THE DEVELOPMENT OF A LOCAL AREA NETWORK; A SYSTEMS ENGINEERING APPROACH

by

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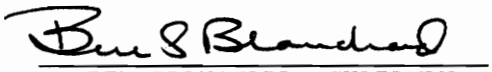
Project/Report submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

SYSTEMS ENGINEERING

APPROVED:



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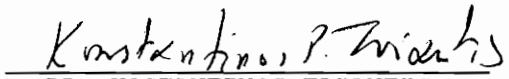

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Nathan Gordon Williams

Committee Chairman: Benjamin Blanchard
Systems Engineering

(ABSTRACT)

The Go-Figure Company has the problem of consolidation and coordinating its current office resources. Go-Figure has grown from 10 employees to an employee base of 50 in a three-year period. During this growth, Go-Figure has become uncoordinated in their office, maintaining several separate databases in several applications on several platforms. Considerable effort is expended translating and transferring data among the databases. There is duplication in the databases where there should be one. Additional equipment has been added as growth demanded, but without any consistent plan. Go-Figure has no connectivity to the Prime Contractor's main office, which is located in a different facility.

This project reflects how the system engineering process is implemented to modernize Go-Figure's existing system, eliminating as much duplication as possible, and allowing the sharing of electronic data and resources. Go-Figure has a significant investment in PCs and software, which it desires to preserve.

Section 1 discusses definition of need, acknowledgment of deficiencies, request for services, questions related to requirements, and cost parameters. A series of memos reflecting the development of the definition of need are located in Appendix A. The conceptual design is then developed, based on the feasibility study performed. Top level operational requirements are established, along with a cost analysis, and a system maintenance concept.

The preliminary design is accomplished in Section 2, and is based on the information derived from dialog between Go-Figure and Wide Insight Engineering. This information is broken down into four subsections.

Section 3 reviews the proposed preliminary design, along with logistical support function. Training is discussed in this section.

Section 4 reviews the detail design. It primarily mentions the tracking of the Office LAN's system activity and anomalies that may occur. Once the system is operational, the results of these trends will be the basis upon which enhancements and upgrades to the new system are recommended in the future, when requested by the customer.

Section 5 discusses the conclusion and final system recommendations.

ACKNOWLEDGEMENTS

In appreciation to my wife, Alice, for her support and encouragement throughout this project and the entire degree process.

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TABLE OF CONTENTS

Page #

Abstract.....ii-iii

Acknowledgements.....iv

Table of Contents.....v

List of Figures.....vi

List of Tables.....vii

List of Appendices.....viii

SECTION 1. INTRODUCTION/DEFINITION OF NEED

A. Definition of Need/Objectives..... 1
B. Conceptual Design
1. Feasibility Study..... 8
2. System Operational Requirements..... 11
3. System Maintenance Concept..... 28

SECTION 2. REVIEW OF LITERATURE

A. Introduction..... 37
B. Summary of References..... 37

SECTION 3. PRELIMINARY DESIGN METHODOLOGY

A. System Functional Analysis
1. Functional Requirements..... 38
2. Operational Flow Diagram..... 54
3. Maintenance Flow Diagram..... 55

B. Preliminary Synthesis & Allocation of Design Criteria
1. Allocation of Performance Factors..... 57
2. System Support Requirements..... 61

C. System Optimization
1. Trade-Offs..... 63

D. System Synthesis & Definition
1. Preliminary Design..... 64
2. Detail Requirements..... 72
3. Test & Evaluation Plan..... 75

E. Life-Cycle Costs..... 78
1. Cost Breakdown Structure..... 79

SECTION 4. DETAIL DESIGN & DEVELOPMENT METHODOLOGY

A. Detail/Functional Design..... 87

B. Logistic Support/Support Function..... 92

C. Utilization & Support..... 95

D. Phase Out & Disposal..... 97

SECTION 5. CONCLUSION & RECOMMENDATIONS..... 98

LIST OF FIGURES

Figure 1. Go-Figure Office Organization 2
Figure 2. Current Office Computer Resources 3
Figure 3. Go Figure Database Architecture 4
Figure 4. Proposed Office LAN Architecture 5
Figure 5. FAD Database Flow Diagram 15
Figure 6. MAD Database Flow Diagram 16
Figure 7. POM Database Flow Diagram 17
Figure 8. GED Database Flow Diagram 18
Figure 9 Typical User Operational Flow Diagram 20
Figure 10. System Daily Mission Profile 23
Figure 11. Projected Installation/Deployment Plan 26
Figure 12. Maintenance Concept Flow Diagram 36
Figure 13. Operational Functional Flow Diagram 54
Figure 14a. Maintenance Functional Flow Diagram 55
Figure 14b. Maintenance Functional Flow Diagram 56
Figure 15. Office Layout 67
Figure 16. Office LAN Logical Layout 68
Figure 17. Office LAN Physical Layout 69
Figure 18. Office LAN Equipment Rack 70
Figure 19. Office LAN Cost Breakdown Structure 79
Figure 20. WISE Contractor Organization 100
Figure 21. Work Breakdown Structure 101

LIST OF TABLES

Table 1. Estimated Life-Cycle Costs 10
Table 2. Employee and Project Fields 44
Table 3. Accounts Receivable 44
Table 4. Accounts Payable 45
Table 5. GED Database Functions 45
Table 6. POM Database Functions 45
Table 7. MAD Database Functions 46
Table 8. Office LAN Life-Cycle Costs 86

LIST OF APPENDICES

APPENDIX A: DEFINITION OF NEED DIALOG MEMOS 104

APPENDIX B: SYSTEM ACQUISITION MANAGEMENT PLAN 123

1. CURRENT DEFICIENCIES/DEFINITION OF NEED

1.A. DEFINITION OF NEED/OBJECTIVE

The Go-Figure Company has chosen Wide Insight Systems Engineering to modernize and resolve the problem of consolidation and coordinating their current office resources. Figure 1 shows Go-Figure office organization. Go-Figure has grown from 10 employees to an employee base of 50 in a three-year period. During this growth, Go-Figure has out grown its current office network, resulting in uncoordination in its office, maintaining several separate databases in several applications on several platforms. Considerable effort is expended translating and transferring data among the databases. Figure 2 reflects Go-Figure's current office resources and Figure 3 shows its database architecture (engineering, finance, marketing and project management). There is duplication in the databases where a single database will suffice. Additional equipment has been added as growth demanded, but without any consistent plan. Go-Figure has no connectivity to the Prime Contractor's main office, which is located in a different facility. Go-Figure's engineering department has wired together its own computing resources to share data and printers. The engineering department is busy and backlogged with projects, and Go-Figure cannot afford the decrease in customer service that would result if it assigned this office consolidation/network problem to them.

The need is to modernize Go-Figure's existing system, eliminate as much duplication as possible, and allow the sharing of electronic data. Go-Figure has a significant investment in PCs and software that it desires to preserve. The objective is to provide the electronic environment that eliminates the depicted copy functions, and provides the data transfer and maintenance functions. Figure 4 shows a general system environment/architecture that can be used to implement the design.

GO-FIGURE
ENGINEERING CONSULTANTS
OFFICE

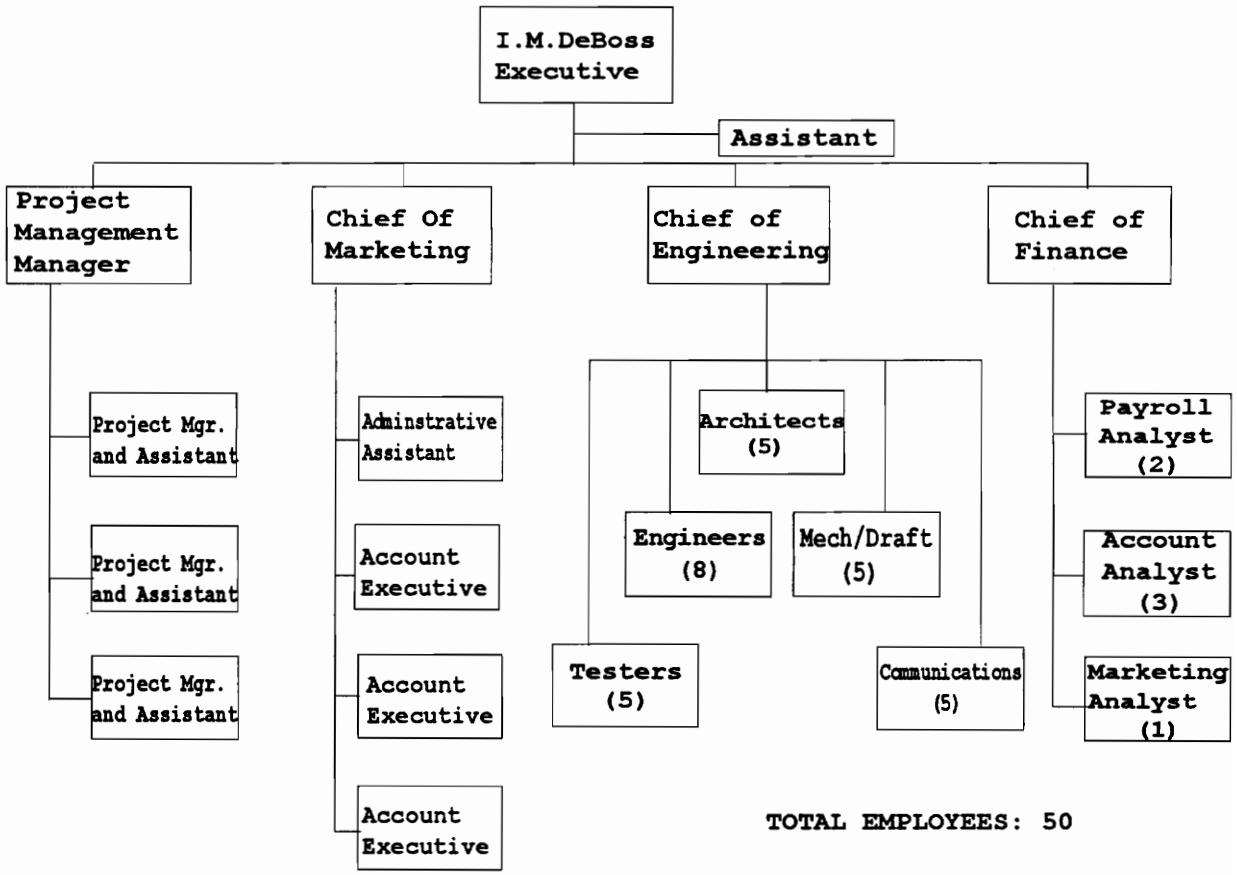


Figure 1. Go-Figure Office Organization

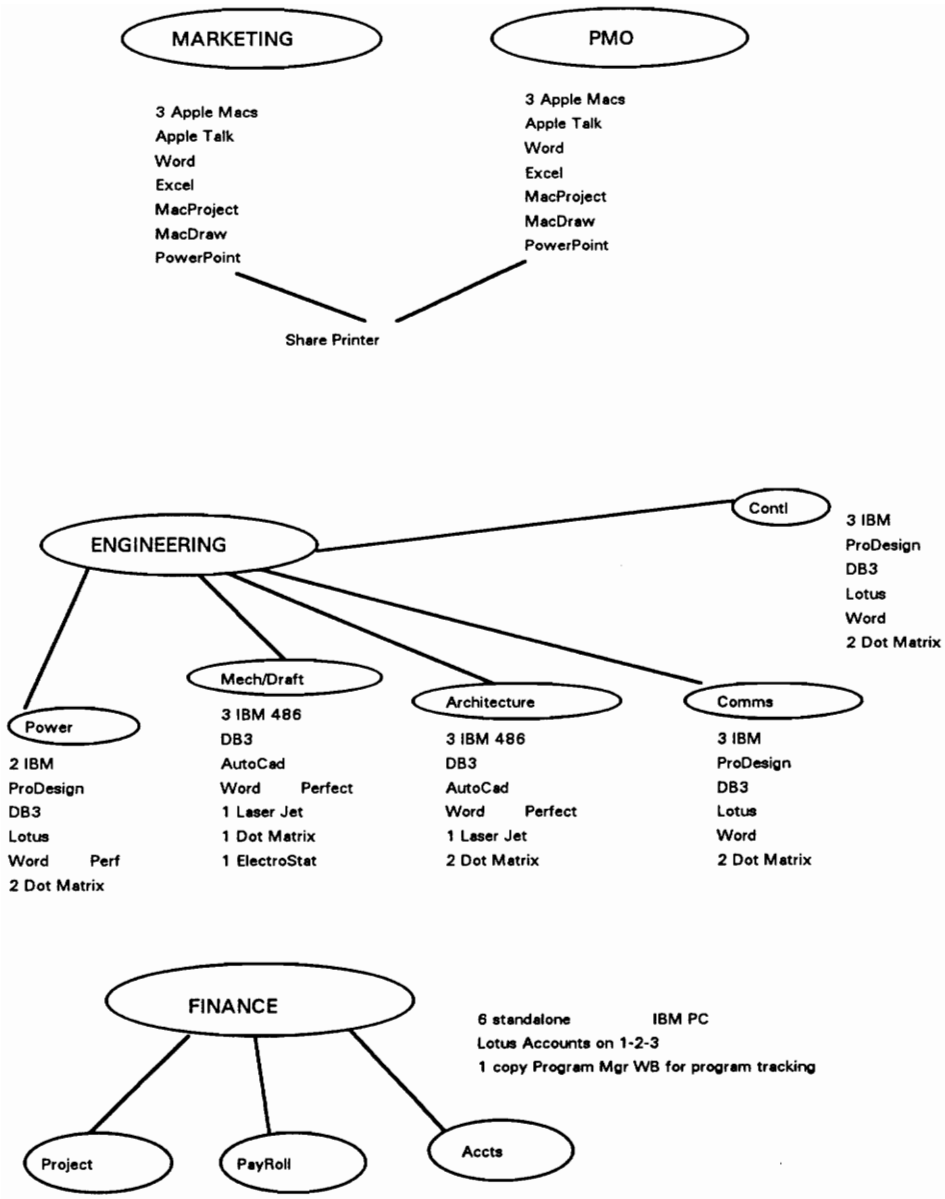


Figure 2. Current Office Computer Resources

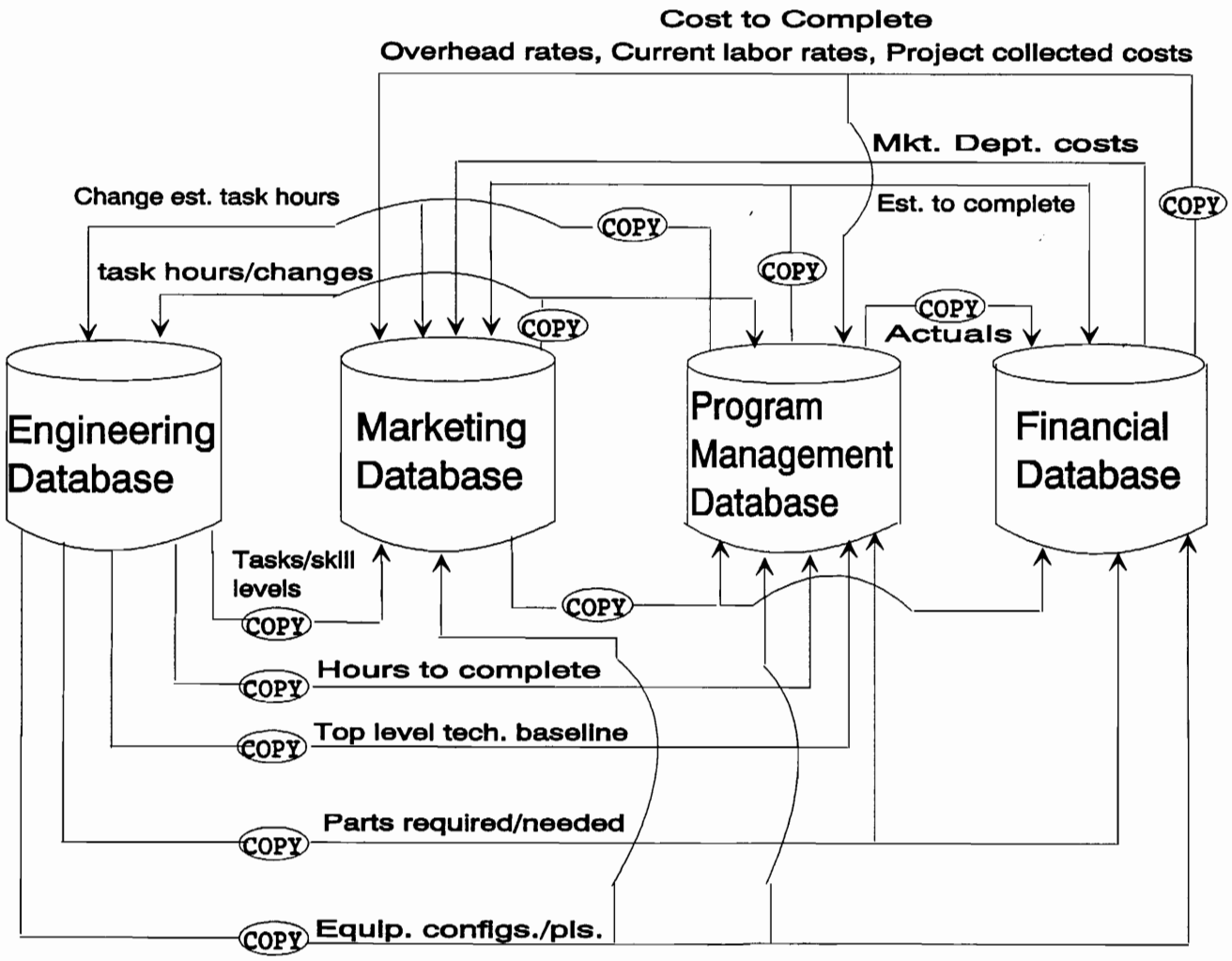


Figure 3. Go-Figure Database Architecture

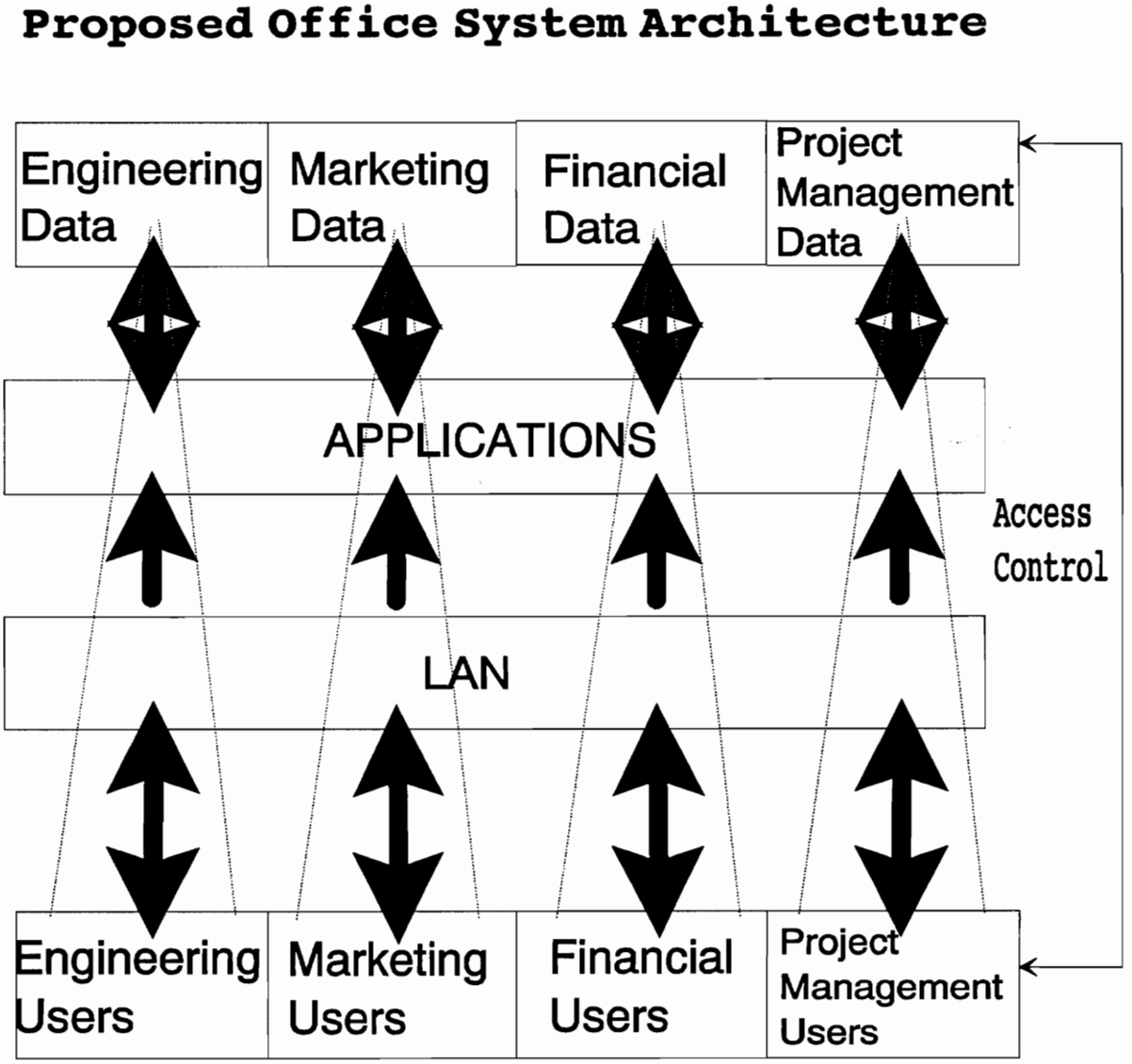


Figure 4. Proposed Office System Architecture

Due to Go-Figure's current office configuration, much billable time is lost due to information maintenance of one sort or another. The following is an estimate of that lost time. Go Figure expects to pay for the new system from the savings. The automated office should be configured to provide service, and after five years, be augmented and updated as necessary. One half the savings will be allocated across the five years to pay for the system. The office efficiency can be assumed constant over the next five years.

The executive, assistant, and finance chief do not charge directly to contracts. All other employees can charge directly to contracts. A special shop order charge accounting number has been opened to cover support that seems to be house cleaning and coordination, and can't be billed to particular projects. The Go-Figure billable year is considered to be 1850 hours. The following overhead charges were applied last year:

Finance charged 3080 hours. A fair part of the time was payroll. Contract charge hours and payroll are separate. Much effort was also spent coordinating with marketing to provide a consistent cost baseline based on hours charged to existing contracts. The average billable rate in finance is 40$/hr, or a $123,200 loss.

Marketing charged 3440 hours. The burden fell on the assistants, which helped keep the cost down. Unfortunately, marketing needs data from all departments, and coordination with finance for cost models as well as engineering for technological information is very time consuming. The pricing data is very sensitive, and considerable effort is consumed segregate this data, although it relies on much of the financial and engineering data, and is not static. The average rate marketing levied against this shop order was $37.50/hr, or a yearly loss of $129,000.

Program management (PM) also charged a significant burden, 2990 hours. There is debate that PM carried some of the engineering burden (program managers hate to sign off on overhead accounts for engineers), but ultimately, what has been charged is history. PM maintained contract performance data (on a productive charge number), but packaged the data for both finance and marketing. The program management hourly rate was $55, and could be more, but assistants are assuming the majority of the work. The year's loss is $164,450.

Engineering charged, on a per capita basis, the least against the overhead account, but a 4200 hour charge was still levied. Some accountants may say not bad out of a crew of 25 engineers, but these are all professional level people, and the billable heart of the company. Much time was spent on maintaining the engineering customized network (which the engineers claim automates enough processes to be cost effective, but which seems to be constantly reconfigured to meet the need of the day), and even more time is spent providing PM, finance, and marketing their packaged data. The average Go-Figure engineer is billed at $75/hr. The loss for the year is $315,000!

A overhead charge number was set up because these maintenance type activities were not bearing the scrutiny of our customers. After the year's review, we discovered that the loss represented by the account was $731,650. Of our potential 86,950 billable hours, 13,710 were lost, or almost 16% gross receipts. Go-Figure Finance department derived these figures from their contract costs. The 13,710 hours equates to almost seven and a half people. It is envisioned that the lack of a good LAN, with the appropriate database structure, is the cause. Analysis of Go-Figure's workflow indicates that a large measure of this exorbitant overhead is attainable to an unwielding LAN and non-integrated or disjointed database structure

SECTION 1.B CONCEPTUAL DESIGN

1.B.1 FEASIBILITY STUDY

1.B.1 INITIAL COST ANALYSIS AND FEASIBILITY

An analysis can be performed to determine the costs that can be expended during the next five years. Approximately one half the potential loss with the existing system configuration is earmarked for the office system. The cost analysis calculations are shown below and the analysis results are presented in Table 1.

There are currently 50 employees in the GO-Figure organization. Of the 50, only three are strictly overhead. The remaining 47 employees can bill their time directly. The billable year per employee is 1850 hours (1/47 of 86,950 of the potential billable hours). Sixteen percent of the billable hours are lost due to data maintenance. This percentage is considered constant regardless of the number of employees. The composite rate has been determined to be $52.97. The composite rate is multiplied into the potential billable hours, totaling $4,605,741. Therefore, the resulting current year's loss is calculated to be approximately $737,000 (16% of $4,605,741).

The growth estimate (in employees) is 10% the first year, and 5% each year thereafter. Inflation is assumed at 5%. Use (F,P,i,n), with P set equal to 1, to index the value of money for the five year initial cycle. Determine the number of employees after the first year (a 10% increase), then use (F,P,i,n) to determine the number of employees for the succeeding years. The escalating number of employees implies an increasing loss magnitude. For each year in the program, multiply the number of employees time by 16% of the available billable hours to determine the lost hours for that year. Multiply the original rate ($52.97) by the value of money for that year. Multiply the given year's

rate by its lost hours to obtain the expected revenue loss, in current dollars, for that year. Sum the losses to obtain the potential five year loss.

From Appendix A, the cost calculations give a total loss of 6.04 million dollars. Half of this sum has been designated the acquisition and operating budget for the office LAN automation project. Half of this sum was arrived at by working with the Finance Department to determine the return on investment alternatives on funds necessary to finance the LAN project. Thus, a budget of $3.02 million is the maximum amount that can be spent for the office LAN over its projected life-cycle.

COST ESTIMATES

Budgetary estimates must take into account the initial investment and recurring expenses. The initial expenses include the following items, using estimated costs:

System Development	$100,000
Hardware Procurement	$170,000
Software Procurement	$ 45,000
Installation & Training	$ 85,000
Operations and Maintenance	$150,000
Spares	$ 10,000
TOTAL First-Year Cost:	$560,000

These expenses total $560,000. The expected life cycle costs are presented in Table 1.

Table 1. Estimated Life-Cycle Costs

	Present	Year 1	Year 2	Year 3	Year 4	Year 5
Number of Employ.	50	55	58	61	64	67
5% Inflat.	1.00	1.05	1.103	1.158	1.216	1.276
Initial Cost	$410k	---	---	---	---	---
Maint. People	$100k	$105k	$110.3k	$115.8k	$121.6k	$127.7k
Maint. Contrs.	$50k	$52k	$57k	$63k	$72.8k	$88.5k
TOTAL:	$560k	$157k	$167.3k	$178.8k	$194.6k	$216.2k

= $1,473.9k

Lost Billable Total E= $6.04 M

Totals are in current dollars, based on 5% inflation. The $1.47 million estimated for the new system is well within the $3 million allowed by the customer. The project is deemed feasible, and the decision is to implement the system.

1.B.2 TOP LEVEL OPERATIONAL REQUIREMENTS

This section derives operational requirements from the customer needs and feasibility explored in Section 1.A. The issues identified in this section drive the maintenance concept and functional analysis of the office LAN system.

1.B.2.1 MISSION DEFINITION

The Go-Figure office LAN is created to provide a more efficient and effective environment to conduct the business of an engineering office. The LAN eliminates manual database copies and synchronization across multiple platforms. The LAN offers the opportunity to consolidate data and applications platforms, which in turn provides a more consistent and efficient work package.

DATABASES

The following databases will be referred to throughout the requirements documentation:

EnGinEering Database - GED
FinAncial Database - FAD
MArketing Database - MAD
PrOgram Manager Database - POM

A database will be installed to allow financial, marketing, engineering, and project management data records to be inputed and stored. Reports will be generated from the data records. The database will be set up to allow different users the capability to query files, have different views of the data, and across the network according to the group each user belongs to.

The Go-Figure office maintains four data areas: finance, marketing, program management, and engineering. The following sectionprovides sketches of each, showing data inputs and outputs, and reports generated.

FINANCIAL DATABASE

The Financial Database Flow is illustrated in Figure 5.

Data types are: payroll, skill levels, labor rates, overhead rates, actuals, profit and loss data, correspondence.

Reports are: Company Profit & Loss (P&L), P&L by project, company overhead, costs per project.

Data Interfaces

Inputs	From	Outputs	To
Actuals (updates)	PM dB	Job/project	PM dB
(updates)		collected costs	Mkt dB
Aggregate bid hrs	Mkt dB	current labor	PM dB
		rates	Mkt dB
Est to complete	PM dB	Est to complete	PM dB
(hours)		(dollars)	Mkt dB
Raw parts cost	ENG dB	Mkt dept costs	Mkt dB

MARKETING DATABASE

The marketing database flow is illustrated in Figure 6.

Data types are: Skills baseline, Tasks & times to complete,

customer data, RFPs, RFP requirements broken down to task, Correspondence.

Reports are: Cost to prepare by project, project estimates to complete, new project bid data.

Data Interfaces

Inputs	From	Outputs	To
Employees, skill levels & types	PM dB	New bid project	FIN dB
Hours to complete task catalog	PM dB	Final winning bid budget data	PM dB ENG dB
Task skill levels	ENG dB		
Equip configs, raw parts lists	ENG dB		
Current rates	FIN dB		
Mkt dept costs	FIN dB		
Estimates to complete	FIN dB PM dB		

PROGRAM MANAGEMENT DATABASE

The Program Management Database flow is illustrated in Figure 7.

Data types are: New jobs, Bid hours, Changes to existing job hours, Bid changes, Job collected Costs, Current Labor hours, Hours to complete.

Data Interfaces

Inputs	From	Outputs
New jobs	Mkt	
Bid hours for new job	Mkt	
Changes to existing job hours	Mkt	
Change to existing parts	Mkt	
Bid changes	Mkt	
Job collected costs	FIN	
Current labor rates	FIN	
Hours to complete	ENG	
Current Job tech baselines	ENG	
Actuals collected/job	PM	FIN
Changed estimate task/hours	PM	Mkt, ENG
Estimate to complete	PM	Mkt, FIN

ENGINEERING DATABASE

The Engineering Management Database flow is illustrated in Figure 8.

Data types are: Task hours existing projects, Task hour new jobs, Hours to complete, Tasks with skill level, Equipment configuration design, Current technical baseline config, Parts needed

Data Interfaces

Inputs	From	Outputs
Task hours existing projects	Mkt	
Task hours new jobs	Mkt	
Hours to complete	ENG	PM
Tasks with skill level	ENG	Mkt
Equipment configuration design	ENG	Mkt, FIN
Current technical baseline conf.	ENG	PM, Corp.
Parts needed	ENG	PM,FIN

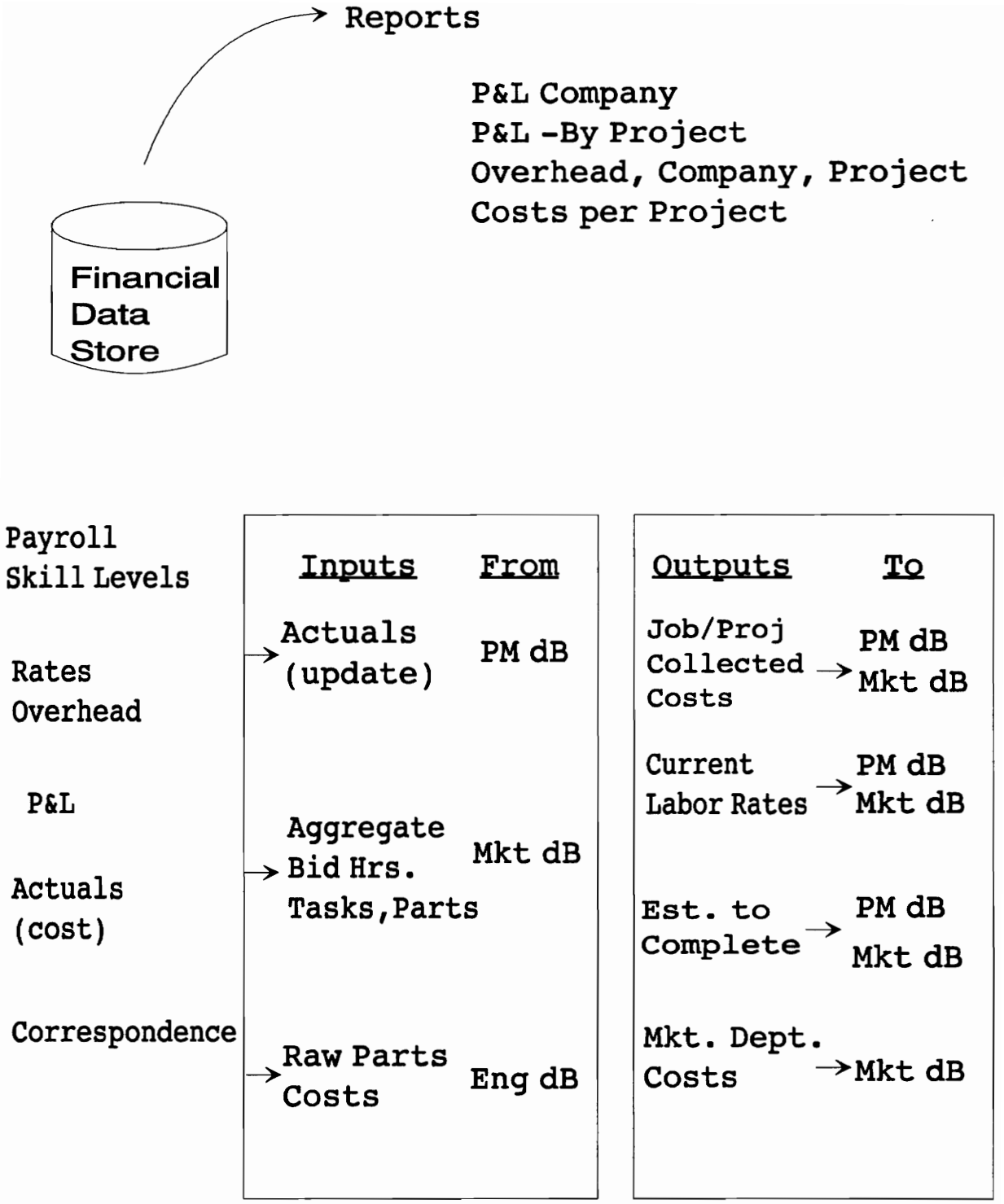


Figure 5. FAD Database Flow Diagram

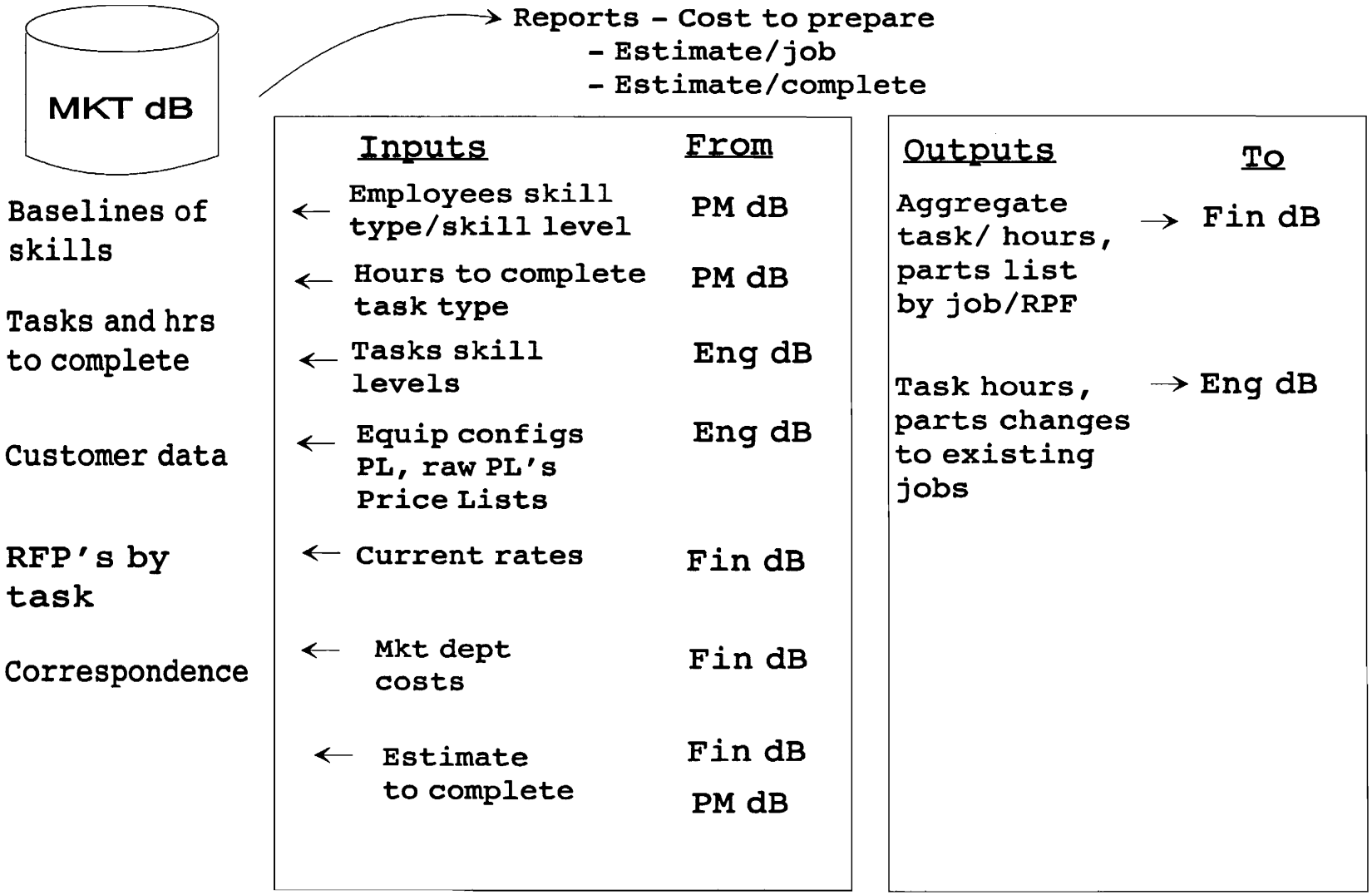


Figure 6. MAD Database Flow Diagram

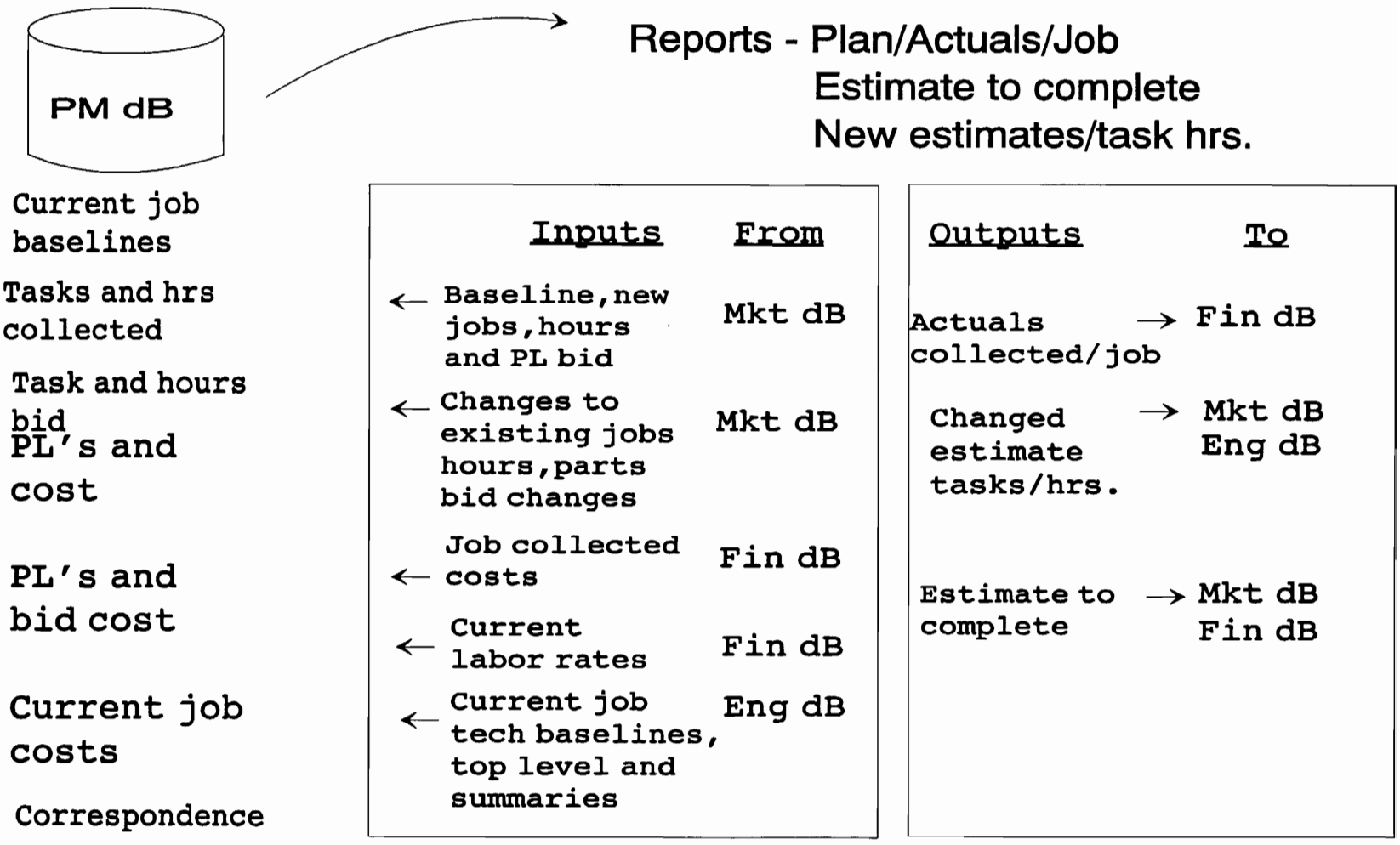
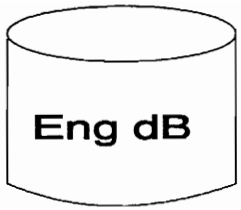


Figure 7. POM Database Flow Diagram



Current Project Configurations (as builts, designs)

Parts lists/ per project design

Task lists/ labor by skills categories

Drawings, supporting design data

Correspondence

Inputs	From
← Changes- Task Hrs, PLs to existing projects	Mkt dB
← Task Hrs PLs, new Jobs	Mkt dB

Outputs	To
Hours to Complete →	PM dB
Tasks, skill Levels →	Mkt dB
Equipment Config design, PLs →	Mkt dB Fin dB
Current tech baseline config (partial) →	PM dB
Parts Acquired/ Needed →	PM dB Fin dB

Figure 8. GED Database Flow Diagram

The flow of events to fulfill a generic Go-Figure office assignment is shown in Figure 9. Typically, a worker reports to the office and logs on to the system. In the old Go-Figure, the worker would check the in basket and mail slot for recent events. On the LAN, the worker checks for electronic mail which may provide assignments, special instructions, or routine office information. After reviewing the mail, the worker initiates the application needed. From the application, the worker creates a work file, then selects the data to be used and reads it into the work file. The worker proceeds to operate on the data as the particular assignment requires. When the assignment is completed, the work file must be dispositioned, and its results placed into the desired databases, and any needed reports generated. The worker can update the data (if he/she has authority), or store the work file for further review, either by a supervisor, or by another department. Upon assignment completion, the worker sends an E-mail statement to reviewers and/or to supervisors concerning work file results and/or data updates.

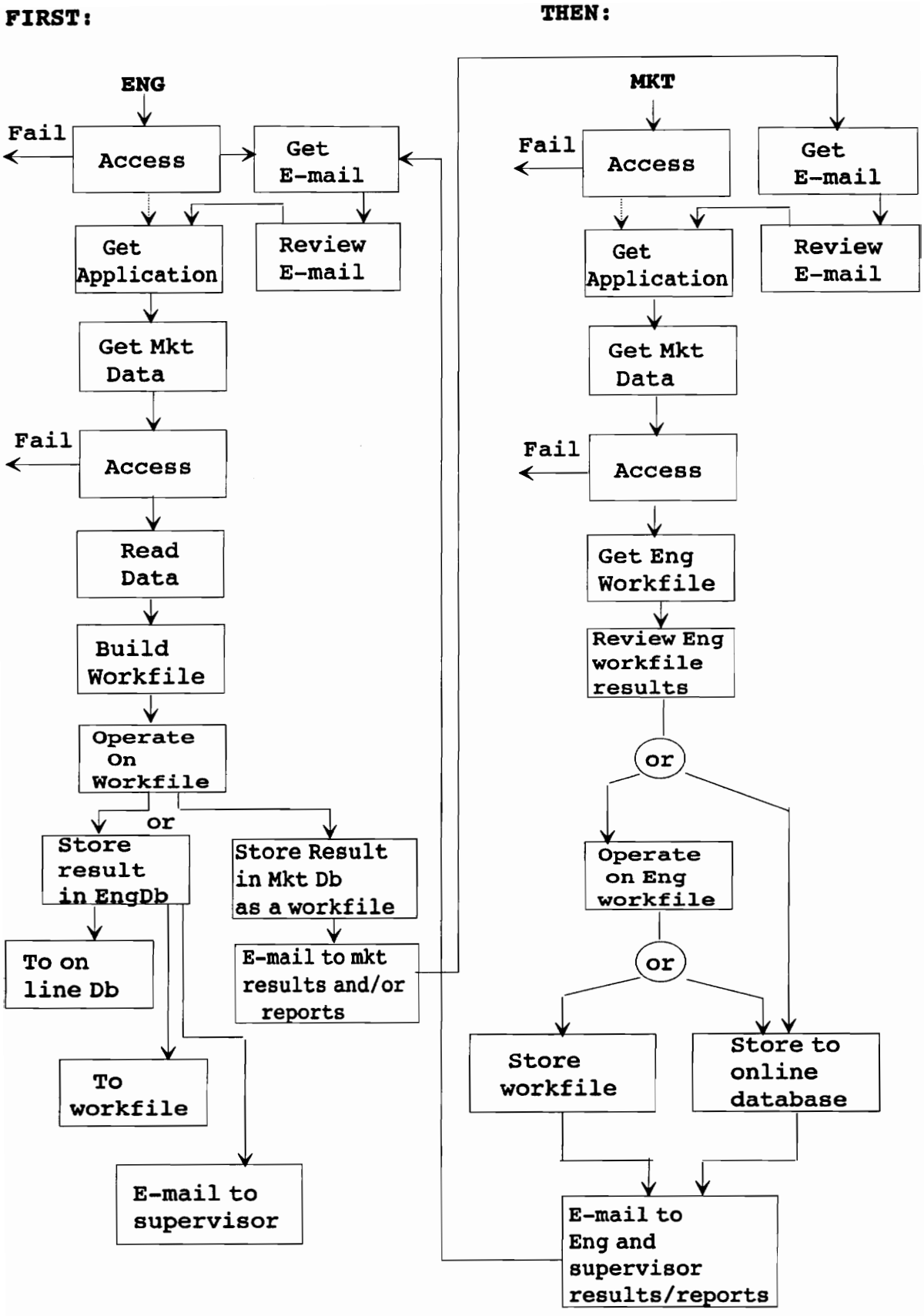


Figure 9. Typical User Operational Flow Diagram

1.B.2.2 PERFORMANCE AND PHYSICAL PARAMETERS

The Go-Figure office LAN must support 50 users at the implementation date, and must subsequently support the office future growth. Typical response times to user database requests are no more than three seconds (TBR). Exceptions are allowed for applications initiation, significant data fetches/stores, and significant calculations. An access control element is required to manage which workers have the authority to review and update data. Access is programmable by the designated Network Administrators. The system must host the applications software and the data. Applications software includes, as a minimum:

- Word processor
- Graphics capability
- Engineering graphics capability
- Database process
- Electronic mail
- Necessary supporting operating systems and utilities

Each user must be able to connect to the LAN and the applications and/or data package required (as allowed by the access control element). The LAN must have sufficient bandwidth to support the condition where 20 users make calls for one megabyte data files simultaneously. This condition models the expected worse case traffic condition. The system must also host the network controlling software, including a maintenance capability. The network maintenance capability collects network use statistics and provides network performance reports.

1.B.2.3 USE REQUIREMENTS

The LAN must support the Go-Figure office hours, including all worker's schedules, and LAN operator time, as well as scheduled maintenance time. The daily use profile is presented in Figure 10. At 06:00, the network administrator reviews the system logs and verifies that the nightly backup successfully completed. The scheduled workday begins at 08:00, but some workers arrive early and log on to the system. Users log on and off the system (random distribution) throughout the day. The curve shown in Figure 10 is hypothetical, but shows a mean expected load of about 60% of the users, with an expected dip during the lunch hour. The scheduled workday end is 1700, but some workers persist until as late as 2000. Between 2000 and 0600 the next day, no user activity is expected. The servers and essential network components remain on during this time. Automatic backup to tape is accomplished by computer schedule during the overnight hours. Scheduled maintenance and certain corrective maintenance may also occur at this time (on a non-interfering basis with the backup).

The system is not scheduled for weekend work, but the business is known to have erratic loads, so it can be put into service on any non-scheduled day. Non-scheduled days include 104 weekend days, and seven declared holidays, so the system is scheduled to operate 254 days per year, 14 hours each day.

The system will be reviewed and evaluated after five years. Technology is expected to provide both software and hardware alternate solutions for many Go-Figure office capabilities. It is also expected that much of the system implemented in this design will continue in service after the review. The life cycle for this system is five years, whereupon, the next system generation will begin, and will demark a new life cycle.

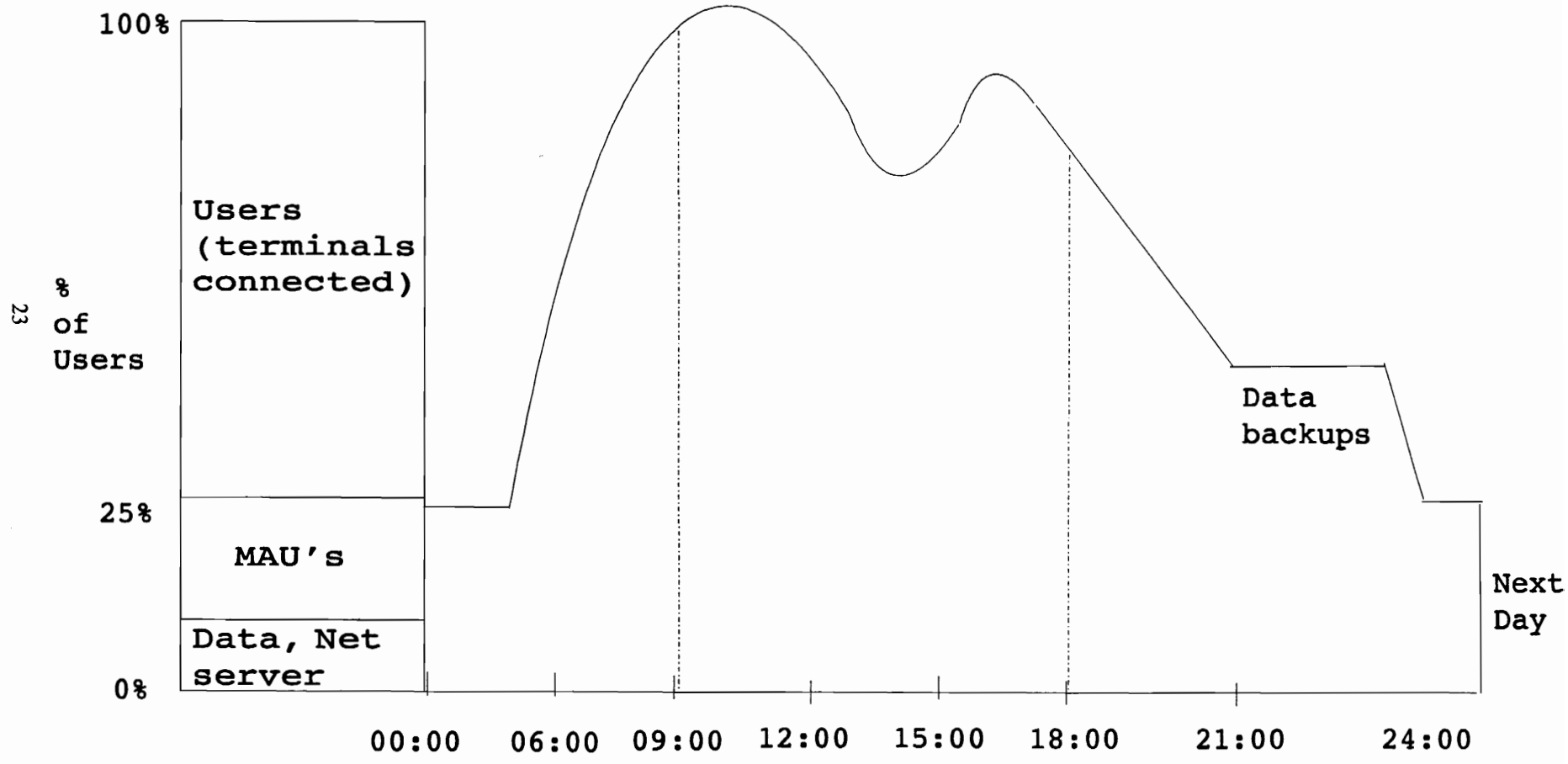


Figure 10. LAN Daily Use Profile

1.B.2.4 OPERATIONAL DEPLOYMENT

The LAN is to be installed in the Go-Figure office spaces. Terminals are to be installed in clusters that map into the four Go-Figure departments.

The LAN is to be installed six months after order date. It is to be installed with minimum office disruption, over a designated weekend is preferable. Equipment may be loaded with software, tested, then staged at the Go-Figure office prior to the installation date. Figure 11 shows a projected deployment plan.

1.B.2.5 OPERATIONAL LIFE CYCLE

The information needed in this section has been developed in the Use Requirements section, 1.B.2.3.

1.B.2.6 EFFECTIVENESS

System effectiveness is measured first by availability. The system is not effective for the user if it is not available. The next measure is response time. Data accuracy is a measure of effectiveness, but is managed by the office Network Administrator, who is trained and provided the tools to maintain data accuracy.

Inherent availability (Ai) of 99% is selected, and is thought to be achievable with available equipment and technology. If six hours is specified as the mean time for corrective action (Mct) when a service call is required, then according to

$$Ai = MTBF/(MTBF + Mct)$$

the MTBF must be 594 hours. This is from a system perspective. System reliability analysis including reliability block diagrams could be used to determine an optimal configuration of workstations to achieve the 594 hour MTBF system. Reliability analysis would also take operational profiles into consideration. For instance, the constant use during the 14 hours, when such saturated use is not expected needs to be taken into account. Also, not all failures will require service calls. The Mct for network administrator correction is 1 hour. The calculation therefore easily supports the worst-case systems scenario.

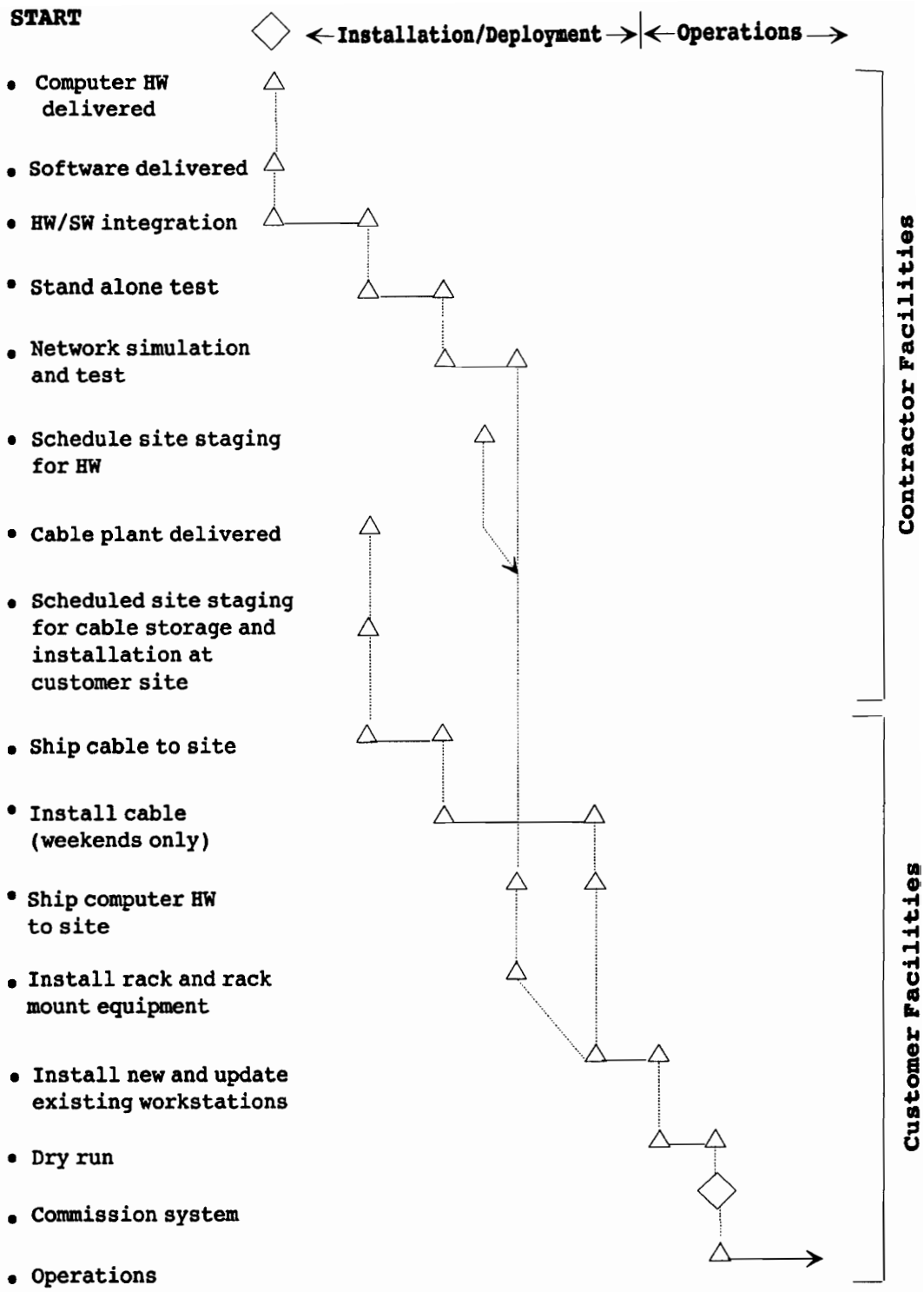


Figure 11. Projected Installation/Deployment Plan

The maintenance and support plans include methods and tools that measure the LAN performance. The number of users per time, workstation(s) out of service and the outage durations, and response times shall be measured. Occasional scheduled reports will detail the system effectiveness, and analysis will dictate what action, if any, must be taken. It is important to note that the system effectiveness baseline is developed during operation, and is then measured against the specified expectation.

1.B.2.7 ENVIRONMENT

The office LAN is to be installed in the Go-Figure office spaces. Temperature and humidity are controlled by the building air handling equipment, and provide for human comfort. Equipment must operate correctly in this environment. No special cooling or raised flooring is provided.

SECTION 1.B.3 SYSTEM MAINTENANCE CONCEPT

1.B.3.1 LEVELS AND RESPONSIBILITY OF SUPPORT

All maintenance actions required to support the office LAN at the customer site is divided into three levels of maintenance: organizational maintenance, intermediate maintenance, and depot maintenance.

Organizational Maintenance

All maintenance tasks performed at this level will be the full responsibility of the network administrators. The maintenance work to be performed at the customer site by the on-site network administrators consists of the following items:

- Preventive maintenance of all equipment
- Checking and monitoring of network performance
- Diagnostics and replacement of components in user workstations to the board level
- Backup and restore of data
- Installation of additional hardware and software in support of new users
- Upgrading of application software

The administrators shall have the option of receiving technical support via phone in accomplishing these tasks. A list of all necessary vendor technical support numbers shall be established and maintained.

The network administrators must be trained according to the skill level necessary to perform these tasks. At a minimum, it should include operating system and personal computer troubleshooting training. Skills are also required in database and user/group maintenance and should be in accordance with the designed network security and database structure.

Intermediate Maintenance

Intermediate maintenance tasks are performed by off-site vendor and support personnel through service requests. Off-site personnel shall be available for on-site technical support. Service requests are to be placed by the network administrators in the event of a major system failure.

The tasks performed through service requests at the intermediate level include the following:

- Repair/replacement of major hardware components such as servers, network drives, etc.

- Addition and modifications to database structures, reports, and format.
- Major servicing, upgrades, or adjustments to network architecture, hardware, or software.

The support personnel and procedures necessary to accomplish these tasks shall be established prior to installations.

Depot Maintenance

All repair and maintenance tasks performed at the depot level is performed off-site by specified vendors. Service support agreements shall be established by all relevant hardware manufacturer vendors and application software vendors. The following tasks shall be performed at this level:

- Component repair and/or shipment of replacement hardware
- Full user support for software application questions
- Provide software upgrades and installation guidance
- Technical and software help via phone

1.B.3.2 REPAIR AND MAINTENANCE POLICIES

The network architecture consists of hardware and software at the network level and user level. The procedures for maintaining and repairing the system are divided into scheduled maintenance and unscheduled maintenance tasks.

Scheduled Maintenance

All preventive maintenance (PM), data backups, upgrades, and network and database performance monitoring tasks are scheduled on a

routine basis. All scheduled maintenance tasks except for significant network upgrades are performed by the network administrators.

Preventive Maintenance

Preventive maintenance consists of disk and file repair, disk defragmentation, hardware cleaning and inspection, and the checking of current storage and network utilization. All PM tasks are expected to be accomplished at least once a year. Certain tasks may be performed more often depending on the final system design. All PM tasks will be scheduled in advance and performed during non-operational hours.

Data Backups

Daily backups shall be implemented and automated to back up only those files that are new or have been modified since the last backup. All backups shall be automated and accomplished only after operational hours. Based on expected operational hours, daily backup shall be required only on Monday-Friday.

Weekly backups shall back up all files on the network and will be performed during non-operational hours. The network administrators shall be responsible for labeling tapes, replacing tapes when needed, and confirming the success of backups.

Network and Database Performance

The network administrators shall perform periodic checks of network performance and database status. This includes system utilization parameters, available storage space, database access, reports usage and performance, and network usage profiles.

Unscheduled Maintenance

Equipment Repair

All system problems are designated as unscheduled maintenance tasks. The troubleshooting and replacement of system component performed by the network administrators at the organizational level shall follow established repair policies. All repairable defective components shall be sent to the appropriate vendor for repair.

All equipment replaced by the troubleshooting and repair of major system components accomplished at the intermediate level shall be sent for repair and/or replaced by the same procedures given at the organizational level.

All repair and replacement shall be performed through established vendor maintenance contracts.

Power Failure

In the event of a total power outage during operational hours, the network administrators will shut down all equipment until power is restored. Equipment will be powered up, in order, by the administrators after power is restored. In the event of power failure at night, the administrators shall ensure that the network is powered up and operational the next morning.

Virus Detection

Upon detection of a computer virus, the user must notify a network administrator before any action is taken. The network administrator shall take the appropriate action to eliminate the virus.

Performance Degradation

If a performance problem is identified from routine monitoring of the network, corrective action shall be implemented as appropriate either at the operational or intermediate level.

1.B.3.3 EFFECTIVENESS FACTORS

Based on user reliability and maintainability requirements, the following support factor specifications are to be met:

- A mean time to repair (MTTR) of 1 hour to correct hardware and software problems on-site. With a maximum downtime of 18.5 hours per 1850 billable hours per year as specified from the customer, the availability of the office LAN must be 99%. From the operational requirements, the associate mean time between failures (MTBF) is 594 hours.

- Upon placement of a service call for support, the corrective maintenance time (MDT) is 6 hours, 2 hours for transportation to site and 4 hours for correcting the problem.

- The minimum turn-around-time (TAT) for vendor equipment repair should be no more than 30 days.

Priorities shall be implemented if multiple problems are detected. Network-wide problems shall have the highest priority for service. architecture problems with MAU's, bridges, etc. take second priority. Workstation problems take lowest priority.

1.B.3.4 LOGISTICS SUPPORT

The network administrators are responsible for inventory control of all spares, test equipment, and documentation necessary to perform their established duties. The quantity of spares must be adequate to ensure at least one spare of each critical part (part identified as such) is available at all times.

The logistics level must be based on the design specifications, the expected repair TAT and maintainability parameters, and costs.

1.B.3.5 OFFICE LAN CONFIGURATION

The network administrators shall be responsible for configuration control and change management of the office LAN.

Configuration Control

During the initial installation, each PC on the network will be set up with a particular hardware and software configuration, some of which will be the same for all of the PCs on the LAN. To ensure the proper operation of the LAN, it is essential that these configurations not be altered by anyone other than the network administrators.

Standard maintenance procedures and designating a network administrator with sole authority and responsibility for altering, adding and removing system files on individual PCs will be implemented. These files set up each PC's configurations and run the necessary commands to connect to the network. They include workstation boot-up files (AUTOEXEC.BAT and CONFIG.SYS) and network access files (e.g., IPX.COM, XMSNET5.COM, AND SHELL.CFG). The network administrator is also responsible for managing the file servers and establishing directory structures that allow for both common applications and files, as well as the protection of each organizational division's private files. A

baseline capturing all of the configuration information of the network will define the level of documentation and control of the system.

Change Management Functions

In addition to the initial configuration management of the network, there is also a need to effectively manage the change in the network. Change management functions will also be performed by the network administrators, including addition and deletion of users and user groups, upgrade of existing software packages, installation of new applications, new hardware stalking inventory, and fine tuning network performance. The baseline of the network configuration will be updated as changes are implemented to ensure accurate documentation, essential for both effective resource management and identification of potential problems.

Change Management Method

The stated configuration information must be documented by the network administrators to ensure a method for defining and changing system parameters. These documents should include the following:

- List of hardware on the network, including location information such as node address, cable number or label, and room number.
- LAN worksheets to document custom network configuration parameters.
- Directory structure of LAN files.
- Current application version number, date, and vendor address and technical support numbers.

1.B.3.6 MAINTENANCE CONCEPT FLOW DIAGRAM

The scope and flow of the major components and support factors of the system maintenance concept for the office LAN is shown in Figure 12.

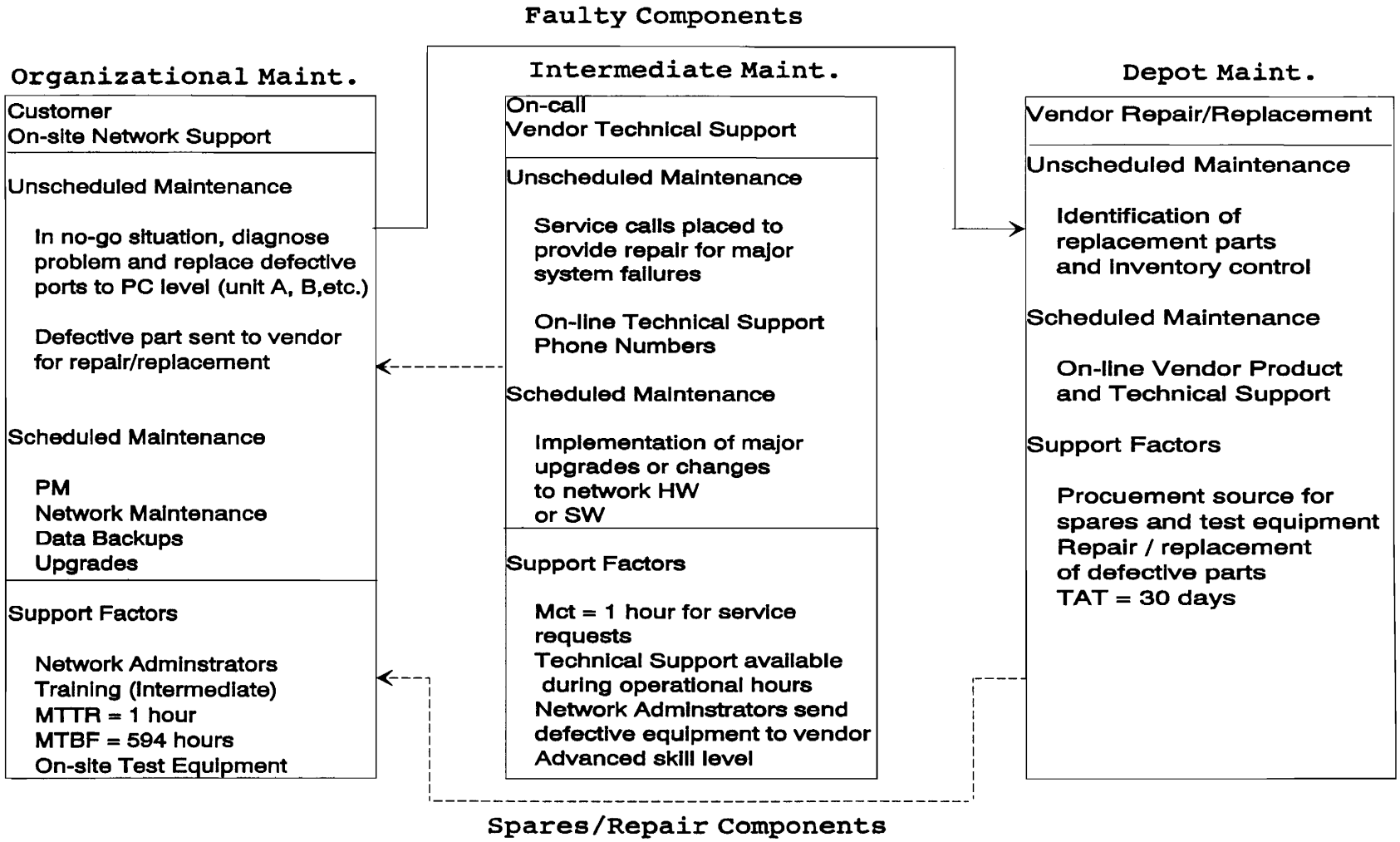


Figure 12. Office LAN Maintenance Concept Flow Diagram

SECTION 2. REVIEW OF LITERATURE

This section discuss the references used to develop this report. The following list of references was used:

- **Systems Engineering and Analysis, Blanchard, Benjamin S., Wolter J. Fabricky, 2nd ED, 1990, Prentice Hall, Englewood Cliffs, New Jersey** - The Systems Engineering and Analysis Manual discusses the process of the bringing systems into being and improving on existing systems. This book provided me with an outline for the implementation of the Systems Engineering Process for this report. It provides a life cycle approach to the process of systems development and considers, at length, how a structured methodology might clarify and simplify this approach.

- **Automated Consolidated LAN System, 1992, Dave Andrex, Angie Lineback, Bridget Robeson, Will Stine, Nathan Williams** - The Automated Consolidated LAN System is a report that reflects an understanding of the primary functions in the different phases of the system life cycle as it relates to a Local Area Network. The System Engineering Process Of The Development Of A Local Area Network embellishes on the practices used in this report.

- **Systems Development, Analysis, Design, and Implementation, Alan L. Eliason, 1987, Scott, Foresman and Co., Glenview, Illinois** - This book describes the type of activities important to the systems engineering process. It also reviews the stages of the project life cycle and it assisted in determining ways of organizing the activities important to systems analysis and design.

- **Novell NetWare Version 3.11: System Manager Student Manual, Netware v3.11 Installation, System Administration, NetWare Concepts and Netware Print Server manuals, 1991 Novell, Inc.** - These manuals assisted in the selection of the network software and the network management tool.

SECTION 3. PRELIMINARY DESIGN

Introduction

This section presents the preliminary design elements that are based on and satisfy the Go-Figure LAN and database requirements. The requirements in this section are derived directly from the interchange with the customer, documented in the preceding section of this paper. The design provides a LAN that interconnects all the office users to the office applications and databases, and which controls the access of the users to their appropriate data.

This section presents the preliminary design in four subsections:

- System Functional Analysis
- Preliminary Design Criteria Allocation
- System Optimization
- System Synthesis and Definition

The system functional analysis translates the customer needs into functional requirements, and operational and maintenance functions. The preliminary design criteria allocation takes the operational and maintenance functions, and defines the system elements and architecture, and allocates functional aspects to these elements. System Functional Analysis includes the Functional Requirements, Operational Flow Diagram, and Maintenance Flow Diagram. Preliminary Synthesis and Allocation of Design Criteria includes Allocation of Performance Factors and System Support Requirements. A brief Trade-Off Study is found in the System Optimization section. The System Synthesis and Definition contains the Preliminary Design, Detail Specification, and Test & Evaluation Plan.

SECTION 3: PRELIMINARY DESIGN

3.A. SYSTEM FUNCTIONAL ANALYSIS

3.A.1 FUNCTIONAL REQUIREMENTS

3.A.1.1 OFFICE LAN ARCHITECTURE

A. Each user on the network will have access to all data, printers, and software packages necessary for their job functions. Information access controls will limit each group's access to the various databases.

B. Each user will experience a 99% network availability during operation hours except for scheduled downtimes.

C. Each user will be able to send a mail message to any other user on the network.

D. User-data shall be backed up to allow restoration of loss data.

E. Two designated Network administrators will receive training to provide the proper support necessary to perform organization, maintenance, etc.

F. The users shall be able to share devices (i.e. printers, plotters, etc.).

G. The Network Administrators shall set-up a subscription services drive (for software applications) and set-up each user's data area.

3.A.1.2 E-MAIL

E-mail shall perform the following functional tasks:

A. Allow users to send, receive, sort, and forward messages to any

other user on the network.

B. Provide mailing lists for defining group members. Users shall be able to send messages to everyone in a defined group.

C. Allow users to send messages written from word processing applications.

D. Provide bulletin boards (i.e. folders), organized according to defined groups.

E. Allow users to delete or archive messages.

F. Allow users to print any message to a printer.

G. Users shall be notified when they have a new incoming message from any Windows application. This notice may be turned off at a user's request.

H. E-mail software shall reside and be executable only from the network.

3.A.1.3 ABILITY TO ACCESS CERTAIN DATA

Users shall be designated to a particular group and shall be able to access only that group's data.

3.A.1.4 GROWTH

The expected addition of new users onto the network over the life-cycle of the system requires the system design to easily accept additional software onto the current desktop platform and new hardware within the

network. The network architecture shall provide for the expected 5% increase in users over 5 years. All software applications and operating systems shall allow for the increase of users.

3.A.1.5 HOURS OF OPERATION

All network applications shall be available during all operational hours.

3.A.1.6 NUMBER OF USERS

The initial system must provide the required network and resource functions for a total of 50 users. Additional procurement of hardware and software shall be implemented when the number of users increases.

3.A.1.7 EXISTING RESOURCES

The current hardware and software used by the Go-Figure organization shall be integrated in the new network as much as possible to minimize costs. The list of items currently in use is as follows:

HARDWARE

Personal Computers:

- 14 IBM model 70's
- 6 IBM model 95's
- 6 Apple Macintosh IIci's

Printers:

- 9 IBM Dot matrix printers
- 2 Hewlett Packard LaserJet series II

SOFTWARE

- MacDraw Graphics
- WordPerfect Word Processing Package
- Autocad

- DOS 4.01
- DBase III+
- Lotus 1-2-3
- Project Scheduler

3.A.1.8 DATA PROTECTION

The data protection hardware and software shall perform the following functions:

- Automatically back up data at the end of every working day onto tape.
- Ensure every computer is protected against viruses
- Provide each computer protection against power surges
- Protect the network server against power failures
- Network shall be password protected & file access protected

3.A.1.9 GED, FAD, MAD, & POM DATABASES

The functional requirements for GED, FAD, POM, and MAD include; general on-line requirements and inventory/configuration requirements.

General On-line Requirements

a. GED, FAD, POM, and MAD shall provide up-to-date information regarding financial, engineering, marketing, and program management records.

b. GED, FAD, POM, and MAD shall indicate which fields are mandatory for processing.

c. GED, FAD, POM, and MAD shall provide Query-by-Example (QBE) on key fields for interactive data retrieval.

d. GED, FAD, POM, and MAD shall display and accept all dates in the format of MM/DD/YY, unless otherwise specified.

e. GED, FAD, POM, and MAD shall display error messages that describe the error and proper corrective action.

Inventory/Configuration Requirements

The following requirements for GED, FAD, POM, and MAD for inventory configuration management are necessary for accurate reporting:

See Tables 2-7 for a complete listing of the Tables required for the GED, FAD, POM, and MAD databases. Following the Tables, are a complete listing of Reports required for FAD, POM, and MAD databases. {see FAD Reports 1-7, MAD Reports 1-2, POM Reports 1-3}

GED, FAD, POM, and MAD TABLES

The following fields and data for the GED, FAD, POM, and MAD databases was inherited from the Go-Figure prior to office automation.

FAD TABLES:

The Financial Database contains very sensitive data including; salary rates and Employee personal data. Certain stored Employee data is legally protected under the Privacy Act.

TABLE 2 . EMPLOYEE AND PROJECT

Fields	Data Retrieved From	Data Output To
1. Employee Name	FAD	
2. Employee Number	FAD	
3. Employee Salary	FAD	
4. Employee Address	FAD	
5. Employee Manager	FAD	
6. Employee Department	FAD	
7. Exempt/Non-Exempt	FAD	
8. Employee Vacation	FAD	
9. Employee Overtime Hours Worked	FAD	
10. Employee Regular Hours Worked	FAD	
11. Employee Tax Deduction	FAD	
12. Employee Billable Rate	MAD	
13. Employee's Project Name	FAD	
14. Project Overhead Cost	GED	
15. Project Actual Cost	POM	
16. Project Bid Rates	MAD	
17. Project Collected Cost	FAD	POM,MAD
18. Project Labor Rates	FAD	POM, MAD
19. Market Dept. Costs	FAD	MAD

TABLE 3. ACCOUNTS RECEIVABLE

Fields	Data Retrieved From	Data Output To
1. Debtor	FAD	
2. Amount	FAD	
3. Due Date	FAD	
4. Interest	FAD	

TABLE 4. ACCOUNTS PAYABLE

Fields	Data Retrieved From	Data Output To
1. Collector	FAD	
2. Amount	FAD	
3. Due Date	FAD	
4. Interest	FAD	

GED TABLE:

TABLE 5. GED Database Functions

Fields	Data Retrieved From	Data Output To
1. Task hours existing projects	MAD	
2. Task hours new jobs	MAD	
3. Hours to complete	GED	POM
4. Tasks with skill level	GED	MAD
5. Equipment configuration design	GED	MAD, FAD
6. Current technical baseline conf.	GED	POM
7. Parts needed	GED	POM, FAD

POM TABLE:

TABLE 6. POM Database Functions

Fields	Data Retrieved From	Data Output To
1. New jobs	MAD	
2. Bid hours for new job	MAD	

3. Changes to existing job hours	MAD	
4. Change to existing parts	MAD	
5. Bid changes	MAD	
6. Job collected costs	FAD	
7. Current labor rates	FAD	
8. Hours to complete	GED	
9. Current Job tech baselines	GED	
10. Actuals collected/job	POM	FAD
11. Changed estimate task/hours	POM	MAD, GED
12. Estimate to complete	POM	MAD, FAD

MAD TABLE:

TABLE 7. MAD Database Functions

Fields	Data Retrieved From	Data Output To
1. Employee's skill type	POM	
2. Hours to complete task	POM	
3. Task skill level	GED	
4. Equipment configuration	GED	
5. Equipment Price Lists	GED	
6. Current Rates	FAD	
7. Mkt. Dept. Costs	FAD	
8. Estimated completion times	FAD, POM	
9. Aggregate task/hour ratio		FAD, POM(winners)
10. Parts list by RFP		FAD
11. Task hours, parts changes to jobs		GED, POM

GED, FAD, POM, AND MAD REPORTS

FAD REPORTS:

Report 1: Monthly Financial Department Report

Description: This report would be distributed to Department Managers. This report would be generated by the Accountant Office.

Report 2: Paycheck

Description: Distribution of paychecks to employees on a Bi-monthly basis. The paycheck would be generated by the Payroll Office.

Report 3: W-2 Generation

Description: Distribution of W-2 Forms to employees on a yearly basis. The W-2 would be generated by the Accountant Office.

Report 4: Accounting Report

Description: This report would show accounts receivable/payable in the company. This report would be generated by the Accountant Office.

Report 5: Project Costs per Project Report

Description: This report would show the costs broken down by component for each project.

GED REPORTS:

No reports generated from this database.

MAD REPORTS:

Report 1: Job Estimate Report

Description: This report reflects the task skill, along with the estimated time to complete.

Report 2: Job Completion Report

Description: This report reflects the expected completion of the job.

Report 3: Project Costs

POM REPORTS:

Report 1: Completion Estimate Report

Description: This report reflects the estimated time it takes to complete specific project; taking into account the tasks specified, the skill level, estimated hours to completed at time of report.

Report 2: New estimate/task hour Report

Description: A report to reflect early/delayed completion of project; accounting for hours completed on tasks and hours to complete project.

Report 3: Planned vs Actuals for job Report

Description: This report reflects the planned hours/costs expected for project versus what the actual hours/costs were for project completion.

3.A.1.10 POWER PROTECTION

The office LAN shall have all of its power lines connected to some form of power conditioning equipment to protect it from power fluctuations and other power disturbances. Three types of protection will be provided: suppression, isolation, and regulation. Suppression

protects against voltage spikes, isolation reduces interference effects, and regulation ensures that the power is steady and reliable.

3.A.1.11 SECURITY

Access Control

Each of the databases (GED, FAD, POM, MAD) shall provide access to only users requiring the data. The engineering database shall be available to every user of the network. The information in the financial, program management, and marketing databases shall be available to only those users who are a member of those groups and management personnel. The data shall be password and rights protected.

Data Protection

All of the computer-generated data from the company shall be stored on the network file server. It is important that this data be protected against failures in hardware, software, or supplied power. Even if the reliability specifications are met, failures will occur on occasion. Data protection must ensure that if a failure occurs, the probability that data will be lost is negligible.

The following data protection procedures apply to all network data:

Backup and Restore Functions

Daily backups are to be performed automatically after office hours when no users are on the system. The backup system must ensure that all new data entered that working day or changes made to existing data is fully backed up. The backup system must also perform automatic weekly and monthly backups, at which time a full system backup of all files is performed.

A. The backup system must use standard magnetic tape and meet the following minimum functional requirements:

B. The system must be able to back up and restore not only data, but all network software programs and operating system files.

C. The system must allow manual backups and restores of either the network server or individual workstation hard drives.

A. With automatic backup capability, tapes should not have to be changed more than once a week by the Network Administrator.

D. The user can specify individual files, particular directories, or whole disk drives when performing manual or automated backups and restores.

E. The tape backup system must display the status and results of each backup and restore on the file server console such that the Network Administrator only has to check the server each morning to see if the previous backup was successful.

F. The backup system software must keep a log of all backup and restore activity, including the time, data, a listing of the files backed up or restored, and whether it was a success or failure.

G. The tape unit hardware and software must be compatible with the network operating system, and be physically connected to the file server.

Computer Virus Protection Functional Requirements

Each network user's computer is required to be fully secured against the introduction of computer viruses which could damage data on workstations hard drive or which could propagate through the network.

Each computer shall check all executable files on the hard drive for viruses whenever it is booted up. Furthermore, each computer must load a memory-resident virus program on boot-up which automatically scans all floppy disks used in the computer before files are copied onto the computer.

The Network Administrators are responsible for ensuring all workstations are protected against viruses. For further protection, the network files must be scanned at least once a month by the Network Administrators. Regular updates to the virus program shall be implemented.

Power Protection Security Functions

Protection against losses in building power must be incorporated into the office automation system. This protection must be built-in andautomated so that data integrity and protection is ensured in the event of a failure in the supplied power. Power protection should be applied to the network server at a minimum. It is not required to keep every individual workstation protected against power failure.

Network Power Security Functions

The network file server shall be protected against not only power failures, but power surges. In the event of power failures during non-operational hours, the server shall automatically shut itself down according to specified shutdown procedures. When power supplied to the server fails, it must first automatically broadcast a message to all users to log out of the network. A minimum of 10 minutes of supplied power must be provided before the automatic shutdown sequence begins. The network power protection scheme must also protect against surges, spikes, brown outs, and fluctuations in the power supply. The office environment must minimize the buildup of static electricity since this

is a significant threat to not only data security, but computer hardware reliability.

Workstation Power Security Functions

Every workstation shall be protected against power surges by the utilization of surge protectors. In addition, the workstation environment must be keep as static-free as possible.

GED, FAD, POM, and MAD Databases

Security requirements are governed by software, hardware, data, and personnel constraints.

Office LAN Architecture

Network Operating system

The network operating system (NOS) shall provide several security aspects: file server security, logon security (password + USERID), file protection, and user privileges. Auditing capabilities of the NOS will also provide network security.

The NOS will also support on-line data protection, support of tape backup system(s), and support of an uninterruptable power supply (UPS).

E-Mail

The E-mail data shall be protected by the network logon (USERID + password).

SECTION 3.A.2 OPERATIONAL FLOW DIAGRAM

Figure 13 illustrates the operational functional flows associated with the office LAN. The functions illustrated are based on the operational requirements and system maintenance concept. It is intended that these functions be used as a basis for system design.

SECTION 3.A.3 MAINTENANCE FLOW DIAGRAM

Figure 14a and 14b illustrate the maintenance functional flow diagram. These functions show the overall support and maintenance procedures necessary to maintain the system.

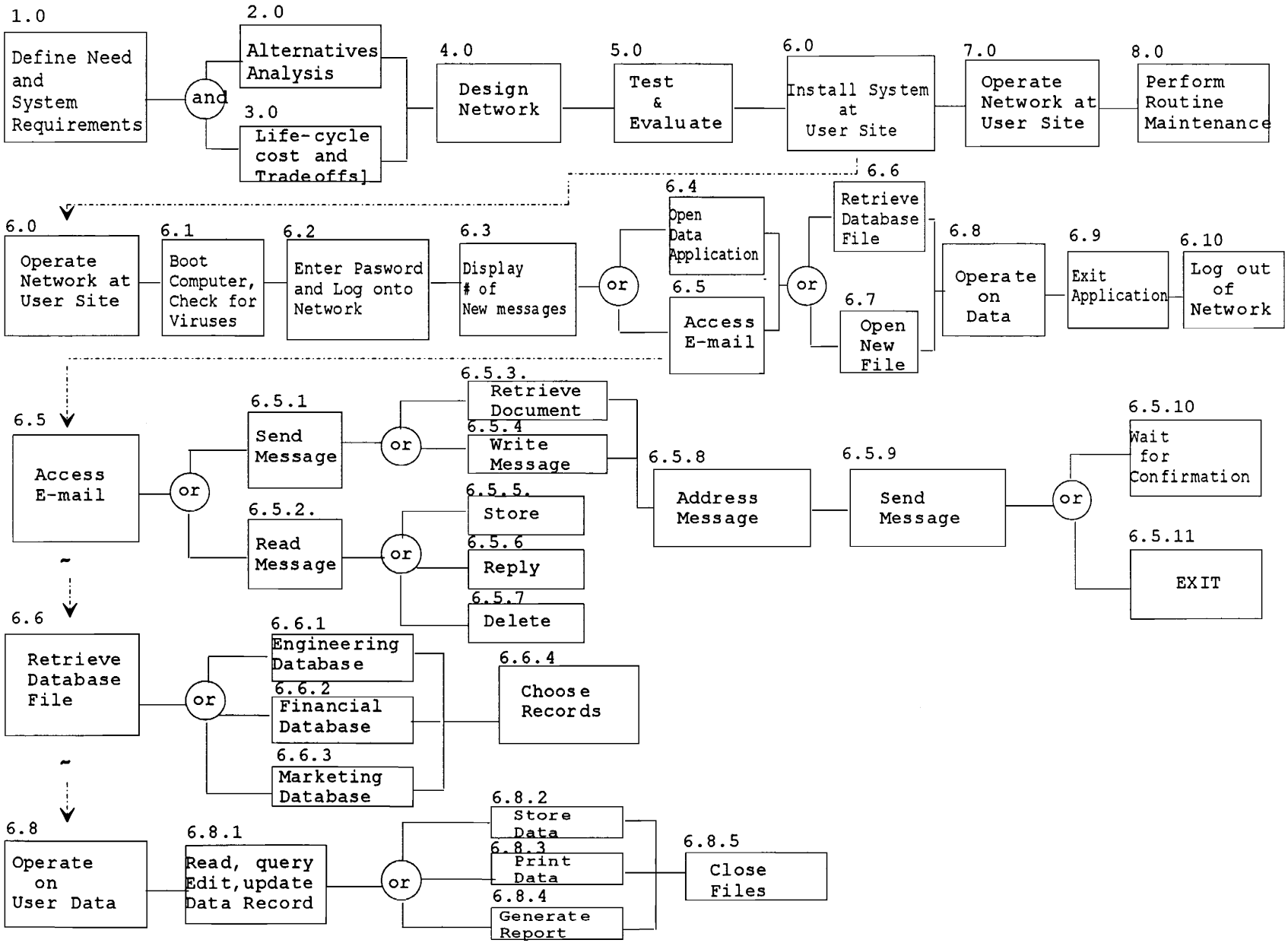


Figure 13. Operational Functional Flow Diagram

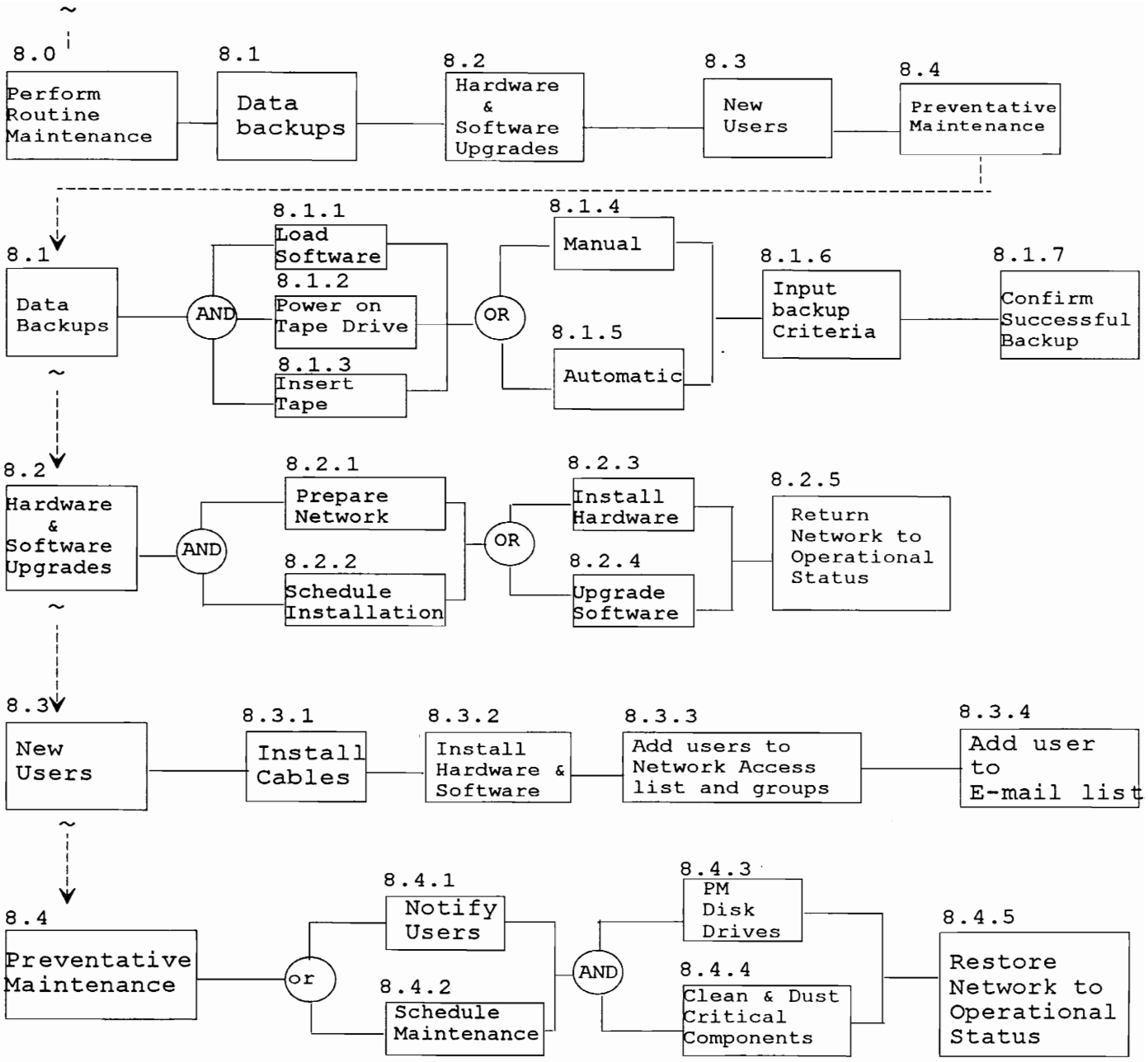


Figure 14a. Maintenance Functional Flow Diagram

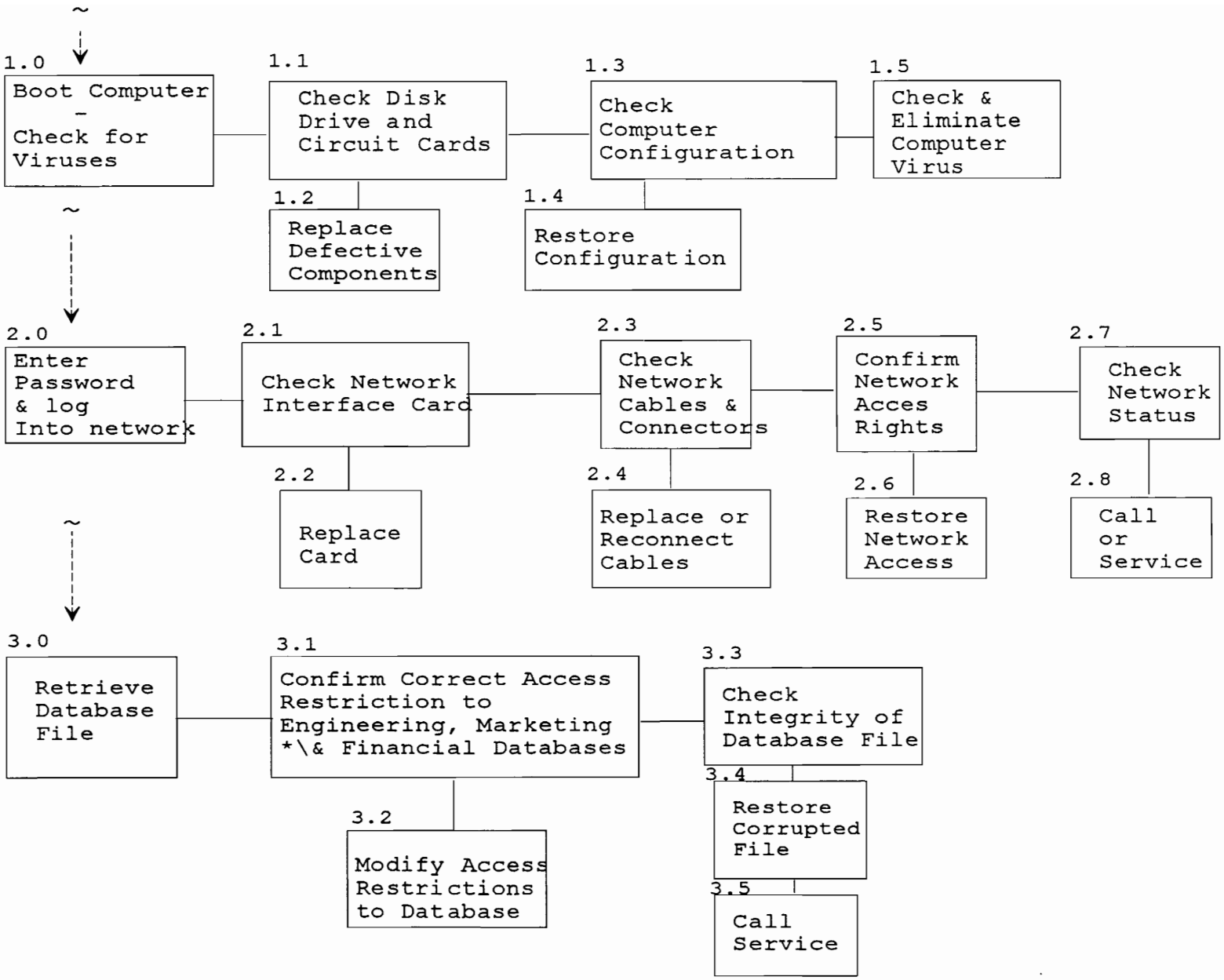


Figure 14b. Maintenance Functional Flow

SECTION 3. B. PRELIMINARY SYNTHESIS & ALLOCATION OF DESIGN CRITERIA

3.B.1. ALLOCATION OF PERFORMANCE FACTORS

3.B.1.1 DOWNTIME

The peak hours shall be designated as 0700 to 1700 Monday through Friday. The off peak hours will be designated as 1700 to 0700, Monday through Friday and all day Saturday and Sunday. The hours of operation will be maintained throughout the 5-year life cycle of the system.

3.B.1.2 HOURS OF OPERATION

All performance criteria shall be met during all office operational hours.

3.B.1.3 NUMBER OF USERS

The performance criteria shall apply to the system where as many as 50 users are on the network at the same time. No performance degradation shall occur with the expected increase in users over the system life-cycle.

3.B.1.4 DATA PROTECTION

The data protection scheme shall ensure 100% data protection against the introduction of computer viruses. The data backup system shall provide 99% reliability.

3.B.1.5 GED, FAD, POM, AND MAD DATABASES

Many factors contribute to the performance of the GED, FAD, MAD, & POM databases. They include reliability, availability,

concurrency, sizing, flexibility, data integrity, backup and archiving techniques, and other constraints.

RELIABILITY

Reliability for GED, FAD, POM, and MAD: 99% available from 0700 to 1700 Monday-Friday.

AVAILABILITY

The GED, FAD, POM, and MAD systems will be available 24 hours per day, 7 days-a-week, except during scheduled backups or downtimes.

CONCURRENCY

Currently, GED, FAD, POM, and MAD will be limited to 50 concurrent users, due to licensing agreement. This number can be increased in the future to accommodate growth.

SIZING

Twelve months of records will remain on-line. GED, FAD, POM, and MAD will require storage and memory to accommodate this need.

FLEXIBILITY

The GED, FAD, POM, and MAD databases need to be flexible and allow changing screens(views) and reports.

DATABASE INTEGRITY

Database integrity is the means by which the data enters the system uncorrupted and remains that way throughout its life. The integrity of the data will be provided for in the following ways:

a. Provision of system security to prevent unauthorized access to GED, FAD, POM, and MAD.

b. Implementation of backup procedures to protect data against software, hardware, and human error.

c. Limitation of data access by allowing groups (financial, program management, engineering, and marketing) access only to their prospective needs. Groups can access data through views and have the ability to update records if access has been given.

BACKUP PROCEDURES

Backup procedures will be performed by the network administrators on a daily basis. Backups of the data will be made to magnetic tape media.

RESTORE

Any files that have been corrupted, will be repaired/replaced by the Network Administrators using backup tapes.

HISTORICAL/ARCHIVE

Data older than twelve months will be archived to tape. At least five years back of financial records shall be maintained for auditing purposes.

3.B.1.6 POWER PROTECTION

The impact to performance from power surges and power failures shall be minimized throughout the use of surge protectors or user computers and UPS for the network servers.

3.B.1.7 OFFICE LAN ARCHITECTURE

RELIABILITY

The network will be 99% available from 0700 to 1700, except during scheduled downtimes and backups.

AVAILABILITY

The network will be available to the users 24 hours a day, 7 days-a-week, except during scheduled downtimes and backups.

CONCURRENCY

The network architecture shall have the initial capability to support 50 concurrent users as designated by license agreements.

SIZING

One year's worth of application data shall be available on the server for on-line retrieval. Any request for archived data shall be made to the network administrators.

FLEXIBILITY

Network flexibility is provided by the MAU. User cable drops can segmented from the network MAU allowing the segmenting of all users attached to that MAU.

INTEGRITY

Network data integrity shall ensure adequate protection against the likelihood of data corruption and unauthorized access.

BACKUP/RESTORE PROCEDURES

All routine backups shall be schedule for non-office hours only. Any necessary restores or backups during office hours shall be scheduled in advance.

HISTORICAL/ARCHIVE

Any data over one year old is archived onto tape. This data can be retrieved by the network administrator upon request.

3.B.1.7 E-MAIL

RELIABILITY

E-mail shall be 99% available during operational hours.

CONCURRENCY

The software must be able to handle up to 50 concurrent users.

BACKUPS/RESTORES

All software and data associated with E-mail shall reside on the network and be backed up using the same backup and restore procedures as identified for all other network software and databases. The network administrators shall have the responsibility of performing all required restores of corrupted or lost E-mail files.

SECTION 3.B.2. SYSTEM SUPPORT REQUIREMENTS

3.B.2 SUPPORT REQUIREMENTS ALLOCATION

Support requirements are derived from the system maintenance plan which supports the customers requirements. Support for the office LAN is required on site at the organizational level, through service requests at the intermediate level, and from equipment repair/replacement at the depot level. The intermediate and depot levels of support are provided through maintenance contracts.

On site support includes the Network Administrators, an inventory of consumable and replaceable parts (and a place to control and store them), and documentation to support the Network Administrator's functions and responsibilities. On-site support also includes all operator and user training.

The Network Administrator's responsibilities include first review of the user complaint, analysis and troubleshooting. The Network Administrator isolates the trouble, and then either initiates the

corrective action, or places a service call with the maintenance contractor.

At the intermediate level, the maintenance contract includes on call support, primarily for replacement of major failed components, such as hosts, Multiple Access Units (MAUs), or user workstations. The maintenance contract provides for removal and replacement with spares for the failed equipment, as well as repair management and reinstallation. The maintenance contractor maintains the inventory of spare hosts, MAUs, and work stations. The maintenance contractor provides tools and small parts necessary for LAN repair/restoration needed for equipment removal/replacement/installation. The maintenance contractor maintains the facilities necessary to keep the spare inventory and the service vehicles. The maintenance contractor provides personnel of the appropriate skill levels to perform the tasks herein defined.

It is a requirement to meet system reliability that the maintenance contractor perform the corrective action within six hours, measured from the time the Network Administrator places the service call. The system availability is a function of the maintenance contractor's performance, therefore the maintenance contract must contain measurement and accountability clauses. The system availability is also a function of system reliability. Given the basic reliability function and the measures associated with failure rate, it would be feasible to consider their application in series networks, parallel networks, and/or combination of the two. These networks are used in reliability block diagrams for reliability prediction and analysis.

Support for applications software is provided by the vendors through the license agreements for that software. Trained users may contact the software vendors directly. This support is considered on

site, and is derived from the user training which qualifies them to review and analyze functionality of the application in use.

SECTION 3.C SYSTEM OPTIMIZATION

3.C.1 TRADE-OFFS

Network Topology

This report does not go into depth on design trade-offs. The Token Ring LAN topology was chosen for the following reasons:

First, the Token Ring topology is the only type of LAN that is fully supported by IBM for use with IBM PS/2s, which has been chosen as the PC that will be the standard for customer expansion. Additionally, of the existing resources, the IBM PS/2 is predominant. The token ring topology will also support the customer's Macintosh base.

Second, the token ring topology has a higher degree of security in that access to the network can be physically controlled at the MAU where all of the cables come together. Workstations in a certain area can be prevented from accessing the network by unplugging them from the MAU.

Lastly, given the token ring network topology, the choice of media is limited to shielded twisted pair and fiber optics. Shielded twisted pair offers the advantage of lower cost per foot than fiber, but other than that aspect, fiber is superior in every way. It is immune to electromagnetic and radio frequency interference and much lighter and smaller. Fiber also has the capability of carrying a much greater bandwidth than the 16 Mbps required by the token ring LAN. Fiber; therefore, can operate at FDDI data rates without further investment in the cable plant. Furthermore, the majority of the cost in installing a new cable plant is in the labor and conduit, not the cable itself, which

reduces fiber's only disadvantage, cost. Given the rapid pace of communication technology development, along with the emergence of standards such as the 100 Mbps Fiber Distributed Data Interface (FDDI), fiber optic cable is the superior choice.

Database & Software Applications

User software was selected on its ease of use, compatibility, and user need. A WINDOWS environment was selected to allow users the option of selecting numerous applications on their desktop.

Word for Windows was selected over WordPerfect, Multimate, and WordStar. This word processing package allows engineering symbols, equations, and diagrams to be easily placed in documents.

The Spreadsheet and Project Management software applications were selected based on cost effectiveness, over TimeLine Project Manager and Lotus 1-2-3.

The E-Mail software was selected due to ease of use for the users and its compatibility with the Windows and Operating System environments. For an office of 50 people, a simple mail system was all that was required.

The Database software, INFORMIX was selected over Oracle, due to lower cost and user friendliness.

SECTION 3. D. SYSTEM SYNTHESIS & DEFINITION

3.D.1. PRELIMINARY DESIGN

Office LAN Layout

The equipment for the Office LAN system is connected via FDDI communications interface. Figure 15 shows the location of user workstations and printers. The cable drops are placed under each workstation and printer location. The network closet shown contains the network and rack equipment.

Office LAN Network Logical Diagram

Figure 16 displays the logical connections of the office LAN. Logically, the LAN is set up as a ring where each workstation will wait for a free "token" traversing the ring in order to put data onto the ring. All user workstations, file server, and LAN management terminal attach to the ring via Optical Data System (ODS) transceivers as shown.

LAN Physical Architecture Layout

Figure 17 shown the physical layout of the office LAN. Physically, the office LAN is a star. Every workstation is directly wired to the patch panel in the rack elevation. From the patch panel, the workstations are plugged into 6 ODS 841-c fiber optic MAUs that form the center of the star. The MAUs will have all ring-in and ring-out ports connected as shown. It is at this point that the LAN can be divided into two rings, if desired, by segmenting MAU ring-in and ring-out ports. This gives users the ability to move from one ring to another by repatching from the patch panel to the MAU. The LAN management terminal is connected directly to an MAU on the ring since it is usually co-located with the file server in the rack of network equipment. The bridge is located in the bottom of the network rack. The bridge allows connectivity of the office LAN to the Prime Contractor's LAN. This connectivity will allow for increased future use of the Prime Contractor's network backbone as the customer, Go-Figure Engineering grows. Additional circuit drops will be in place in case of an immediate need for more ports connections. The additional circuits

drops will not be connected to any workstations by WISE unless an addendum to the contract is written.

Equipment Rack

Figure 18 shows the rack elevation of the office LAN backbone and management equipment. Topology allows local work group LANs (Token ring & Ethernet) to be bridged to the Prime Contractor's backbone. The bridge will utilize a Synoptics 3324S-ST local bridge module with in-band and out-of-band management capability, plus a remote-cross communications ILAN, which will allow for Ethernet connectivity at the Prime Contractor and Token Ring connectivity at Go-Figure. Six ODS MAUs will be mounted in the rack to perform the ring connection. A LAN Management terminal (IBM Model 57 SX) is also mounted into the rack to allow central management of the ring MAU's and facilitate troubleshooting. The management terminal is placed in the center of the rack to facilitate human physical and visual access. Lastly, a 72 port patch panel will be installed in the top of the rack to allow the patching of the user drops, the file server, and the management terminal into the ring.

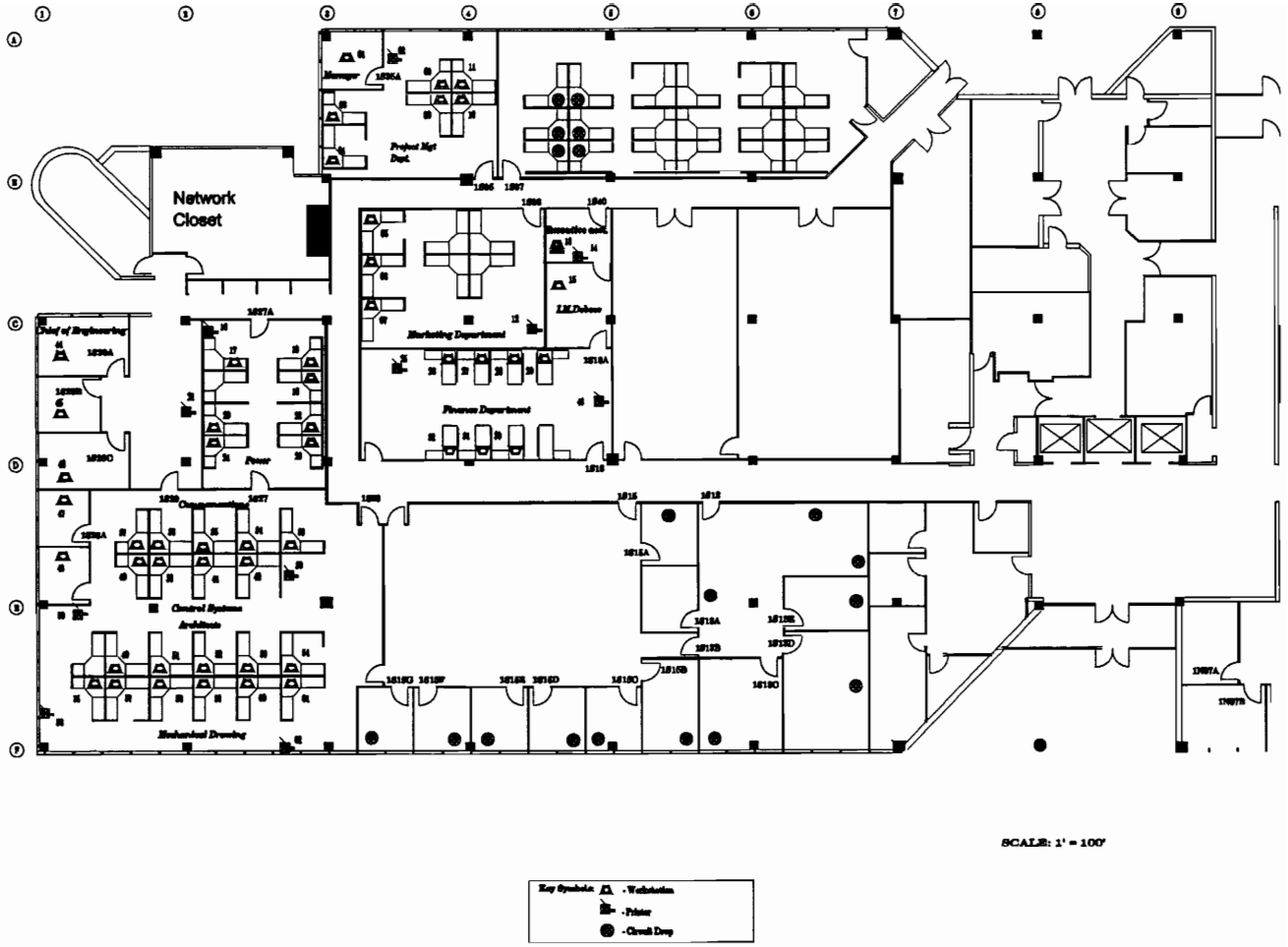


Figure 15. Office LAN Layout

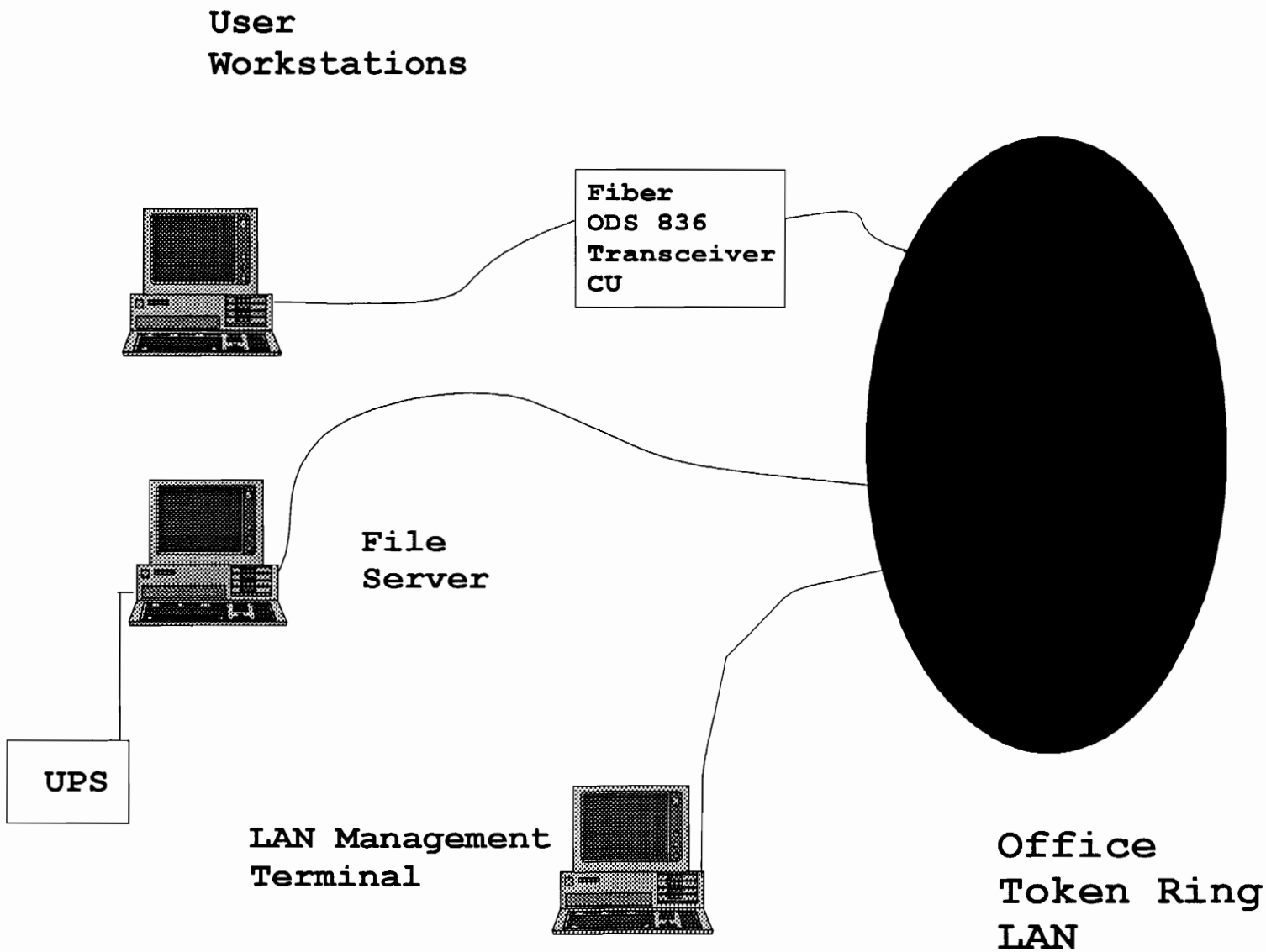


Figure 16. Office LAN Logical Layout

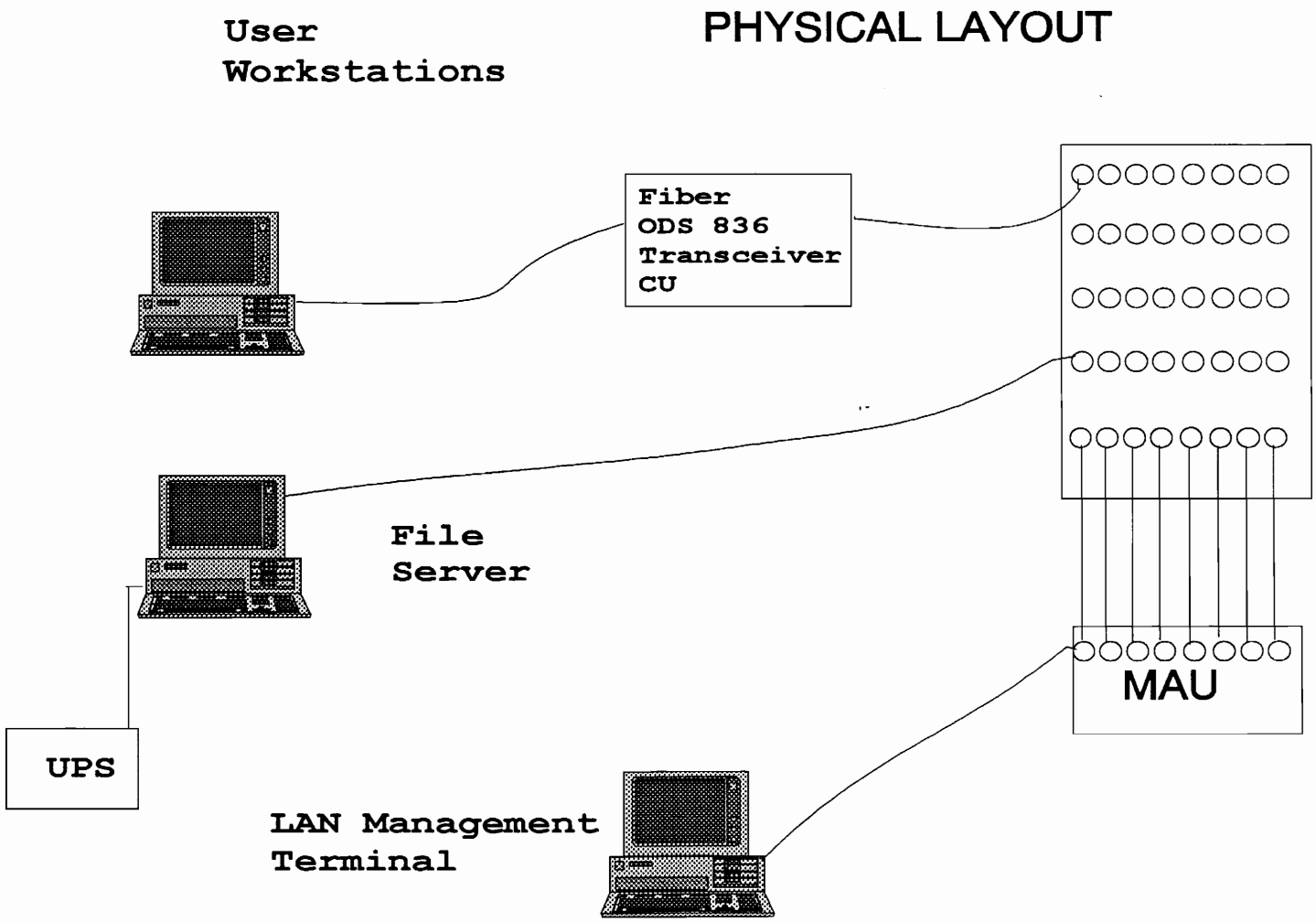


Figure 17. Office LAN Physical Layout

LOCAL AREA NETWORK

CUSTOMER EQUIPMENT ELEVATION

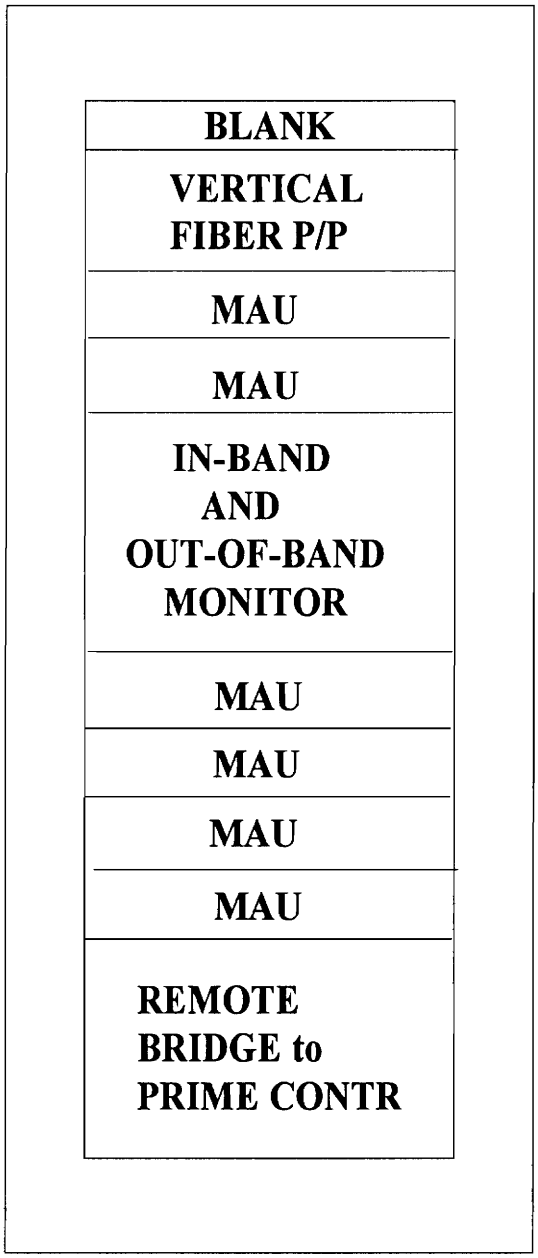


Figure 18. Office LAN Equipment Rack

Network Port Assignments

Each computer attached to the network has a network node address and an associated MAU port assignment. An up-to-date listing of all address and port configurations is maintained by the network administrators. Through the use of the patch panel, any relocation of computers can be accomplished by simply reconnecting the corresponding ports on the patch panel.

The port configuration listed below is designed so that all users within a group are not connected to the same MAU. This ensures that in case of an MAU failure, an entire group does not lose the ability to access the network.

The port assignments for the initial 50 users are as follows:

MAU	NODE ADDRESS	PORT ASSIGNMENT	DEPARTMENT
A	**A234**	**1-16**	**Marketing** **Proj.Mgt.**
B	**B234**	**17-32**	**Proj. Mgt.** **Engineering** **Marketing**
C	**C234**	**33-48**	**Engineering** **Finance**
D	**D234**	**49-64**	**Engineering** **Finance**
E	**E234**	**65-96**	**Available**
F	**F234**	**96-112**	**Available**

3.D.2 DETAILED REQUIREMENTS

The design objective of the Office LAN must meet the operational and maintenance requirements of section 1 and support the allocated design criteria. The proposed office LAN system design must incorporate the necessary characteristics that utilize an optimum balance between parameters such as reliability, performance, supportability, and life-cycle cost.

The detail functional characteristics listed in this section describe the minimum necessary elements that the office LAN design must incorporate to obtain an optimal and cost-effective system design.

3.D.2.1 LAN PERFORMANCE FUNCTIONS

When operational, the office LAN must exhibit the following performance characteristics:

- Provide a communications medium between users, provide applications software and databases, and support the sharing of peripheral devices such as printers and plotters
- Connect 50 users with the capability to expand to 100 over 5 years
- Respond to user requests for database records by no more than 3 seconds during periods of maximum utilization
- Provide adequate storage space for a year's storage of database records

3.D.2.2 DATABASE FUNCTIONS

The office LAN shall support the four identified databases and provide the following capabilities:

- Allow user-specified report generation and creation
- Restrict database access to user groups and/or individuals
- Provide database search and query functions

The LAN shall ensure adequate storage space for future expansion and database use beyond the initial specification.

3.D.2.3 MAINTAINABILITY/RELIABILITY

The office LAN hardware and software baseline design must ensure that the specified reliability requirements are met. Given the fixed reliability parameters of some existing equipment such as personal computers, the specified reliability requirement of 99% with a MTBF of 594 hours must be achieved at the network level as part of the network design.

Inherent availability is "the probability that a system or equipment, when used under stated conditions in an ideal support environment, will operate satisfactorily at any point in time as required." (i.e. 2nd Edition Systems Engineering and Analysis, Chapter 13.3). An example of inherent availability using requirement for this system is expressed as

$$Ai = \frac{MTBF}{MTBF + \overline{Mct}}$$

Where MTBF is the mean time between failure and $\overline{Mct}$ the mean corrective maintenance time. Using the requirements for this project

$$Ai = \frac{594}{594 + 1} = .99 \text{ or } 99\%$$

results in a inherent availability of 99%.

The network architecture must be designed to maximize network integrity and reliability. For example, if users are to be physically connected to the same network interface equipment, the connections should be distributed between groups so that a hardware failure of that piece of the network will not impact an entire group. Also, designed or built-in features must ensure that if one hardware component fails at the network topology level (i.e. cable), it should not bring down the entire network.

The architecture must ensure the easy physical transfer of users from one area to another without a significant cost is running new cable or reconnections.

Adequate network monitoring tools must be provided to the network administrators so that potential problems can be identified in advance of system failures.

3.D.2.4 SUPPORTABILITY

The hardware/software design configuration and the logistic support procedures of the office LAN must ensure that the established maintenance procedures and objectives are maintainable and cost-effective throughout the life-cycle. On-site spares must be adequate so that the specified turn-around-time and expected failure rates does not decrease the number of spares to zero at any time for a particular part.

Intermediate maintenance and depot maintenance contracts described in the maintenance concept must be implemented according to the specified corrective maintenance cycle times. The contracts must be available and contracted throughout the 5-year life-cycle.

3.D.2.5 MANABILITY/HUMAN FACTORS

The skill levels required of the LAN users must not go beyond what they are familiar with in terms of using computers and applications software. Users should only require training on how to take advantage of network capabilities such as E-mail, network printers, how to report problems, and on how to use the new application software. Network function such as security, database maintenance, or modifying user computer configurations are not to be required of the users.

Changes to the existing system and the training plan must be justified by minimizing the potential for user error.

3.D.2.6 ECONOMIC FEASIBILITY

The design decision must take the overall life-cycle costs into consideration. The life-cycle cost must not exceed the projected 1.5 million dollars budgeted for the system.

SECTION 3. D. 3. TEST & EVALUATION PLAN

3.D.3.1 ANALYTICAL TESTING - NOT APPLICABLE

3.D.3.2 TYPE I TESTING

This testing is performed with "jury-rigged" test equipment and is accomplished during the detail design phase of the project.

Procedure

Set-up a stand-alone workstation in Lab (Test Domain/Ring) with IBM PC Model 70, file server, and printer. Load the application software, database software, and several database records.

a. Verify Logon/Logoff to Test domain works properly.
b. Verify workstation can access software.
c. Verify database records can be accessed.
d. Verify that documents can be printed from all applicable applications:
   - Word for Windows
   - Spreadsheet document
   - Graphics example
   - Note from E-Mail

3.D.3.3 TYPE II TESTING

This testing is performed while network and workstations are being created. The first five workstations built are selected to determine the following:

a. Performance factors
   - Is response time adequate for users?
   - Does workstation contain all available icons?
   - Simulate user data loss and verify that data can be effectively retrieved for user
   - Simulate two users logging onto POM, GED, FAD, and MAD databases. Update record at same time. Verify that only one user could update successfully, and the other user received error message that record was locked.

b. Environmental/Structural Testing

This testing has been completed by vendor. Vendor has provided specs on equipment that will be used in network.

c. A verification will be made that all hardware and software are compatible within the network.

d. A verification that the five users can successfully logon and have access to all software applications on their desktop, and that they are successfully communicating with the output devices connected. A test should be run to all known output devices.

3.D.3.4 TYPE III TESTING

This testing is performed during the network evaluation, after having successfully connected all the users to the ring.

a. Verify availability for all users.
b. Verify user satisfaction.
c. Verify software applications on desktop are compatible.
d. Verify database applications are interacting successfully among the various offices - Eng, Fin, PM, and Mkt.

3.D.3.5 TYPE IV TESTING

This testing is performed during Production/System use of the entire network ring. The testing throughout this phase will be to test the hardware of the network, as opposed to software testing. This will be done by monitoring the bridge statistics and overall user performance from the LAN Manager Terminal. If new software is delivered to the desktop, it will go through Testing Type I-III before delivering to the all the users on the ring.

Initial Network test and checkout will consist of the following parts:

Backbone MAU Inspection

Verify that ODS 861-c MAU ports are enabled.

LAN Connnection/Drop Testing

Verify that each user connection/drop location has the capability to log on to the LAN.

LAN Manager Testing

Verify that all monitored components are reporting to LAN Manager and that all segments are operating in Normal condition.
Shut down and MAU and check for LAN Manager event. Bring MAU back up and check LAN Manager for event

Stress and Error Path Tests

Disconnect Ring In or Ring Out of an MAU and verify that other MAU wrap; therefore, healing the LAN. Check that the Auto loop light flashes and LAN segment status is normal. Then Reconnect both connection and verify that the LAN segment status is normal.

SECTION 3.E Life-Cycle Cost

3.E.1 COST BREAKDOWN STRUCTURE

All costs inherent throughout the life-cycle of the proposed office LAN design are illustrated in the cost breakdown structure shown in Figure 19. As shown, the cost are broken down into 4 main categories: System Development, System Procurement, Installation and Training, and Operations & Maintenance.

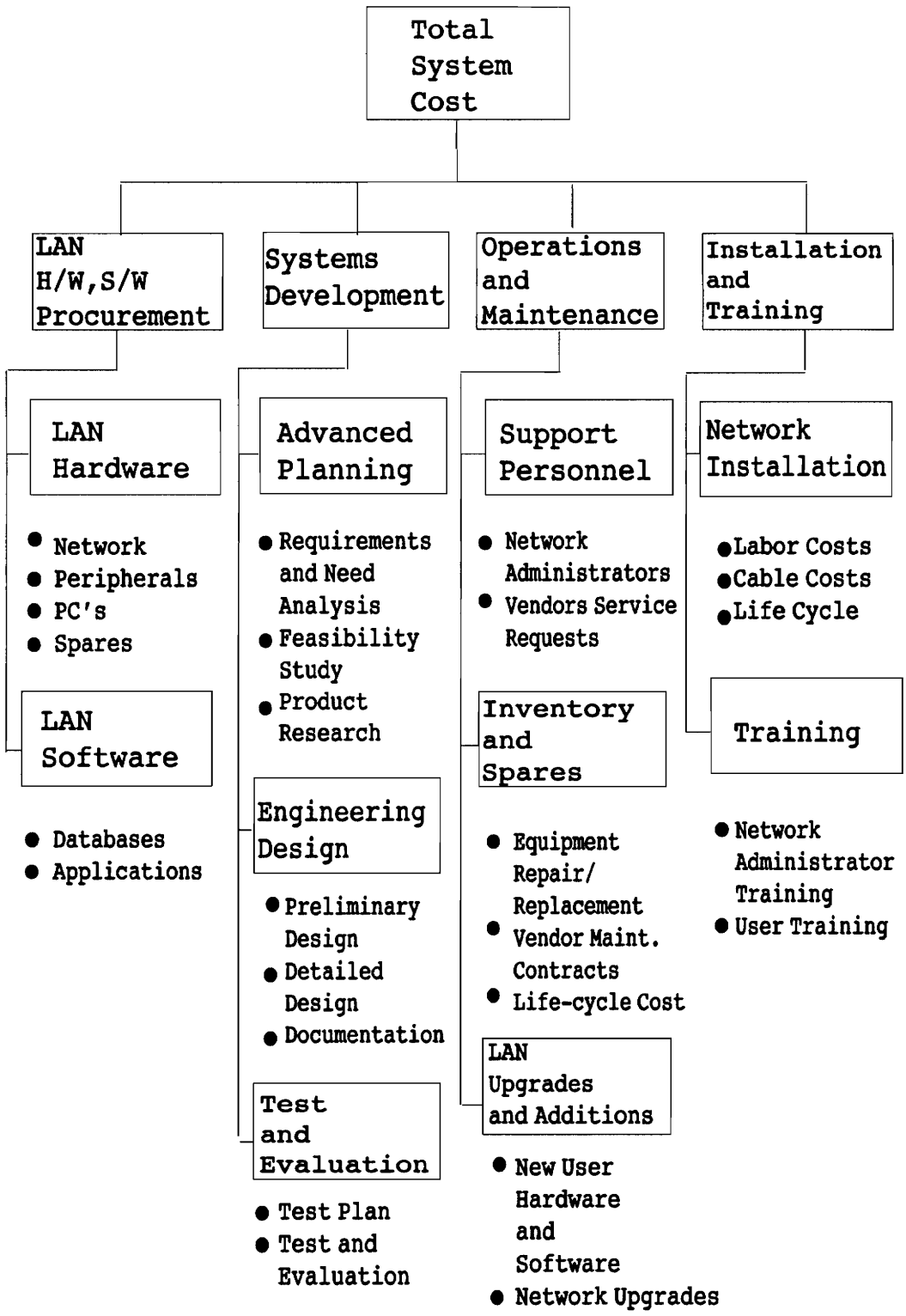


Figure 19. Office LAN Cost Breakdown Structure

3.E.1.1 SYSTEM DEVELOPMENT COSTS

The costs associated with the planning and development of the office LAN system by the WISE contractor are calculated from the number of man-hours required to accomplish the job. Each man-hour costs $50.

TASK	# MAN-HOURS	COST
Advanced Planning	500	$25,000
- Requirements		
- Feasibility Study		
Engineering Design	1000	$50,000
- Preliminary Design		
- Detail Design		
- Design Documentation		
Test & Evaluation	500	$25,000
	TOTAL:	$100,000

3.E.1.2 HARDWARE COSTS

Procurement costs of the LAN consist of all hardware and software costs associated with the installation of the LAN. The hardware costs are as follows:

Equipment Description	**Equipment Part No**	**Design Quantity (Full)**	**Unit Cost**	**Total Cost**
RISC-6000 Database Computer		1	$5,000	$ 5,000
ODS Multistation Access Units	ODS841-c	6	$3,500	$21,000
ODS Token Ring Transceiver	ODS836-G	50	$ 459	$22,950
Token Ring Network 16/4	16F1133	50	$ 601	$30,050

Seicor Consumable Kit	TKT-017	1	$ 190	$ 190
Seicor 2 Fiber	002K81-31141	6000 ft	$ 3	$18,000
Seicor ST/ST Patch cords 1m	J252A4-00000	10	$ 70	$ 700
Seicor ST/ST Patch cords 2m	J252A4-00002	10	$ 73	$ 730
Field Installable ST Connectors	95-100-01	150	$ 8	$ 1,200
PS/2 Type Keyboard		1	$ 75	$ 75
4mb Expansion Memory Option	34F2866	1	$ 788	$ 788
IBM Model 57sx(LAN Manager)	8555081	1	$1,798	$ 1,798
IBM PS/2 Model 70 (20MHz, 106Mb)	8570161	22	$2,014	$44,308
IBM PS/2 Model 70 LAN Server	8570161	1	$2,014	$ 2,014
Brady Data B Labels	DAT40-292-1.0	1	$ 200	$ 200
Amco Rack	S-2258	1	$2,300	$ 2,300
Amco Fan for Rack	BMIPX	1	$ 300	$ 300
800 RT UPS	American Power	1	$2,150	$ 2,150
Draftmaster Color Plotter		1	$7,343	$ 7,343
HP Laserjet III		7	$1,100	$ 7,700
Gigatrend Tape Drive	SL 8309	1	$5,026	$ 5,026
Power Strip Surge Protector		50	$ 30	$ 1,500
Synoptics Local Bridge Module	3324S-ST	1	$4,000	$ 4,000
		Total Hardware:		**$179,322**

3.E.1.3 INITIAL SPARES LIST

The following spares list will be purchased and delivered along with the office LAN.

Part	**Quantity**	**Cost**
ODS MAU	1	$3,500
IBM PS/2 Model 70	1	$2,014
IBM 12" Display	2	$ 880
ODS Transceiver	2	$ 918
Token Ring Network 16/4	3	$1,803

ST Connectors	5	$ 40
HP Toner Cartridges	5	$ 250
	TOTAL COST:	$9,605

3.E.1.4 SOFTWARE COSTS

The total costs for the procurement of the Office LAN software are as follows:

PRODUCT	# OF USERS	LICENSE
INFORMIX Database & Tools	50	$ 2,000
ODS Out-of-Band PS/2 SW	1	$ 200
OS/2 Extended Edition SW	1	$ 398
IBM LAN Manager SW	1	$ 800
Novel Netware 3.11	1	$ 2,202
DOS 5.0	50	$ 1,450
Windows 3.1	50	$ 3,450
Microsoft Word for Windows 2.0a	50	$ 4,500
Excel 4.0		$ 4,700
Autocad	12	$ 4,111
DBase IV	50	$ 1,500
Freelance for Windows	50	$ 3,500
Project Scheduler V	50	$ 4,100
Calendar Creator Plus	50	$ 1,100
CC_Mail	50	$ 2,500
SCAN/VSHIELD Virus software	50	$ 1,250
Gigatrend ServerDat Backup S/W	1	$ 900
	Total Software Cost:	**$38,661**

3.E.1.5 OPERATIONS & MAINTENANCE COSTS

The cost of employing a full-time and backup network administrator is based on the expected number of man-hours required to perform their duties. The expected man-hour costs are as follows:

PERSONNEL	MAN-HOURS	COST PER HOUR	COST
Network Administrator	40/week	$25	$52,000/year
Backup Network Administrator	20/week	$25	$26,000/year
	TOTAL:		**$78,000/year**

Service Requests

It is estimated that one maintenance service request per month will be placed. At $100/hour and an average Mct of 6 hours gives $600 per service request. Thus, the cost of service request per year is $7,200.

Repair/Replacement

The costs for equipment repair and replacement is estimated to be $10,000 per year.

System Upgrades

At 5% growth per year, the system baseline will grow 25% over the 5-year life-cycle for a total increase of 12 users. Neglecting inflation for simplification, an additional 25% is added to the procurement and installation costs.

3.E.1.6 INSTALLATION AND TRAINING COSTS

The labor cost for installing the system is estimated to be 20% of the initial hardware cost, or $36,000. The cost for the drop cables is $2,600 per drop. At 50 drops, the cost is $130,000.

The training costs for the network administrator based on the recommended training plan are as follows:

CLASS	# OF PERSONNEL	COST/PERSON	COST
Introduction to Networking	2	$ 295	$ 590
Netware on Windows 3.1	2	$ 695	$ 1,390
Netware 386 System Manager	2	$ 895	$ 1,790
Netware Service & Support	2	$1,745	$ 3,490
LANalyzer Basics	2	$ 795	$ 1,590
Initial User Training	50	$1,500	$75,000
		TOTAL COST:	$83,850

The cost identified in the cost breakdown structure are summarized as follows:

COST ELEMENT	COST
System Development	$100,000
Hardware Procurement	$175,722
Software Procurement	$ 36,511
Installation & Training	$249,850
Operations and Maintenance	$ 95,200
Spares	$ 9,605
TOTAL First-Year Cost:	**$666,488**

3.E.1.7 Total Life-Cycle Cost

The costs throughout the 5 year life-cycle of the office LAN are shown in Table 8. An inflation factor of 5% is assumed.

TABLE 8. Life-Cycle Costs

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Initial Cost	$666,488	------	-----	-----	----
Network Administrators		$82,000	$87,000	$92,000	$ 98,000
Maintenance Contract		$20,000	$25,000	$31,000	$ 38,000
Additional Users		$112,500	$123,025	$134,600	$148,200
Spares		$ 10,000	$10,600	$11,800	$13,500
TOTAL:		$214,500	$235,025	$268,400	$297,700

TOTAL LIFE-CYCLE COST: $1,025,625

The total life-cycle cost of the office LAN system is about one million dollars. This is 500k below the projected budget of 1.5 million dollars.

SECTION 4. DETAIL DESIGN AND DEVELOPMENT

4.A. DETAIL DESIGN OF FUNCTIONAL SYSTEM

4.A.1 HARDWARE REQUIREMENTS

4.A.1.1 NUMBER OF USERS

The token ring configuration will provide 50 drops for the initial number of users.

4.A.1.2 EXISTING RESOURCES

All the computer hardware currently used in the office shall be fully integrated into the proposed network architecture. Each computer will have a token ring network interface card and be attached to a MAU drop.

4.A.1.3 DATA PROTECTION

The proposed tape backup system is the Gigatrend ServerDat v.4.0 Tape drive using 1.2 Gigabyte DAT tapes. This system is fully compatible with Novell Operating System and token ring configuration.

4.A.1.4 GED, FAD, POM, AND MAD DATABASES

The database with the INFORMIX software is designed to operate on a RISC-6000 computer. This computer will be attached to an MAU port and be located with the Token Ring LAN server in the network closet shown in the office layout diagram.

4.A.1.5 POWER PROTECTION

Surge protection for user computers shall be provided by power strips with in-built surge protection. The UPS for the server shall be provided by the 800 RT UPS from American Power Conversion Company.

4.A.1.6 OFFICE LAN ARCHITECTURE

The following additional computer resources shall be procured for the new system to accommodate 50 users:

Additional Computing Resources

1 Draft master Color Plotter

(6) ODS 841 Multistation Access Units (MAUs)

ODS Token Ring Transceiver (one for each terminal on the LAN and bridges

(1) Seicor Consumable Kit

(150) Field Installable ST Connectors

(1) PS/2 Type Keyboard

(1) IBM Model 57SX (for LAN Management Terminal and local bridges)

(1) IBM Mouse

(1) Brady Data B Labels

(1) Amco Rack

fiber (ft)

(1) 4mb Expansion Memory Option (for LAN Management Terminal)

Token Ring Network 16/4 Adapter/A (1 for each terminal on the LAN)

(1) Amoco Fan for rack

(23) IBM Model 70's (386)

(7) HP LaserJet III printers

(1) 800 RT UPS American Power Conversion Corp.

4.A.1.7 CABLE CONNECTIVITY

A total of 6000 feet of fiber optic cable will be used for the wiring plant.

4.A.1.8 CABLE DISTRIBUTION AND ROUTING

All of the workstation attached cables will be returned to a central distribution point where they are all connected to the network via a MAU. Multiple MAUs are 'daisy chained' together to connect all of the nodes together, forming the network token ring.

The fiber cable will be distributed to the 50 locations chosen by the customer shown in the office LAN layout diagram. It was recommended to distribute fiber to each possible work location within the customers workspace to allow for future expansion. The bridge is connected to the Prime Contractor's location via fiber.

4.A.2 Software Requirements

4.A.2.1 E-MAIL

The E-mail software CC_MAIL satisfies all the functional requirements and is fully compatible with the chosen local and network operating system environments.

4.A.2.2 EXISTING RESOURCES

The existing Windows environment with upgraded software versions shall be used on the new Office LAN. Updated versions of the software shall be procured when necessary.

4.A.2.3 DATA PROTECTION

Gigatrend ServerDat v.4.0 Tape backup software shall reside on the network server and is fully compatible with the Novell operating system.

Computer Virus Protection software is provided by the program SCAN and the memory-resident program VSHIELD, both manufactured by McAfee Associates.

4.A.2.4 GED, FAD, POM, AND MAD DATABASES

The database computer shall be a RISC-600 computer attached to the LAN and utilizing the following software:

OS/2 Operating System
INFORMIX Database Software (1 copy used for all 3 Databases)
INFORMIX - 4th Generation Tool for Report Writing
1 copy used for all 3 Databases)

4.A.2.5 POWER PROTECTION

The built-in Novell Operating System UPS interface software shall be used to establish the necessary communications and interface with the identified UPS unit.

4.A.2.6 OFFICE LAN ARCHITECTURE

There is a variety of software required. Every workstation will require an operating system and access to a word-processing, database, spreadsheet, drawing, project management, calendar, and E-mail program. In addition to the application software, a network operating system is

required to connect all users together. Utility software is also necessary to operate and maintain the network.

Since the office must continue to operate throughout the transition to the new system, consideration is given to existing software owned by Go-Figure in order to minimize the learning curve. Go-Figure's existing software packages were examined to determine which would optimally support all LAN users whereby one package was chosen in each of the functional areas. Note that some of the existing packages will become obsolete in this design and where there is no existing package to meet a desired need, a commercial package is chosen.

User Application Software

Graphical User Interface: Windows 3.1
Word-processing: Microsoft Word for Windows 2.0a
Spreadsheet: Excel 4.0
Graphics: Auto cad
Database Package: Database IV
Presentation Package: Freelance for Windows
Project Management: Project Scheduler V
Calendar Program: Calendar Creator Plus
E-mail Program: CC_MAIL

A site license for 50 people will be purchased for the software listed above.

LAN and User Computer Operating System Software

(1) ODS Out-of-Band PS/2 SW (for LAN Management Terminal)
(1) OS/2 Ver 2.0
(1) IBM LAN Manager SW
(3) Token Ring Bridge Program V2.2

(1) Novell Netware 3.1.1

(50) DOS 5.0

SECTION 4.B. LOGISTIC SUPPORT/SUPPORT FUNCTION

This system requires minimal logistics support. The Go-Figure engineering office is not in the computer maintenance business, so most support functions will be handled in a maintenance contract. The needs must be defined in that contract. The few on site requirements must be defined, as well as the training program.

4.B.1 ONSITE NEEDS

List Inventory - hard drives, I/O cards, Network Interface Cards, keyboards

List consumables - paper, ribbons, toner cartridges, floppy diskettes, tape cartridges

Trained operators and users.

Network operators shall be trained, shall reside onsite, and shall maintain the LAN operating capability. In the case of degradation or failure, the onsite LAN operator shall resolve the problem and either

correct or initiate a maintenance call to the contracted provider, depending on the type and severity of the discovered condition.

4.B.2 TRAINING NEEDS

System requirements dictate two operators, each trained in systems, network, and database operation and maintenance functions. Training shall be conducted onsite by a qualified contract trainer with an instruction plus OJT method. Training shall include:

- network configuration initiation and maintenance;
- bringing the network up and shutting it down;
- utility, diagnostic, and performance monitoring tools;
- analysis techniques regarding network performance;
- access control establishment and maintenance;
- database access control;
- database synchronization and maintenance.

System Manager and Advanced System Manager Training Plan

The System Manager course teaches system managers new to Netware, the skills necessary to effectively manage a NetWare version 3.11 network. Through hands-on training, worksheets and team projects, students will learn to create login scripts and menus, select network applications and archiving procedures.

The Advanced System Manager course is designed for experienced Netware v3.11 system managers and teaches skills in monitoring and maintaining a NetWare v3.11 network. It features higher-level system management such as maintenance and memory management procedures. This course is software oriented; students use NetWare utilities to perform system management activities.

User training shall be provided in one day sessions, half in the classroom, half at the terminal. User training shall include;

- Logon, Logoff procedures;
- access to applications;
- access to and from mail;
- I/O management and maintenance;
- Error messages and meanings, and recovery methods.

Introduction to Networking

The Introduction to Networking course will provide an overview of networking concepts for people relatively new to the computer industry who need an overall view of networking technologies; and sales and marketing people who need to know industry terms. Networking literacy is enhanced through introduction to the industry language and expanding technical expertise. Networking is introduced, a data communications framework provided, and the popular industry protocols are introduced.

NetWare for Macintosh Connectivity

This course teaches students the skills necessary to effectively manage a NetWare for Macintosh network. Students learn Macintosh network terminology, addressing routine and user interface. Students receive hands-on experience using the Netware Desk Accessory and the NetWare Control Center.

Networking with Windows v3.1

This course covers the network concerns for planning, implementing, and managing Windows on a Netware or LAN Manager network.

4.B.3 MAINTENANCE CONTRACT

The majority of the system support shall be supplied through a maintenance contract. Response to failures shall be categorized and prioritized as to severity, and shall be quantified to meet the system availability requirements.

There shall be four failure categories, listed from the most to least severe:

1. Host failure - the system is down
2. Bridge failure - a portion of the backbone is down
(note that cable and connection failures can cause symptoms that simulate bridge failures. The network operator should be sufficiently well trained to diagnose the difference).
3. Terminal failure - one user is down.
4. Other failure - system is somewhat degraded, but operating and supporting full connectivity.

SECTION 4.C. UTILIZATION & SUPPORT

Once the system is put into service, the Network Administrators shall audit and log system activity. Particularly, they shall maintain logs of all failures, the nature of the failures, the downtime and level of downtime, and response times for return to service. These statistics shall be maintained in addition to the normal day to day logs and analyses that are performed.

These statistics shall be the basis for failure and trend analysis, and these analyses in turn will indicate whether corrective action is required. Should the system availability become unsatisfactory, then these statistics shall be reviewed to try to find the cause and then correct it.

SECTION 4.D. PHASE-OUT & DISPOSAL

The system shall be fully configured and operated for five years. At that time, and while continuing to operate, the system shall be studied and the design reviewed. The review goal shall be to recommend modifications needed to continue service to the office. The following issues must be included in the review:

- Equipment age and effectiveness
- Software obsolescence
- Office size and growth, and expected growth
- Data maturity
- Company configuration and focus
- Maintenance plan for the next five years
- New products.

Again, an attempt shall be made to conserve existing resources as much as possible and to streamline the work. The study shall begin at the fifth year of the system life cycle. New recommendations are to be implemented beginning at the sixth year with the objective to be complete by the middle of that year.

SECTION 5. CONCLUSION AND RECOMMENDATIONS

SUMMARY

Wide Insight Systems Engineering is tasked to design and install an Office LAN that will consolidate and coordinate the office resources of the Go-Figure Consultants organization. WISE shall provide all systems engineering support activities from design to installation.

ORGANIZATION

The organization structure of the WISE team consists of employees from the Research and Engineering division. Teams are broken down in areas of research, engineering, design, and test & installation. The general WISE organization structure used in systems development efforts is shown in Figure 20.

SUPPLIER OR SUBCONTRACTOR REQUIREMENTS

Subcontracts are required from the appropriate hardware and software vendors to provide logistics support. In addition to procurement and logistics support, service maintenance contracts for technical support shall be established through WISE.

WORK BREAKDOWN STRUCTURE:

Figure 21 illustrates the work breakdown structure of all the program tasks required of WISE to develop and integrate the office LAN for the Go-Figure organization.

SCHEDULE

Go-Figure has indicated an immediate need for a LAN but will accept as much as one year before having a fully operational LAN. Based on this

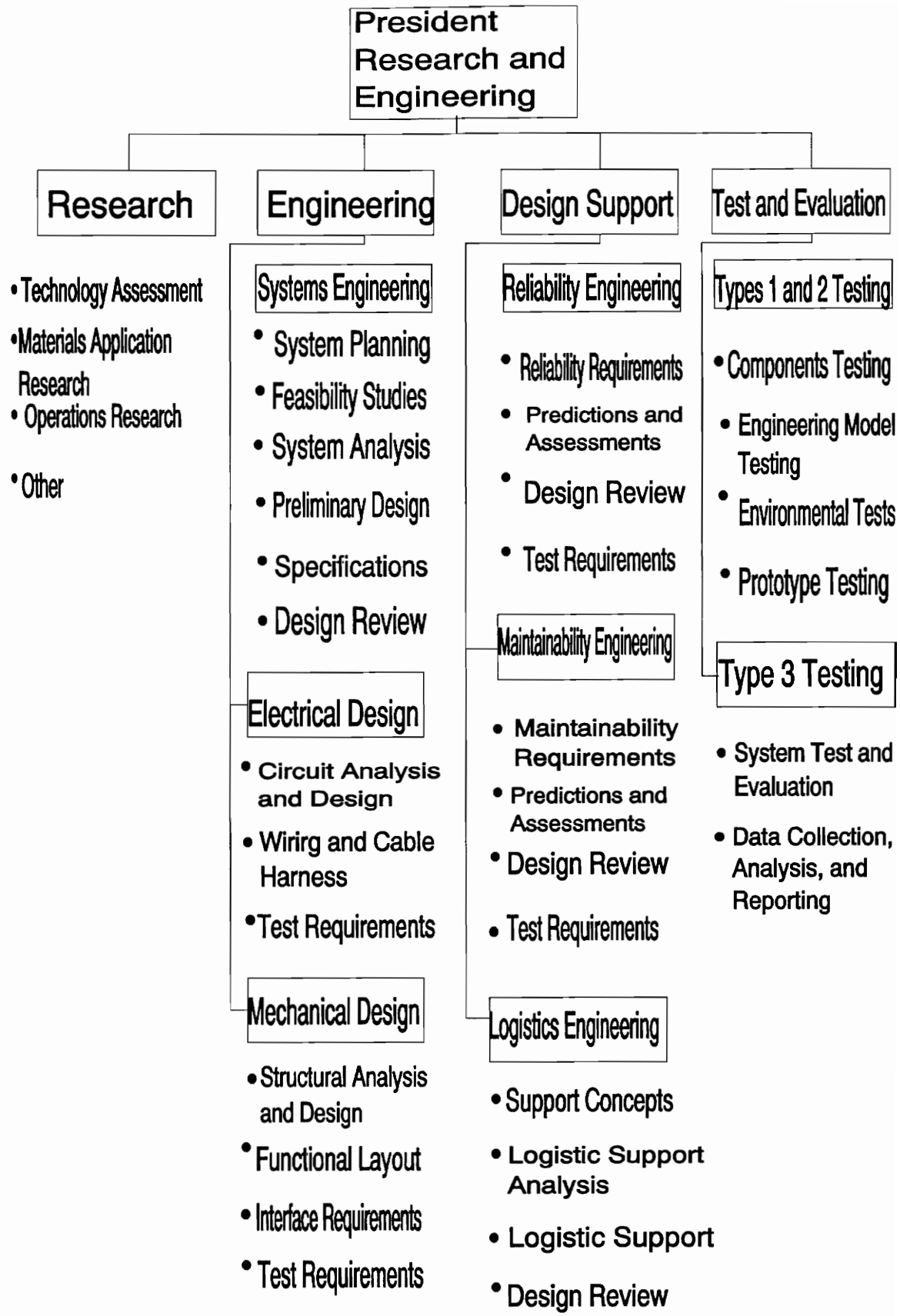


Figure 20. WISE Contractor Organization

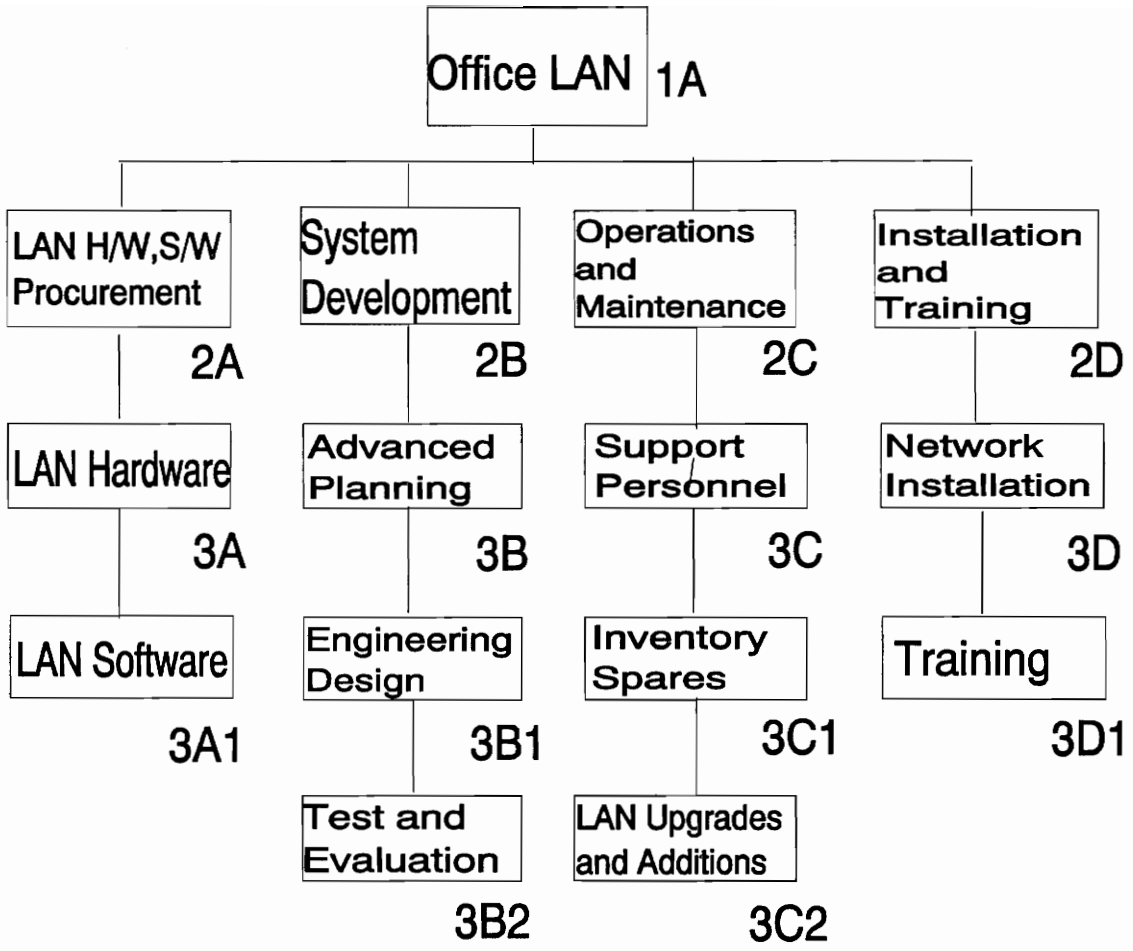


FIGURE 21. Work Breakdown Structure

requirement, WISE has appropriated resources and proposed the following schedule.

- Three months for system need and requirements development
- Two months for systems analysis and preliminary design
- Two months for detail design with developed Test, Installation, and Training Plans
- Two months to procure and test system design
- One month for training and installation of system

Thus, the total time estimated from the WISE statement of work and resource considerations to deliver a working system is estimated to be 10 months. Every effort will be made to work within this schedule and keep the customer informed of all progress made, delays, or changes to the design or requirements.

RECOMMENDATIONS

The System Engineering Process proved useful in arriving at a favorable configuration for this project.

The System Engineering Process is recommended for this project because of:

- Cost
- Complexity
- Performance

The System Engineering Process of the Development of a Local Area Network Report can be used as a format to assist the Systems Engineer in following the Systems Engineering process for any project.

The System Engineering Process of the Development of a Local Area Network Report can also contribute to giving insight to the entry level engineer as to what it takes to complete a major project.

There are a number of tools that may have been utilized in this project to support the selection of critical spares. One of the more common tools is the Failure Mode and Effect Analysis (FMEA). The FMEA is implemented during the early stages of preliminary system design to identify possible problems that could developed as a result of system failures. The FMEA is oriented to equipment only. The objective is to determine ways in which equipment can fail and maintain a critical spares inventory to minimize downtime.

The system engineering process requires the systems engineer to have some knowledge of the functions necessary for bringing this system into being. Depending on the scope and the complexity of a system, the application of engineering functions implemented will vary.

APPENDIX A. DEFINITION OF NEED DIALOG MEMOS

1.A.1 CUSTOMER NEED DEVELOPMENT

This section contains the process followed to develop the customer needs. The requirements development is presented as a case study, beginning with the customer contact and proceeding to the identification of the customer's operational requirements and the deficiencies with their current system.

An engineering consulting group call Wide Insight Systems Engineering (WISE) has been chosen to develop an automated office information system to meet the needs of Go-Figure Engineering.

The customer need identification was accomplished by the following events:

1.A.1.1 Customer contact letter. This letter outlines the customer's need for a LAN and management system to augment the office computing resources.

1.A.1.2 Customer responses to system requirements posed by WISE. The customer was unable to provide complete answers to all questions. This is expected since the customer is relying on a third party for support in this endeavor.

1.A.1.3 A customer memo giving insight into database use, the duplication of effort and data, the fundamental customer need, and the customer statement of cost parameters that set the project cost environment.

1.A.1.4 Statement of customer growth expectations and LAN resources required to service that growth.

1.A.1.5 Top level WISE financial analysis which confirms the cost constraints and possible strategies.

1.A.1.6 Top level WISE operational analysis, based on the customer description. This analysis identifies the duplication of effort, and drives the design for the Go-Figure office LAN.

1.A.1.1 **CUSTOMER CONTRACT LETTER**

7 September 1992

To: Wide Insight Systems Engineering (WISE)

From: Go-Figure Engineering, Consultants

Subject: Office Information Consolidation

We are a consulting engineering firm that has grown considerably since our start 3 years ago. We have gone from our original 10 members to a staff of 50.

Our original staff, 5 engineers, finance boss, sales boss, project manager, my assistant and myself each began with our own personal computer. The PCs were stand-alone and selected to each person's taste and purpose.

With our expansion to an employee base of 50, we have become uncoordinated in our office, maintaining several separate databases in several applications on several platforms. We expend considerable effort translating and transferring data among the databases. There is duplication in the databases where it should be in synch; that is, the same in each database at a given moment. We have added equipment as growth demanded, but without any consistent plan. In addition, we have no connectivity to the Prime Contractor's main office, which is located in the same city. Included as a separate attachment is a brief outline of our resources, provided by our chief engineer, Izzy Digitkopf.

Our engineering department has wired together their own computing resources to share data and printers. This network is unofficial, and not built to any standard. The engineering department is busy and backlogged with projects, and we cannot afford the decrease in customer service that would result if we

assigned this office consolidation/network problem to them.

Our need is to consolidate and coordinate our office resources. We need to eliminate as much duplication as possible, and allow the sharing of electronic data. As you can see in the attachments, we have a significant investment in PCs and software that we desire to preserve.

Figure 1 illustrates the organization of personnel and groups within the company. Figure 2 displays the current computer resources and how they are distributed among the various groups.

We would like your thoughts concerning our situation. If interested, please respond with any questions, or we can meet at your earliest convenience.

Sincerely,

I. M. DeBoss

1.A.1.2 CUSTOMER RESPONSE TO REQUIREMENTS QUESTIONS

21 September 1992

To: Wide Insight Systems Engineering

From: Go-Figure Engineering

Subject: Initial Response to 17 September, 1992, meeting.

Reference: Minutes of the Meeting 17 September, 1992.

This memo contains the initial responses to questions raised at our recent meeting where we discussed your request for additional information concerning our requirements. Not all questions are answered, and some are answered only partially. Some items require more research and some need your further review.

1. What is the projected budget?

It is our desire to identify a feasible system, then have Wise Insight review the system and provide a relative order of magnitude estimate. We are committed to this quality improvement to our company, as we have studied lost productivity due to duplication and inconsistent data.

2. Are departments to be segmented? Describe department interaction.

We wish to establish inter-departmental information flow as a result of our office consolidation. Our financial data is sensitive and will be subject to close control. Our costs, especially including payroll, billing rates, and overhead structures are to be maintained separately and accessed by the Finance department only. However, models that include the

amount of time taken to accomplish identified tasks are to be shared with marketing and engineering for project development.

The engineering databases and libraries are to be shared by all engineering disciplines and marketing. Document production facilities, especially including company templates, are to be available company wide.

3. What are the E-mail requirements, if any?

All users will be able to send and receive messages.

4. What access control is needed?

A more detailed discussion on this issue is needed. In brief, company financial data must be protected. This data includes payroll, accounts payable and receivable, cost structures, and proposal cost data. By law, personnel records must also be kept confidential, so protection of this data must also be guaranteed. Engineering data, by contrast, is to be largely available to the users.

Entry into the data from outside the office is not to be allowed. There are cases we expect to share data, but only when packaged by an engineer and approved by management.

5. How much down time can be tolerated for installation and cut-over?

The office cannot afford to be out of commission. We realize that some disruption will be necessary. We will have to negotiate a reasonable cut-over plan, perhaps in phases, but we will have to maintain some capability throughout the process.

6. What training will be needed?

We will need to have all users be familiar with start and stop procedures, sign-on, sign-off, and how to navigate the system to find and use their data. Again, the whole office

cannot be out at the same time, so a phased plan is attractive. For most users, a "how to drive" simplified training should be sufficient. For a few designated employees, a more in depth "how the engine works" training is desirable.

7. What are the plans for the office? Will it be growing? Will it move?

For the purpose of preliminary plans, the office as it exists should suffice. The contemplated system should be at no more than 50% capacity when installed.

8. When is the new system to be put into operation?

The need is immediate. Full capability within a year, phased capabilities as soon as possible is desirable. Connectivity to the Prime Contractor's main office to be installed within the first year.

9. What will be the hours of operation?

Generally we work one shift during the weekdays (about 0800 to 1700), but hours frequently extend into the evening. Some employees also like to work on the weekends.

10. How many people will use the system, and how many terminals are to be provided?

The office has 50 workers, and each requires a terminal.

11. What software packages are to be used ,and by which users?

A variety of software is used throughout the office now. A more complete profile will be developed. In our previous letter, we gave a general indication. We will need a word processor, a database, a spreadsheet, autocad, a simpler graphics/presentation program, project manager, and a company calendar.

12. What communications facilities (if any) are desired with outside entities?

Open for review. We have no clear requirement at this time.

13. What are the requirements for network management? Will Go-Figure provide a network manager?

We need to review this topic more to see what is needed.

14. A set of mechanical drawings is needed showing office layout, existing conduit, piping, wiring, etc. Drawings are needed in lieu of a site survey.

Will be supplied at a later date.

15. Can existing resources be assigned to the file server?

Probably, if the existing plant has suitable equipment. You can use the existing resources in the configuration you think is most beneficial. We look forward to your suggestions.

16. What down time can be tolerated?

With fifty terminals to serve fifty users, some outages can be tolerated, but not for long. We certainly do not want a whole department down if possible. Out of 1850 billable hours per year, budget no more than 18.5 hours downtime per operator per year.

17. Is redundancy desired? What system reliability is desired?

If redundancy is the best way to ensure we keep working, we will consider your suggestion. As in the previous item, some workstation outage can be managed, but a department down is a loss we cannot manage. About the only advantage we can see to our current stand alone configuration is that we never lose them all.

18. What data protection is needed?

Automatic daily backups of data is required at a minimum.

Further statement/clarification is needed to define additional measures.

19. A profile of databases is needed to plan operational concept.
Data profile will be supplied later.

20. What power protection is needed?

Computer equipment should be protected from power company events, Sufficient power resources should be provided to prevent loss of configuration or significant data during extended power events. Our assumption is that the commercial power will provide sufficient continuity for our daily activities. Power protection backup facilities to run all office terminals are probably not necessary. We would need to protect central stores and controllers.

21. Describe office environment: temperature, ventilation, activity, any special issues.

Office is typical air conditioned and ventilated space. No special facilities are provided. Sufficient power exists, but is supplied from the commercial grid.

I hope we can continue to work together to develop this project.

1.A.1.3 CUSTOMER COST PARAMETERS

20 Oct. 1992

To: Wide Insight Systems Engineering

From: Go-Figure Engineering, Consultants

Subject: Cost Parameters for Office LAN

This memo discusses the range of cost that Go-Figure Engineering can bear for the office LAN system. Although we have considerable computing equipment, lack of planning and coordination have lead to significant duplication of effort and data maintenance. We have 50 employees, and of these, only three are strictly unapplied. The rest can bill their time directly to the contract. The goal of the automated office system is to approach the 100% billable hours. If this goal cannot be met, a realizable target should be identified.

Due to our current office configuration, much billable time is lost due to information maintenance of one sort or another. The following is an estimate of that lost time. We expect to pay for the new system from the savings. The automated office should be configured to provide service, and after five years, be augmented and updated as necessary. One half the savings will be allocated across the five years to pay for the system. The office efficiency can be assumed constant over the next five years.

The executive, assistant and finance chief do not charge directly to contracts. All other employees can charge directly to contracts. A special shop order charge accounting number has been opened to cover support that seems to be house cleaning and coordination, and can't be billed to particular projects. The Go-Figure

billable year is considered to be 1850 hours. The following overhead charges were applied last year:

Finance charged 3080 hours. A fair part of the time was collecting charges to projects and translating them to payroll. Contract charge hours and payroll are separate. Much effort was also spent coordinating with marketing to provide a consistent cost baseline based on hours charged to existing contracts. The average billable rate in finance is 40$/hr, or a $123,200 loss.

Marketing charged 3440 hours. The burden fell on the assistants, which helped keep the cost down. Unfortunately, marketing needs data from all departments, and coordination with finance for cost models as well as engineering for technological information is very time consuming. The pricing data is very sensitive, and considerable effort is consumed segregate this data, although it relies on much of the financial and engineering data, and is not static. The average rate marketing levied against this shop order was $37.50/hr, or a yearly loss of $129,000.

Program management also charged a significant burden, 2990 hours. There is debate that PM carried some of the engineering burden (program managers hate to sign off on overhead accounts for engineers), but ultimately, what has been charged is history. PM maintained contract performance data (on a productive charge number), but packaged the data for both finance and marketing. The program management hourly rate was $55, and could be more, but assistants are assuming the majority of the work. The year's loss is $164,450.

Engineering charged, on a per capita basis, the least against the overhead account, but a 4200 hour charge was still levied. Some say not bad out of a crew of 25 engineers, but these are all professional level people, and the billable heart of the company. Much time was spent on maintaining the engineering home brew network (which the engineers claim automates enough processes to be cost effective, but which seems to be constantly reconfigured to meet the need of the day), and even more time is spent providing PM, finance, and marketing their packaged data. The average Go-Figure engineer is billed at $75/hr. The loss for the year is $315,000!

The overhead charge number was set up because these maintenance type activities were not bearing the scrutiny of our customers. After the year's review, we discovered that the loss represented by the account was $726,200. Of our potential 86,950 billable hours, 13,710 were lost, or almost 16% gross receipts, or almost seven and a half people!

Please use this information to tailor your system design. Remember that we intend to budget half the loss, considered for the next five years, to this project.

1.A.1.4 EXPECTED COMPANY GROWTH

20 Oct 1992

To: Wide Insight Systems Engineering

From: Go-Figure Engineering, Consultants

Subject: Expected Company Growth

This memo addresses your question about growth and future system usage. The next year, due to a backlog, we will grow 10%. Each of the following four years, our target is to grow by 5%, which we feel is modest and achievable. For your design, translate this data directly into new users. Connectivity to the corporate office is also vital. It will save us travel to and from that location. It is our intent to review this system in four years, and assess its value to the company. Should our sales targets be met, we will need to update and expand our system accordingly. Your design should address the first five year's growth, and consider the possible next five years.

1.A.1.5 COST ANALYSIS REVIEW

26 October 1992

To: Wide Insight Systems Engineering

From: Go-Figure Engineering

Subject: Cost Analysis Review
Design Statement
System Architecture

Reference: Cost Parameter for Office LAN (1.A.1.3)

Per your review of the cost loss analysis provided in the reference memo, we are providing more details on the current operating environment and depicts the activities that cause the loss. Figure 3 is the database architecture of the Go-Figure office, based on the referenced memo. Each encircled copy depicts a manual data copy onto media which is then physically transported to another electronic platform. Loss is incurred in transfer time and data accuracy: there is no systematic check for data coherence.

The design objective, then, is to provide the electronic environment that eliminates the depicted copy functions, and provides the data transfer and maintenance functions. Figure 4 shows a general system environment/architecture that can be used to implement the design.

Sincerely,

I.M. DeBoss

1.A.1.6 OFFICE OPERATION

29 October 1992

To: Wide Insight Systems Engineering

From: Go-Figure Engineering, Consultants

Subject: Office Operation

We appreciate the analysis in your most recent memo. We agree and are excited by the prospect that such a system can be provided. To give a better picture of how our office works, we have produced a flow chart describing database activities. The database flow describes the mechanism for processing changes to existing projects (Step I), processing new proposals (StepII), and project processing once a bid is accepted (Step III).

1.A.1.7 DATABASE STRUCTURE AND OPERATION

To: Go-Figure Engineering

From: Wild Insight Systems Engineering

Subject: Database Structure and Operation

Ref: Office Operations

The reference memo provides considerable insight into your system needs. Our perceptions have been recorded here for your review.

The Go-Figure office maintains four data areas: finance, marketing, program management, and engineering. We have provided sketches of each (attached), showing data inputs and outputs, and reports generated.

FINANCIAL DATABASE

The Financial Database Flow is illustrated in Figure 5.

Data types are: payroll, skill levels, labor rates, overhead rates, actuals, profit and loss data, correspondence.

Reports are: Company Profit & Loss (P&L), P&L by project, company overhead, costs per project.

Data Interfaces

Inputs	From	Outputs	To
Actuals (updates)	PM dB	Job/project	PM dB
(updates)		collected costs	Mkt dB
Aggregate bid hrs	Mkt dB	current labor	PM dB
		rates	Mkt dB
Est to complete	PM dB	Est to complete	PM dB
(hours)		(dollars)	Mkt dB
Raw parts cost	ENG dB	Mkt dept costs	Mkt dB

MARKETING DATABASE

The marketing database flow is illustrated in Figure 6.

Data types are: Skills baseline, Tasks & times to complete, customer data, RFPs, RFP requirements broken down to task, Correspondence.

Reports are: Cost to prepare by project, project estimates to complete, new project bid data.

Data Interfaces

Inputs	From	Outputs	To
Employees, skill	PM dB	New bid project	FIN dB
levels & types			
Hours to complete	PM dB	Final winning bid	PM dB
task catalog		budget data	ENG dB

Task skill levels	ENG dB
Equip configs, raw parts lists	ENG dB
Current rates	FIN dB
Mkt dept costs	FIN dB
Estimates to complete	FIN dB PM dB

PROGRAM MANAGEMENT DATABASE

The Program Management Database flow is illustrated in Figure 7.

Data types are: New jobs, Bid hours, Changes to existing job hours Bid changes, Job collected Costs, Current Labor hours, Hours to complete

Data Interfaces

Inputs	From	Outputs
New jobs	Mkt	
Bid hours for new job	Mkt	
Changes to existing job hours	Mkt	
Change to existing parts	Mkt	
Bid changes	Mkt	
Job collected costs	FIN	
Current labor rates	FIN	
Hours to complete	ENG	
Current Job tech baselines	ENG	
Actuals collected/job	PM	FIN

Changed estimate task/hours	PM	Mkt, ENG
Estimate to complete	PM	Mkt, FIN

ENGINEERING DATABASE

The Engineering Management Database flow is illustrated in Figure 8.

Data types are: Task hours existing projects, Task hour new jobs, Hours to complete, Tasks with skill level, Equipment configuration design, Current technical baseline config, Parts needed

Data Interfaces

Inputs	From	Outputs
Task hours existing projects	Mkt	
Task hours new jobs	Mkt	
Hours to complete	ENG	PM
Tasks with skill level	ENG	Mkt
Equipment configuration design	ENG	Mkt, FIN
Current technical baseline conf.	ENG	PM, Corp.
Parts needed	ENG	PM,FIN

APPENDIX B. SYSTEM ACQUISITION MANAGEMENT PLAN

PART I

PROGRAM REQUIREMENTS (STATEMENT OF WORK):

Wide Insight Systems Engineering is tasked to design and install an Office LAN that will consolidate and coordinate the office resources of the Go-Figure Consultants organization. WISE shall provide all systems engineering support activities from design to installation.

ORGANIZATION

The organization structure of the WISE team consists of employees from the Research and Engineering division. Teams are broken down in areas of research, engineering, design, and test & installation. The general WISE organization structure used in systems development efforts is shown in Figure 20.

SUPPLIER OR SUBCONTRACTOR REQUIREMENTS

Subcontracts are required from the appropriate hardware and software vendors to provide logistics support. In addition to procurement and logistics support, service maintenance contracts for technical support shall be established through WISE.

WORK BREAKDOWN STRUCTURE:

Figure 21 illustrates the work breakdown structure of all the program tasks required of WISE to develop and integrate the office LAN for the Go-Figure organization.

SCHEDULE

Go-Figure has indicated an immediate need for a LAN but will accept as much as one year before having a fully operational LAN. Based on this requirement, WISE has appropriated resources and proposed the following schedule.

- Three months for system need and requirements development
- Two months for systems analysis and preliminary design
- Two months for detail design with developed Test, Installation, and Training Plans
- Two months to procure and test system design
- One month for training and installation of system

Thus, the total time estimated from the WISE statement of work and resource considerations to deliver a working system is estimated to be 10 months. Every effort will be made to work within this schedule and keep the customer informed of all progress made, delays, or changes to the design or requirements.

PART II

SYSTEM ENGINEERING PROCESS

The System Engineering Process applied to the office LAN development effort is outlined in the life-cycle diagram shown in Figure 14. It describes the system engineering process as it applies to the

definition of system requirements and the development of those requirements into a final product configuration.

PART III

ENGINEERING SPECIALTY INTEGRATION

- Reliability/Maintainability Engineering

  Reliability and maintainability characteristics are analyzed by the engineering and design teams. Throughout the design phase, the teams will use specified requirements from the initial need and operational requirements sections to ensure a reliable and maintainable system design throughout the life-cycle.

- Human Factor Engineering

  Human Factors Engineering is worked by the design team through the logical breakdown of operation and maintenance functions during early system design. The results provide the identification of system activities and the allocation of human resources and training requirements.

- Value Cost Engineering

  Value cost is reflected in the initial cost analysis, feasibility study, and the cost breakdown structure of the project. The development of the cost breakdown structure was implemented with an

engineering approach to insure that all cost categories are relevant and significant in terms of cost as related to the total life cycle.

- Quality Engineering

Quality Engineering is implemented throughout the development cycle of this project. Quality assurance is the responsibility of all project teams. Their objective is to achieve a quality system that reflects the identified maintenance characteristics and logistics budget allocations. The goal of the systems engineering process is to create quality systems in response to customer established needs.