPI)
B6393-3	1	96 KB Unit Control
B6350	1	Data Comm. Processor
B6350-5	1	24,576 Bytes of DCP Memory
B6350-1	1	Adapter Cluster for B6350
B9350	3	Teletype Inquiry Station
B6650-1	3	Line Adapter

Source: DLSC

TABLE 3. IBM 360/65J CONFIGURATION

Description	Type	Model	Quantity
Central Processor	IBM 2065	J	1
Processor Storage (1024K)	Ampex 2365		1
Console with operator control panel	IBM 2150	1	1
Console Keyboard	IBM 1052	7	1
Control Unit	IBM 3272	2	1
Display Station	IBM 3277	2	2
Hardcopy Printer	IBM 3286	2	1
Tape Control Unit with 7-track compatibility and data conversion feature	IBM 2803	1	1
Tape Control Unit capable of handling 1600 BPI tapes	IBM 2803	2	3
Selector Channel (two channels are contained within one physical unit)	IBM 2860	2	2
Drum Printer (1250 lines per min.)	Mohawk 3160	1	3
Forms Stacker	Mohawk 1901		3
Disk Controller (2-channel switch on channels 1 and 3)	Potter 5314	1	4
Disk Drive (312KB data rate)	Potter 4314	A1	32
Multiplexor	IBM 2870	1	1
Tape Drive (7-track, 200, 556, and 800 BPI, 90KB data rate at 800 BPI)	Ampex 1624	3	4
Tape Drive PE/NRZI (9-track, 800 and 1600 BPI, 90KB data rate at 800 BPI)	Ampex 1624	6	4
Tape Drive PE (9-track, 1600 BPI, 180KB data rate)	Ampex 1624	6	8
Card Reader (1200 cards per min.)	IBM 3505	B2	1
Interpret/Punch (300 cards per min.)	IBM 3525	P3	1
Tape Switching Unit	IBM 2816	1	1
Tape Drive GCR (9-track, 6250 BPI, 780KB data rate)	STC 3650		8
Tape Control Unit capable of handling 6250 BPI tapes	STC 3800-IV		2

Source: DLSC

Maintenance and Publications) that are either separate from the Primary B6700 primary workload, or cannot be processed on the B6700's because of capacity limitations.

The IBM 360/65J is currently undergoing an upgrading of its operating system, which, when completed, will give it the latest field version operating system.

DIDS DATA BASE[6]

The principal data source in the DIDS is the Total Item Record (TIR), which now contains about 8 billion characters. The TIR is organized hierarchically, as shown in Figure 2. Each file or data set shows the physical location of other related files. The part of the record that utilizes the National Item Identification Number (NIIN) is the starting point to access information about an item. For requests that do not contain the NIIN, it is necessary to utilize cross-reference indices to determine the NIIN.

The DIDS data base was designed to combine within a single integrated file all the Federal cataloging and management data for stock numbered items. In addition to the TIR, the DIDS data base contains a System Support Record (SSR) File (about 34 million characters), an alternate relocation site (ARS) data file (an extract of the TIR), and some 192 other master files and 1,300 transitory files. All these data are used to manage and provide information for about 4.5 million active items. Additionally, the file contains 1.5 million inactive items.

DIDS WORKLOAD

Currently, only the Primary B6700 has direct access to the TIR file and processes a variety of functions. However, some non-TIR Mass Interrogations, SSR File Maintenance, Publications, Statistics, and other processing are done on all three systems. Figure 3 illustrates the different functions either affecting or generated from the DIDS data base.

Table 4 lists the DIDS workload by functional requirement and indicates the approximate workload distribution across the functional categories. The percentages are

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[6]See Reference 7.

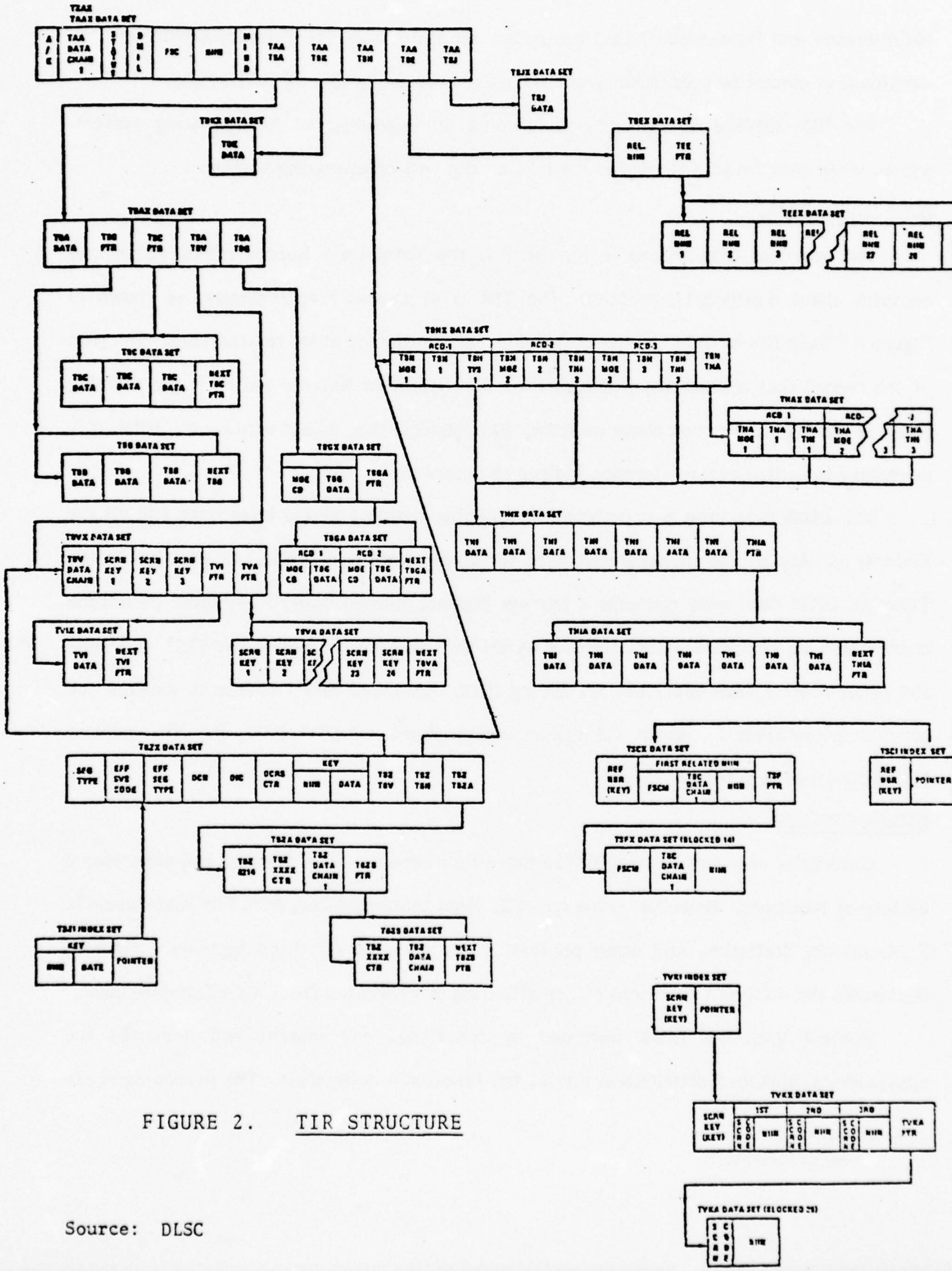
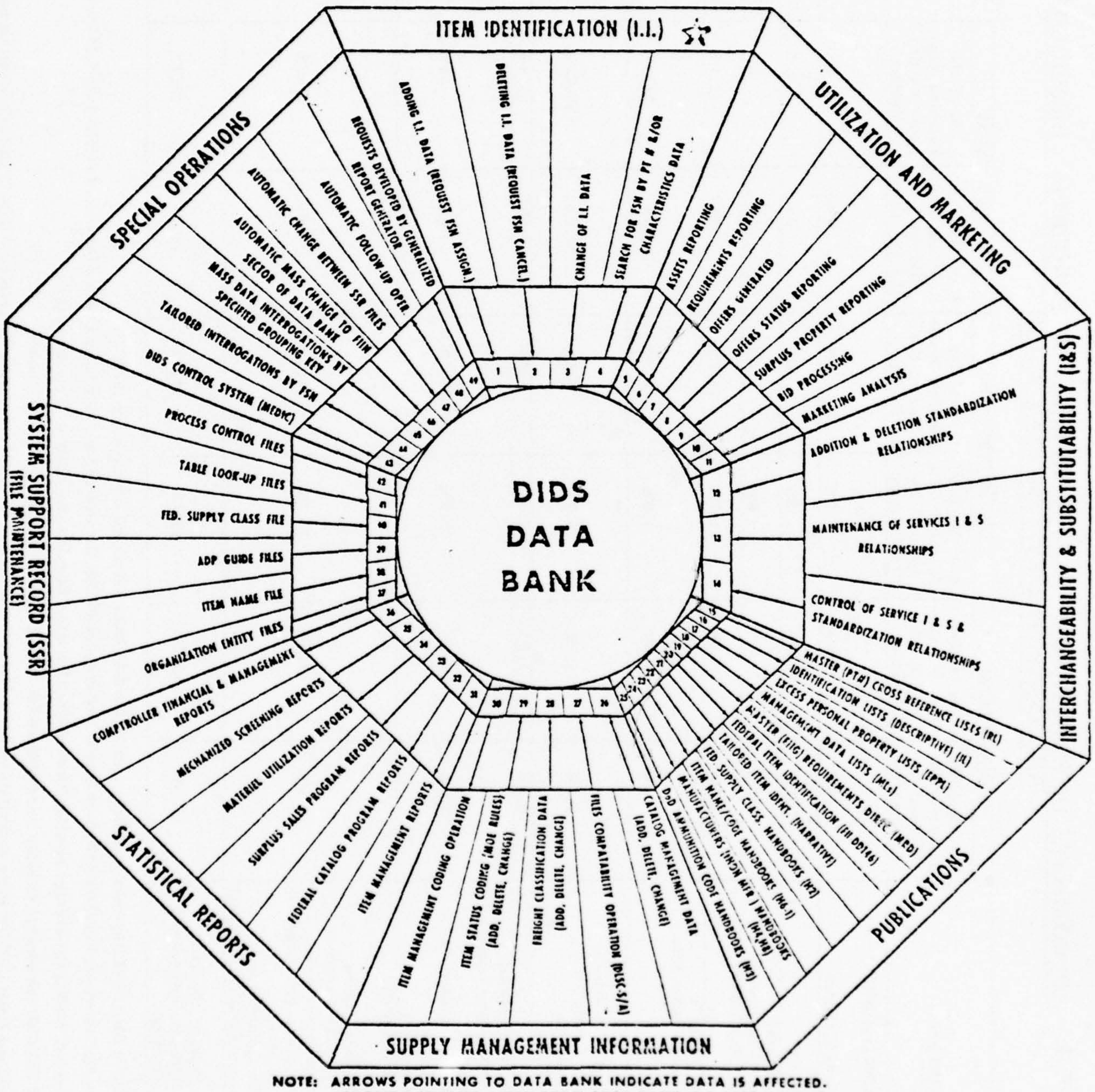


FIGURE 2. TIR STRUCTURE

Source: DLSC

FIGURE 3. DEFENSE INTEGRATED DATA SYSTEM OVERVIEW



NOTE: ARROWS POINTING TO DATA BANK INDICATE DATA IS AFFECTED. ARROWS POINTING AWAY FROM DATA BANK INDICATE DATA IS BEING PUSHED OR PULLED WITH NO AFFECT ON DATA BANK CONTENT.

Source: DLSC

TABLE 4. APPROXIMATE DISTRIBUTION OF DIDS WORKLOAD BY FUNCTIONAL REQUIREMENT[1] AND COMPUTER SYSTEM UTILIZATION

Functional Requirement	PRIMARY B6700		SECONDARY B6700		IBM 360/655		
	% of Machine[2] Reported Time Utilized for the Function	% of the Function Work-load on this Machine	% of Machine[3] Reported Time Utilized for the Function	% of the Function Work-load on this Machine	% of Machine[4] Repaired Time Utilized for the Function	% of the Function Work-load on this Machine	% of[5] Total DIDS Workload
DAILY FILE MAINTENANCE (TIR & SIR) IIM, CMDN, O.E. Cycles	17%	100%	0%	0%	0%	0%	8.5%
DAILY SEARCH & INTERROGATIONS	26%	100%	0%	0%	0%	0%	12.4%
TRIGGER PROCESSING CMDN and IIM Triggers	3.5%	100%	0%	0%	0%	0%	1.7%
MASS INTERROGATION/MASS CHANGES	0.5%	26.3%	1.2%	31.6%	1.2%	42.1%	0.8%
SSR FILE MAINTENANCE Cross-Reference Index File INC Application MRD, MOE	1%	11.4%	1.8%	9.3%	11.25%	74.3%	4.3%
PUBLICATIONS CMDN/ML, IL, MCRL Civil Agency Catalog SAMMS Microfiche H4/H8/H2/H3/H6	2.6%	14.3%	2.2%	5.5%	23.6%	80.25%	8.8%
STATISTICS	0.3%	3.2%	9.3%	50%	6.5%	46.8%	4.1%
FIIG PROGRAM PROCESSING FIIG Revision (page changes) PAC Summary Edit Guide/Sec. II Pre-edit Key Computation V Segment Extract	8.8%	78.3%	5.3%	21.7%	0%	0%	5.4%
OTHER DIDS PROCESSING ARS Processing FILDR File Maintenance Simplified File Maintenance NATO Output Consolidation Mail Sort/Suspense Processing History Processing Trigger File Maintenance Not Elsewhere Classified (Other)	25.8%	46.6%	38.1%	31.9%	19%	21.5%	26.5%
DPDS Air Force Support, Special Projects, Systems Management Functions, Testing	13.5%	23.6%	42.1%	34.2%	38.5%	42.2%	27.4%

1. Based on data in Chart 2 of Appendix A of Reference 2, for data from the period January-July 1976.
2. Machine reported times are based on wall clock hours. For Primary B6700, the average monthly hours utilized for these functions are 2,164 wall clock hours.
3. For the Secondary B6700, the average monthly hours utilized for these functions are 1,007 wall clock hours.
4. For the IBM 360/65J, the average monthly hours utilized for these functions are 1,360 wall clock hours.
5. The total machine hours used for these computations are 4,531 wall clock hours. It is not clear from the reference data if all the production hours were tabulated. However, it is expected that the relative values of the precentages are essentially correct.

based on average monthly machine utilization in wall clock hours, and may not reflect the distribution of the workload over the data base accurately. The average relative monthly machine utilization in wall clock hours by functional requirement is tabulated in Table 5.

TABLE 5. AVERAGE RELATIVE MONTHLY MACHINE UTILIZATION BY FUNCTIONAL REQUIREMENT

(wall clock hours)

DIDS Functional Requirements	Primary B6700	Secondary B6700	IBM 360	Total
Daily File Maintenance (TIR & SSR)				
IIM	237			237
CMDN	70			70
O.E. Cycles	78			78
TOTAL	385			385
Daily Search & Ingerrogations				
Search	264			264
Interrogations	300			300
TOTAL	564			564
Trigger Processing				
CMDN Triggers	54			54
IIM Triggers	22			22
TOTAL	76			76
Mass Interrogation/Mass Changes	10	12	16	38
SSR File Maintenance				
Cross-Reference Index File	9	7	150	166
INC Application	13	6	3	22
MRD	.2			.2
MOE		5		5
TOTAL	22	18	153	193
Publications				
DMDN/ML	8	5	55	68
IL	41	12	195	248
Civil Agency Catalog	4	1	10	15
MCRL			49	49
SAMMS Microfiche	1	2		3
H4/H8	3		11	14
H2/H3/H6		2	1	3
TOTAL	57	22	321	400
Statistics	6	94	88	188
FIIG Program Processing				
FIIG Revision (page changes)	49	23		72
PAC Summary	68	18		86
Edit Guide/Sec. II Pre-edit	17	12		29
Key Conputation	50			50
V Segment Extract	7			7
TOTAL	191	53		244
Other DIDS Processing				
ARS Processing	45	51	109	205
FILDR File Maintenance		107		107
Simplified File Maintenance	3	68	27	98
NATO Output Consolidation	16	1	7	24
Mail Sort/Suspense Processing	114	2	38	154
History Processing	261	86		347
Trigger File Maintenance	16			16
DPDS	36	116	34	486
Air Force Support	6	28-		34
Special Projects	41	10	9	60
Systems Management Functions	164	52	36	252
Testing	46	218	145	409

Source: Chart 2 of Appendix A of Reference 2, and DLSC data.

Note: These tabulations are in terms of wall clock hours not processor hours, and represent data for the period January-July 1976.

The basic DIDS transaction processes submitted by users (Military Departments, Civil Agencies, etc.) consist of: Daily File Maintenance, Daily Search and Interrogations, and Trigger Processes. All these transactions are currently processed only on the Primary B6700, and consume about 46.5% of its resources. While these transactions constitute only about 25% of the total DIDS machine workload, they are very visible to DIDS users and do dominate the Primary B6700 workload.

An indication of the average monthly volume of the DIDS transaction processing for interrogations, searches, new items, Item Intelligence Maintenance (IIM), CMDN, IIM triggers, and Catalog Management Data (CMD) triggers is provided in Table 6. The average input transaction workload is about 2.4 million per month or 78,000 per day. In comparison, based on an 8-day sample, the total DIDS input workload, which includes mailed magnetic tapes and cards, total Autodin traffic (including the daily transactions), triggers and special projection is about 176,000 data items per day. These data are tabulated in Table 7. Thus, relative to the total input workload in terms of input data actions, the daily transactions account for approximately 44% of the total. However, as can be seen in Table 7, the input activity fluctuates from day to day.

TABLE 6. DIDS TRANSACTION PROCESSING

(1 October 1976 through 15 January 1977)

	Interr.	Search	New Items	IIM	CMDN	IIM TRIGGERS	CMD TRIGGERS	TOTAL
Monthly Average Receipts	583,632	784,373	22,844	338,357	220,640	68,457	202,575	2,350,967
Daily Average Receipts	19,271	25,899	754	13,153	9,596	2,263	6,689	77,626
Average Processing Rate Per Hour (106 Days Experience)	3,154	2,594	326	1,747	3,963	2,594	4,836	2,537
Daily Time Required to process the Avg. Daily I/O at the Avg. rate per hour	6.11	9.98	2.31	7.53	2.42	.87	1.38	30.60

Source: DLSC DIDS workload data.

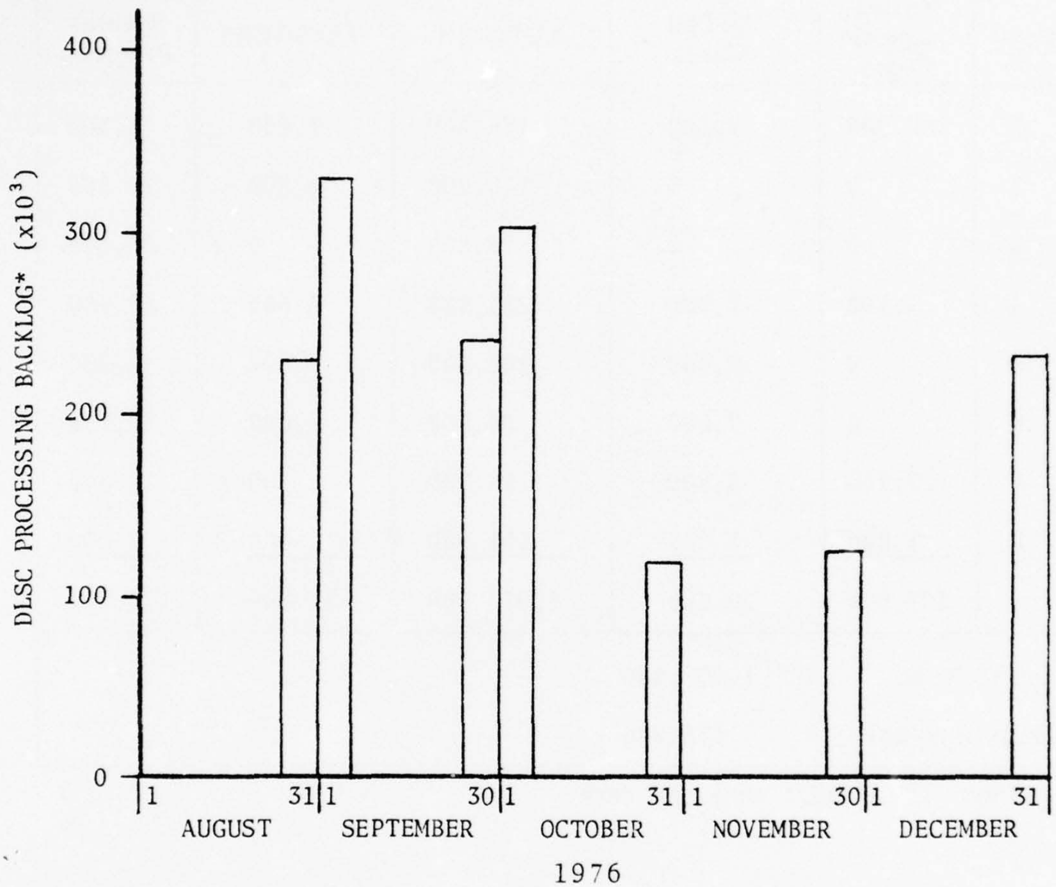
TABLE 7. DIDS INPUT DATA ITEMS VOLUME
(8-day data sample)

Day	Mailed Magnetic Tapes	Mailed Cards	AUTODIN	TRIGGERS	Special Projects
1	269,000	9,500	138,300	1,800	19,500
2	0	0	113,200	5,900	23,800
3	0	0	78,800	0	23,100
4	2,100	2,500	231,900	3,600	62,500
5	0	2,700	165,800	1,800	13,300
6	0	7,000	96,500	4,000	18,100
7	7,700	3,700	99,700	100	12,600
8	1,000	5,200	151,800	600	2,900
	107,000	30,600	1,076,000	17,800	175,800
Grand Total = 1,407,200					
Daily Average = 175,900					

Source: DSLC DIDS workload data

For the current DIDS computer equipment and workload levels, there are various levels of backlogged data items awaiting processing and additional functions scheduled to be implemented, as well. A general indication of the status of backlogged items is given in Figure 4 and Table 8, and a workload projection based on machine wall clock hours in Table 9. A more thorough discussion of backlogged items and "get well" dates can be found in References 2 and 3. For the purposes of this analysis, it is sufficient to indicate that there are transactions and other data items awaiting processing and there is a projected increase in the workload. DIDS workload problem areas are summarized in Table 10.

FIGURE 4. APPROXIMATED DIDS PROCESSING BACKLOG*



*Processing backlog Includes:

- Interrogations
- Searchs
- New Items
- II Maintenance
- CMD/SoS
- II Triggers
- CMD Triggers

Note: The processing backlog, or more accurately the number of transactions in house to process, varies from day to day. The totals indicated reflect the amount of backlogged items at the time of the month indicated, and should not be taken to infer a time based trend.

Source: DLSC, Workload Plan, 8 February 1977

TABLE 8. INDICATION OF DIDS BACKLOGGED WORKLOAD

Functional Area	As of August 1976 Estimated Backlogged Workload
Daily File Maintenance	13,200 to be processed
Daily Search & Interrogation	99,000 to be processed
Trigger Processing	None
Mass Interrogations & Changes	2,000,000 to be processed
SSR File Maintenance	None
Publications	None
FIIG Processing	9 completed out of 53 scheduled by 12/77
Other DIDS Processing	1,870,000 items to be processed
DPDS	None
Special Projects	None
System Management	None
Testing	None

Source: Part IV Reference 2.

The daily transactions are currently processed within a four-level priority structure. The distribution of the daily transactions and the required processing completion times are tabulated in Table 11. Priority 1 and 2 transactions collectively account for 10 to 12% of the volume and are the critical items affecting the workload scheduling.

In summary, the current system is experiencing workload backlogs, and the projected increases in workload will clearly exacerbate the current situation unless additional processing capability is made available. By the end of 1977, current DLSC projections prepared in December 1976 call for a 10% increase over the current (1/77) DIDS workload, based on machine wall clock hours.

TABLE 9. PROJECTED WORKLOAD FOR DIDS IN MACHINE PRODUCTION WALL CLOCK HOURS

Functional Requirements	WORKLOAD[1]								
	CURRENT (1/77)			PROJECTED (4/77)			PROJECTED[2] (4/78)		
	Primary 6700	Secondary 6700	360	Primary 6700	Secondary 6700	360	Primary 6700	Secondary 6700	360
Daily File Maintenance	1,425	--	--	1,680	--	--	1,680	--	--
Daily Search & Interrogations	2,316	--	--	2,968	--	--	2,968	--	--
Trigger Processing	225	--	--	225	--	--	225	--	--
Mass Interrogations/Mass Changes									
SSR File Maintenance									
Publications									
Statistics									
FBG Processing	6,922	4,990	4,887	7,099	5,049	5,818	6,719	4,973	5,670
Other DIDS Processing									
DPDS									
Air Force									
Special Projects									
System Management									
Testing									
Total By System	10,888	4,990	4,887	11,972	5,049	5,818	11,592	4,973	5,670
% $\frac{\text{Proj.-Current}}{\text{Current}}$	0%	0%	0%	10%	1.2%	19%	6.5%	-0.3%	16%
Total DIDS		20,765			22,839			22,235	
% $\frac{\text{Proj.-Current}}{\text{Current}}$		0%			10%			7.1%	
Estimated Capacity of[3] Current EDP Systems	10,911	4,818	5,498	10,911	4,818	5,498	10,911	4,818	5,498
Difference Between Current[3] EDP System Capacity and Projected Workload									
- Hours	+23	-172	+611	-1061	-231	-320	-681	-154	-172
- %	+0.2%	-3.6%	+11.3%	-9.7%	-4.8%	-5.8%	-6.2%	-3.2%	-3.1%

Source: Chart 3 of Appendix A of Reference 2, and DLSC DIDS Workload Projections as of December 1976

Notes:
1. All estimates are in wall clock hours for 3 months or quarters of a year
2. DLSC projects the 1979 workload to be no higher than the 4/78 level indicated
3. DLSC workload capacity for current configurations as per the December 1976 estimates

TABLE 10. SUMMARY OF DIDS PRIORITY PROBLEM AREAS

APPLICATIONS/OPERATIONS (Functional Requirements) \ PROBLEM AREAS (By Priority)	1 Not Consistently Meeting Transaction Timeframe	2 Significant Backlogs are the Rule	3 I&S requirement Not Implemented	4 FIIG Revisions/Page Changes Not On Schedule	5 Nonparametric Characteristic Search Not On Schedule	6 Parametric Characteristic Search and Screening Not On Schedule	7 Features/Requirements Not Implemented	8 FILDR File Maintenance and FILDR Distribution Not On Schedule
ITEM INTELLIGENCE (TIR) MAINTENANCE								
1. Add, Delete, Change II data	X			X		X		
2. Add, Delete, Change Cat. Mgt. Data	X							
3. Add, Delete, Change Freight Class. Data								
4. Add, Delete, Change Item Status Data	X							
5. Interchangeability and Substitutability (I&S)			X					
6. Mass Change to TIR				X				
SEARCH AND INTERROGATION								
7. Search for NSN by Part # and/or Characteristic Data	X				X	X		
8. Tailored Interrogation by NSN	X							
9. Mass Interrogation by Specific Grouping Key		X						
STATISTICAL REPORTS								
10. Recurring External Reports								
11. Reports Generator							X	
PUBLICATIONS								
12. Book Type Catalogs/Handbooks								
13. Federal Item Logistics Data Record (FILDR)								X
14. Tailored Narrative Item Identification							X	
MISCELLANEOUS								
15. NATO Interface							X	
16. Item Study List							X	
17. Files Compatibility							X	

Source: Appendix B of Reference 2.

TABLE 11. DAILY TRANSACTIONS WORKLOAD BY PRIORITY CLASS

Priority Class	% of Daily Transactions
1. To be processed within 4 hours or receipt	0.2%
2. To be processed within 12 hours of receipt	10-12%
3. To be processed within 48 hours of receipt	10-12%
4. To be processed within 72 hours of receipt	73%
Other work to be processed on a time available basis	5-7%

Source: DLSC DIDS Monthly (IMS 22) Statistical Report.

ANALYSIS OF CURRENT DIDS LIMITATIONS

The primary purpose of our on-site visit was to determine the nature of the capacity limitations that DIDS is experiencing, and to assess the need for equipment augmentations to handle backlogs and prospective workload increases.

The following discussion reflects the investigations and observations made during the on-site visit and analysis, and incorporates written comments from different members of the study team.[7]

Importance of the Data Processor

One of the first analyses performed was to determine the amount of time the data processors (central processing units) were active in performing the DIDS workload. This emphasis was chosen because of the operating characteristics of the Primary B6700 system and the critical importance of the data processor resource to workload throughput.

[7] Specifically Dr. Tom Bell, Mr. Michael Bealmear and Mr. Bob November of PMM&Co. (Reference 1), Mr. Bill Dickson, a consultant, and the author.

We first explain why one resource can be the prime determinant of throughput and then describe the specific situation on the Primary B6700 system.

Workload Bottlenecks

A modern computer system includes various resources that are in simultaneous use. For example, a B6700 may include several data processors (up to three), several I/O processors (up to three), a number of data channels (up to 36), and a variety of peripheral equipment, including disks, tape drives, card punches, card readers, and so on. The operating system of such a computer tries to employ the individual resources so that several jobs concurrently advance toward completion. Each job may simultaneously use several resources (e.g., two disks, a pair of channels, an I/O processor, and a data processor), but only a few resources (primarily memory) may be used by more than one job during a particular instant of time. If all the jobs made heavy demands on one resource in relatively scarce supply, they will tend to be awaiting the availability of that resource much of the time.

In a "balanced" computer system, jobs tend to wait on the availability of several resources at different times. No one resource is predominant in limiting the production of the system. On the other hand, jobs running on a computer with a "limiting" or "bottlenecked" resource have to wait for that resource, because it is in use nearly all the time. Meanwhile, other resources may be used very little. A single resource will almost never be in use 100% of the time, however, because all the jobs will occasionally need to use some other resource. Therefore, a resource with a very high, but not 100%, utilization is probably a bottleneck. The additional indication of such a bottleneck is the very low utilization of other resources.

In a "balanced" computer, the effects of removal or addition of a certain amount of resource is difficult to determine, because of the complexity of all the possible interactions among other jobs and resources. If the computer is bottlenecked on a single resource however, the effects are reasonably easy to determine, because performance is essentially linearly related to the amount of the resource added or deleted.

DIDS Primary B6700 Processor Utilization

Our initial impression, based on reports from the SUMLOG file, was that the data processors at DSLC were not heavily utilized. (SUMLOG is the machine usage reporting file produced by MCP, the Burroughs Master Control Program.) The reports for recent weekly activity indicated utilization that varied between 32% and 55%. This level of utilization indicates that the processors are not bottlenecked, but in fact less active than they should be, due to some other limiting resource.

The impression of under-utilization proved to be incorrect. We assumed that overhead (which would not be reported in SUMLOG) was no more than 10% and that all the processor time consumed was reported. Both assumptions turned out to be untrue.

We employed software tools written by Burroughs to determine the extent of processor utilization and to evaluate our initial assumptions. These tools were parts of Burroughs' SPARK (System Performance Analysis Review Kit) and included SAMPLER, SAMPLEANALYZER, and LOGSTATISTICS. SAMPLER examines the computer's performance data about every 5 seconds and outputs the data for subsequent analysis by SAMPLEANALYZER. LOGSTATISTICS, on the other hand, uses the data directly from the SUMLOG file and produces reports much like the ones regularly produced at DSLC. The advantage of LOGSTATISTICS over the DSLC programs is its indication of the amount of data in SUMLOG excluded from the reports of total processor utilization.

We found, with SAMPLER, that processor utilization on the Primary B6700 is about 95% during most periods of operation. MCP overhead and other unreported time made up approximately 25% to 40% of the total processor time. This time is larger than would normally be expected and is covered in the discussion below on overhead analysis.

Finally, we discovered that other resources (disks, packs, channels, I/O processors, etc.), were not heavily used. If we believe SAMPLER and disregard the DSLC-produced reports, the processor is the limiting resource.

With LOGSTATISTICS, we found that much of the data in the SUMLOG file is not processed in the regular way. One record out of a pair is lost in reporting the activity of each job. We did not determine the precise cause of this "dropping" of records, but we did observe that it is most prevalent for long-running jobs. Such jobs typically consume great amounts of processor time, and the failure to report their consumption grossly distorted the reported processor utilization in DSLC and LOGSTATISTICS summaries.

We concluded that the utilization reported by SAMPLEANALYZER reflects the actual situation, and that, because of dropped records and high overhead, the low processor utilization reported from SUMLOG is incorrect. Therefore, the Primary B6700 is actually processor-bound; its performance is determined almost solely by the allocation of this resource. Accordingly, projections of its performance must be based on an analysis of its processor activity.

Primary B6700 - Overhead Analysis

In the process of making SPARKANALYZER runs against several SAMPLER tapes from the Primary B6700 system, it was noted that approximately 25% to 40% of the total available central processor time was devoted to non-user overhead (i.e., MCP, DMS II, and related activities). At the average this overhead, taken as an aggregate number, implies that one out of the three processors on the Primary B6700 system is unavailable for processing application programs. The SAMPLER tapes used in this analysis were created at various intervals during normal processing periods, with the sampling duration ranging from 2 to 10 hours. While system overhead rates in the 20% range are more typically experienced on other Burroughs configurations, the 25% to 40% overhead appears to be typical for the Primary B6700.

This overhead rate appears to be comprised of the following elements:

- High activity in the GEORGE procedures of MCP[8]
- Periodic peaking of Presence-Bit overhead
- Indirect overhead of DMS II, and
- Other.

Each point is briefly discussed below.

GEORGE Activity

We found that the "Calls/Second" recap on the Processor Time Summary report from SPARK was consistently high. The total calls/second typically were in the 400 to 500 range. This is equal to a call being handled every 2 milliseconds. For certain telecommunications applications in which the MCP monitors every EVENT switch such a number of calls/second is not abnormal, however for the DIDS application, a rate of 100 calls/second would be expected. Generally 80% to 90% of these calls were in the GEORGE category. We have learned from Mr. Jim Omah of the Burroughs Corporation that calls to the GEORGE Procedures of the MCP are typically to field I/O interrupts from the multiplexors and DCPS, or to effect synchronization between processors or application tasks.

We concluded from analysis of the I/O Summary and Datacom Summary Reports that the high GEORGE activity was not directly attributable to I/O rates. There is currently no way of tracking processor to task synchronization from existing SPARK reports. Modifications to the MCP are required to retrieve the data to determine what is invoking the GEORGE calls.

Presence-Bit Activity

Although the average processor utilization devoted tc Presence-Bit (P-BIT) overhead is not excessively high, we noted from processor time series analysis that P-BIT

[8]GEORGE is the Burroughs Corporation designation for one of the Master Control Program (MCP) executive routines.

activity peaked periodically at as high as 80% of the processor utilization. P-BIT peaking suggests that a "leveling" of processor mix could prevent a "thrashing" mode of operation. This leveling could be achieved by reviewing the operations job schedule and then ensuring that schedules and priorities not be overridden by computer operators.

Data Management System (DMS II) Activity

Because DMS II does not appear as an application task on any SPARK reports, it is not possible to quantify DMS II overhead from SPARK data. The situation is complicated by the fact that any DMS II task management associated with an application stack is captured in the processor time charged to that application, while activities such as I/O and traffic management are not captured and reported at all. This problem is further illustrated by the fact that on every Processor Summary Report examined, only 84% of all available processor time could be accounted for, including idle time. The remaining time simply does not appear on the SPARK reports. Although not all of the 16% differential is attributable to DMS II, we certainly suspect that a significant portion of it is. (The balance of the unlogged time is probably due to random occurrences in MCP, errors in the sampling software, and to other unknown effects.)

Other Activity

Other observations indicate inefficiencies in the processing of variable length data records on the Primary B6700, and the occurrence of "move spaces" pattern on the panel lights of the Primary B6700 system. Both of these conditions have been known to DLSC-D personnel for some time. Despite previous optimization efforts, the problems continue to exist.

Estimation of Workload Transferable from the Primary B6700 to the Secondary B6700

The transfer of workload currently on, or planned for, the Primary B6700 to the augmented Secondary B6700 is a central consideration in the DLSC plan to increase DIDS processing capacity. In the DLSC request for B6700 equipment augmentation submitted in

November 1976, the workload in current production (wall clock) hours that could be moved from the Primary B6700 to the Secondary B6700 was estimated at 475 (wall clock) hours per month. In December 1976, DLSC revised their estimate to 636-799 (wall clock) production hours per month.

Because the issue of workload transferability was central to this study, we employed two different approaches and two different groups of analysts to make two independent estimates. We also wanted an independent check on the DLSC estimates and projections based on wall clock hours, since wall clock hours are an inaccurate representation of the "net" processor resource requirements in a multiprogram and multiprocessor environment.

Estimate A

This approach started with estimates of the jobs DLSC personnel had identified that could be transferred. We first identified the program workload that is functionally separable from the Primary B6700 and especially the TIR data base. Secondly, we utilized the "Monthly Summary of Job Elapsed Processing Requirement Reports" for November 1976 and December 1976. This gave us a 2-month sample of: elapsed (wall clock or production) time, processor, and I/O time by application program. Thirdly, with DLSC assistance, we estimated the most likely percentage of the program workload (identified in Step 1 of our effort) that could be transferred confidently.

With these data, we estimated the amount of "net" workload in processor hours that could be transferred from the Primary B6700 to the Secondary B6700. These computations are tabulated in Table 12. The results of this computation indicate that about 85 processor hours per month can be transferred. If we assume that all the appropriate application programs could be transferred, which is not practicable, the estimate is about 121 processor hours per month.

For a 30-day month, the Primary B6700 system with three processors has potentially 2,160 processing hours available. Adjusting for the current preventative

TABLE 12. ESTIMATE OF APPLICATION PROGRAM WORKLOAD TRANSFERABLE FROM THE PRIMARY B6700 TO THE SECONDARY B6700

Job I.D. Number[1] of Programs That are Candidates for Transfer	Description of Application Programs	Historical Primary[1] B6700 Processing Hours per Month (2-month average)	Percentage of[2] Application Program Functions that Can be Actually Transferred	Projected Monthly Processor Hours to Transfer from the Primary B6700 to the Secondary B6700
LDIR 1000 to 8000	FIIG Revisions	3.2	50	1.6
LDIY 0500 LDIY 1000 to 2000 LDOT 2000	PAC Summaries	1.0	90	0.9
LDDE 1500 to 9200	Organization Entity (OE) Cycle Maintenance	13.6	100	13.6
LDIM 8300 to 8500	Edit Guide	3.6	100	3.6
LDCU 1500 to 2000	Mail Sort and Suspense-Output Control	13.3	95	12.6
LDCH 0500 to 2500	History Process; I/O Transaction History	78.2	60	46.9
LDPH 0400 to 4000	DSA Civil Agencies Catalog	5.5	50	2.8
LBIA 1000	System Audit	2.4	100	2.4
Total (hours per month)		120.8		84.4

[1]From "Monthly Summary of Job Elapsed Processing Requirements (DLSC LIBC3600) Report." Using those data implicitly presumes that the future requirements for these functions will be the same as the historical levels.

[2]From discussions with DLSC staff, DLSC request for B6700 Augmentation (dated November 9, 1976) and backup material.

maintenance schedule (about 185 hours per month for the three processors), and assuming very idealistically no unscheduled maintenance (which currently exceeds the preventative maintenance time), leaves about 1,975 hours per month. Depending upon the actual overhead rate on the Primary B6700, the 85 hours of workload to be transferred to the organization Secondary B6700 would amount to about 5.8% (for a 25% overhead rate) or about 7.2% (for a 40% overhead rate) of the processing capacity of the Primary system. This 5.8% to 7.2% reduction is based on empirical data, but also assumes that DLSC personnel have identified all the appropriate jobs for offloading.

Estimate B

The data for this analysis were obtained by the SPARK/LOGSTATISTICS Program over the period of February 2, 1977, through February 9, 1977 (196 continuous hours). Data were obtained from the "Total Processor Time" and "Exception" reports of the program product. The "Total Processor Time Report" contains a summary of the various elements of the application programs, including processor time usage. The "Exception Report" only includes those executions which the analyzer identifies as starting and ending in the sample time period. We have called these executions "matched" data. The "Exception Report" also includes detailed data on programs that the analyzer could not identify as starting, but that could produce facility usage data. We have called these executions "unmatched data." Finally, the "Exception Report" identifies, but does not summarize, tasks running but terminated by HALT/LOAD. These are not included in the summary analysis.

Source of Application Programs Subject to Transfer - Various application programs were identified as wholly or partially transferable from the Primary B6700 to the Secondary B6700 system. These applications included those that did not access the TIR data base at all and/or those that did not substantially access the TIR. Among the non-transferable applications that did not access the TIR were such applications as Input and Output Control, which is an integral part of transaction processing. The list of transferable application programs was taken from the Program Functional Flow Charts (or I/O charts) and conversations with DLSC personnel. Given the time constraints, we were not able to identify the appropriate category for some applications. They were considered separately (unknown) and, assuming the best possible case, completely transferable to the Secondary B6700.

Computation Methodology for Program Transfers - The following procedure was used to compute the processor time of the Primary B6700 workload that could be moved to the Secondary B6700.

Produce Summary of Matched and Unmatched Processor Time Data -

- Applications (or shares) subject to transfer (TRANSFER)
- Applications (or shares) not subject to transfer (NOT TRANSFER)
- Applications that could not be readily identified as either TRANSFER or NOT TRANSFER (UNKNOWN)
- SPARK applications (ANALYSIS)[9]

Combine Data For Calculations -

- Combine matched and unmatched data
- Determine total application processor time (without ANALYSIS) (TRANSFER + NOT TRANSFER + UNKNOWN)

Compute -

- Monthly time saved from TRANSFERS.

  TIME = TRANSFERS x (30/7).

  (30/7 factors the weekly time up to a full month.)
- Monthly time saved by TRANSFERS and UNKNOWN.

  TIME = (TRANSFERS + UNKNOWNS) x (30/7).

[9]The processor's time consumed in SPARK applications was excluded from the analysis because this time was consumed only to support our analysis; it is not regular work.

Computation Methodology for Application Utilization - The following procedure was used to compute the processor time utilization on the Primary B6700:

Determine Processor Time Used -

- All applications except ANALYSIS.

  TOTAL TIME = TRANSFERS + UNKNOWN + NOT TRANSFERS.

- All applications except ANALYSIS and transferable applications.

  TOTAL TIME = NOT TRANSFERS.

Determine Total Processing Time Available -

- TIME AVAIL = (total time in time period less preventative maintenance) x number of processors (3).

Computations - Table 13 contains the summary of MATCHED and UNMATCHED times. Table 14 summarizes the calculations below:

Application Transfers to the Secondary B6700:

- Monthly Time Saved on Primary B6700 for TRANSFERS only =

  TIME = 70,897.408 x (30/7) = 303,846.02 seconds = 84.4 Processor Hours.

- Monthly Time Saved on Primary B6700 for TRANSFERS and UNKNOWNS =

  TIME = 88,591.748 x (30/7) = 379,678.91 seconds = 105.5 Processor Hours.

Secondary B6700 Capacity Analysis

A SPARK analysis similar to that performed on the Primary B6700 was carried out for the Secondary B6700. Two observations were made almost immediately. One, all but approximately 3% of the total available processor time could be accounted for, a marked contrast with the 16% figure on the larger system. This variance can be interpreted as the difference in mix and type of applications run on the two systems. For example, DMS II runs almost continuously on the Primary B6700 system, but is used only during testing on the Secondary B6700.

TABLE 13. TIME SUMMARY FROM LOGSTATISTICS

(Processor Seconds)

Data	Matched	Unmatched	Combined
A. Not Transfers[1]	602,447.15	52,408.232	654,855.382
B. Transfers[1]	67,858.3	3,039.108	70,897.408
C. Unknown	17,262.0	432.34	17,694.34
D. Analysis	35,740.0	0.00	35,740.00
E. Total Application Time (A+B+C)			743,447.12
F. Total Transfer Time (B+C)			88,591.748
Application Tasks (Total): 16,155			
Application HALT/LOAD: 524			

[1]Transfer/not transfer reflect applications that are both totally and partially transferable.

TABLE 14. TRANSFERABILITY SUMMARY

Processor Time of Transferable Programs	
Transfers only	84.4 hours
Transfers and unknown combined	105.5 hours

Second, the relative percentage of GEORGE activity on the Secondary B6700 is considerably less than on the Primary B6700. This is partly attributable to the fact that the idle time on the Secondary B6700 processors approaches 50%. Similarly, an average mix factor of 32 was observed on the larger system, while the average mix on the

Secondary B6700 rarely exceeded 12. This disparity is too large to be explained by the difference between a 3-processor and a 2-processor system, given enough work to overload each system at any time.

This second observation prompted us to examine the processor and core utilization time series reports. The analysis led to our major conclusion regarding the Secondary B6700 system. That is, while memory is being used to its fullest extent, there is often 50% processor idle time on the system, which implies that on the average one of the two processors is idle during production.

In analyzing the peripheral units utilization reports, we observed no heavy demand on either tape or disk units. This could be attributed to the lack of memory constraint, but is difficult to determine at this point in time. However, there is no evidence of any form of I/O contention on the system during production.

Application Program Analysis

Processing TIR records for application consumes more of the computer's resources than any other DIDS activity. We examined the application programs LDIM3500 and LDEC3500, which update the TIR. These programs process large volumes of data and require extensive EDP resources. Discussed below are three broad categories where processing improvements are possible: AFARS Interface, Trigger File Processing, and Optimizing Application Programs.

Asynchronous File Accessing Routine System (AFARS) Interface

Considerable processing is required for the application programs to access the TIR. This is accomplished through the AFARS programs (LBEN6900 and LBEN9900). Greater efficiency in the interface process could be achieved by:

- Changing the processing technique, using CAUSE, WAIT, and RESET

- Building an entire TIR entry with one access to AFARS
- Reducing the number of TBZR segments used.[10]

The CAUSE statement, followed by WAIT and RESET, was designed for asynchronous processing. A CAUSE is issued to initiate processing in the caused program while the causing program continues its processing. When the causing program is ready for the caused program's results, it then issues a WAIT, RESET. In the applications examined, the CAUSE is immediately followed by the WAIT and RESET statements. Hence, no asynchronous processing is accomplished.

The retrieval of an entire TIR entry is now accomplished one segment at a time, and one subsegment at a time for multiple-sectioned segments. The update program, for example, requires all segments for editing. Each such retrieval is a separate invocation of AFARS. Similarly, when updating or record creation takes place, each segment to be updated or created must be passed to AFARS separately. The process could be improved by allowing the program to access AFARS only to retrieve or update an entire TIR entry. For those searches and inquiries in which only one segment is required, the current procedure is effective.

Trigger File Processing

Trigger transactions are created for each future update. They have two purposes: One, to change a future update to a current (i.e., permanent) update, and two, to initiate the notification required when this change is made. These are high volume transactions that currently must be processed near the 15th and end of each month. This requirement seriously affects the normal transaction processing.

One way to modify trigger processing would be to handle the notification portion of the process completely outside of the TIR. At present, notification is done both

[10]These are data fields used to store information on future users of the item. The DLSC Maintenance Management Release (MMR) 8 (DID360) action includes the requirement to reduce the number of TBZR segments used.

when the future update is made and on the effective date as well. If the initial notification were saved and reissued on the effective date (e.g., from a tape file), the second notification could be accomplished off-line. A further modification would be to eliminate effective date notification altogether, since the DIDS users to be notified have already been notified during the initial update processing.

The change from future to current updating could be handled as a part of daily processing rather than as a separate operation. For example, the next time that a TIR record is updated, it could first be checked for future updates on past dates. If such updates have been made, the change could be effected immediately. Some additional daily processing and perhaps a larger future file would be required, but a portion of the large volume of trigger transactions and their bi-monthly processing would be eliminated.

Optimization of Application Programs

Numerous application program optimizations could be implemented. DLSC applications programmers are aware of and have documented many of them, including those noted below. We understand that many of the recommended optimizations have not been implemented. Inefficient processing of variable length records and utilization of work areas are significant problems. Several possible solutions are:

- Use only variable length records when a fixed length record is not warranted.
- Call on ALGOL programs to accomplish the MOVE to the areas in question.
- Modify the COBOL compiler to handle variable length records properly.
- Change the working storage area to ensure that the MOVES are fixed.

Instead of COBOL, ALGOL could be used as the application programming language for selected programs. The B6700 architecture designed is based on the ALGOL logic structure, and ALGOL-coded programs will run more efficiently than COBOL programs on these computers.

Improved use of working storage areas could reduce the core requirements of the application programs. An example, already under consideration at DLSC, is to use different versions of the update programs to process different length records. Working storage can be reorganized to make better use of core memory. For example, many 77 and 01 levels in memory require more core than the data areas defined. Redefining work areas that are not required in different parts of the program would also reduce storage requirements.

Similarly, application program procedure divisions offer opportunities for improvements. They can be better organized so that executed COBOL paragraphs are physically near the place of performance in core.

Workload Scheduling

The current method of scheduling batches of transactions through the computer is a manual process. There are 48 types of batches queued up for processing (16 types of transactions and three priorities within each).

One of the requirements for updating the data base is to have a recovery point in the event a problem is encountered while the update is in process. In order to establish such a recovery point, all updating must cease and a checkpoint must be taken. DLSC has established the checkpoint frequency at one hour. Operating experience has been used to set the maximum batch size such that the processing time would average one hour per batch. Some types of transactions contain 2,000 actions per batch, while batches for other types of transactions, which require more processing time, contain 1,500 actions.

The high priority transactions (priority 1 and 2) are batched every half hour and therefore rarely reach the maximum batch size. Many high priority batches were observed containing only one transacton.

The computer operator monitors the 48 queues and manually selects the batch to be processed next. He is aided by a listing that reflects the relative priority of batches awaiting processing.

In order to take advantage of the multiprocessing capability of the Burroughs computer, several batches are processed concurrently. The current system requires that the processing be completed for all batches updating the data base, in order to establish a recovery point. While the processing time averages one hour per full batch, the actual time required to process each batch varies greatly. A significant amount of computer time is therefore lost between the time the first batch, operating concurrently, is completed and the time the last batch is completed. DLSC has estimated that on the average 22.5% of the residence time of the three queues is not utilized properly because of this practice. This process is made more inefficient by the preemptive introduction of high priority transaction queues, which rarely reach maximum batch size.

Members of the DLSC staff have a project under development that will allow a time dependent checkpoint to be taken without waiting for a batch to terminate. The project offers other advantages, such as allowing larger batches to be generated, thereby saving the overhead involved in the termination and initiation of batches.

DIDS Data Base

The TIR data base was found to be organized efficiently for processing transactions where the National Item Identification Number (NIIN) was known. The data base is organized so that the NIIN itself points to the location on DISC storage where the information about the NIIN is stored. Given a NIIN, the computer can quickly and efficiently retrieve the desired data. This same degree of efficiency does not exist, however, for processing transactions where the NIIN is not included as a part of the transaction search argument.

For this study, the only statistics available that reflected compute processing time by data base segment were for the 7.5 hour period from 9:08 to 16:38 on February 7, 1977. During this period, 47% of the computer input/output time used for data base processing was spent on transactions that did not include a NIIN.

Statistics for the months of November and December 1976 and January 1977 indicated that 24% of all inquiry transactions did not include the NIIN as a part of the transaction search argument.

DIDS Workload Policy and Priority Considerations

Changes in policy and procedure could smooth and control the current and projected DIDS workload. In general, such changes would require the concurrence of DLA, OSD, and other affected organizations. The central issue is to reduce the irregularities in the workload on the Prime B6700 and to relieve the congestion in the processors.

The DIDS transactions workload now consists of several different transaction types (Interrogations, Search, New Issues, IIM, CMDN, IIM Triggers, CMDN Triggers) that are processed within a four-level priority scheduling structure. The average monthly transaction workload is about 2.35 million, of which less than 0.5% are priority 1 (to be processed within 4 hours of receipt), about 10% are priority 2 (to be processed within 12 hours of receipt), about 10% are priority 3 (to be processed within 48 hours of receipt), and about 73% are priority 4 (to be processed within 72 hours of receipt). The usual technique is to allow the transactions to age until they approach 2 hours of their priority response threshold before they are processed.

As the priority 1 and 2 transactions are received, they are introduced in a preemptive manner into the workflow, necessitating operator and processing adjustments. The result is that the workflow is not as smooth as it could be, and additional processor resources are consumed. An alternative is to use a simple 24-hour response time requirement for all transactions. This would allow for a smoother scheduling of the work, but would require an adjustment on the part of the priority 1 and priority 2 DIDS customers.

Based on the aggregate statistics available, it is not clear that the effects on users would be too severe. For example, DIDS December 27, 1976, to January 28, 1977, statistics on monthly processing indicate that 71% and 89% of the priority 1 and priority 2 transactions, respectively, were processed within their time thresholds. On the average, some 13,400 priority 1 and 60,600 priority 2 transactions per month were not processed within their priority time goal. Based on the DIDS statistics in Follow-Up Transactions (which are inquiries about previously submitted transactions), we found that an average of about 6,250 such inquiries were made over the 30-day period following the inquiries. Even if they were related only to priority 1's and 2's, the total follow-up inquiries amount to less than 10% of the priority 1 and priority 2 transactions that were not processed within their priority goals.

Everyone who does not receive a response within the appropriate priority time does not submit a follow-up request, of course. At the very least, however, these data suggest that the user requirements for priority 1 and priority 2 time responses are questionable. Also, we note that statistics on total follow-up transactions indicate that less than 25% of them are submitted within 30 days of their submitted date. These data are tabulated in Table 15.

TABLE 15. STATISTICS ON FOLLOW-UP TRANSACTIONS

Date of Processing	Date Range For Follow-ups That Matched (Days)			Over 90 Days Or Not Matched	Total
	1 to 30	31 to 60	61 to 90		
77020	838	20	10	750	1,618
77022	1,925	105	1	10	2,041
77023	1,332	206	0	339	1,778
77024	49	1,185	3	5,318	6,555
77025	46	143	1	506	696
77026	138	32	6	582	758
77028	24	59	0	1,822	1,905
77029	336	3	3	102	444
77030	578	404	13	599	1,594
77031	3	186	0	460	649
77032	393	39	100	617	1,149
77033	127	0	0	149	276
77034	99	1,275	4	5,412	6,790
77035	316	26	0	760	1,102
77036	4	0	0	12	16
77037	44	65	0	475	584
77038	0	86	0	0	86
TOTALS	6,252	3,834	141	17,913	28,140
PER DAY	345	-	-	-	-
% OF TOTAL	22.2	13.6	.005	63.7	100%

Source: DLSC

Additionally, offloading from the Primary B6700 system will contribute to smoothing its workload. DLSC plans to utilize the ARS file on the IBM 360/65J would allow this kind of adjustment in the Primary B6700 workload.

III. ASSESSING THE OPTIONS TO DEAL WITH THE CONSTRAINTS ON DIDS PROCESSING CAPABILITY

In this chapter, we discuss the basic options considered for solving the current DIDS processing capability problems. All of these options deal principally with the supply or capacity side of the DIDS workload. None of them deals explicitly with ways to reduce the workload volume to be processed. Consideration of the demand (workload generation) side of the DIDS workload is outside the scope of this task, but it is clearly an important part of the total systems assessment of DIDS.

We reviewed five options from the viewpoint of their feasibility (Is it possible?), practicability (Will it work well?), and relative cost. We did not perform detailed cost-benefit analyses. The five options include:[11]

One - Maintenance of the status quo

Two - Use of off-site computer facilities

Three - Augmentation of the Primary B6700 with larger Burroughs computers

Four - Augmentation of the Secondary B6700 as proposed and offloading of work from the Primary B6700

Five - Optimization and limited hardware changes to increase the effectiveness of current machines

OPTION ONE - MAINTENANCE OF THE STATUS QUO

The essence of Option One is to leave the EDP systems as currently configured and to continue with minimal or no application program optimization. The current workload congestion would continue, and probably gradually worsen, due to the saturation of the Primary B6700. While this option is feasible (DLSC is operating this way now), it is not

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[11] We note that we do not consider any options that would require any new equipment or replacements of equipment not compatible with Burroughs' hardware.

judged practicable by either DLSC or DIDS users. We concur that the option is not viable and does not merit further consideration.

OPTION TWO - USE OF OFF-SITE COMPUTER FACILITIES

Option Two would make use of EDP resources compatible with the B6700 at installations where computer time could be purchased piecemeal. DLSC has tried this option; in 1976, some 566 hours were used on the State of Michigan Treasury Department's B6700 installation. We question the feasibility of transporting sufficient DIDS work to an off-site facility to affect the workload saturation on the Primary B6700 significantly. As DLSC has noted, the logistics are complex and costly. This option only makes sense for those emergency situations in which an alternate relocation site is essential for continuance of minimal DIDS processing. For the alleviation of a daily workload saturation problem, use of off-site facilities is impracticable.

OPTION THREE - AUGMENTATION OF THE PRIMARY B6700 WITH LARGER BURROUGHS COMPUTERS

For Option Three, only Burroughs-compatible equipment have been considered.

As currently configured, the Primary B6700 has the maximum number (3) of CPUs, and is about at the maximum in memory modules and physical connections to mass storage devices. Increasing the memory to the maximum (to 6 megabytes from the current 4.7 megbytes), or adding additional peripheral storage would not change the processor bottleneck situation.

As a means of roughly sizing the potential costs of this option, we considered reconfiguring the DLSC existing and functionally separate B6700 computer systems into an integrated system via a Burroughs Global Memory with a B6800 single CPU computer. In this integrated configuration, all six CPUs (three on the primary B6700, two as the Secondary B6700, and one on the B6800) can have access to the TIR. For the smallest B6800 processing system (the B6807) with the minimum Global Memory (~1.5 MB), and retaining both B6700 systems, this augmentation is estimated to cost $1,104,000 (in 1977 dollars). If the next larger B6800 system (the B6811) and the maximum Global

Memory (~3 MB) are used, this augmentation is estimated to cost $1,768,000 (in 1977 dollars). These options are tabulated in Table 16. These augmentations would provide between two to four times the capacity of the current DLSC DIDS workload processing potential.[12] Further, they are no more costly and an order of magnitude more effective than the augmentation of the Secondary B6700 proposed by DLSC. Both of these augmentations maintain full compatibility with the existing systems for minimal conversion and implementation costs and time, and incorporate the potential for additional, substantial growth. For either of these configurations, a 16–month lead time from order to installation is estimated.

This option does not offer short-term (3 to 6 months) relief for the Primary B6700 processor saturation problem. If the long-term prospects for the DIDS workload exceed the current projections and/or call for continued growth throughout the 1980-1990 period, then this option or its cost-effective equivalent will be required. Additionally forecast and analysis of workload would be required to estimate future DIDS requirements, which opens the subject to considerations of growth management and long-term planning.

OPTION FOUR - AUGMENTATION OF THE SECONDARY B6700 AS PROPOSED AND OFFLOADING OF WORK FROM THE PRIMARY B6700

This option reflects the pending DLSC proposal that involves the changes listed in Table 17. Based on an unsolicited proposal from the Burroughs Corporation, the estimated cost for the equipment (hardware) shown in Table 16 is $1,628,547 (in 1977 dollars), with an additional $56,710 for maintenance, installation and shipping costs.[13]

This augmentation would leave the Primary B6700 essentially in its current configuration, but almost double the size of the Secondary B6700. A comparison between the current and proposed augmentation of the Secondary B6700 is given in Table 18.

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[12] New Product Announcements, B6800 Systems, Business Machine Group, Burroughs Corporation, September 17, 1976.

[13] From DSAH-LS, Funding Requirement for DLSC ADD B6700 Equipment Augmentation Request, November 18, 1976.

TABLE 16. B6800 AND GLOBAL MEMORY OPTIONS

OPTION A - MINIMUM B6800 and GLOBAL MEMORY CONFIGURATION

BASIC COMPONENT		DESCRIPTION	PURCHASE PRICE (1977 Dollars)
B6807 System	1	Central Processor, 6.7 MHz (1.5 μs main memory access)	$ 227,000
	1	Input/Output Processor with 20 I/O Channels	
	1	Memory Control	
	1	Power Supply	
	1	Peripheral Control Cabinet	
	1	Maintenance Processor and Display	
	1	Operator Console and Control with Dual Displays	
Main Memory	4	B6009-5 Main Memories for a total of 1.5 Megabytes	336,000
Global Memory and Control	1	B6009-11 Global Memory and Control (786,432 bytes)	288,000
Additional Global Memory	3	B6009-12 Global Memory (786,432 bytes) (This and the above component provide ~1.5 megabytes of Global Memory)	205,440
Global Memory B6700 Interface	1	B6009-13	47,136
			$1,103,576

OPTION B - LARGER B6800 AND GLOBAL MEMORY CONFIGURATION

BASIC COMPONENT		DESCRIPTION	PURCHASE PRICE (1977 Dollars)
B6811 System	1	Central Processor, 6.7 MHz (450 ns main memory access)	480,000
	1	Input/Output Processor with 20 I/O Channels	
	1	Memory Control	
	1	Power Supply	
	2	Peripheral Control Cabinets	
	1	Maintenance Processor and Display	
	1	Operator Console and Control with Dual Displays	
Main Memory	4	B6009-5 Main Memories for a total of 1.5 Megabytes	336,000
Global Memory and Control	1	B6009-11 Global Memory and Control (786,432 bytes)	$ 288,000
Additional Global Memory	3	B6009-12 Additional Global Memory (2,359,296 bytes) (This and the above component provide ~3 Megabytes of Global Memory)	616,320
Global Memory B6700 Interface	1	B6009-13	47,136
			$1,767,456

Notes:

(1) Option A would more than double the current DIDS computer system capacity, if both DLSC B6700's are interfaced with the B6800 via the Global Memory.

(2) Option B would more than triple the current DIDS computer system capacity, if both DLSC B6700's are interfaced with the B6800 via the Global Memory.

(3) All these equipments are available from Burroughs on a monthly lease basis as well.

(4) The expected availability date for the Global Memory is March 1978.

Source: New Product Announcements, B6800 Systems, Business Machine Group, Burroughs Corporation, September 1976, and discussions with Burroughs personnel.

TABLE 17. REQUESTED EQUIPMENT TO AUGMENT DIDS COMPUTER SYSTEMS

Equipment to be Added to Secondary B6700

Qty	Number	Description
1	B6373	Disk File Control (Will fit in existing cabinet)
1	B6471	Disk File Exchange (Will require new cabinet, no cost, and will fit alongside current system)
2	B6471-5	Control Adapter
2	B6471-6	EU Adapter
1	B6009-4	Planar Memory with Memory Control and Testor (393,216 bytes of 325ns)
2	B6009-5	Planar Memory (393,216 x 2 = 786,432 bytes)
3	B9486-4	Dual Drive Increments (6 spindles) (Will fit behind current disk packs)
2	B9383-8	Dual Disk Pack Controllers with 5 dual drives (10 spindles) on each disk pack controller
2	B6393-2	Tape controls (Will fit in existing cabinet)
6	B9393-3	240 KB PE Tape Drives
4	B6304-1	Disk Pack Drive Controller
6	B9495-5	320/400 KB Mag. Tape Unit (9 CH-1600 BPI)
2	B6395-7	320/400 KB Mag. Tape Unit Control
1	B6493-2	PE Tape Exchange (Fits in tape drive)
1	B9499-12	2x8 Master Electronics Exchange
1	TD830	CRT Display/Adapter

Equipment to be Added to the Primary B6700 System

Qty	Number	Description
3	B9486-4	Dual Drive Increments (6 spindles)
1	TD830	CRT Display/Adapter

Equipment Moved From Primary B6700 System to Secondary B6700 System

Qty	Number	Description
1	B9375-10	HPT Disk File (1 Electronic Unit (EU) and 5 Storage Units (SU)).

Source: DLSC, Request for B6700 Equipment Augmentation, October 22, 1976.

TABLE 18. COMPARISON BETWEEN THE CURRENT AND PROPOSED AUGMENTATION OF SECONDARY B6700 HARDWARE

Current Configuration	Proposed Configuration After Augmentation	Approximate Impact On Configuration
2 CPUs	2 CPUs	No Change
100 Megabytes of HPT Disk Storage	200 Megabytes of HPT Disk Storage	Double Capacity
~1 Megabyte of Core (Memory)	~2 Megabytes of Core (Memory)	Double Capacity
8 Disk Packs	21 Disk Packs	2½ - Fold Increase in Capacity
10 1600 BPI Tape Drives	22 1600 BPI Tape Drives	Double Capacity
--	1 CRT TD830 Display/Adapter	New

The central issue is how much this added capability will relieve the CPU congestion on the Primary B6700. As discussed in Chapter II, two different efforts were made to estimate the likely workload volume that could be transferred from the current and projected Primary B6700 workload to the Secondary B6700. Both the efforts yielded estimates of about 85 hours of processor time per month as the likely workload that could be transferred. That would amount to about 5.8% to 7% of the current monthly Primary B6700 processor time potentially available for application programs. This offloading of work is obviously desirable, and while it will help relieve the Primary B6700 processor bottleneck, it is not large enough to solve the problem by itself.

We conclude that no amount of equipment augmentation on the Secondary B6700 will be adequate by itself to solve the congestion problem on the Primary B6700. Some other alternatives must be pursued in addition to offloading work from the Primary B6700 to the Secondary B6700 if the DIDS workload bottleneck is to be relieved.[14]

OPTION FIVE - OPTIMIZATION AND LIMITED HARDWARE CHANGES TO INCREASE THE EFFECTIVENESS OF CURRENT MACHINES

Given the current DIDS situation and assuming the DLSC DIDS workload projections of December 1976, we feel that this option is the most effective in the short term of the five considered. It is feasible—both DLSC and Burroughs personnel concur.

Increased efficiency of the existing system could be achieved by optimization, smoothing the DIDS workload, reducing the CPU congestion in the Primary B6700, and offloading a maximum of work from the Primary B6700 to both the Secondary B6700 and the IBM 360/65J. Limited hardware adjustments would be necessary.

We estimate that improvements of 10% to 20% CPU utilization on the Primary B6700 and at least 20% on the Secondary B6700 are possible. These improvements, plus a concerted strategy to offload work to the Secondary B6700 and IBM 360/65J, will relieve the current CPU congestion on the Primary B6700. Basically, we expect Option Five to achieve everything Option Four does, in addition to yielding additional opportunities to increase the Primary B6700 effectiveness, and at less cost.

We will discuss this option in terms of the actions that can be taken on the different EDP systems. We have not attempted to be exhaustive in identifying all potentially useful actions, but have instead listed only those that we were able to derive or infer through the study analysis and on-site observations.

The recommended actions are presented in three major groups: Actions for the Primary B6700, Actions for the Secondary B6700, and Management Improvements Actions. The presentation sequence in each group indicates roughly the preferred ranking of the actions. Table 19 summarizes the actions by indicating, in terms of a three level

[14]There is a subtle issue related to the differences between wall clock hours and processor hours. In the course of this study, we observed ratios of processor time in hours to wall clock hours (roughly equivalent to program resident time) from 1:2 to 1:10. Consequently, we have ignored the wall clock projections and concentrated on processor hours as the measure of workload processed. This issue is discussed in Action 20.

TABLE 19. INCREASE EFFECTIVENESS OF CURRENT MACHINES THROUGH OPTIMIZATION AND LIMITED HARDWARE CHANGES: RECOMMENDED ACTIONS

	ACTIONS[1] / CRITERIA[2]	Impact On Primary B6700 Processing Congestions (H = High, M = Med, L = Low)	Time to Implement Action (S-M-L[3])	DLSC Resource (Personnel) Required (H = High, M = Med, L = Low)	Action Approval Or Dependency On Agencies Other Than DLSC
Primary B6700	**Software Improvements**				
	1. Identify the Cause of and Reduce the Excessive Volume of GEORGE Calls	H	M	-	Burroughs
	2. Remove MCP Inefficiencies in Processing Variable Length Data Records[4]	M	M	-	Burroughs
	3. Reduce the Periodic Peaking of Presence-Bit Overhead[4]	L	S	L	-
	4. Reduce Excessive DMS II Activity	L-M	M	-	Burroughs
	Application Program Improvements				
	5. Modify Trigger File Follow-Up Processing[4]	H	M	L	DLA/OSD/DIDS Customers
	6. Modify the COBOL Compiler to Handle Variable Length Records More Efficiently	M-H	M	M	Burroughs
	7. Use ALGOL For Selected DLSC Application Programs	M	S-L	-[5]	DLA/OSD
	8. Increase the Efficiency of Programs Processing the TIR File[4]	M	S-L	H	-
	9. Increase the Efficiency of TIR Accesses by AFARS	M	L	M	-
	10. Reduce the Number of Future Update Records Processed[4]	L	M	M	-
	Improvements in the DIDS Data Base				
	11. Reduce the Impact of Inquiries Without a NIIN[4]	M	M	L	DLA/OSD
	Increase the Efficiency of Workload Scheduling				
	12. Implement the DLSC Revised Queuing/Processing Concept with a Time Dependent Check Point[4]	H	M	M	DLA
	13. Utilize Automated Scheduling for B6700 Workloads[4]	M-H	M	M	-
	14. Process Only Full Batches[4]	M	S	M	-
	Hardware Changes				
	15. Modify Primary B6700 Hardware	M	S	M	OSD/DLA
Secondary B6700	16. Modify Secondary B6700 Hardware	M-H	S	M	OSD/DLA
	Job Shop Scheduling				
	17. Improve the Scheduling of Jobs on the Secondary B6700	L	M	M-H	-

1. Actions 18-20 dealing with Management Improvements are not listed because their impact on the Primary B6700 CPU congestion is indirect and long term.
2. These rankings are relative to the set of 17 actions considered and are based on subjective judgments.
3. S = short term, 1 to 3 months; M = mid term, 3 to 6 months; L = long term, 6 to 12-plus months.
4. DLSC has similar ideas under consideration as part of planned actions or future actions.
5. The negligible effort indicated is for new programs. For the conversion of old programs the resource requirements would be high (H).

qualitative scale, their impacts on the Primary B6700 CPU congestion, implementation times, and DLSC resource requirements.

Some of these actions are dependent on other actions, while others are independent or mutually exclusive. Where there are dependency or mutually exclusive relationships, we have tried to identify them. In several instances we have listed actions that DLSC either has considered or is presently considering, and we have tried to identify this fact.

Primary B6700 - Software Improvements

The objective of these software improvements is to reduce the Burroughs Master Control Program (MCP) and Data Management System (DMS) consumption of processor resources from the current 25% to 40% level to a more satisfactory 20% level.

Action 1. Identify the Cause, and Reduce the Volume of, GEORGE Calls

Implementing this action requires a modification to the MCP to collect the data necessary to determine what is invoking the GEORGE calls. Currently, the number of GEORGE calls is 400 to 500 calls per second. For the DIDS application, a rate of 100 calls per second is considered to be an acceptable upper bound. Reducing the number of calls per second will contribute to the reduction of the current overhead in the Primary B6700. DLSC-D will require Burroughs assistance to make the required software modification, and to achieve more effective processor and/or application program synchronization.

Action 2. Remove MCP Inefficiencies in Processing Variable Length Data Records

DLSC has been concerned about this problem for some time.[15] Any COBOL READ or WRITE statement on the B6700 entails a movement of data in core either to/from the MCP buffer to the "01" area in memory that identifies the recorded description. When a READ INTO or WRITE FROM is used, two data movements in memory are necessary. Unless explicitly avoided, data of variable lengths, are moved

[15] DLSC has apprised Burroughs of this problem.

character by character, under the Burroughs word length used to define the receiving field. Any portion of the receiving field not filled with the moved data is then blanked out. This causes inefficiencies in the use of both processor resources and core (memory). Since an estimated 10% to 20% of the DIDS daily workload (e.g., all input inquiries and searches) processing involve variable length records, this is a significant problem, especially when a sort is required. Currently, the B6700 software will "pad" out all variable length data records to a fixed size prior to processing the sort. The fixed size is set for the largest possible occurrence of a record size. For DIDS data records that can typically range from less than 20 to over 6,600 characters in length, the sort can be very inefficient.

In a DLSC experiment, a COBOL program entailing a READ, RECORD, CHECK, REMOVAL of a bad record, and a WRITE was run on the Primary B6700 and the IBM 360/65J. The data were variable length records. In that experiment, the IBM 360/65J required considerably less than one-half of the Primary B6700 processing time to perform the identical tasks. The differences are judged to be principally a function of the ability of the two machines and their software to handle variable length records.

Two strategies could reduce the inefficiences related to processing variable length records. The first is to modify the software (both MCP and the COBOL compiler) so that it handles variable length records more efficiently. This will require assistance from Burroughs who currently has the problem under study. The second strategy is related to Action 9 under the Application Program Improvements.

<u>Action 3. Reduce the Periodic Peaking of Presence-Bit Overhead</u>[16]

The most straightforward way to reduce this peaking is to maintain a better mix of programs in the system. The intent is to avoid the "thrashing" that periodically

[16] DLSC has noted this problem in their optimization efforts.

occurs and unnecessarily uses processor resources for job management overhead. This action is related to Action 14 under Application Program Improvements.

Action 4. Reduce Excessive DMS II Activity

We suspect that a significant portion of the overhead consumption of the Primary B6700 processor resources is attributable to DMS II. The intent of this action is to determine whether changes in DMS II usage would reduce the amount of processor activity for DMS II. Implementing this action will require a software modification to provide the data necessary to account for all DMS II activity. These modifications would be best made by Burroughs, as DMS II is part of their proprietary software.

Primary B6700 - Application Program Improvements

Processing TIR records consumes more of the computer resources than any other application area. Specific improvements can be effected through an improved interfacing between AFARS and application programs and more effective processing of the TIR. The following actions are examples of changes that should be made.

Action 5. Modify Trigger File Follow-Up Processing[17]

Trigger transactions are created for each future update. They are used for two purposes: 1) to change a future update to a current (i.e., active) update, and 2) to initiate the notification required when this change is made. These are high volume transactions that currently must be processed near the 15th and end of the month. This twice-a-month requirement seriously affects the normal transaction processing.

The change from future update to current updating could be handled as part of daily processing. The next time that the TIR record requires a content change under normal processing, it could first be checked for future updates on past dates; the changes could then be effected immediately. This would require some additional processing and

[17]DLSC has explored similar ideas in the past. Proposals are being developed by DLA/DLSC for Service/Agency and MRA&L review.

perhaps a larger future file, but a significant portion of trigger transaction processing eliminated. Two variants of the notification process can be considered.

Off-Line Notification - The notification portion of the process can be handled completely outside of the TIR. Currently, notification is made both when the future update is made and on the effective date as well. By saving the initial notification and reissuing it on the effective date (e.g., from a tape file), this second notification can be accomplished other than on the Primary B6700.

Eliminate Effective Date Notification - Consideration should be given to eliminating effective date notifications altogether, since the users concerned will already have been notified during the initial update processing. We recognize that this is an extreme action, but nonetheless it should be considered.

Action 6. Modify the COBOL Compiler to Handle Variable Length Records[18] More Efficiently

This action would improve the processing of variable length records and the utilization of work areas and reduce the overhead processing for COBOL programs.

Action 7. Use ALGOL for Selected DLSC Application Programs

Instead of COBOL, ALGOL should be considered as the DIDS application programming language for those few programs which account for 80% of the DIDS workload. The B6700 architecture is designed with the ALGOL structure in mind, and ALGOL-coded programs are processed more efficiently. Not only will this conversion to ALGOL increase the efficiency of the processing, but it will also reduce the MCP and COBOL compiler inefficiencies in handling variable length records (Action 6), the number of GEORGE calls, and possibly the P–BIT activity.

Action 8. Increase the Efficiency of Programs Processing the TIR FILE[19]

The use of CAUSE, WAIT and RESET commands could be changed to allow more asychronous processing. For the application programs examined, the CAUSE

[18] DLSC has similar ideas under consideration as part of planned actions or future actions.

[19] See Footnote 18.

statement is immediately followed by the WAIT and RESET statements and no asychronous processing is accomplished. Hence, the advantages of re-entrant processing are lost.

Action 9. Increase the Efficiency of TIR Accesses by AFARS[20]

An entire TIR entry could be built with only one access to AFARS. Currently, an entire TIR can be retrieved only one segment at a time, and one subsegment at a time for multiple-sectioned segments. The update program, for example, requires all segments for editing. Each such retrieval is a separate invocation of AFARS. Similarly, when updating or record creation takes place, each segment to be updated or created must be passed to AFARS separately. Allowing the application program to access AFARS only to retrieve or update an entire TIR entry would be an improvement. In those instances when only one segment is required, the current technique is effective.

Action 10. Reduce the Number of Future Update Records Processed[21]

Reduced processing of TBZR segments could reduce processing requirements. These segments in the TIR contain data needed for future owner information. Presently, if a single future update is to be made, a TBZR segment is produced. If a second future update is entered, then a TBZH is created for both updates and the TBZR is deleted. If a TBZH were created in the first place, the redundant process of creating and deleting a record could be eliminated.

Primary B6700 - Improvements in the DIDS Data Base

The TIR data base is organized quite efficiently for processing transactions where the NIIN is known. This same degree of efficiency does not exist for processing transactions where the NIIN is not included as a part of the transaction search.

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[20] See Footnote 18.

[21] See Footnote 18.

Action 11. Reduce the Impact of Inquiries Without a NIIN[22]

- Collect and maintain statistics that can be used to measure the degree of efficiency with which each segment of the data base is accessed.
- Investigate alternative methods of cross referencing part number to NIIN within the data base.
- Process all inquiries without a NIIN as a special batch job within a 24-hour response time priority rule.

Primary B6700 - Workload Scheduling Improvements

The current method of scheduling batches of transactions through the computer is a manual process. There are 48 types of batches queued up for processing (16 types of transactions and 3 priorities within each).

One of the requirements for updating the data base is to have a recovery point in the event a problem is encountered while the update is in progress. To establish such a recovery point, all updating must cease and a checkpoint be taken. In the current Primary B6700 system several batches are processed simultaneously, and the time to process each batch varies greatly, due to the different sizes of the queue and the checkpoint logic. Opportunities to process additional transactions (like those in the queue) are consequently lost, and the average transaction service turnaround time (elapsed time) is greater than it should be.

Action 12. Implement the DLSC Revised Queuing/Processing Concept with Time-Dependent Checkpoint[23]

DLSC has a project under development that allows a time-dependent checkpoint to be taken without waiting for a batch to terminate. The project offers other advantages, such as allowing larger batches to be generated (see Action 9), thereby saving

[22] See Footnote 18.

[23] See Footnote 18

the overhead involved in the termination and initiation of batches. This project offers a greater immediate potential for improving transaction throughput than any other system change. Improvement of the system's capability to select the transactions to be processed in priority sequence should be part of the project. Sufficient resources should be assigned to complete the project as soon as possible, and ALGOL, rather than COBOL, should be the programming language required.

Action 13. Utilize Automated Scheduling for B6700 Workloads[24]

This action depends upon the implementation of Action 12, because the full benefits of automated scheduling will be best achieved in conjunction with the improved transaction queuing/processing concept. In order to have the scheduling take place remotely, Action 15 must also be implemented.

Action 14. Process Only Full Batches[25]

The way in which high priority transactions are batched should be modified to allow full batches rather than many small batches, which are costly in terms of queue management and computer overhead. One method of accomplishing this is by filling the high priority batches to their predetermined maximum with lower priority transactions whenever less than the maximum number of high priority transactions is available. Since Action 12 implies that only full batches will be processed, this action is really only a short-term alternative.

Primary B6700 - Hardware Changes

Actions 15 and 16 are variations of the proposed DLSC ADP Augmentation Plan. We estimate that total additional hardware costs would be from $350,000 to $400,000 in 1977 dollars.

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[24]See Footnote 18.

[25]See Footnote 18.

Action 15. Modify the Primary B6700 Hardware

The Primary B6700 hardware should be augmented by adding the remote Cathode Ray Tube (CRT) display/adapter for scheduling and by removing the excess 100 megabytes of Head Per Track (HPT) Disk Storage. After the 100 megabytes of HPT are moved, the Primary B6700 will still have 400 megabytes of the HPT mass storage. The remote display/adapter will aid in the automated scheduling of the workload on the Primary B6700. This capability will help smooth the workload.

Based on our analysis that the critical bottlenecks are the Primary B6700 CPUs, adding 3 more disk packs will not improve that situation. The disk pack mass storage current capacity on the Primary B6700 is apparently adequate. There are now 66 dual drive disk packs with 174.4 megabytes each, for a total of 11.5 billion characters of on line disk pack mass memory. This equates roughly to about 11 billion characters of usable storage, of which about 8 billion are currently required by the DIDS TIR data base.

Secondary B6700 - Hardware Changes

All the software and virtually all the application program actions noted for the Primary B6700 apply to the Secondary B6700. The two actions noted for the Secondary B6700 focus on changes to its hardware and improvement of its workload scheduling.

Action 16. Modify the Secondary B6700 Hardware

The Secondary B6700 should be modified by adding 1 megabyte of core (memory), 100 megabytes of HPT mass storage memory (from the Primary B6700) and the remote CRT/display console. This modification is different from the one described in the ADP augmentation proposal. (See Option Four.) All the TIR data processing and updating would still have to be done on the Primary B6700. Based on our analysis, only about 5.8% to 7% of the Primary B6700 workload (in processor hours) could be transferred to the Secondary B6700, regardless of how large it is made.

The rationale for our proposed augmentation is as follows:

- Currently, the Secondary B6700 is memory-bound. That bottleneck causes the CPUs to be idle about 50% of the time. Doubling the current 1 megabyte of core would allow fuller utilization of the currently idle CPUs.
- The Secondary B6700 now has only one electronic unit (EU) for its 100 megabytes of HPT disk storage. The additional 100 megabytes of HPT would double the capacity of this mass storage medium and add one more EU. The additional EU will provide needed redundancy, and the extra 100 megabytes will provide additional useful storage space.
- The console/display device will enhance the ability to schedule the Secondary B6700 workload. However, given the nature of the work on this system, the real justification for adding such a remote console is that it will provide a useful test bed for new scheduling concepts intended for the Primary B6700.

This action does not include the other changes to the Secondary B6700 in the pending request. The basic reasons for not including all the disk and tape mass storage devices are outlined briefly in Table 20. All the workload to be transferred will fit on the Secondary B6700 as currently configured. The thrust of the augmentation proposal is to have sufficient capacity for almost all the applications both old and new, to reside concurrently in the system. Since the majority of the new workload to be transferred is to be processed on an "as required" basis, it can be processed on the current configuration with an improved scheduling procedure. More mounting and dismounting of disks and tapes will be necessary, but this is a standard procedure in job shop-type applications. This notion is discussed further in Action 17.

TABLE 20. BRIEF ASSESSMENT OF PROPOSED MASS STORAGE DEVICES FOR SECONDARY B6700 AUGMENTATION

Proposed Augmentation To Secondary B6700 Hardware*		Purpose of Augmentation By Application	BRIEF Assessment of Augmentation Proposed
Disk Packs	Tape Drives		
3 (~523MB)	-	To Facilitate Processing of current Workload	• No I/O contention was observed on this system.
3 (~523MB)	6	FIIG Revisions	• This work involves both testing ahd production processes. • The FIIG Revision entails updating the FIIG Master File for either specific or mass changes. • Currently, the Secondary B6700 can hold 1 FIIG without removing any disk packs. The intent is to load 4 FIIGs on the system at one time on disk packs. However, FIIG Revisions are strictly a tape oriented process and an off-line activity that can be done on an "as required" basis and it can be off-line for extended periods of time. This process can be carried out without additional mass storage with mounting and dismounting of disks and tapes on the current configuration. • The test keys and parametric screening process is strickly a testing application. • The proposal is to load 4 full FIIGs on the disk packs for testing. • Since this is a testing application it is more reasonable to utilize a statistical sample of the FIIGs. This way all the unique FIIG characteristics could be loaded as well as a statistical sample to insure 95% or 99% confidence in the test. One existing disk pack could handle 5 or 6 FIIGs this way.
-	5	PAC Summaries	• This work involves a production process. • It is essentially a tape operation with a disk sort that is done on an "as required" basis and can fit on the existing configuration with improved scheduling.
1½	11	Organizational Entity	• This work is a production process in which the maintenance of the OE file will be done on the Secondary B6700. • The main reason for the tapes is to physically separate the different products generated. • With improved scheduling this process can fit on the current system.
3	12	Edit Guide	• This process is basically an "edit" of the Edit Guide rules used in the FIGGs to catalog and describe items. • With improved scheduling this process can fit on the current system and run on an "as required" basis.
<1	8	MAIL/SORT Suspense	• This is a production process and is a tape based operation that can fit on the current configuration. • This process is run on an "as required" basis.
<1	7	Civil Agencies Catalogs	• This is a production process which manipulates, decodes, reformats information extracted from the Master File. • This process is done on an "as required" basis and it appears logical to put the entire process on the IBM 360/65J because it involves publications.
<1	7	History Process	• This is a production process that is a tape and disk based operation. The disks are used for scratch files. • This process keeps track of the transactions processed or not processed in the last 90 days. It provides an audit trail and a data base for statistics and responding to follow-up inquiries. • This process must be run once every 24 hours and as well generates daily, weekly and monthly reports, but can be put on the current configuration and processed by an improved scheduling procedure.

*DLSC, Request for B6700 Equipment Augmentation, 23 October 1976.

Secondary B6700 - Workload Scheduling Improvements

Action 17. Improve the Scheduling of Jobs on the Secondary B6700

Actions 16 and 17 are interdependent. The purpose of Action 16 is to remove the current bottleneck on the Secondary B6700 by adding core memory. No additional mass storage devices are proposed. All the applications either on, or to be transferred to, the Secondary B6700 will fit on the current configuration, but, in most instances, concurrent processing will not be possible. Since virtually all of the workload on the Secondary B6700 is periodic in nature, it must be effectively scheduled and the system efficiently operated. Tapes and disk packs will have to be mounted and dismounted, but this is a common practice in job shop environments.

Application Program Management

For a large-scale computer system such as DIDS, with some 525 application programs, management of applications is essential. Such an effort would build upon existing DLSC efforts.

Action 18. Improvement Application Program Design Review and Maintenance

The focus of Action 18 is on quality and satisfaction of requirements. The aim is to detect program errors and inefficiencies, and to support the development of programming standards and program control. This action would expand on efforts by the DLSC Optimization Task Group, standard documentation products, and acceptance testing procedures.

DLSC should institute software design reviews to improve communication among users, programmers and managers, and to minimize the suboptimal, incremental solution process. Such reviews are working sessions in which the programs are reviewed by those who have an interest in that product. Typically, the review team includes an "outside" professional (an experienced programmer or systems analyst within DLSC), designers (programmers) of the program under review, the user of the program product, and other designers whose programs interface with the program under review. These design reviews have two objectives: to assess the quality of the program and its effectiveness in meeting specified requirements. The review should be systematic and well documented to establish an audit trail for subsequent reviews. The design reviews are carried out in addition to the daily quality controls instituted by the chief programmer, and should be performed only at carefully selected milestones, such as at the completion of the preliminary design.

Reviews conducted by competent professionals (outsiders) have resulted in the early detection of program design deficiencies, reduced downstream maintenance, and high quality products. One technique currently used for these reviews is the systems or structured walk-through method.

Action 19. Improve Implementation of Software Refinements

A number of useful program improvements have been identified by the DLSC Optimization Task Group. However, many of the recommendations have not yet been implemented, either to correct operating programs or to improve new program development. The focus of this action is on the implementation of corrections of detected program deficiences, and the formal feedback of the impact of the change.

EDP Workload Planning and Forecasting

Due primarily to the brevity of the task schedule, it was necessary to utilize the DIDS workload projections developed by DLSC based on processing requirements in wall clock hours. As noted in the analysis of the workload transferable from the Primary B6700 to the Secondary B6700, wall clock hours are not an appropriate measure of workload throughput or capacity of multiprogramming, multiprocessing systems.

The estimation of the capacity of, and throughput for a multiprogramming, multiprocessing system can be very complicated, and a discussion of the many potentially relevant considerations is beyond the scope of this task. However, for those systems where the processor is the limiting resource (the Primary B6700 and possibly the augmented Secondary B6700) processor hours are a reasonable surrogate for EDP system capacity.

By processor hours, we mean the amount of time the CPUs are actively processing a program. For the Primary B6700 multiprocessors, the processor hours for a program are dramatically different from the wall clock hours, which measure approximately the amount of time the program resides in the system. In the course of this analysis, we observed ratios of processor hours to wall clock hours for specific programs of 1:2 to 1:10 in the Primary B6700. In the workload projections, the estimates in wall clock hours reflect various multiples of processor hours for different applications. The result is that the annual aggregated estimates yield awkward and hypothetic daily averages for workload required and capacity (maximum production hours) available. Examples are 40.4 hours of machine production time available per Primary B6700 CPU per "day," 26.8 hours of machine production time available per Secondary B6700 CPU per "day," and 54.4 hours of machine production time available for the IBM 360/65J CPU per "day."

Wall clock hours can indicate workload volume and machine capacity, but they are rough estimates, meaningful only if the workload mix, software and application programs do not vary, or to provide a rough estimate of the job turnaround time for a system customer. For the DIDS situation, we judge that wall clock hours are too imprecise and require too many untenable assumptions to be useful for workload planning and forecasting.

Action 20. Improve DIDS Workload Planning and Forecasting

Based on this analysis, processing hours are a more appropriate measure of both workload and machine capacity for the DIDS EDP systems. This is clearly true for the Primary B6700 and, at the very least, more correct than wall clock hours for the Secondary B6700 and IBM 360/65J.

Data are available to make the DIDS workload and EDP processor hour computations. Two sources are the DIDS Monthly Summary of Job Elapsed Processing

Requirement Reports and the SPARK/LOGSTATISTICS, Total Processor Time and Program Exception Reports.

With the workload and EDP capacity estimates expressed in terms of processor hours, the projections and EDP surplus or deficit capacities can be assessed more precisely. This would be particularly useful for smoothing the workload, identifying transferable work and for sizing future augmentations.

APPENDIX A

ASSISTANT SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

INSTALLATIONS AND LOGISTICS

DATE: 11 January 1977

TASK ORDER SD-321-62
(TASK 77-5)

1. Pursuant to Articles E-1 and E-3 of the Department of Defense Contract No. SD-321 with the Logistics Management Institute (LMI), the Institute is requested to undertake the following task:

A. TITLE: DIDS Computer System Evaluation

B. BACKGROUND:

(1) The Defense Integrated Data System (DIDS) is a large-scale, centralized, multi-processor data processing system that utilizes a functionally integrated, random-access data base in excess of five billion characters and processes three million transactions monthly. DIDS is designed to provide logistics data services to support logistics managers in nine functional areas: cataloging, item utilization and marketing, interchangeability and substitutability, supply management, Military Standard Item Characteristics Coding Structure (MILSTICCS), publications, provisioning, item entry control and screening, and statistics.

(2) The hardware and software design and development of DIDS were initiated in 1965 and, though close to completion, the system is still in the process of being implemented.

(3) Overall responsibility for DIDS resides in the Office of the Assistant Secretary of Defense (Installations and Logistics) where both policy and guidance are developed and issued. Authority for the development and implementation of DIDS has been delegated to the Defense Supply Agency, which in turn has made the Defense Logistics Services Center (DLSC) responsible for the development and design of DIDS, and the development, coordination, and maintenance of its operating procedures. Close ties with the Military Departments, General Services Administration, and Department of Transportation are maintained for monitoring, executing, and interfacing activities.

(4) Over the past year there has been growing concern over DIDS efficiency and capacity. Both hardware augmentation and software optimization have been utilized to achieve improvements. Notwithstanding these efforts, DIDS still is not achieving its planned goals.

C. OBJECTIVE: To perform a DIDS computer system performance evaluation to assess whether additional hardware is needed or whether the present hardware is adequate but must be utilized more effectively to process the existing and planned workload.

D. SCOPE OF WORK: In performing this work the LMI will draw upon the current DIDS design, plan, documentation and evaluation of reports. Interviews with selected DLSC personnel will be included, as will on-site gathering of required data. The focus of the analysis will be on:

(1) Determining whether the current hardware configuration has the capacity to process the existing and projected near-term workload;

(2) Assessing the efficiency of the current software (both for the B6700 operating system and applications programs) and the file design;

(3) Preparing a basic conversion and implementation plan to correct the deficiencies in the hardware and software; and

(4) Assessing the cost effectiveness of optimizing the existing Automatic Data Processing system versus expanding its hardware configuration.

LMI will utilize consultants as required to achieve the appropriate mix of skills.

2. SCHEDULE: The task will be completed with submission of a final report by 28 February 1977.

[signature]

ACCEPTED: [signature]

DATE: 12 January 1977

APPENDIX B

DIDS WORKLOAD PROJECTION UNCERTAINTY AND IMPLICATIONS FOR THE STUDY FINDINGS

A central assumption in the analysis was that the DLSC/DLA DIDS workload projection prepared in December of 1976 was an accurate representation of future DIDS demand requirements. Based on that projection, if the December 1977 workload levels could be satisfied, so could the workload throughout 1978 and 1979. We still feel that the optimization and limited augmentation proposed as Option 5 in the report is correct and adequate for this projection. With a deliberate and intensive assignment of critical resources, the necessary optimization improvements are possible.

Since the study was performed, it has been pointed out by DLSC and DLA that their December 1976 DIDS workload projection was not complete. A considered estimate of an additional 10% for the December 1977 levels was made by DLSC/DLA, and a growth of 4% to 5% per annum for the years 1978 through 1980 was anticipated. This prospect of a burgeoning workload increasing montonically at 5% per annum, coupled with an uncertainty factor of plus 10% for December 1977, results in a 20% plus difference for the December 1979 workload level assumed in the study.

If this estimate of a greater workload is more realistic, then Option 5 can only provide short-term relief. If we refer to Option 5 as Part 1 of a larger and long-term plan, then it can be viewed as a contribution to Part 2 of the strategy to augment the DIDS computer system.

This long-term (Part 2) strategy assumes the following actions: first, that the recommended augmentation and optimization takes place for short-term relief, and, second, that DLA/DLSC prepare a comprehensive five-year DIDS workload projection in terms of monthly increments for the next calendar year, and quarterly increments for the subsequent four years. This workload projection should include: DIDS functions, frequency of operation, estimated processor time, estimated I/O times (note that wall clock hours are not acceptable measures), growth rates, and uncertainty (displayed in terms of a ± range for a 90% to 95% confidence interval).

Based on the new workload projection and the determination that there is sufficient cause for additional hardware capacity, then the augmentation described as Option 3 or its cost-effective equivalent should be pursued, given that the necessary Federal requirements are satisfied.

The augmentations as described in the study maintain full compatibility with the existing system for minimal conversion and implementation costs and time, and also incorporate the potential for additional growth. They consist of integrating the Primary B6700 and Secondary B6700 via a Burroughs Global Memory with a B6800 single CPU system. In this configuration, all three systems, consisting of six CPUs (three on the Primary B6800, two on the Secondary B6700, and one on the B6800) can have access to the TIR. Depending on the size of the B6800 selected, the configuration will at least more than double the capacity of the current DLSC DIDS workload processing potential. Assuming that both B6700 systems are retained,[1] and depending on the size of the B6800 Global Memory selected, this augmentation is estimated to cost between $1,104,000 and $1,768,000. For either of these configurations, a 16-month lead time is estimated.

A concerted effort is clearly needed to determine the long-term (10 to 15 years) expected growth for the DIDS workload. Whether or not ceilings should be placed on certain functional volumes, what should be done about inactive items, and what effect the expected foreign military sales will have are all important questions. An analysis of these matters would be based on the five-year workload forecast called for above and have as an objective the provision of a comprehensive DIDS growth strategy and management plan for DLSC, DLA and OSD.

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[1] Given that a B6800 is rated at 2 1/2 times the processing capability of the B6700, a special determination should be made to keep or trade the Secondary B6700. It could still be used as a test bed when connected to the Global Memory.

In summary, we still recommend the short-term augmentation and optimization strategy outlined as Option 5 in the report. The expected hardware expenditures for the augmentation under Option 5 are $350,000 to $400,000 in 1977 dollars. If the expected workload growth trends materialize, a subsequent augmentation will be required. In this event, the recommendations for Option 5 can be viewed as a Part 1 of the overall computer resources augmentation plan. A candidate for Part 2 could consist of adding selected Burroughs hardware to be available in early 1978, and integrating all the DLSC Burroughs computer systems with a B6800 via a Global Memory device. This augmentation can be expected to cost between $1,104,000 to $1,768,000 in 1977 dollars. That augmentation or its cost-effective equivalent must be preceded by Part 1 and, most importantly, a comprehensive five-year DIDS projection of DIDS workload must be prepared.

APPENDIX C

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