The Development of a Computer-based Product Definition for Artillery Products

DAVID F. VAN WYK
Support Services
LIW, PO Box 7710, Pretoria, 0001
Facsimile: 012 6202283
SIEBERT J. BENADE
Artillery Business Unit
LIW, PO Box 7710, Pretoria, 0001
Facsimile : 012 6203229
PROF AL STEENKAMP
Department of Computer Science and Information Systems
University of Pretoria, PO Box 392, Pretoria, 0001
E-Mail:STEENAL@ALPHA.UNISA.AC.ZA
Facsimile:012 4293434

Abstract: Any company that is involved in manufacturing, must be able to tell the exact difference between any two products of the same family. This is necessary to enable such a company to support these products during the total life cycle, and becomes possible if the product definition is kept under configuration control. Traditionally, paper copies of all the specifications and drawings etc., were kept under configuration and the real electronic source information was not. The objective of this system is to maintain the electronic source data for every product. This system enables the product developers to access the total product definition from a Windows based personal computer. The genuine source data is available, not only paper copies. At the same time , the logistic, functional and manufacturing definitions can be accessed in a user friendly way.

Keywords: Electronic Source Data, Product Definition, Manufacturing, Configuration Control

Computing Review Category : Software Engineering

1. Introduction

Any company that is involved in the development, manufacturing and support of complex, high technology products has certain unique problems and requirements that must be addressed by the company information system [3]. Traditionally, part of the product definition is maintained on some type of computerised information system and the rest is maintained on paper copies of specifications, drawings, etc.

The need for more timely, relevant, high-quality information is being driven today by the increasing competitiveness of global markets, and coincides with the fast evolution of information technology. Although it is unrealistic to expect any technology to respond to the subtle and diverse needs that organisations have for information, computers are great enablers and highly efficient tools for storing, retrieving, distributing, and manipulating information [1]. These factors have obliged manufacturing companies to maintain their product definitions as part of information systems.

In 1992, a decision was taken by the management of LIW, a weapon manufacturing company, that the future software development platform would be personal computer(PC) based configured into local area network(LAN) architecture, and that applications would be MicroSoft Windows based. At the same time a request was made by the artillery business unit for a system which would integrate the product definitions of the artillery products. This request subsequently resulted in the project reported on in the rest of this paper.

2. Historic perspective of information technology in manufacturing

Flaig[1] has expressed the following in 1993 about information technology in manufacturing:

"Today, the typical manufacturing company's information technology is characterised by an extraordinary array of totally incompatible computers and networks. IT functions are supported by a very large collection of sometimes gigantic and intricate applications that have been substantially modified and patched over the years in an attempt to support the firm's changing needs."

"Islands of automation " have become a standard operating condition for IT in virtually all major manufacturing concerns.

This scenario, was also experienced within LIW. People would run a report on one application, then type the results into another application to get another report in a different format.

2.1 Factors leading to non-standard action.

There are several reasons why a big company, like LIW, experienced the problem of islands of automation. Some of the reasons are discussed below.

Non-standardisation

Within the IT department , no real standards are set for the languages to be used, the format of the data or even the hardware and operating system platform .

Ignorant users

Many employees, especially newly appointed employees, are not aware of the services provided by the IT department. Newly graduated employees, not familiar with a company structure are not even aware of the IT department.The reason for this is that companies do not have an appropriate induction program where newly appointed employees are briefed on the company structure, and services provided by the different business units or departments.

Inadequacy of code generators

Many code generating languages, especially those of database management systems, are so easy to use that many users can build their own applications very quickly. The only problem is that these users usually know too little about software engineering concepts to be able to draw company data electronically into a database. The result is error-prone, duplicated data in separate, stand alone databases.

Non-integrated database systems

As a result of the lack of integration, numerous small databases are found company wide, each with duplicate data, but seldom in synchronisation with one another. The solution to this problem is to have one integrated database, containing all relevant corporate data, which can be easily accessed by all users.

Human attitude problems

a) The computer staff typically do not understand the global picture of the business or the various business processes.
b) People tend to stand by their specific software packages because they are familiar with it and thus have a resistance to change to other packages.
c) A tendency can be identified that the personnel of a company is divided into two groups, namely those who associate themselves with the mainframe environment and the rest.
d) The co-operation between the computer staff and the rest of the personnel in the company is bad.
e) Specialization in the company forces people apart because every group tends to get so involved in what they are doing and the software that they are using, that they do not share it with anyone else.

2.2 Technology advances for standardisation

There are three technologies which any company should take advantage of to be able to standardise and be competitive in the years to come[1].

Desktop computers

The main advantage is the rapidly increasing processing power of desktop computers and the affordability of these microprocessors.

LAN servers and superservers

Superservers are high-powered microprocessors with processing power many times that of a normal PC. It runs the same operating system as a normal PC server, but they operate at much higher speeds through the integration of multiple high-performance microprocessors in a single computer system. The low cost and ease of use of PC-based computing enable cost-effectiveide access to information systems to many sites and users, a situation not feasible before.

Networking technology

Computer networks play a more and more critical role in tying enterprises together. This is also true of a manufacturing enterprise. The truly enabling network infrastructure should exhibit several key characteristics:

a) Be seamless, to allow users and application programmers to use the network without getting involved in the complexities of the network connections .
b) Be optimised for dynamically allocated bandwidth, allowing applications to use as much bandwidth as is available, but only for the brief duration needed to transmit the relevant information.
c) Be able to accommodate the very high bandwidths on local area networks, as well as the moderate bandwidths available in the public wide area network.
d) Allow interoperability where any resource can connect to any other resource, which will ensure that future connectivity needs can be satisfied without having to re-deploy network resources.
e) Allow many simultaneous logical connections from every computer to support the next generation of distributed and integrated applications.
f) Have the same technical standards from very small networks to very large networks.

3. Integrated product definition

The most important requirement for survival of manufacturing companies today is the existence of an integrated product definition. To start with, the product definition must be able to assist the manufacturing process during three phases, namely the Development phase, the Manufacturing phase, and the Support phase. A typical entity diagram of such an integrated product definition is shown in figure 1.

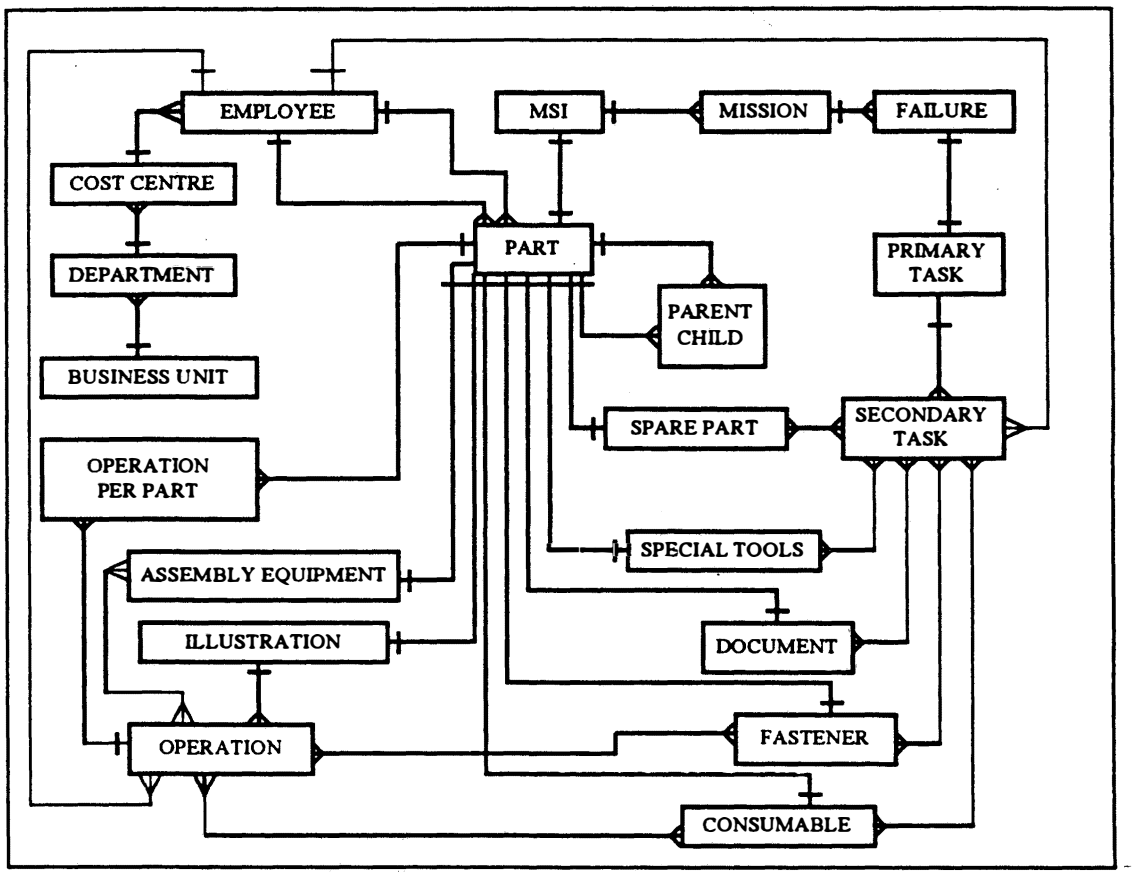

Figure 1. Typical entity diagram for an integrated product definition

The three phases are the following :

Development phase : There must be a data structure that contains all the parts that are needed to build the product. There are different logical ways to implement this data structure.

Manufacturing phase: There must be a data structure that can be used to define the different workstations where the product is to be manufactured and assembled. At the same time the structure must be able to handle all the resources that is needed at a specific workstation for a specific operation.

Logistic Support phase There must be a data structure that can be used to define the support data needed to support the specific maintenance significant items(MSI) in the product. This data structure is called the Logistic Support Analysis record (LSAR). Logistic support is defined as the composite of all considerations necessary to assure the effective and economical support of a system throughout its programmed life cycle [4].

LIW has adopted a functional approach for its product structures. A relational database which integrates the current product structure with the financial data, employee data and other relevant data, is maintained on a mainframe computer, henceforth referred to as the main computer system The main computer system keeps all data about all products produced by the company. The only missing component for completion of the product definition, was the source documentation. These documents are not kept in a configured electronic format today. The only link between the product structure on the main computer system and the relevant supporting data, is a number for every piece of supporting data (paper copy) which is registered at the Configuration Centre.

LIW's product definitions are thus currently composed of the following :

a) The main computer system containing the relational database with all the company's data definitions.
b) The Configuration Centre containing all documentation supporting the data definitions. These are paper copies with strict revision control.
c) The real source information uncontrolled and scattered all over the company on standalone PC's and an assortment of small networks.

4. The MATMAN Project

The main concern of the project is to supply the user with the means to access accurate, reliable and timely information of any artillery product defined within the manufacturing environments of LIW. The information has to be supplied in an integrated manner, and be related to the product structure. This information, and the means to access it, should be presented in a user-friendly manner.

4.1 System functionality

The request from the user addresses the concept of being able to access the total product definition of any part in the system in the following way::

a) The system must support the user in navigating through the product structure.
b) The system must support the user to access the complete definition for a selected part.
c) The system must support the user to submit or access graphical and textual information pertaining to the selected part in the product structure.
d) The system must support the user responsible for the support documentation in accessing and using the data needed to create the documents.

4.2 Technology platform

The project is to be implemented on a client-server configuration with the following architecture:

a) A relational database running on the mainframe and used as primary storage for the product structure of products which are produced by LIW.
b) A minimum configuration PC of a 386DX 40 Megahertz (MHz) central processing unit (CPU), four megabytes (Mb) of random access memory (RAM) and a video graphics adapter (VGA) monitor will be a required from all users in the artillery business.
c) Microsoft Windows 3.1 presentation software, together with MicroSoft Office Pack, consisting of the word processor package, Word for Windows, the spreadsheet package, Excel for Windows and the graphics presentation package, Power Point will be supplied to all users.
d) A local area network (LAN), with operating system Operating System 2 (O/S 2) connecting all users in the artillery business unit will be implemented.
e) The network server, a 486DX type PC with 16 gigabytes (Gb) of disk space.
f) The middleware, Sybase Standard Query Language (SQL) running on the server and interrogating the relational database on the mainframe computer.
g) Network communications between the network and the mainframe will be handled by Windows Commserver, residing on the network server.

h) The front end, called MATMAN, developed in Visual Basic with a copy of this software residing on every user's PC.

5. Analysis and design

5.1 Data modelling

5.1.1 LIW item numbering policy

The item numbering policy of LIW states the following [2] :

a) Structure
Group A - Character 1-3 : Contains the product number or stock group number.
Group B - Character 4-8 : Unique item number
Group C - Character 9-12 : Application group(e.g. Tools or documents)
Complete or repair status
Modification status
Group D - Character 13 : Used to identify sub-system for production tooling, otherwise empty.
Group E - Character 14-15 : Check digits calculated from numbers in the previous groups to eliminate a percentage of typing errors in the number.

b) Every document is identified by a unique number. Changes to documents are indicated by changing the issue status. The unique identifier for documents therefore includes the issue status.

This numbering policy means that any document, picture or drawing that is created to add to the definition of a part, is treated exactly as any other part and is also linked to the relevant parent in the product structure.

5.1.2 Source files

One of the main requirements for the system is that it must allow the electronic source files of every document to be linked to the specific part in the product structure and be accessible to every user. A further investigation revealed the following:

a) The same document may appear at different places in the product structure. The source file must however be unique when viewed from these different places.

b) The document may consist of more than one source file. Packages like Autocad and Pro-Engineer should be able to reference existing drawing files in other drawing files to enable reusability. Furthermore, with the additional functionality of the Windows environment, it should be possible to link files from different applications into one another.

A further requirement is that the document attached to a part, must be easily identifiable. The user would like to identify the specific document before using it.

5.1.3 Entity model

Based on the investigation thus far, an entity model can be put together as shown in Figure 2

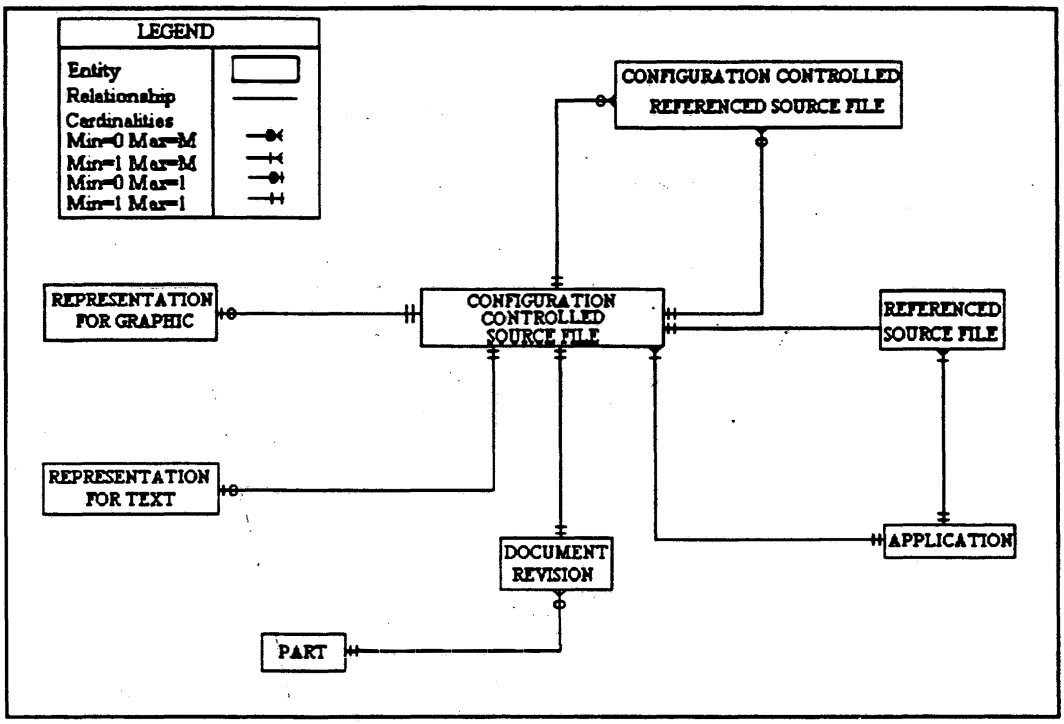

Figure 2. Entity model of the system

The identified entities are as follows:

PART - The part with all its attributes which exists in the main computer system
DOCUMENT REVISION - The revision of the document describing a part . This entity exists in the main computer system.
CONFIGURATION CONTROLLED SOURCE FILE - The electronic source file in which details about the part is kept.
REFERENCED SOURCE FILE - An electronic source file that is only referenced by one CONFIGURATION CONTROLLED SOURCE FILE
CONFIGURATION CONTROLLED REFERENCED SOURCE FILE - An electronic source file that is a CONFIGURATION CONTROLLED SOURCE FILE and is referenced by other CONFIGURATION CONTROLLED SOURCE FILES.
APPLICATION - The application in which the source file was created.
REPRESENTATION FOR GRAPHIC - The identification for a graphic CONFIGURATION CONTROLLED SOURCE FILE.
REPRESENTATION FOR TEXT - The identification for a textual CONFIGURATION CONTROLLED SOURCE FILE

5.2 Process modelling

A representation scheme of the MATMAN system based on the data flow paradigm is presented in figure 3.

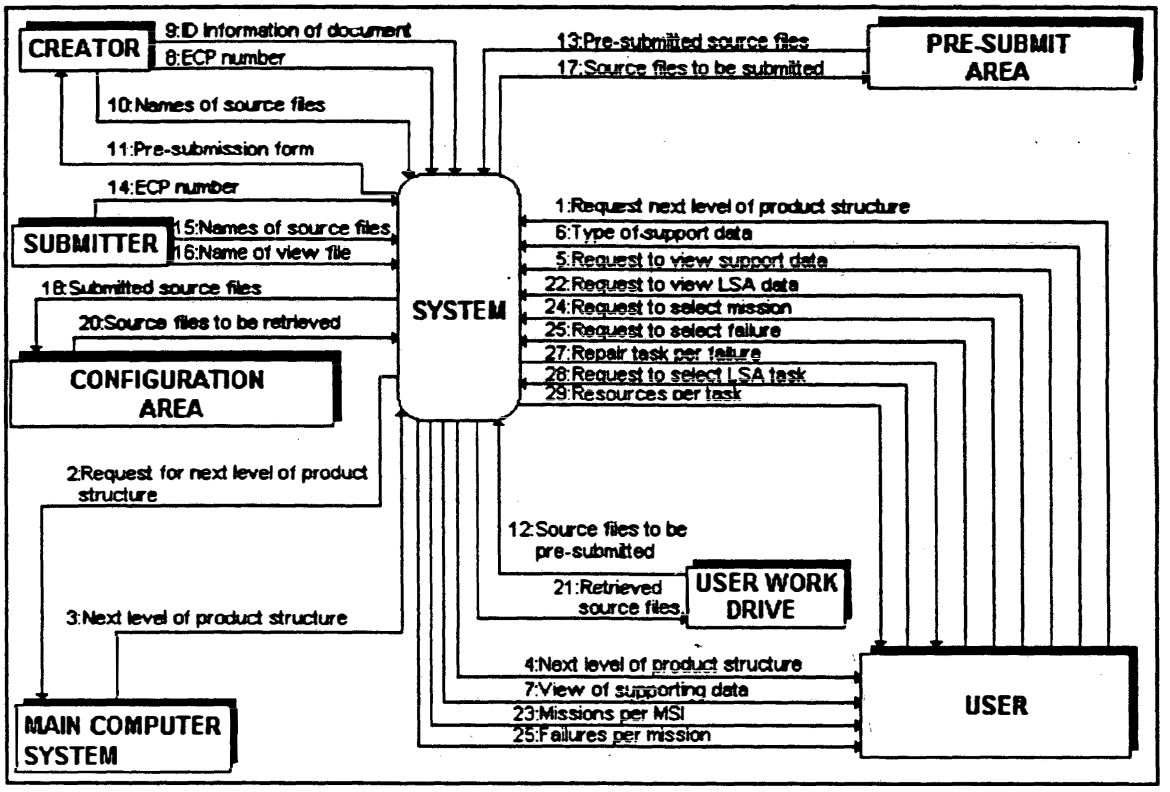

Figure 3. Context diagram for the MATMAN system

In this context diagram, seven external entities can be identified. They are defined as follows:

CREATOR :	Any person who creates any number of source files which have to be configuration controlled via the system.
SUBMITTER :	The person(s) responsible for submitting the source files that was created by the creator, into the system.
USER :	Any person who uses the submitted information from the system.
PRE-SUBMIT AREA:	An area on a central device on which all source files resides that a creator wishes to submit into the system.
USER WORK DRIVE:	The local hard disk of any user.
MAIN COMPUTER SYSTEM:	The main frame based system containing all information concerning all parts used by LIW, as well as all product structures.

Other relevant definitions applicable on the context diagram are the following:

PRE-SUBMIT: The electronic transfer of source files and referenced source files to a central device by the creator to enable the submitter to view the source files before submitting them.
SUBMIT: The presenting of view files and/or source files to the system to be registered against a certain document and revision number on the main computer system.
RETRIEVE: The electronic transfer of source files from the configuration area of the system to the local hard drive of the workstation.

5.2.1 Overview of the context of the system

The first activity that will take place when a user enters the system, is that he will request the next level of a product structure (data flow 1). This request must be sent to the main computer system (data flow 2), which will return the relevant information (data flow 3) to the system and then to the user (data flow 4).

The user may then choose to view certain supporting data (data flows 5 and 6) and a view of the chosen supporting data must then be displayed to the user (data flow 7).

A creator might want to pre-submit source files for a specific supporting document of a part. To do this, he must supply an engineering change proposal (ECP) number (data flow 8), the identification information of the document (data flow 9) and the name(s) of the source file(s) to be pre-submitted (data flow 10).

During the process of pre-submission, the relevant source files must be transferred from the user work drive (data flow 12) to the pre-submit area (data flow 13).

After the pre-submission process, the system must provide the creator with a pre-submission form (data flow 11) . This form must then be presented to the submitter as a request to submit the source files. To do this, the submitter must also enter an ECP number (data flow 14) and the names of the source files (data flow 15). In case of a graphic image, the name of the graphic view file (data flow 16) must also be entered.

The pre-submitted source file(s) must then be transferred from the pre-submit area (data flow 17) to the configuration area (data flow 18).

Whenever a source file is submitted, a user must be able to retrieve such source file(s) by requesting it (data flow 19). The source file must then be copied from the configuration area (data flow 20) to the user's work drive (data flow 21).

Whenever a user encounters a MSI in the product structure, he must be able to access its LSA data starting at the missions for the MSI (data flow 22). The missions per MSI must then be displayed to the user (data flow 23). Upon selecting a certain mission (data flow 24), the system must display all failures of the selected mission (data flow 25). At this stage the user may select a specific failure (data flow 26) and get a list of all tasks necessary to repair that failure (data flow 27). When the user then selects a task (data flow 28), the system must display all resources attached to the specific task (data flow 29).

Some of these resources might be supporting documentation again. It must be possible to pre-submit, submit and retrieve source files for these documents as well.

6. System design concepts

6.1 Creating unique file names

LIW did not previously have a file naming convention as it was never before deemed necessary to perform configuration management on computer files.

For this system, the following computer file naming convention was thus developed. This may also be used on a wider scale in the company in future.
All data created within the artillery business unit in support of the product definition, will always have a unique combination of part number and version number.

In order to identify a specific data item uniquely, the combination of the following attributes must be unique:

a) Part number
b) Revision number
c) Sheet number (Sheet for drawings, it could also be chapter for documents etc.)

The only way to convert such a combination into a unique computer filename is by using a combination of directory and filename.

The assembly of such a filename, is as follows:

Example LIW document number: 450 / 00034 / 5000 / A / 07 Revision 2
If the number is broken down into the different parts , it can be shown as follows:

P = '450'
Q = '00034'
R = '5000'
S = 'A'
Check digit ='07'
Revision = '02'

The directory structure in which the source file for this document must be created, is the following:

First directory = 'M'&P, resulting in M450
Second directory = 'M'&R&.Revision, resulting in M5000.02

The filename must thus be created in the following directory on drive M: M450\M5000.02

The first character of filename is determined as follows:

If S = space then 'M'
else
the character found in S
Next 5 characters : Q
Next 2 characters : Sheet number (eg. 01)

The example document will thus be saved as:

Directory : M:\M450\M5000.02
Filename: A0003401.xxx (Extension is created by application)

Any referenced or linked file that is used by this main source file, will be found in the same directory , but the sheet number will differ.

Table 1 shows some examples of the assignment of filenames of source files and referenced source files. In figure 4 the displays the relevant directory structures for creating the relevant source files are displayed.

Part number	Rev	Application	Directory	Filename	Reference file	Sh
361000010126	00	Word f W	M361\M0126.00	M0000101.doc		01
		Auto cad	M361\M0126.00		M0000102.ppt	02
361000100126	10	Word f W	M361\M0126.10	M0001001.doc		01
361000120126	02	Word f W	M361\M0126.02	M0001201.doc		01
		Excel f W	M361\M0126.02		M0001202.xls	02
		Paintbrush	M361\M0126.02		M0001203.bmp	03
		Power point	M361\M0126.02		M0001204.ppt	04
376000210054	08	Auto cad	M376\M0054.08		M0002111.dwg	11
376000010054	07	Paintbrush	M376\M0054.07	M0000101.bmp		01
376000025001	10	Power point	M376\M5001.10	M0000201.ppt		01

Table 1 Examples of file names for source files

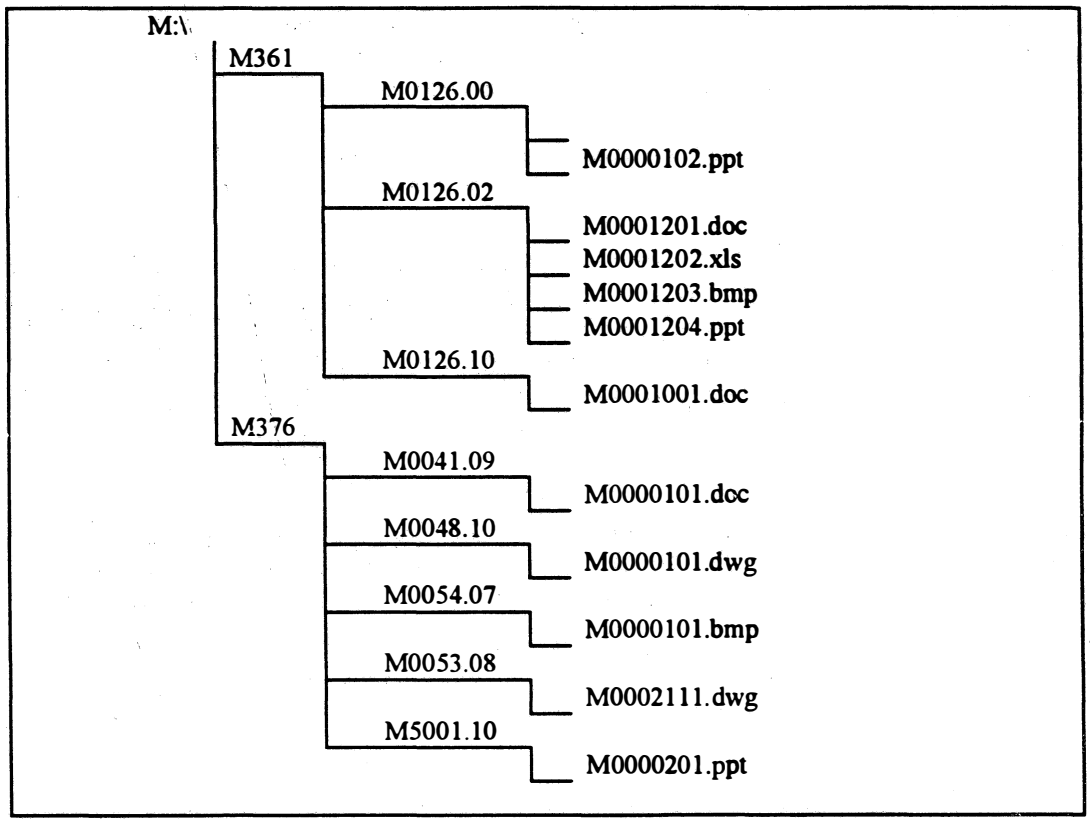

Figure 4 Directory structure for source files

6.2 Network architecture

The network architecture must be such that the "Configuration area", as indicated in Figure 3 as well as the "Pre-submit area" must be accessible to all creators and submitters. Normal users must also have access to the "Configuration area".

The access rights for different users, must thus be allocated as indicated in Table 2

USER TYPE	PRE-SUBMIT AREA	CONFIGURATION AREA
Creator	Create,Read,Execute	Read,Execute
Submitter	Read,Execute,Delete	Create,Read,Execute
User	No access	Read,Execute

Table 2 Access rights of different users of the system

The rights are organised as such to allow only submitters access to the Matman configuration area and not to allow anybody to update anything that has been pre-submitted or submitted.

6.2.1 Assignment of drive names on the network

Some applications, such as Autocad applications, use referenced files to increase reusability. The path to such a referenced file is hard coded into the main file. This means that if the referenced file is not found on the specific drive and path as is stated in the main file, an error occurs.

For the submitter to be able to view and then submit source files that was pre-submitted by the creator, these referenced files must be in the exact path as it was on the creator's workstation.

The following strategy was thus devised:

a) All new source files will be developed on drive M. This drive M will be created on all creators' and users' workstations using the command "SUBST M: C:\MAT".
b) The pre-submit area will be connected to all creators' workstations as drive P.
c) The pre-submit area will be connected to all submitters' workstations as drive M.
d) The configuration area will be connected to all users', creators' and submitters' workstations as drive Z.

Following this strategy all work done by a creator on his M drive with main and referenced source files will be pre-submitted to drive P (Pre-submit area). The submitter will then be able to view all these pre-submitted source files, as he is connected to this area as drive M. The network setup is illustrated in Figure 5.

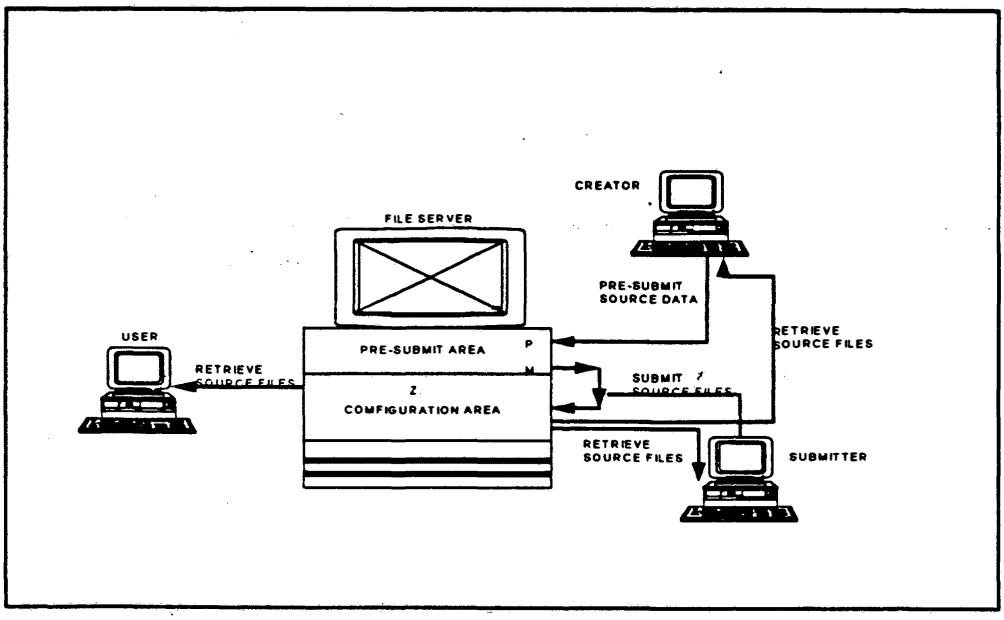

Figure 5. Network architecture

7. Summary

The business unit for which this system was developed, consists of a high percentage of engineers which makes it a very professional environment. Professional users also normally expect a high level of professionality in any service rendered to them. For this reason, the project team was accepted well among the users when everything was delivered in a professional way. The fact that the project was modelled thoroughly and in great detail also made it more acceptable to the users, who are used to model everything in their own environment before building it.

The clients have accepted the fact that they must manage their data very well to be able to deliver acceptable products. This has further initiated an interest for data modelling by clients. It was thus necessary to explain some of the data modelling aspects to them to ensure that their requirements were met.

The IT industry is moving into a direction where the users come to know a lot more about data modelling than before. As they are getting more acquainted with it ,IT professionals will be forced to become experts in the application domains, otherwise the client will not accept the outputs as easily as was previously the case.

During this project the client was constantly involved in the analysis and design phases. Before any design specification was handed over to the programmers, the essential features were first discussed with selected members of the artillery business unit. The different screen layouts proved to be a good method of communication with the client. This way the client can relate to the system even before any coding has been done and some misunderstandings cleared.

Other aspects that were found to be important in this project, were prototyping and incremental development and delivery. When the client approved of a certain sequence of screen layouts and see it on his system some two weeks later, it improves his positive attitude towards the IT department immensely. It also brings a great deal of satisfaction to the client if he knows that these screen layouts or concepts were cleared with him first. This is very important for the good relations between the client and the IT department.

Furthermore it was found that it is very helpful to the programmers if the systems analyst include the exact screen layouts and other specifications,like the parameters for the SQL codes, in the technical specifications. The reason being that the programmer knows that what he is doing, has been cleared with the client. It is however, important not to give the programmer too much design detail, because he himself must also feel that he has a strong input into the system.

With this specific system , which operates across different technology platforms, it is also very important for the project manager to manage the integration across the platforms as far as possible. If this is left to the programmers, it removes their concentration from their important program design work.

The implementation of a system of this nature is another major undertaking which requires a lot of proper planning. Once it has been succesfully implemented, it could alter the the way in which manufacturing companies do their business to benefit themselves as well as their clients.

Books:

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