

Towards a Real-time Decision Support System

for

Fire Incidence Management

in

South African Forestry

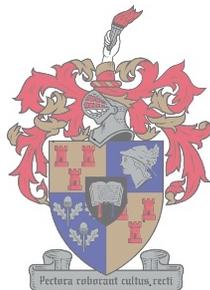
by

Johan Fourie

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at the

University of Stellenbosch



Promoter:

Dr. H.J.E. Uys

Co-promoter:

Dr. J.M. Theron

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DECLARATION

I, the undersigned, hereby declare that the work contained in this dissertation is my own original work and has not previously in its entirety or in part been submitted at any university for a degree.

SYNOPSIS

This study presents the development of the conceptual structure for an applications model, which has the objective of improving the effectivity of South African fire incidence management in an elementary and cost-effective way. The proposals reflect reality in that:

- a) international standards, guidelines and technological trends were considered;
- b) the capabilities of existing and developing computer and communication infrastructure within forestry, especially in the rural areas, were considered and utilized and
- c) the requirements and problems of operations managers were considered.

Most managerial decisions which have a direct influence on the natural environment, are executed at the operational level. Providing this level with effective, affordable, maintainable and purpose-specific computer systems, is therefore the correct avenue for improved managerial practices within our natural heritage.

OPSOMMING

Die ontwikkeling van 'n konseptuele struktuur as voorbeeld van 'n toepassingsmodel, wat die effektiwiteit van Suid-Afrikaanse bestuursmetodes met betrekking tot bosbrande op 'n eenvoudige en bekostigbare wyse sal verbeter, word binne hierdie studie voorgestel. Die voorstelle weerspieël realiteit aangesien:

- a) internasionale standaarde, riglyne en nuwe tegnologiese ontwikkelinge oorweeg is;
- b) die vermoëns van bestaande en ontwikkelende rekenaar en kommunikasie infrastrukture binne die bosbedryf, veral in die platteland, oorweeg en benut is en
- c) die behoeftes en probleme van bestuurders op die operasionele vlak in ag geneem is.

Die meeste bestuursbesluite wat 'n direkte invloed op die natuurlike omgewing het, word op operasionele bestuursvlak uitgevoer. Om hierdie bestuursvlak dus toe te rus met effektiewe, bekostigbare, onderhoubare en doelspesifieke rekenaarstelsels, word beskou as die korrekte manier om verbeterde bestuursbesluite binne ons natuurlike erfenis te verseker.

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PREFACE

The forest industry, such as any other industry, is constantly on the lookout for ways in which to maximize profitability and to minimize costs and risk. This is a natural process essential to the survival of any company and to this effect, it is certainly true that computer technology has been a means to an end in many areas of importance. It is however necessary to realize that the capabilities of computer technology is still vastly underutilized given the applications currently used by the forest industry. This dissertation introduces the forest manager to a real-time decision support system and the work is an extension of local and international trends.

The research done for this dissertation was initially normative, but later followed by an analytical (non-statistical) and experimental approach. The results were formulated into a proposal based on the capabilities of modern technology but within the boundaries of sound systems analysis and design principles. Applying the proposal to real-time fire incidence management is demonstrative in nature and was chosen merely to investigate the strengths and weaknesses of technology in a hectic environment within which the principles of 'chaos' management applies.

This study would not be complete without a word of thanks to:

- (i) Our Heavenly Father and Jesus His Son, for providing the driving force in my life;
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**STELLENBOSCH
SEPTEMBER 1992**

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CHAPTER 1 : INTRODUCTION

South Africa has a widespread system for fire incidence management in the different regions of the country, but the decisions taken by forest and fire managers at the operational real-time level, are weakly aided by the capabilities of computer and communication technology (Cesti, 1988; Grey, 1990; Le Roux, 1987).

In the rural forestry areas the reasons could perhaps be found in old and unreliable voice communication equipment (Le Roux, 1987; Le Roux, 1988), while the near absence of data communication infrastructure had a negative effect on the usefulness of remote computers. For example, the introduction of the United States Fire Danger Rating System (FDRS) in 1984 had failed for several reasons, one being the lack of computer equipment after managers had been trained (Van Wilgen and Manders, 1990).

Over the past three years, the timber growing communities in the Transvaal¹ and Natal² have increased their support of two aerial fire-fighting units, which operate from several airports throughout the Transvaal Lowveld and Natal respectively. These fire-fighting units have been very successful with their spotter and water bombing efforts. The growing requirement for a co-ordinated effort with the timber growers has recently lead to the implementation of a computer Local Area Network (LAN) at each of the main airports. During the 1992 fire season a real-time operations management computer system, implemented on a Personal Computer (PC) in the operations room, was tested against the harsh realities of operational eventualities. In South Africa this first and very basic system represents a clear indication of the trend in real-time computing requirements and could be regarded as a first attempt towards computer-aided fire incidence management for the duration of a fire season.

The effort of producing such a real-time system can now be extended to be more efficient

¹ The Forest Fire Association (FFA).

² Natal Fire Protection Association (NFPA).

by means of sound planning, analysis and design methodologies.

1.1 PROBLEM DEFINITION

The computer system required to implement the set of operational events generated by the activities of a fire-fighting unit during the fire season, will be virtually unusable if any subset event cannot be timeously or adequately processed, or cannot be processed at all.

From a managerial viewpoint several broadly stated, but specific sub-problems exist namely:

- a) insufficient system functionality introduces a higher workload on all staff members and increases the probability of errors;
- b) seamless integration with other systems e.g., the weather and financial packages are non-existent;
- c) the generation of the reports required as a feedback to those timber growers who were affected by the fire is slow;
- d) reporting detail and quality is inadequate if seen against a background of e.g., evidence in court cases and
- e) there is no integration at the applications level with the capabilities of modern telephone, radio, satellite and landline communication systems.

1.2 STUDY OBJECTIVE

The objective of this study was to develop and present an applications model which integrates the process of real-time fire incidence management for organizations such as the FFA, NFPA¹ as well as forestry managers. The implementation should function with maximum effectivity and efficiency but reflect low maintenance costs.

Potgieter (1973) indicates that fires are the largest single destructor of veld and forests in

¹ The FFA, NFPA combination will be referred to as the FFA.

South Africa. This statement remains true given the two massive fires (besides others) which destroyed an estimated 7 000 hectares of veld, sugar cane and commercial forests in Natal as well as 1 000 hectares of commercial forests in the Eastern Transvaal during August 1992. In September 1992, fires again destroyed several thousand hectares (exact areas unknown) of veld and commercial forest in the same provinces. This is not acceptable from an economic or conservational viewpoint and therefore everything possible should be done to limit destruction.

This dissertation, which is an attempt to blend the best of several technological disciplines into an effective fire incidence management system, is a contribution to that effort.

1.3 RECONNAISSANCE AND PREPARATION

This study was conducted using a combination of recognized study methods (Leedy, 1974). During the reconnaissance phase of the study, a normative approach was followed, while an analytical (non-statistical) approach was combined with an experimental approach during the technical phase.

Over a period of four years information was collected by:

- a) visiting the Boise Interagency Fire Centre (BIFC) in Idaho, USA (Fourie, 1989);
- b) doing a literature study on some of the international efforts most applicable to the objectives of RIMS¹ (chapter 2);
- c) writing a letter² to South African timber growers, explaining the purpose of the study and asking them for input on perceived problem areas (chapter 3) and additional requirements (chapter 4) and
- d) visiting the FFA to study the operational methods used for controlling wild fires during July 1992 (chapters 3 and 4).

¹ Real-time Incidence Management System (RIMS).

² Refer to appendix E.

A systems approach was taken along the Infomet guidelines (Viljoen, 1990) and supported by the work of other authors such as Rennhackkamp¹ (1990) and Yourdan² (1989). Firstly a series of analyses were conducted (chapters 2, 3 and 4 as well as appendices A, B, C and D) which resulted in the creation of a hypothetical computer system. The latter was used to develop the most critical aspects of the applications model and it contains the following elements (which also provides the necessary acronyms for reference purposes):

- a) a central computer system collectively called RIMS;
- b) a communications network called FIN³ (Fourie, 1988);
- c) a communications controller called the FIN controller;
- d) a sensor network called ESN⁴ (Fourie, 1986);
- e) a terminal suitable for field operations called a FTU⁵ and
- f) a logger unit collecting data from a set of sensors called an ESU⁶ (e.g. a weather station).

Chapter 1 presents the general strategy for the fire incidence management system, while the introductory paragraphs of chapters 5 to 8 describe the strategy and locality of each sub-system. The conceptual structure of the hypothetical RIMS system is shown in figure 1.1.

1.4 CONSTRAINTS

The FFA and the timber growers have clearly indicated that a lack of funding as well as other pragmatic problems (chapter 3) limit the implementation of computer technology. Against this background the design had to be adapted to a low-cost hardware platform with

¹ Problem analysis, requirements definition, data analysis and functional prototyping.

² Data analysis and the characteristics of a real-time system.

³ Forest Industry Network (FIN).

⁴ Environmental Sensor Network (ESN).

⁵ Field Terminal Unit (FTU).

⁶ Environmental Sensor Unit (ESU).

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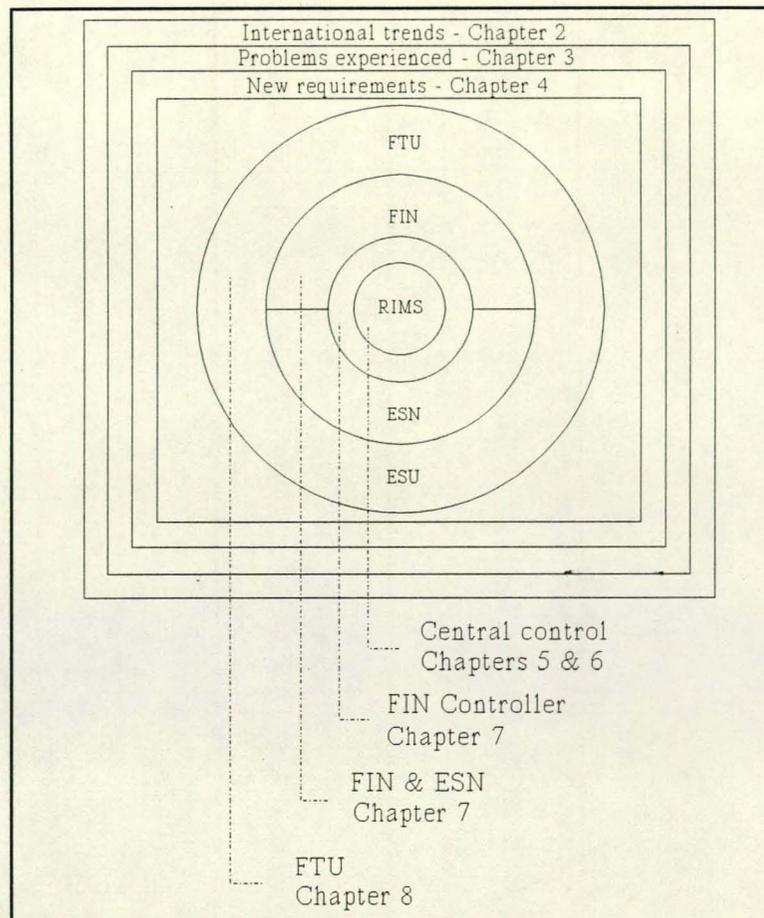


Figure 1.1: Conceptual system

maximum practical functionality and speed (appendix A).

In the rural areas of South Africa communication technology is still primitive and in terms of forestry mostly based on radio and telephones. The internal telephone systems of many plantations are based on the party-line system which places a constraint on access to important links in the chain fire-fighting events, e.g. the interpretation of incoming reports from the lookout towers. This situation can be reversed overnight with satellite communications technology, but it will be several years before the whole national system is modernized.

Fire related computer simulation models as well as Geographical Information Systems (GIS) will be discussed if they influence, interface or require to be integrated to RIMS or ESN operations in any way. The role GIS systems play in research, planning as well as databases

containing historical data, mostly fall outside the scope of this study.

1.5 SUMMARY

The implementation of an operational RIMS with all supporting elements functioning as a system comparable with the functionality of systems available in the United States and Canada, requires the integration of several technologies and techniques, of which the most crucial will be presented and evaluated in this study. The basic guidelines were to design for simplicity, fast system responses, reliability under harsh conditions, low acquisition and maintenance costs.

The correct assessment of climatic and related issues plays an increasingly important role in the natural and socio-economic future of Southern Africa. If seen against the backdrop of the severe droughts over the past 10 years, the increase in population as well as other disasters such as large fires and floods, scientifically based management practices supported by the necessary electronic infrastructures are long overdue (Botha, 1992).

This dissertation is based on the assumption that bad managerial decisions within the natural environment inevitably jeopardize conservation values, property, human lives and the forestry economy and therefore requires our scientific attention. Von Gadow (1987) underlines this by pointing out that a considerable proportion of the higher rainfall areas in South Africa is forestry land and that this environment is increasingly affected by decisions made by foresters.

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CHAPTER 2 : A SURVEY OF COMPUTER AIDED FIRE MANAGEMENT

In a study of this nature, operational functionality and development trends in international fire incidence management systems, provide important clues. This chapter analyzes the activities of several countries with regard to computer aided fire incidence management to establish the different elements, problems and requirements of such a system.

The main causes of fires within each country are briefly reported, as these statistics are a strong indication of the functionalities required for a sensor network.

2.1 AUSTRALIA

Luke (1960) noted that Australia had a wide-spread organization for fire-control in operation. He saw the necessity to improve this organization by employing whatever tools and methods could be devised, while at the same time borrowing from other countries where necessary. Australian researchers have since heeded that call by improving the mechanisms for information display, analysis and modelling while also incorporating some of the modelling techniques from the U.S.A. (Kessel, 1976; Kessel, 1990).

2.1.1 Causes of fires

About ninety-four percent of the fires in Australia are man-made. Approximately fifty percent originate from prescribed fires which have escaped from private property or from illegal fires in forestry areas. The other fifty percent can be attributed to a near even mixture of travellers, smokers, trains, children, incendiarism and power lines. Natural causes of fire, e.g. lightning, amount to about six percent of the total. The very dry summers in the western parts are most susceptible to fire (Luke, 1960; Luke, 1979).

2.1.2 Computer aided fire management

Two Australian systems, i.e. Geographical Information and Modelling System (GIMS) and Wildfire Incident Management System (WIMS) are discussed. The two-way interface which GIMS provides to the GIS ArcInfo, is also of importance.

2.1.2.1 *Geographical Information and Modelling Systems (GIMS)*

The prototype was implemented in Kosciuska National Park, New South Wales in 1980 and has since been refined and implemented by various co-operating groups in five Australian states. It is being used to manage 6 million hectares of fire-prone rural land in Eastern Australia and depending on the government organization, research group, as well as the variation in the basic suite of programs, GIMS is variously known as (Kessel, 1990):

- a) the gradient modelling system;
- b) **PR**istine Environment Planning LANguage (PREPLAN);
- c) **FIRE** Planning LANguage (FIREPLAN) and
- d) **Resource Management Information System (RMIS).**

The initial intent for GIMS was to be a decision support tool for representing research findings, e.g. vegetation, succession, fuel, fire behaviour and fire effects models in a form appropriate to decision making. Functionally GIMS was to model fire behaviour, assess strategies for fire control and determine the potential impacts of fire.

These models however, required data on the distribution and characteristics of vegetation, particularly with respect to the identification of vegetation types and flammable fuel loadings. At that time this data was lacking because of factors such as non-existent maps, wrong or unusable mapping information and inappropriate mapping scales. Therefore the necessary supporting models for the subsequent modelling of fire behaviour had to be developed.

On demand of fire-control personnel, a limited version (no database) of GIMS has since 1985 provided simpler, cheaper and portable operational support with the aid of a Sharp 1500A

pocket calculator, but Kessell (1990) foresees that the more powerful 'laptop' computers will replace this system.

Models such as the prediction of the rate of spread via the Rothermel 3-strata model, have shown consistent accuracy at approximately 70 percent, which is sufficiently accurate to reveal the most appropriate managerial action.

The development of GIMS was influenced by earlier developments in the U.S.A.. The original implementations of gradient modelling in the Glacier National Park, United States in 1975, were aimed at operational real-time decision making (Kessell, 1976). Subsequent developments in the US Forest Service shifted the emphasis towards medium- and long-term planning. Kessell (1990) reports that the thrust of systems applications have now come full circle in that current activity, e.g. WIMS, is again aimed at operational decision support.

2.1.2.2 *Wildfire Incident Management System (WIMS)*

The Western Australian Department of Conservation and Land Management and the Curtin University's School of Computing Science are developing WIMS as a joint project. WIMS is aimed at the operational fire management level by using the modelling techniques of GIMS and providing routines which represent the range of managerial tasks involved in incident management, e.g. (Beck, 1989):

- a) personnel;
- b) equipment;
- c) supply;
- d) logistics and
- e) basic record keeping.

WIMS is a fairly new development and should provide a broad-based and effective emergency decision support system.



2.1.2.3 Geographical Information Systems (GIS)

Linking GIMS with the GIS ArcInfo is receiving high priority. ArcInfo can provide the data capture, management, spatial operations and graphical display facilities, whereas GIMS will extract coverages from ArcInfo, model and then return them as 'new' coverages. Kessel (1990) believes this to be the most cost effective method to proceed.

2.1.3 Summary

From the above it is evident that the derivatives of GIMS and the subsequent development of WIMS have made a useful contribution to medium- and long-term planning, policy determination, training as well as the decision making process. The reported prediction accuracies are also useful in court cases as was demonstrated in 1983, when GIMS was successfully applied to prove that the fire-control methods of a particular organization were not at fault (Kessel, 1990).

Problem and potential problem areas are that:

- a) the fire behaviour models are imperfect;
- b) coverage look-ups, vegetation and fuel predictions as well as weather extrapolations prior to fire behaviour modelling, cause amplified errors;
- c) the complexity of the models (especially Rothermel) requires a large number of inputs which is another source of error and
- d) test data for the models are sparse because fire control personnel have more urgent duties than data collection.

2.2 CANADA

The province of British Columbia annually exports wood products valued at \$13 billion, but the annual cost of forest protection in this province averages \$52 million and could rise to as high as \$120 million (British Columbia Enterprise, 1989).

Canada had abundant forest resources prior to 1984, but shortages have since developed in several regions. Increased forest management could moderate the shortages but the necessity for protection will not diminish (Mercier, 1985).

2.2.1 Causes of fires

Prior to 1975, Canada recorded averages of 1 000 fires per annum with 60 000 hectare losses in timber. After the introduction of water bombers, the losses decreased to an average of 20 000 hectares per annum. Lightning accounts for 35% of these fires but causes 85% of the losses due to the random occurrence causing access problems. Man causes the remaining 65% (Mercier, 1985; Stocks, 1990a; Stocks, 1990b).

2.2.2 Computer aided fire management

The computer aided fire management system used in Canada is similar to that used in the United States. The system is known as the Canadian Forest Fire Danger Rating System (CFFDRS) and collectively consists of the following basic elements (Stocks *et al.*, 1989):

- a) databases on weather, topography, fuels and fire risks from lightning and man;
- b) Fire Weather Index System (FWI);
- c) Fire Behaviour Prediction system (FBP) and
- d) Fire Occurrence Prediction system (FOP).

The functions of this computer system can be summarized as:

- a) the tracking of lightning storms in real-time by a lightning detection network consisting of 24 sensors;
- b) real-time data from a fire weather sensor network;
- c) real-time resource analysis in terms of quantity and distribution;
- d) real-time dispatching of air-patrols, bombing forces and resources;
- e) preparation of detailed fire maps using the inputs from (a)-(d);
- f) the prediction of fire danger rating and fire occurrence using historical data and the

inputs from (b);

- g) the prediction of fuel moisture content using the input from (b);
- h) the prediction of fire behaviour using the input from (b), digital terrain maps and fuel coverage;
- i) archiving and off-season data acquisition and
- j) fire behaviour training (British Columbia Enterprise, 1989; Forest Technology Systems, 1990; Stocks *et al.*, 1989)

Besides weather, lightning, topology and fuel, the computer system also takes man-caused fires into account for the prediction of fire occurrences (FOP) per given area, by making use of historical data (Stocks *et al.*, 1989).

The dispatching of resources and weather forecasting are complex tasks and few people have the necessary experience. This has developed into the experimental use of Expert Systems (Dyer, 1987; Kourtz, 1987).

Landline and satellite communications are used for the main inter-computer networks while radio networks are used extensively for the support of remote sensors. The radio telemetry protocols are similar to packet radio networks while telephone dial-up modem systems use the XMODEM (appendix F) protocol for transmitting data.

Tithecott (1992) (Canadian Ministry of Forests) reports that they have not succeeded in implementing GIS technology for real-time fire management purposes although they can see it being used in near real-time applications in the immediate future. The GIS technology is developing in this direction and may become useful later in this decade.

2.2.3 Summary

The Canadian CFFDRS system has evolved over a period of 30 years into a complex but functional system which incorporates all levels of fire management. The history of system development indicates that the operational level of the system was first established before

advanced functions such as fire behaviour were implemented. The system is operated on a national basis by making extensive use of communication systems.

2.3 EUROPE

Many fires occur in Europe every year, mainly along the Mediterranean coast. The areas with the highest incidence are Sardinia and the Italian Province of Bolzano. During the period 1977-1982 more than 11000 fires occurred in Italy, approximately 7000 in Spain and 3200 in France (Cesti, 1988; Author Unknown, 1982).

2.3.1 Causes of fires

Incendiarism is given as the main cause of fire in Italy, Spain, Britain and Poland while burning-off, especially in the farming communities on the Mediterranean side of the Alps, are given as the second largest cause. Natural causes are responsible for less than three percent of fires and can mostly be attributed to lightning (Cesti, 1988; United Nations, 1982; Van der Merwe, 1987).

Deductions made by Stocks (1990b) and others from NOAA 9 and NOAA 10 satellite imagery indicate that large fires burn in Russia every year. It is estimated that an average of 300 000 ha per year are lost in these fires. The causes are unknown.

2.3.2 Computer aided fire management

Very little evidence of computer aided fire management could be found, but Cesti (1988) reports that fire look-out towers use close-circuit television while the forecasting of fire hazards in Spain and Italy is done with the aid of the Spanish ICONA system. This system, which is based on the Australian McArthur Fire Danger Rating System (FDRS), was found to be reliable in the Mediterranean regions but less reliable in the Alpine regions. In the

latter regions an experimental computerized system based on the Penman evaporation formula is in progress and seems to provide good reliability in the zones where it is used.

The Military Aeronautical Division is investigating the possibility of interfacing the ICONA FDRS with the existing meteorological satellites (Cesti, 1988).

2.3.3 Summary

McArthur's work is perhaps best suited to grassland, open-forest vegetation types and woodlands. Kessell (1990) found that the combustion physics-based 3-strata Rothermel fire behaviour model is vastly superior to the empirical McArthur model.

2.4 UNITED STATES OF AMERICA

The Boise Interagency Fire Centre (BIFC) in Idaho is a national organization directly concerned with operational fire-fighting, but is also called upon to aid in emergencies such as floods, earthquakes and other natural disasters, and is therefore logically based at Boise airport. The BIFC is staffed by fire management personnel from the following government departments:

- a) four federal land resource agencies from the US Department of Interior (the Bureau of Land Management (BLM), the Bureau of Indian Affairs, the National Park Service and the Fish & Wildlife Service);
- b) one federal land resource agency from the U.S. Department of Agriculture (the US Forest Service) and
- c) the US Department of Commerce (the National Weather Service) (Author Unknown, 1988a; German, 1988).

During the fire season and especially during multiple fire-fighting operations, up to 8 000 fire fighters must be supported from the BIFC with regard to food, clothing, ground and air transportation, payrolls and other commodities. The BIFC must also keep all equipment, for

example approximately 6 000 radio sets, 600 weather stations and 33 lightning sensors (11 western states only), in peak working condition. If requested, the Centre also supports emergency operations in Canada and Alaska.

Each BIFC agency functions according to its own mission and funding but all co-operate and contribute to issues of mutual interest (e.g. the central computer system) which could improve the efficiency and economical operation of the Centre.

2.4.1 Causes of fires

Banks (1966) found that 90 percent of all forest fires in Maine are started by man, while Donoghue and Main (1985) conducted a study over 24 states and found that man caused 85 percent of all fires. This contrasts to the findings of Taylor and Jonathan (1988) who drew on four surveys (1976, 1982, 1983 and 1986) for the Northern and Southwestern United States. These surveys show lightning to be the principle origin of fire. No particular reason for this apparent contrast could be found, other than the difference in geographical area.

Banks (1966) also shows children under 12 years of age as well as prescribed burning to be the primary human causes of fire. These results correlate with the Australian (section 2.1.1) and South African (section 2.5.1) experiences.

2.4.2 Computer aided fire management

The BIFC operates a central computer system globally known as the Initial Attack Management System (IAMS) (German, 1988) and can also deploy a portable field computer system, called InciNet (Incidence Network) at the scene of a fire or an emergency.

2.4.2.1 Initial Attack Management System (IAMS)

The main goal of IAMS is to provide district and state fire managers with as much fire

suppression and management information as possible in real-time via a network (German, 1988). To do so, IAMS integrates the Automatic Lightning Detection System (ALDS) and the Remote Automatic Weather System (RAWS) with:

- a) several geo-referenced databases (not GIS);
- b) a fire fuel system fed by satellite data and
- c) several fire and resource management software systems (e.g. BEHAVE).

The real-time data collection and storage nature of the system allows non-mission critical issues such as short-, medium- and long-term resource management and research to take place by allowing a variety of organizations to use the data (Fourie, 1989; German, 1988).

2.4.2.2 Incidence network (*InciNet*)

InciNet was created as part of a national standardization project to give diverse federal, state and private agencies a common computer framework from which to organize their efforts (Taylor, 1989). Before InciNet was created, up to 80 different computer systems were involved in various aspects of fire-fighting.

InciNet is connected to the central BIFC computer system via radio, microwave or satellite using mainly X.25 (appendix F) and the Data General XODIAC network combined with the Tymnet X.400 Telemail system for relaying messages on the Wide Area Network (WAN). InciNet therefore has direct access to data collected in real-time as well as a host of software packages but can also function alone if for example the network fails (Lee, 1988; Robb, 1989). It is utilized for (Lee, 1988; Lee, 1991):

- a) resource management;
- b) electronic messages;
- c) electronic conferences;
- d) weather updates and
- e) fire and smoke dispersion simulations.

InciNet was operationally used for the first time in August/September 1988 at the large

Yellowstone Park fire and has since been reasonably successful (Greenfield, 1988; Lee, 1988; Lee, 1991; Palmer, 1988).

2.4.3 Summary

Greenfield (1988), sums up the InciNet philosophy as follows: 'It should not matter what agency has jurisdiction for a fire; the computer equipment and software should be the same'.

2.5 SOUTH AFRICA

In the Cape Province fire-fighting operations are still done in the traditional manner and there seems to be no plans to use computer technology for incidence management.

The Forest Fire Association (FFA) in Northern, Eastern and Southern Transvaal and the Natal Fire Protection Association (NFPA) in the Natal Midlands were created by the shared interests and efforts of the private and state timber growers in those areas. The FFA and the NFPA are actively involved in fire-fighting activities with the use of aircraft, and they have a dynamically growing computer system to support the operation. The main bases are at the Nelspruit airport in the Eastern Transvaal and Oribi airport at Pietermaritzburg respectively. Although new to the fire-fighting scene in South Africa, the statistics presented in table 2.1 may be appropriate (Heine and Heine, 1992).

Table 2.1 indicates a steep growth pattern in the activities and successes of the FFA which has led to increased and wide-spread support. In May 1992 the area owned by members that are subscribed under the protection program of the FFA, exceeded 500 000 hectares (Heine and Heine, 1992; Sheedy, 1992).

Description	1991	1990
Number of fires attended by FFA	101	82
Hectares lost	661	909
Hectares saved by using aircraft ¹	7 934	4164
Flying hours:		
Spotters	562	788
Bombers	398	290
Charters	309	540
Hectares of members	401 404	375 757
Estimated annual profit (Rand)	200 000	29 000
Permanent staff	6	3
Temporary staff	6	3
Labour	2	0

Table 2.1: 1990/91 FFA (Transvaal) statistics

2.5.1 Causes of fires

During 1985-1986, lightning caused approximately 29 percent of the fires in state forests and man was responsible for 71 percent (Van der Merwe, 1987).

In the 1979-1985 period Le Roux (1988) reports that lightning caused an average of 12.1 percent of the fires in private forests and according to Van der Merwe (1987) was responsible for one percent of the damage. In the same period powerlines caused 0.9 percent of the fires in private forests but was responsible for 27.67 percent of the damage while man caused 87 percent of the fires (Le Roux, 1988; Van der Merwe, 1987). Kromhout (1990) reports a similar pattern for the 1985-1989 period.

Wilson (1992) reports that during 1991 the two largest fires in the Western Cape at the La Motte and Highlands State Forests were caused by lightning, while numerous smaller fires (up to two fires per day at Kluitjieskraal State Forest) were caused by children and prescribed burning.

¹ Determined by rough estimation and general verbal consensus amongst the parties involved.

2.5.2 Computer aided fire management

The FFA and the NFPA are both using a Novell 3.11 network based on Ethernet and which consists of a fileserver, currently with a 120 Mb disk and five PC's. Any of the PC's may be used for any of the following tasks (Sheedy, 1992):

- a) weather data collection and FDRI predictions;
- b) resource scheduling and aircraft operations;
- c) secretarial functions using WordPerfect 5.1 and
- d) accounting.

Only functions (a), (c) and (d) are operational at this stage. The weather data is received via phone or radio at 10h00 and 14h00 and this is entered into the system which then forecasts the FDRI. To a large extent this task is still accomplished manually (Heine and Heine, 1992).

2.5.3 Summary

The functions of the different computer systems used by the FFA are not integrated which causes data flow problems. The introduction of the amount of hours flown into the financial system is for example done manually at first and then entered into the system at a later stage. The incident management software is inadequate for operational use and the basic task of tracking events is therefore done manually and then typed into a document when time allows (Heine and Heine, 1992; Sheedy, 1992).

2.6 DERIVED SYSTEM REQUIREMENTS

According to German (1988), Kessell (1990) and Taylor (1989) planning systems (e.g. GIS) and incident management systems are complementary but separate systems. Tithecott (1992) confirms this by pointing out that Canadian operational real-time fire incidence applications have developed parallel to GIS because Canada has so far failed to apply GIS to real-time fire management. In Australia, Kessell (1990) reports similar experiences. Australia, America

and Canada are however following technological developments with GIS to implement the technology where applicable. It is therefore concluded that RIMS should be structured to reflect co-existence with GIS systems.

The system functionalities required are:

- a) aircraft operations management (German, 1988; Heine and Heine, 1992);
- b) equipment management (Author Unknown, 1988c);
- c) FDRI calculation and prediction (Sheedy, 1992);
- d) personnel management (Heine and Heine, 1992; Kessel, 1990);
- e) provision for administrative tasks (Heine and Heine, 1992; Sheedy, 1992);
- f) resource scheduling (Author Unknown, 1988b; Heine and Heine, 1992);
- g) reporting method usable in court cases (Kessel, 1990; Le Roux, 1992);
- h) supply management (Lee, 1988; Kessell, 1990) and
- h) weather data collection (German, 1988; Sheedy, 1992).

Computer interfaces are required between the fire incidence management system and:

- a) the accounting system (Heine and Heine, 1992);
- b) organizations directly or indirectly affected by fires (Chandler, et.al. 1983) and
- c) the weather and lightning sensors (German, 1988).

Kessel (1990) indicated that fire-fighting managers prefer a field unit which is simpler to operate while a trend towards laptop computers is expected. The Field Terminal Unit (FTU) presented in this study will model some of the functionalities required (to be derived at a later stage).

Statistics (Kromhout, 1990; Le Roux, 1998) indicate that most of the large fires in South Africa can be attributed to man. This corresponds to the trends in Europe, south of the Alps reported by Cesti (1988), and indicates that a South African electronic fire detection sensor system, similar to that used in Europe should be investigated.

CHAPTER 3 : DETAILED PROBLEM ANALYSIS

This chapter analyzes the problems present in the management of wildfires in South Africa with the purpose of isolating those problems which could be solved by an improved computerization strategy.

Besides the reconnaissance letters and visits described in chapter 1, the analysis is based on telephonic and personal interviews, personal reading as well as participation in a forest mensuration, economics and management task team during 1990.

Computer technology tends to intimidate people and therefore the letter was not structured as a questionnaire but as a background story, hinting at the required input. This strategy seemed successful and a written and telephonic response of 67 percent was received against the normal expected return rates of less than two percent on questionnaires (Du Toit, 1992).

Yourdan (1989) warns against the danger of becoming irrelevant during the lengthy analysis of an existing system, and therefore no attempt will be made to document and model the existing fire-fighting system, especially as each region has a slightly different method of implementing operational fire fighting.

3.1 HUMAN FACTORS

Humans all respond differently when confronted with 'new' technology and it is therefore necessary to take note of the criticisms, objections and fears that are raised.

3.1.1 Fears and dislikes

Managers who are afraid of computer technology are to be found at all levels of an organization. In the older and (usually) more senior generation, this trend makes it difficult

to implement modern solutions. Managers and staff in the (usually) more junior positions also fear that the implementation of computer technology will cost them their jobs (De Beer, 1990).

Operations managers and personnel show a distinct dislike of complex computer systems with multi-volume manual support, which create the impression of 'being-worked-for' (Kessell, 1990; Le Roux, 1992).

3.1.2 Scepticism

Van Wilgen and Manders (1990) report on some of the aspects associated with scepticism with regard to new technology. The most common arguments taken from other sources are:

- a) sheer disbelief (Wilson, 1992);
- b) too expensive (Cesti, 1988);
- c) too complex (Le Roux, 1992) and
- d) the current system is working fine (De Beer, 1990).

Many respondents also believe that voice and/or audio (e.g. pagers or synthesized voice) communication are the only communication techniques usable at a fire, mainly because of the real-time pressures involved.

3.2 FIRE MANAGEMENT

Activities during the fire season and during fires are still largely manual operations with broadcast voice (radio), telephone and personal communication being the carriers of data and information.

This leaves room for some inefficiency as observed during the visit to the FFA in July 1992, where for example, a critical message was not delivered in time, because the messenger was inexperienced and did not understand the importance of urgent delivery. In a properly defined

computer system this would not have happened as the system would have recognized the type of message as important.

3.2.1 Stated real-time managerial problems

The reported real-time problems are:

- a) weather data are not always timeously accessible (Rabie, 1992);
- b) the 10h00 and 14h00 distribution of weather data as well as related information such as the FDRI¹ as shown in figure 3.1, are difficult during operational fire control activity (Heine and Heine, 1992);
- c) the monitoring of multiple frequencies in voice is difficult, especially if more than one fire is in progress (Heine and Heine, 1992; Sheedy, 1992);
- d) collecting enough detail for reporting purposes on specific fires becomes difficult as the workload increases on operations management (Heine and Heine, 1992);
- e) there is currently no integration of the weather data system and the operations management software, which were newly implemented for the 1992 fire season (Sheedy, 1992);
- f) the operations management software contains serious 'bugs' rendering it useless until it has been reworked (Sheedy, 1992);
- g) the operations management software lacks functionality leaving the operational manager (and also the manager of the administration control point during larger fires) no choice but to remember events and to use paper where necessary (Heine and Heine, 1992);
- h) the weather data collection system has become unacceptably slow at times (Heine and Heine, 1992);
- i) resource distributions in the field are unclear (Naude, 1992);
- j) the immediate and proper location of a fire is sometimes unclear (Rabie, 1992);
- k) drivers lose their way to a fire causing delays (Heine and Heine, 1992; Rabie, 1992);
- l) water point locations, capacity and whether they are gravity or suction feed systems;

¹ Fire Danger Rating Index (FDRI).

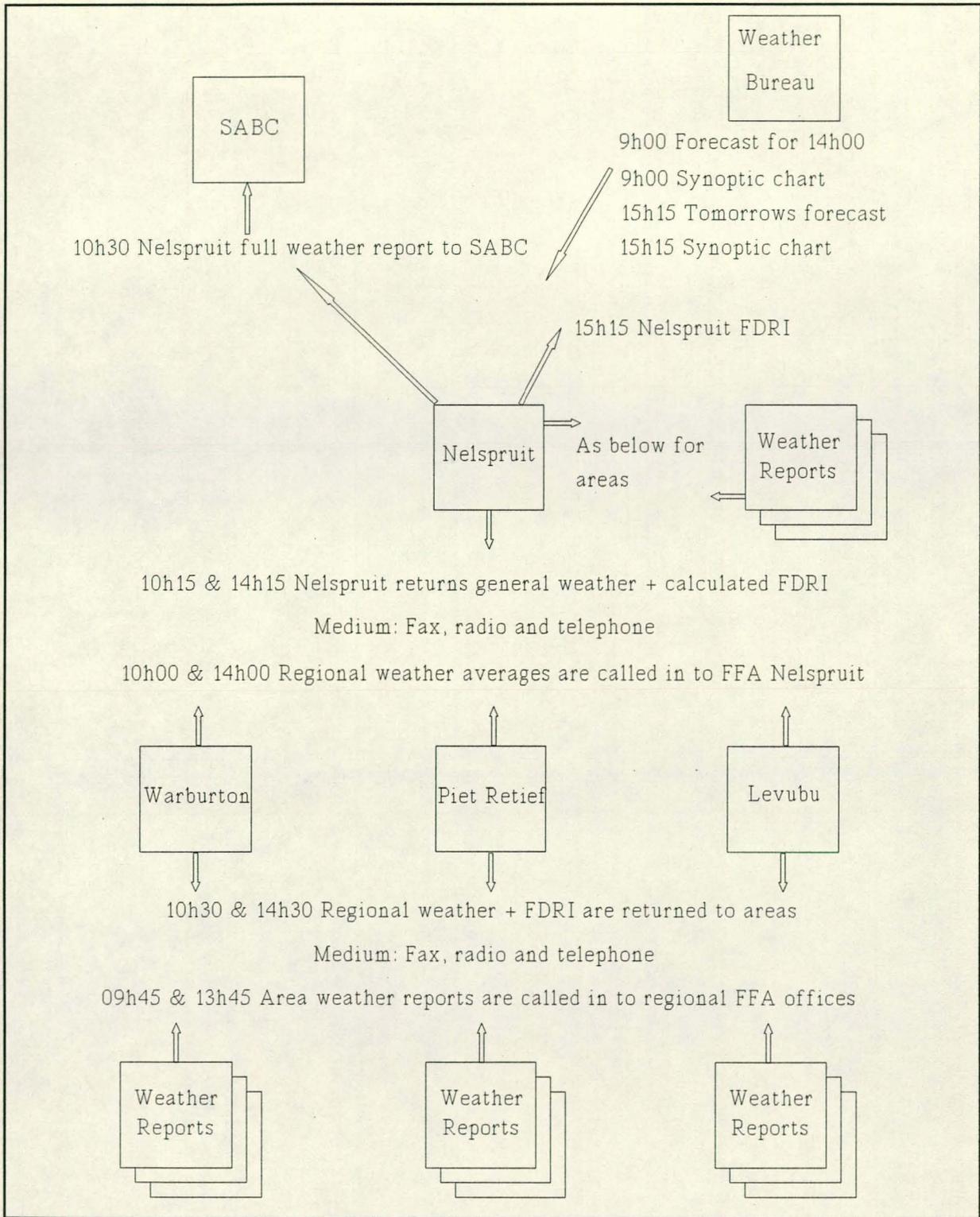


Figure 3.1: Manual distribution cycle of weather data at the FFA

are unclear (Heine and Heine, 1992; Rabie, 1992) and

- m) central operations managers (especially more inexperienced officers), have difficulty in visualizing the operational activity under their control (Heine and Heine, 1992).

3.2.2 Stated fire season managerial problems

The reported fire season problems are:

- a) the calculation of the FDRI is slow and not coupled to the much required system of predicting 'burnable days'¹ (Wilson, 1992);
- b) inadequate FDRI predictions lead to backlogs in the scheduled APO of block and firebreak burns and also limit the dynamic (de)activating of standby crews and the shifting of resources in a region (Rabie, 1992);
- c) the quality of reporting on fires is currently nothing more than an event log which contains little or no detail on aspects such as the area and type of plantation that has burnt (Heine and Heine, 1992) and
- d) after a fire it is necessary to consolidate costs e.g. time and materials, but the operational system is not integrated with the financial system (Heine and Heine, 1992).

3.2.3 Projected managerial problem areas

Some of the respondents have indicated that effective fire and fire season management activities extend well beyond the physical activity of extinguishing a fire and therefore a spectrum of processing needs and database capabilities are required during fire season activities (e.g. planning and mapping) and range from fairly simple history and forecast, to the more sophisticated GIS (Grey, 1990; Rabie, 1992; Sheedy, 1992; Author Unknown, 1991). A number of such systems (intermixed with other applications) already exist as 'islands of information' in different forestry organizations, causing a potential hazard with

¹ Sappi in Zululand report that out of 89 'burnable days' in 1990, they only managed to utilize 23 because of prediction problems.

regard to database consistency. Operational use as a reference base for managerial input during fire fighting operations is therefore not possible (Greenfield, 1988).

Databases and GIS systems demand a large investment in time because of the enormous quantities of data and information that have to be collected and updated, and the financial impacts of such activities are not always visible (Hine and Olivier, 1991; Prime Computer Inc., 1986). To counteract this problem, technology has to be used where necessary to feed these systems in an automated manner, e.g. the data collected from RAWs and ALDS at the BIFC in Idaho (German, 1988; Lee, 1988).

The feedback received from the respondents has allowed the identification of the sources and destinies of data and information and these will be referred to as endnodes¹. Table 3.1 summarizes the system endnodes and thereby provides a methodology of visualizing and describing data and information flows within the fire-fighting system. It is also an indication of the communication problems that have to be addressed in an incidence management system. This is an extension of the basic requirements for a forestry communication system proposed by Chandler *et al.* (1983).

Some of these endnodes will be reachable but rarely used, especially in a non-fire situation (e.g. a hospital).

3.3 FORESTRY COMMUNICATION SYSTEM

The radio communication technology currently operated by the South African forest industry has been in use for many years but, if seen against the backdrop of identified industry challenges and objectives (Grey, 1990; Von Gadow, 1990), the utility for forestry managers in the field seems to be limited unless extended by similar services such as described in chapter 2.

¹ Also referred to as terminators (Rennhackkamp, 1990; Yourdan, 1989).

Forestry related	
Description	Num
Administration control point	1 ⊙
Assistance : (1st, 2nd calls)	2
Environmental sensors	3
Fire crews	4
Fire boss	5 ⊙
Fire lookouts	6
Forestry companies	7
Observation posts	8 ⊙
Other (e.g. farmers, house owners, etc.)	9
Plantation Duty Officer	10
Regional Duty Officer	11
Resource control point	12
Vehicles	13
Aircraft related	
Airlift	14
Air Traffic Control	15
Airport Controller	16
Bombers	17 ⊙
Ops room	18
Spotters	19
External organizations	
Fire brigades	20
Hospitals	21
Local governments	22
Paging companies	23
Police	24
Weather Bureau	25
Computer systems	
Electronic Mail (E-Mail)	26
Geographical Information System (GIS)	27 ⊙
Real-time Fire Control System (RIMS)	28
Voice Mail	29
Telephone systems	
Public Branch Exchange (PABX/PBX)	30
⊙ : Active when there is a fire	
⊗ : Loosely identified - strictly not part of RIMS	

Table 3.1: System and communication endnodes

Organizations such as the FFA and the NFPA are, however, continuously looking at ways to improve their voice communication system and are also hoping that Standard-M¹ voicegrade channels over satellite will enhance the reliability of the voice system in all kinds of weather conditions (Naude, 1992).

Except for the LAN's of the FFA and the NFPA as reported in chapter 1, data communication systems (as opposed to voice), are currently limited to taking readings by direct cable or dial-up links to a sensor station (e.g. a weather station) (Sheedy, 1992).

3.3.1 Stated real-time communication problems

The reported real-time problems are:

- a) the voice system has no way of queuing messages, should a particular radio unit move into a radio shadow;
- b) the paging (bleeper) system has no way of knowing if personnel are reachable other than to wait for response;
- c) the forestry voice system has no way of limiting traffic during emergencies (other than discipline) and this results in system overloads which lead to communication failures during the (usually) critical phases of a fire;
- d) communication breakdowns occur during peak times;
- e) the destination is busy or unreachable;
- f) multi-channel switching for different areas causes confusion and lost messages (e.g. during fire emergencies up to 70 potential radio channels are available and used in Natal (Naude, 1992) and
- g) communication disturbances occur frequently as especially some of the older radio sets (notably state forestry) interfere across channels.

¹ Standard-M voicegrade channels should be available in S.A. late in 1993.

3.3.2 Stated fire season communication problems

The reported fire season problems are that:

- a) items (a, b, d, e) of section 3.3.1 apply, but to a lesser extent and
- b) the voice system has limited use in reconstructing the events associated with a fire, as well as monitoring the extent of damage caused by fire for later use in e.g. lawsuits.

3.3.3 Projected communication problem areas

One method of minimizing human intervention in feeding a database or GIS with data is to make use of a network, but in rural areas most of this communication infrastructure either does not exist or the nature thereof is very primitive (e.g. dial-up) (Fourie, 1992).

3.4 ELECTRONIC ENVIRONMENTAL SENSOR EQUIPMENT

Environmental sensor equipment usually consists of one or more sensors, a data logger and some form of supporting structure (e.g. a mast). The absence of standards and a standard terminology in this field necessitated the development of some definitions and acronyms (appendices F and G).

Environmental parameters are constantly changing, often in countrywide or global patterns, making it difficult (if not impossible) to follow trends in the isolation of sensor units in the immediate vicinity. Many environmentally oriented organizations in South Africa own and operate private sensor units, but these are either primitively linked to a base station via a dial-up system or not networked at all. Sensor equipment linked via a dial-up system as used by many of the weather stations operated by the Weather Bureau (Laing, 1992), virtually eliminates rural area usage. The time needed to dial, combined with problems such as link-reliability and software-control, totally eliminate usage in a real-time environment (Schulze, 1992).

3.4.1 Environmental Sensor Unit (ESU) network

Environmental Sensor Units that are not networked, e.g. those operated by FORESTEK¹, are difficult and expensive to operate and maintain, especially in very remote areas (Fourie, 1986). The absence of a supporting network was probably one of the major reasons why the South African introduction to the Fire Danger Rating Index (FDRI) used by the US Forest Service failed, as managers were simply not prepared to walk or drive to a weather station to make an (in their opinion) obvious deduction about the fire weather (Fourie, 1992).

3.4.2 ESU network standards

The most pressing problem about sensor equipment is the absence of standards in the design of the data logger. In contrast with the usually excellent electrical specifications aimed at survival in harsh circumstances, the network interface in terms of higher level protocols and the functionality necessary for real-time operation are weakly defined. There are no known standards and vendors are delivering to specification which limit the possibilities of a flexible networking solution. This is in sharp contrast to international developments in for example, the USA and Canada where a fire weather network is a facility of national importance and therefore standardized and integrated (Stocks *et al.*, 1989).

3.4.3 ESU access

The managerial support system associated with fire control is only one of several potential users of an ESU. Although the control of fires may command a higher priority usage of a particular set of sensor stations for the duration of a fire, other users may not be denied service. This potential for the concurrent usage of an ESU, via a network interface, poses several operational problems which require a special communication strategy. These problems are:

- a) different users need data at different time intervals and

¹ FORESTEK is a division of the CSIR.

- b) ESU access will be difficult while a particular user is downloading the history data contained in the logger memory, as there will be too much traffic.

During fire control it is necessary to link with a particular ESU while ignoring others. This facility allows organizations to control sensor usage during active fires, thereby increasing system efficiency and supporting the fire operations management by being specific to a fire in a specific area.

3.5 FIELD TERMINAL UNIT (FTU)

Field Terminal Units (FTU's) which would satisfy the requirements of fire season activities in especially the real-time sense, are not readily available. A limited but functional example of such a terminal was developed and will be presented in chapter 8.

3.6 REGIONAL

The current wildfire incidence management system used in South Africa is structured on a regional basis and each region usually has a main coordinating centre (e.g. NFPA at Oribi airport). The communication system between regions and especially between organizations e.g. the FFA and the NFPA who are combatting fires bordering each other, is under-developed but receiving attention (Naude, 1992, Sheedy, 1992).

3.7 SUMMARY

The fears, doubts and scepticism of people are real and need to be dealt with. Designing for efficiency with the most simplicity seems to be the answer, therefore RIMS and its associated elements FIN, ESN and the FTU must cater for this.

Fire incidence management will benefit by conducting fire-fighting operations with

standardized software within the group of involved organizations to minimize system interface and training problems (Chandler *et al.*, 1983).

The current communication system used for fire management has specific problem areas which could only be addressed by combining the advantages of both voice and data. Examples of such processing will be demonstrated in subsequent chapters.

Establishing a field communication system capable of seamless integration to forestry telephone and computer systems is faced with obvious technical difficulties such as the absence of modern telecommunications infrastructure in the rural areas. Given the fulfilment of the current and ongoing negotiations for African satellite coverage by organizations such as SATV, Telkom and Grinsat (Van der Watt, 1992), the *status quo* will soon (1993/94) change to a situation of full coverage with unlimited possibilities. The implementation of this technology may, however, take several years. The communication segments of RIMS, FIN and ESN should therefore be designed to cater for this transfer period by providing seamless integration with all the identified system endnodes. The basic elements of such a communication system will be discussed in chapter 7.

oooOOOooo

CHAPTER 4 : USER REQUIREMENTS

Efficient functionality for computer-aided real-time fire incidence management can only be obtained by a careful consideration of the user requirement¹. This chapter presents an analysis of the requirements based on the same inputs identified in chapters 1 and 3:

4.1 HUMAN FACTORS

Gaining human confidence in new technology can be difficult but the secret is to provide a simplistic user interface backed by adequate training and support (Von Gadow, 1990). The GUI² standard developed by IBM Corporation (1989) and used by Microsoft Corporation in their well known MS-Windows product, is an example of the ongoing effort to simplify the user interface by providing an intuitive approach.

4.2 REQUIREMENTS FOR IMPROVED FIRE MANAGEMENT

Respondents (appendix E) indicated the requirements discussed in the subsequent sections which includes an attempt to project (relate) the managerial requirements in terms of the respective elements of the real-time system.

4.2.1 Central control

Besides providing solutions for those problems mentioned in section 3.2.1, the requirements stated as real-time for central operations management are (i.e. comparable to RIMS

¹ A requirement is defined as functionality not available in the present system.

² Graphical User Interface (GUI).

functionality):

- a) keeping time based chronological record on the progress of the fire (Rabie, 1992);
- b) comparing local weather changes with advancing weather systems before starting backburns (Reyneke, 1992);
- c) predicting weather changes over the next few hours in the region (Esterhuysen, 1992; Godwin, 1992; Reyneke, 1992);
- d) monitoring changes of weather at the scene of a fire¹ (e.g. the windshift reading 10 minutes ago, currently, as well as the trend) (Rabie, 1992; Wilson, 1992);
- e) selecting (using) a particular weather station for information updates (e.g. northwest of the fire) (Rabie, 1992);
- f) the approximate value of the plantation or property likely to be sacrificed, should a backburn be started in a particular area (Wilson, 1992);
- g) the proximity, fastest access routes and availability of resources (people, water, retardant and equipment) (Godwin, 1992);
- h) monitoring parameters such as the water levels at various sources (Naude, 1992) and
- i) determining the size, spread and fuel type of the fire (Rabie, 1992).

4.2.2 Aircraft operations management

Operational aircraft management is associated with the airstrip controller of a remote airstrip who requires a tally of resource levels (e.g. fuel, airstrip water levels and phos-chek²), loading times and the number of loads. This information must be sent regularly to the fire boss for managerial purposes and to central control for logging purposes (Naude, 1992; Rabie, 1992).

¹ This requirement refers to weather changes local to the fire and does not involve the overall prediction given by the Weather Bureau.

² Phos-chek is a biodegradable foaming agent added in 0.2-1.0% mixtures to the water carried by water bombers and rapattack teams.

4.2.3 The administration control point

The administration control point usually functions during large fires and has to manage requests for resources, respond to orders from the fire boss, respond to requests for help in terms of resources or medical aid and report on the status of the fire (Rabie, 1992). In Canada this complex task has been approached by applying Expert System technology (MPROLOG) (Kourtz, 1987).

4.2.4 The observation control point

The observation control point has the function of monitoring the progress of a fire from a vantage point and to keep the fire boss up to date. The spotter plane usually functions in this role on smaller fires, but with larger fires it becomes difficult to follow all the action (Rabie, 1992). This task has no computerization requirements and is merely identified for the sake of completeness.

4.2.5 Field management

The real-time requirements for operational field management (i.e. comparable to voice supported by FTU functionality) are associated with the task of the fire boss. He has total responsibility for the fire and therefore requires input from and gives instructions to central control, the airstrip controller, the observation point and the administration control point. The information he receives must be brief, which is in contrast to central control who logs all available data and information (Rabie, 1992; Wilson, 1992);

4.2.6 Managerial requirements

Requirements stated as being seasonal or general in nature are:

- a) providing solutions for the problems mentioned in section 3.2.2;

- b) determining if the following day is going to be suitable for prescribed burning in order to complete the list of prescribed burns scheduled in the Annual Plan of Operations (APO);
- c) planning for and effectively placing regional fire fighting resources based on regional changes in the Fire Danger Rating Index (FDRI) (Godwin, 1992; Moodley, 1992);
- d) the implementation of fast reporting cycles (Heine and Heine, 1992);
- e) the improvement and extension of lookout capabilities with more modern equipment (e.g. an electronic alidade) (Moodley, 1992; Rabie, 1992) and
- f) a flexible reporting system which after a fire could report on, e.g. the efficiency of fire breaks, equipment and assistance, and also combine other detail such as fire weather, times fire was first reported, started, ended, times of spotter callout, spotter arrival, bomber callout, bomber arrival, other companies involved, scheduled resources and changes in the fire weather (Godwin, 1992, Rabie, 1992).

4.2.7 Projected managerial requirements

Crucial requirements in the real-time management of fires (especially during multiple fires within a region) are:

- a) an average reading from a group of sensors, e.g. the average windspeed of all available weatherstations northwest of the central control system is required to allow proper directions to especially the pilots (Fourie, 1992);
- b) the tracking of lightning storms and the plotting of lightning strikes (square kilometer accuracy) will allow fire and forestry managers to take appropriate and timeous action (Fourie, 1992) and
- c) that the capabilities of 'FIN' and 'ESN' type networks will allow the real-time function of advanced systems, for example fire spread prediction¹, FDRI calculations and smoke dispersion models (Davis and Irwin, 1976; Kromhout, 1990; Le Roux, 1988).

¹ For example the American Fire Behaviour (BEHAVE) modelling system.

4.3 FORESTRY COMMUNICATION SYSTEM

The current forestry communication system is well developed for voice transmissions but needs to be developed to ensure greater reliability during times of heavy use (e.g. when combatting fires). Restructuring parts of the system to support data transmissions on an event-driven basis, as outlined in this study, will limit traffic loads.

4.3.1 Stated real-time communication requirements

Stated real-time communication requirements are the solutions for the problems mentioned in section 3.3.1.

4.3.2 Stated fire season communication requirements

Stated real-time communication requirements are the solutions for the problems mentioned in section 3.3.2.

4.3.3 Projected communication requirements

The basic problem of overloading the system with excessive voice traffic can for example be solved by extending the well-known American APCO 'TEN' code (e.g. 10-4 = Acknowledge) (Chandler *et al.*, 1983) for the purposes of fire incidence management. The extension of such a coding system will not only minimize network traffic when transmitted as data, but could initiate complex processing (e.g. GIS requests) at the central site without lengthy voice explanations. The communication system between regions must support voice, data and disaster backup services on a physical level and handle logical issues such as the sharing of resources when fires occur on regional borders.

Distant fire-related requirements seen as problems of the voice communication system

currently used in the field are:

- a) access to compartment registers;
- b) preparing or requesting administrative data (e.g. capturing extraction data);
- c) checking or validating licences and permits;
- d) discussing mutual problems with peers not within reach of radio;
- e) using electronic voice mail facilities and
- f) privately discussing personnel matters with regional office.

These requirements illustrate integration possibilities with other disciplines, for example silviculture.

4.4 SENSOR NETWORK

To study the full capabilities of the technically advanced managerial support system under discussion, it had to be assumed that multi-access sensor networks exist on a national and regional basis (section 3.4). By implication this assumption is supported by some of the stated requirements above (e.g. section 4.3.3 b, c, d).

Due to the complex nature of data communication amongst computers, as opposed to the more primitive networking used for communication between an environmental sensor and a computer, the sensor network and the computer network would have to be two separate logical networks until it would be possible to combine them.

The sensor network could again be split into a widely spaced national network (e.g. operated by the Weather Bureau) and a mobile regional network (e.g. operated by the FFA and the LFPA).

Both the national and fire management network should use modern data communication techniques and equipment and must seamlessly interface with one another. These aspects are investigated in subsequent sections.

4.4.1 National sensor network

Scientific sensor reading activity on a national scale requires (Lee, 1988; Stocks *et al.*, 1990):

- a) an advanced national sensor network (e.g. weather stations, lightning detection and fuel moisture probes) in all regions of the country with communication functionalities such as the real-time adaption of the sampling cycle and a remote management mode;
- b) that this sensor network be electronically available to any registered organization enabling the dynamic extraction of data **depending on the mission** (e.g. agriculture and forestry) of the user organization and
- c) that new stations could be added to, or removed from this network in a dynamic way to enable the system to cater for high activity or crisis (e.g. wild fires) situations.

4.4.2 Regional forestry sensor network

Regional organizations such as the FFA and timber growers, are bound to have their own sensor network (e.g. mobile weather stations). The data coming from this network will be greatly enhanced by the availability of a national network allowing for additional input or correlation by intelligent programs specially written for the real-time interpretation of data.

4.5 SUMMARIZED DEDUCTION OF SYSTEM REQUIREMENTS

The requirements and problems identified in the previous chapter are multi-disciplinary and therefore have to be studied as a system with several elements. The concept of RIMS, ESN, FIN and the FTU was therefore created to study some critical details of such a working system.

South African forestry, unlike America or Canada, cannot afford to implement and operate expensive computer systems and therefore the solution has to reflect low costs (Tew, 1990). Fortunately the latest computer and network technologies have shown remarkable price

decreases (and performance increases) as opposed to the gigantic and expensive systems the Americans and Canadians had implemented, considering the available technology when they started some 10 years ago.

The operational problems and requirements identified thus far implies that:

- a) a network system is required which can seamlessly transfer voice, data and information to all the endnodes identified in chapter 3, table 3.1;
- b) the identification of often occurring voice phrases and requests, allows encoding (refer to appendix B) for shorter data instead of more lengthy voice transmissions which in turn controls overloading the network (e.g. the data terminals used by American and South African Police mobile units);
- c) the same principle explained in (b) can aid operational managers in visualizing the active fire area by activating area photographs and images at a central console (e.g. the area view from a particular lookout in a particular direction) after receiving a single short network event from a lookout reporting a fire;
- d) to comply with (b) and (c), all functions, data and events relevant to fire incidence management need to be identified (refer to the examples in appendices B, C, D);
- e) a standardized fire incidence management package needs to be implemented for use within all participating organizations to ensure the system integration is comparable to international trends (Chandler *et al.*, 1983; Greenfield, 1988);
- f) the central software needs to be designed for speed to enable rapid switching amongst different active fires to log incidents reported at random over different frequencies;
- g) the central system requires a flexible reporting system which can be rapidly generated and dispatched to interested parties and
- h) the routine transfer of data, for example the data transfer cycle shown in figure 3.1, must be automatized using network capabilities to relieve operator loads.

4.5.1 Real-time Incidence Management System (RIMS)

The current fire fighting system used in South Africa is structured on a regional basis and each region usually has a main co-ordinating centre (e.g. the FFA at Nelspruit airport). Each

region is then divided into sub-regions, for example the FFA at Piet Retief is a sub-region of the FFA at Nelspruit but functions independently.

Besides the central operations management effort, American and Canadian efforts have shown that any field computer support system (i.e. conceptually the FTU) has to be supported by a more sophisticated central service (i.e. conceptually RIMS) while the connections are supplied by a network (i.e. conceptually FIN and ESN).

The central control system (RIMS) would typically be based in a region or sub-region and is intended for use by the FFA or the timber growers. Operational fire-fighting efforts could require two or more active RIMS systems to intelligently know of each other and exchange information where necessary. Given the South African situation of bad communication reliability in rural areas, RIMS should be fully portable so that it could be transported to the vicinity of a fire.

Real-time computer systems at the applications level are characterized by the following features (Yourdan, 1989):

- a) many processing activities are taking place simultaneously;
- b) each task is prioritized, so that some tasks can be processed immediately while others can be delayed;
- c) tasks can be interrupted to allow the processing of higher priority tasks;
- d) extensive inter-task communication is required (e.g. the triangulation process from lightning detectors);
- e) simultaneous access to common data and memory requires 'mail-box' handshaking to prohibit data corruption and
- f) the dynamic use of RAM¹.

The correct choice of operating system is therefore important and this selection is presented in appendix A, section 4.0. Given an operating system such as the newly released Windows NT, the real-time system in itself can therefore be written as a multi-tasking program, each

¹ Random Access Memory (RAM).

responding to an identified set of events, for example each fire is spawned as a separate, independent task. In a busy system, these events are scheduled into a processing wait-queue(s) according to the event type, classification and priority. Events may also be waiting in a queue for reasons such as waiting for a prerequisite event. The initial development of an event scheduler suitable for fire incidence management is presented in chapter 5.

There are numerous report format requirements, some of which have to be produced during or soon after a fire. As most operations staff have a basic knowledge of a commercially available word processor, the possibility of RIMS reporting directly into the format of WordPerfect 5.1 (text and graphics) was investigated and some of the results are presented in chapter 5.

The aid of graphic images for reporting purposes and the presentation of a working background for central operators to facilitate better co-ordination, are essential and in line with international developments. Graphical technology is however expensive and the costs tend to escalate in a direct proportion to the level of sophistication required. Alternative solutions for a low-cost environment will be investigated in chapter 6.

4.5.2 Forest Industry Network (FIN)

Voice, audio and data communication techniques all have a role to play during fire season operations and maximize the effectiveness of managerial decisions. This has been demonstrated in the computer driven, real-time fire control systems used in America and Canada. The combination of these services were investigated and some of the most important trends are presented in chapter 7.

The central control computer system of any particular region must never become inoperable (e.g. by a lightning strike). Should this happen, an adjacent regional system must take control and process for both regions. Solutions had to be investigated and are also presented in chapter 7.

4.5.3 Forest Industry Sensor Network (ESN)

Co-operation with the Weather Bureau is necessary from a forecasting point of view but the weather stations used by this organization are inadequately networked to support the demands of a flexible fire fighting system. The Weather Bureau however seems to understand this problem and would probably be co-operative once the forest industry gives a clear requirement (Schulze, 1992).

Fire lookouts should be upgraded with more advanced early warning systems (e.g. the accurate plotting of fire positions via a computerized alidade). Fire reports from a lookout coupled to compass direction, can therefore be translated into actions, for example calling up the correct map backgrounds for a fire, using event-driven techniques. This system can function in parallel to the functionalities required from the Global Positioning System (GPS) described in chapter 7 and can serve as a redundancy or backup measure for pinpointing fires.

In addition to RIMS, a centrally based system must be responsible for the management of the data coming from the sensors in real-time. This system must manage sensors of all types and store their data to suit the incidence management system (e.g. fast retrieval). Some of this research is presented in chapter 5 and appendix B.

4.5.4 Field Terminal Unit (FTU)

Data processing on a FTU at the scene of a fire should continue providing critical information (e.g. calculation of windshifts and FDRI) to a fire manager, given a breakdown in the main communication system.

Functioning under real-time pressures is difficult and therefore a FTU must have a simplistic user interface which typically does not have more keys than the frequency selectors found on modern portable radios. Relayed information should be displayed in understandable, telegramstyle messages or synthesized voice.

The FTU must be robust¹, portable and/or dashboard mountable.

The design and implementation of a system meeting the requirements as described should recognize the practical problems of working in a harsh environment under real-time pressures.

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¹ Should a Laptop or Notebook be chosen as a FTU, the robustness of the equipment could be in question.

CHAPTER 5 : DEVELOPMENT OF THE CENTRAL CONTROL SYSTEM (RIMS)

This chapter presents the development of the systems structure and most important functional characteristics of the RIMS application model. RIMS, which comprises several elements, represents the central control system under the command of the operations manager. This work was based on experimental computer code, the input from the previous chapters and a series of analyses which are presented in appendices B, C and D.

5.1 OVERVIEW OF THE SYSTEM STRUCTURE

The FFA at Nelspruit in the Transvaal Lowveld monitors almost 100 different frequencies for incoming calls requesting spotter, bomber or rapattack-team support. Similar situations apply to other regions and sub-regions. On confirmation of a fire, one frequency is usually allocated for the monitor and control of that particular fire. During this period the operations room staff experiences an intensely active period which does not allow for slow computer responses or lengthy menu procedures, especially when multiple fires are active.

Figure 5.1 shows that the function of the system as described below, takes place against the background of a map image of the area in which a particular fire is burning. If the operations manager switches to a new fire, the background image changes appropriately. The accurate manipulation of such graphical images on a known coordinate system is specialized, therefore chapter 6 was devoted to a detailed discussion thereof.

The logical system structure and main functional structure with its associated databases are shown in figure 5.2 and table 5.1 respectively. The functional structure was as far as possible kept to 3 levels to eliminate lengthy menu procedures. The identification and analytic classification of fairly static data¹ within the real-time fire-control system, allow data encoding to take place for transport purposes on slow networks, provides for fast decoding

¹ The 'reference data' as presented in appendix B.

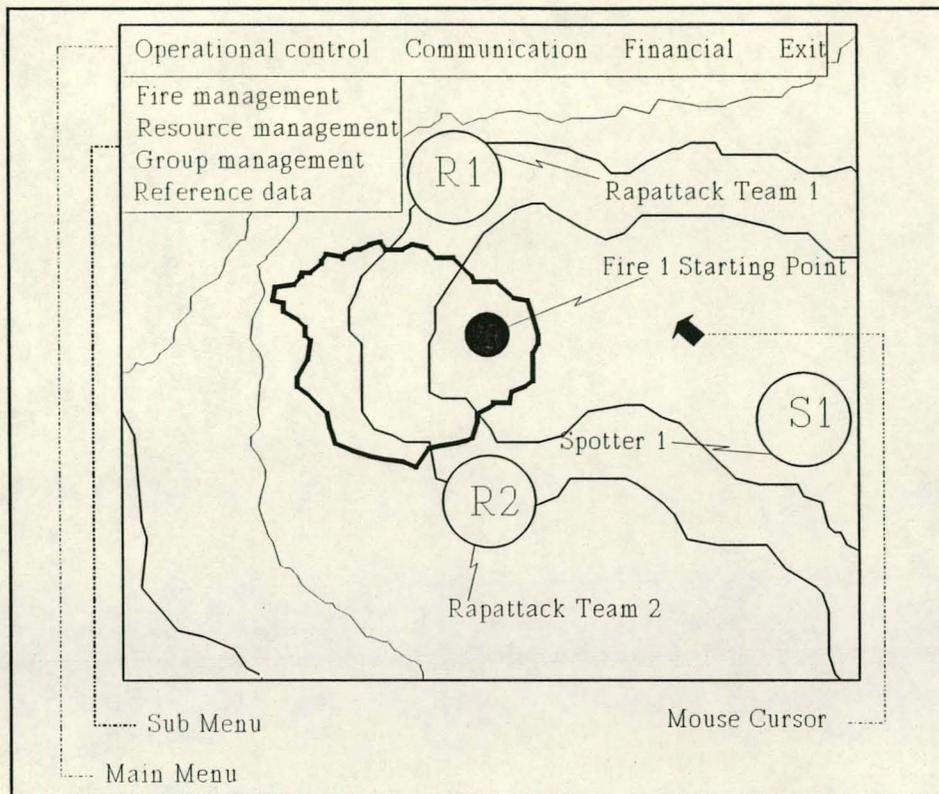


Figure 5.1: Example of RIMS menu system

procedures because of the known classification, improves integrity control (consistency, completeness, accuracy and reliability) and minimizes data redundancy. The application of reference data will be demonstrated in a subsequent section.

Several background (automatic) scheduled services were identified and tested, for example:

- a) backup memory tables to disk in a configurable time interval;
- b) monitor and react to events and
- c) update the real-time clock and time-slice counters.

5.2 EVENT PROCESSING IN A REAL-TIME SYSTEM

Real-time systems are event driven and these events define the actual operations performed by the system (Yourdan, 1989). The event processor developed to demonstrate these

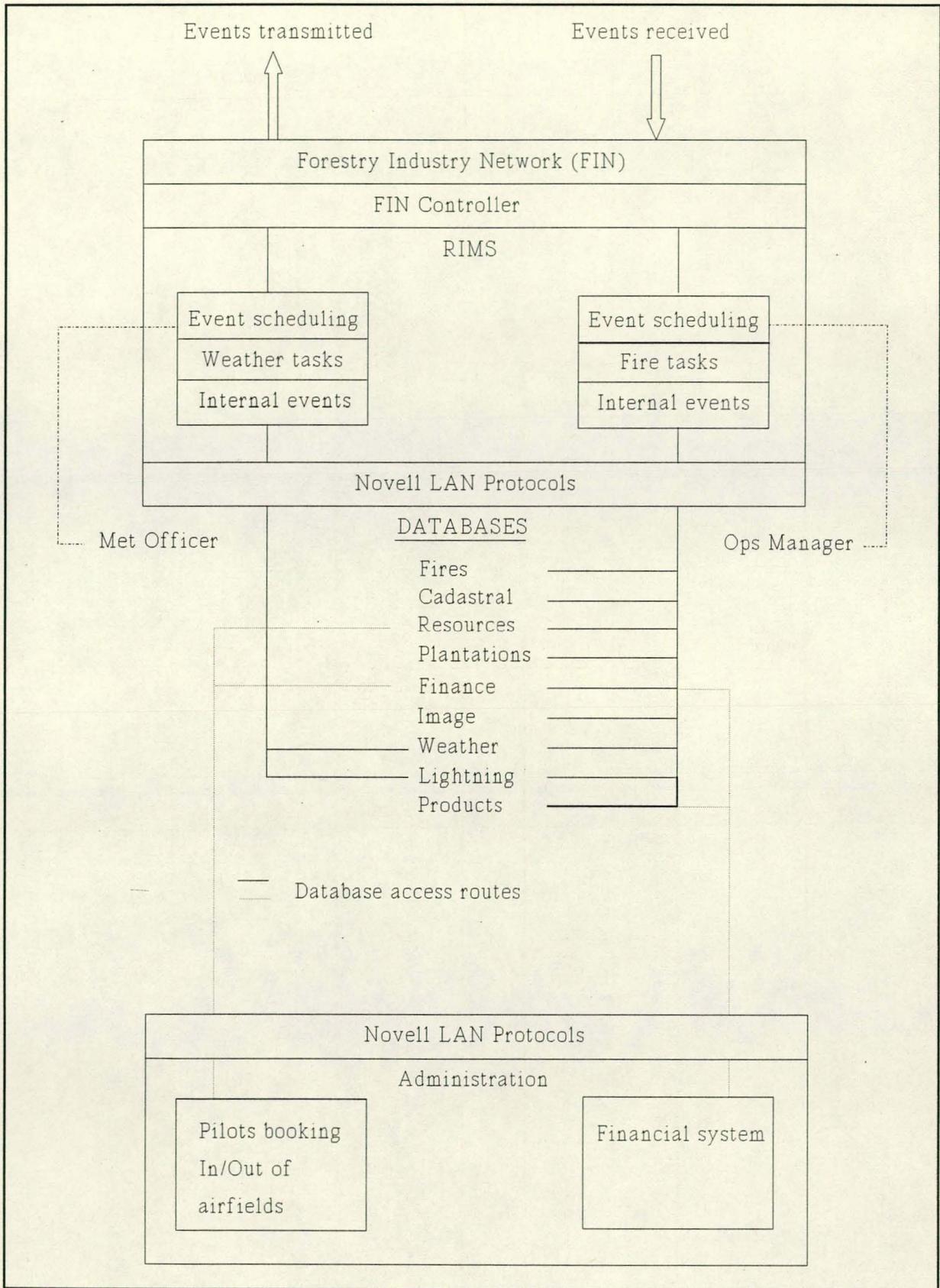


Figure 5.2: Logical RIMS system structure

RIMS main functional structure

<u>Operational Control</u>	<u>Communication Services</u>	<u>Financial Services</u>	<u>Reports</u>	<u>Sensor services</u>	<u>System</u>	<u>Training</u>	<u>Exit</u>
Fire management	Digital messages	Invoices	Bomber	Add a new sensor	Backup services	Operational Control	Yes
Group management	Electronic mail	Orders	FDRI	Allocate/de-allocate	Down/upload data	Emulate a FTU	No
Resource management	Monitor communications	Loss control	Fire	Browse and select	Event logs		
Reference data management	Page a person		Losses	Group management	Image control		
	Voice-mail		Network	Real-time monitor	Print functions		
			Spotter	Setup			
			Weather	Select by key			

Functional structure : Level 2

<u>Fire management</u>	<u>Digital messages</u>	<u>Invoices</u>	<u>Fire report</u>	<u>Allocate/de-allocate</u>	<u>Backup services</u>	<u>Operational control</u>
Add a new fire	Broadcast a message	Add an invoice	Detailed report	Allocate to a fire	Backup all databases	Refer ops control
Complete this fire	Prepare message	Add invoice by Smart Card	Real-time event log	De-allocate from a fire	Backup selectively	
Join two or more fires	Transmit to a number	Browse and select			Reload all databases	<u>Emulate a FTU</u>
Log real-time events		Select by number		<u>Selection</u>	Reload selectively	Refer appendix D
Select another fire	<u>Monitor communications</u>		<u>Network report</u>	Sensor type		
Split into more fires	Refer appendix C	<u>Orders</u>	Event statistics		<u>Down/upload data</u>	
		Add a new order	Real-time event log	<u>Group management</u>	FTU programs/data	
<u>Group management</u>	<u>Page a person</u>	Browse and select		Refer operational control	Financial data	
Add a new group	Prepare message	Select by number	<u>Weather</u>		Sensor data/formats	
Allocate/de-allocate	Transmit message		10h00	<u>Real-time monitor</u>		
Browse and select		<u>Loss control</u>	14h00	Activate/de-activate log	<u>Event log</u>	
Join two or more groups	<u>Voice-mail</u>	Add a new loss	Current weather		Null the event logs	
Select by key	Broadcast a message	Browse and select	Frontal activity	<u>Setup</u>	Read the event logs	
Split a group	Prepare a message	Select by number	Sensor station	Date, time		
	Transmit to a number			Data format	<u>Image control</u>	
<u>Resource management</u>				Network addressing	Add reference data	
Allocate/de-allocate				Real-time poll interval	Browse and select	
Browse/select type/sub-type					Correct (skewness)	
Select by type/sub-type					Select by key	
Transfer a resource						
<u>Reference data management</u>						
Browse/select type/sub-type						
Select type and subtype						

Functional structure : Level 3

Note: Level 3 of the functional structure provides more detailed functions, e.g. update/delete data (also an add if specialization is present), requests for key values and database/filenames.

Table 5.1: Functional structure for the central RIMS system

principles makes use of a three level priority scheme which, under MS-DOS 5.0, implements interrupt '08' as a high priority interrupt, interrupt '1C' as a medium level interrupt, while all other events are handled on a FIFO¹ basis. Interrupt '08' is a hardware interrupt which is scheduled by MS-DOS every 1/18th of a second and this interrupt in turn calls interrupt '1C'.

The experimental event scheduler processed an average of 6 message-events per second with display wait-states and an average of 35 events per second (typically a FIN routing function) with no wait-states. These results show that the experimental scheduler will be capable of processing the messages as generated by three large American fires.

5.2.1 Event description

Real-time systems must be designed to respond to any event from the set of identified events within the user environment. Failure to do so renders the system virtually useless and therefore external and internal events must be identified, precisely documented and appropriately implemented (Yourdan, 1989). Appendix B gives examples of the event identification process, and the data associated with the processing of these events, are presented in table 5.2.

An event is processed by a particular function or set of functions and could be reliant on the results of previous events or could in itself influence the outcome of successive events.

Examples of high priority events are:

- a) responding to operator input and display a particular map image;
- b) displaying a directional area photograph associated with a fire lookout report and
- c) displaying an urgent message.

Examples of medium priority events are:

- a) joining the resources associated with two (or more) fires;

¹ First In First Out (FIFO).

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- b) joining the resources associated with two (or more) groups;
- c) splitting the resources associated with two (or more) fires and
- d) splitting the resources associated with two (or more) groups.

Event elements	Type and Range	Function
Event ID	Word (0-65535)	Identification
Event type	Byte (0-255)	Classification
Event priority	Byte 1 = Low 3 = High (urgent)	Prioritization
Event status	Byte 0 = Successful 1 = Waiting for associated events 2 = Failed	Status report
Event queue ID	Byte	Processing queue
Event cost	Real (cent fraction)	Cost of event type
Event associates	Byte (Event Type) List of event types	Description list of the inter-dependent events
Fire ID	Word 0 = Undefined	The fire which this event is associated with
Seniority level	Byte 0 = None 1 = Operations manager 2 = Fire boss	Managerial decision level
Time to live	Word (seconds)	Time event is allowed in the waiting queue
Event data	64 Kb	Maximum data length

Table 5.2: Data appropriate to event processing functions within RIMS

Examples of low priority events are:

- a) transferring a resource to another fire;
- b) transferring a resource to another region and

- c) updating the event log file.

The manipulation of resources with a computer system will generate events that will require managerial decisions to be taken at various levels. This possibility is shown in table 5.2 while examples of such situations are described in section 5.3.

Many other events were identified using the procedures as described in appendix B, but the examples above were chosen for reference purposes at a later stage.

5.2.2 Event processing

Events could enter RIMS via the FIN controller (i.e. external events) or could be generated internally (e.g. the results of a function). All events receive a unique ID number and are classified according to type and priority before delivery to the processing queue. External events are classified according to the data presented in chapter 7, table 7.1.

If the system is busy and events cannot be processed immediately, they are queued to the processing wait-queue on the merit of their event priority.

Should an event be dependent on the results of other events that have not yet occurred, the system will mark this event as 'Waiting for an event' and queue it to a special wait-queue. An example of this situation is where only one lookout has reported a fire and the system is now waiting for a cross-bearing reference¹ from either another lookout or a spotter to calculate the position of the fire. When events of a similar type subsequently occur, the system processes the wait-queue for possible matches.

During times when the system is idle, the waiting queue is processed to remove events that have exceeded the time limit specified in 'Time to live'. This prevents the waiting queue from becoming too long. An example of this situation is where one lookout reports a fire

¹ This methodology is discussed as a possible function of the FTU in chapter 8.

which was never confirmed by another (i.e. a false alarm). This situation is marked as an uncompleted event and logged in the system log file.

The BIFC in the United States keeps basic statistics on matters such as messages per hour or messages per day. In South Africa this may not be sufficient as timber growers could either use RIMS to combat the fire as an internal organizational matter, or they could become clients of the FFA. The FFA could in turn invoice a particular timber grower with the number of events that have been processed.

The following statistics are therefore calculated and kept for the purposes of system management, reporting to clients and motivation for future system extensions:

- a) erroneous events;
- b) events/day, events/hr;
- c) events/day/fire, events/hr/fire;
- d) event type/day, event type/hr;
- e) event type/day/fire, event type/hr/fire and
- f) event type-cost/fire.

5.3 RIMS PROCESSING EXAMPLES

This section describes the logical operation of functions which process resource management in the fire incidence context. The most important data associated with resources are presented in table 5.3.

5.3.1 Join the resources associated with several fires

When two or more fires and their associated resources in terms of personnel, vehicles, equipment and aircraft are active in an area, they could become connected as the fires spread towards one another. At some stage, management could now regard this as one fire and RIMS must be able to follow this decision rapidly to continue the fire-fighting process

without disruption.

Data	Explanation of data purpose
Facility/resource ID number	Unique resource ID number
Organization ID number	The owner of the resource
Allocated group ID	The operational group allocation of the resource, e.g.: 0 = Not allocated 2 = Bomber and pilot
Resource type Resource sub-category	Personnel is an example of a resource type while a manager is identified as a resource sub-category (specialization).
Sharability amongst fires	Resources such as spotters are sharable while a unimog team is not sharable.
List: Allocated fire ID's	The fire ID number(s) to which this resource is allocated
Current location X Current location Y	The Gauss X, Y co-ordinates (m) as explained in chapter 6.

Table 5.3: Resource data

Table 5.4¹ represents this situation by joining fires 1, 2 and 3 into a new fire called fire 4². After the physical join operation, management is prompted for a set of decisions regarding redundant resources. For example, each fire was utilizing a frequency (i.e. a resource) and a decision is required for selecting a single frequency on which the 'new' fire is to be controlled. The resource data shown in table 5.3 reflect this possibility by:

- a) allowing some resources to be sharable amongst fires (e.g. a spotter plane) and
- b) allowing some resources to be unsharable amongst fires (e.g. a fire crew).

¹ A '1' indicates that a resource has been allocated and a '0' indicates that it has not been allocated. The nature of a real-time system requires these allocation tables to be kept in e.g. extended memory (using MS DOS terminology).

² Note that some resources are usable at several fires simultaneously (e.g. a spotter plane).

	R1	R2	R3	R4	R5	R6	R7	R8
Fire 1	1	0	1	0	0	0	1	1
Fire 2	0	0	1	0	1	1	0	1
Fire 3	0	1	0	0	0	1	1	1
Fire 4	1	1	1	0	1	1	1	1

Table 5.4: Joining several fires and their associated resources (R1-R8)

The functions associated with this operation are:

- a) selecting the ID numbers of the fires to be joined (mouse operation);
- b) selecting a new fire ID number (e.g. the next logical number) (mouse operation);
- c) changing the fire ID number of the applicable resources to the new fire ID number (system operation);
- d) prompting operations management for decisions attributed to redundant resources (system operation);
- e) selecting the release of a redundant resource or leave it in place (mouse operation) and
- f) logging the event as being completed.

5.3.2 Re-allocate the resources associated with a fire

The opposite situation with reference to the previous section could occur when a single fire creates more fires (e.g. spot fires) and it becomes necessary to re-allocate resources.

This set of managerial decisions can be made easier by requesting RIMS to create a set of 'new' fire ID numbers. By a step-through process of all the allocated resources of the initial fire, operations management then has to decide which fire must receive the resource.

The functions associated with this operation are:

- a) selecting the fire ID number (mouse operation);
- b) selecting a set of new fire ID numbers (mouse operation);

- c) displaying the single 'old' fire ID number and the 'new' selected fire ID numbers (system operation);
- d) searching for resources allocated to the 'old' fire (system operation);
- e) displaying the resources and request re-allocation (mouse operation);
- f) repeating (d) and (e) until completed and
- g) logging the re-allocation event as completed (system operation).

5.3.3 Join the resources associated with several groups

Grouping resources, for example Unimog or Rapattack teams, is natural to the fire environment. Joining one group with another to form a new group can be processed along the same lines as explained in section 5.3.1. In a situation where groups have been allocated to different fires, the operations manager should be prompted for the decision whether such a grouping was possible.

5.3.4 Re-allocate the resources associated with a group

The re-allocation or withdrawal of resources allocated to a group is similar to the process explained in section 5.3.2 with the exception that the system must take note of the group (or single resource) status which could be:

- a) undefined;
- b) active;
- c) in transit from;
- d) in transit to;
- e) off duty;
- f) resting;
- g) standby;
- h) unreachable;
- i) unservicable and
- j) withdrawn.

Re-allocation must for example not allow the spotter pilot to be re-allocated while the group (i.e. the aeroplane and crew) is marked as being 'in transit'.

5.3.5 Transfer a group or resource to another region

Fires do not have boundaries and therefore a resource or group must be transferable from the computer system of one region to that of another. This event type can be processed over FIN (chapter 7) but technically falls into the realm of the Distributed Database Management System (DDBMS) (Fourie *et al.*, 1988).

5.4 PROCESSING TIME CRITICAL EVENTS

In this section an example of a time critical event, similar to the 'time to live' concept of section 5.2.2, is discussed in more detail. The graphical background (map image) mentioned in section 5.1 refers.

As a fire progresses, parameters such as the fire perimeter (graphical) or the allocated resources may change. For example, a court case between two organizations on fire damages may require detailed information on the (half) hourly progress of a fire. It is therefore important for RIMS to provide a reporting sequence (figure 5.3) from the events that were logged to a special file during the course of a fire. The event log stores the data and the map images¹ in the form of a series of text and 'photographs' which could be replayed at a later stage for reporting purposes.

This task is aided by a timer function which triggers the appropriate logging event when either the timeout values for an image elapses, or when the operations manager wants to check on the map image of another fire, but changes have occurred to the data or map image of the one he is currently monitoring. The operations manager may also choose to initiate

¹ Each 16 colour image log contains 153 600 bytes.

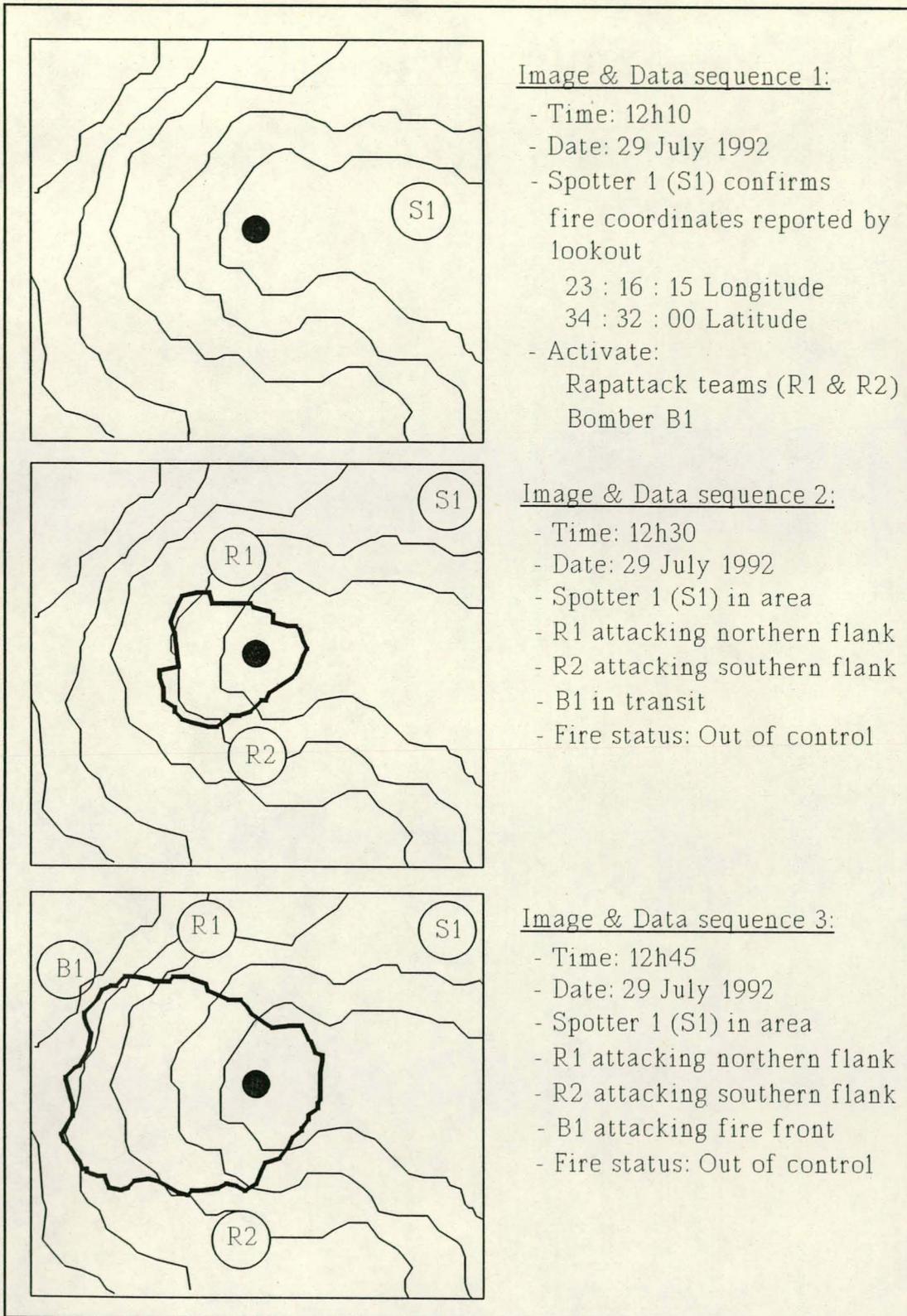


Figure 5.3: Time-critical reporting sequence.

a logging event if important information has changed (e.g. the wind has changed direction).

The set of functions associated with this operation are:

- a) monitoring the map images of active fires for changes (system operation);
- b) monitoring if the user wants to move to another map image (system operation);
- c) in the event of (a) and (b) being true, copy the image and the associated data to a logfile (system operation);
- d) monitoring the timeout value associated with a map image (timer operation);
- e) in the event of an elapsed timeout, warn the system (timer operation) and
- f) in the event of (e) becoming true, copy the image and associated data to a logfile (system operation).

5.5 REPORTING

Previous chapters have shown that reporting is a major requirement and that operational reality requires a variety of (everchanging) reports formats. This dynamic situation on report formats is technically a problem, as the design of reports and the associated programming effort¹, can be expensive in terms of manhours. In addition, with exception of word processing and spreadsheets, the relative computer illiteracy associated with operational units such as the FFA, inhibits experimentation by staff members.

The basic philosophy investigated was to format output from RIMS into the file formats of a commercially available word processor or spreadsheet system such as WordPerfect or PlanPerfect, respectively. The Advanced Programming Interface (API) for Borland C++, Microsoft C 6.0 or Assembly language programmers, distributed by the WordPerfect Corporation², was acquired and evaluated in terms of the direct interface possibilities with RIMS. The file formats of current interest supported by this API are shown in table 5.5.

¹ A larger programming effort implies a more expensive system.

² The average price is approximately R 300.00.

i)	WP 5.0/5.1 DOS and WPWin 5.1	Word processor documents
ii)	PlanPerfect 5.1 Worksheet File Format	Spreadsheet documents
iii)	WordPerfect 1.1 Graphic File Format	Graphical images

Table 5.5 File formats of interest for dynamic real-time reporting

Subsequent testing proved it to be possible for RIMS to generate sophisticated reports directly from the real-time events taking place (chapter 8, section 8.1.1). These reports can be pulled into other documents¹, edited or printed directly via WordPerfect. Documents can therefore be ready for printing and timeously distributed at any point during the operational life of a fire.

Another issue investigated was the question of how much detail would be needed before a decision could be taken. This will be demonstrated below by using the concept of working 'closely behind' a commercial word processor.

5.5.1 Reporting detail : An image example

With the aid of a network such as FIN, it is possible to watch and report on advancing weatherfronts using low-cost radio technology (chapter 7). By using the fast graphical manipulation methods described in chapter 6, in conjunction with the actual time between images², an average speed of frontal approach³ can be calculated by an operator.

The issue of providing enough information for decision purposes mentioned earlier in this chapter, can now be demonstrated. In figure 5-4 a 16 colour METEOSAT image sequence

¹ For example the Annual Plan of Operations (APO).

² Approximately every 3 hours in South Africa.

³ An Artificial Intelligence problem for pattern recognition in a possible subsequent study.

of an advancing weather system is presented for comparative purposes with the same sequences reduced to two colours as shown in figure 5-5. Not only is the two colour image cheaper to process, but it provides adequate information (and even better) for a decision to be taken, e.g. should a backburn be started.

5.5.2 Reporting : A set of reference data examples

A substantial amount of reference data were identified, extracted and detailed in appendix B. RIMS uses the mouse as an intuitive reference data selector which minimizes typing, while the availability of the reference data helps in maintaining database integrity and consistency. The FFA has already identified a smaller subset of such a system, but it is not yet operational for the reasons mentioned in chapter 3.

5.5.2.1 Example 1: *Maintaining the real-time log of a fire*

This section refers to the verb and noun set identified in appendix B which allows the operations manager to use a mouse when building a cryptic real-time eventlog. The events are reported via radio, telephone or verbally and each event is logged with a date and time, for example:

- a) 09/09/92 10h00 : Bomber 1 took off from Nelspruit to Kruisfontein fire;
- b) 09/09/92 10h05 : Bomber 1 commencing drop and
- c) 09/09/92 10h06 : Spotter 5 reporting Bomber 1 load dropped,

During a situation where multiple fires are burning, even the easier data selection process can become a burden. More automatic event tracking capabilities are described in chapter 8.

5.5.2.2 Example 2: *Data input*

During data input on the computer screen (e.g. fire registration), a field may require the title

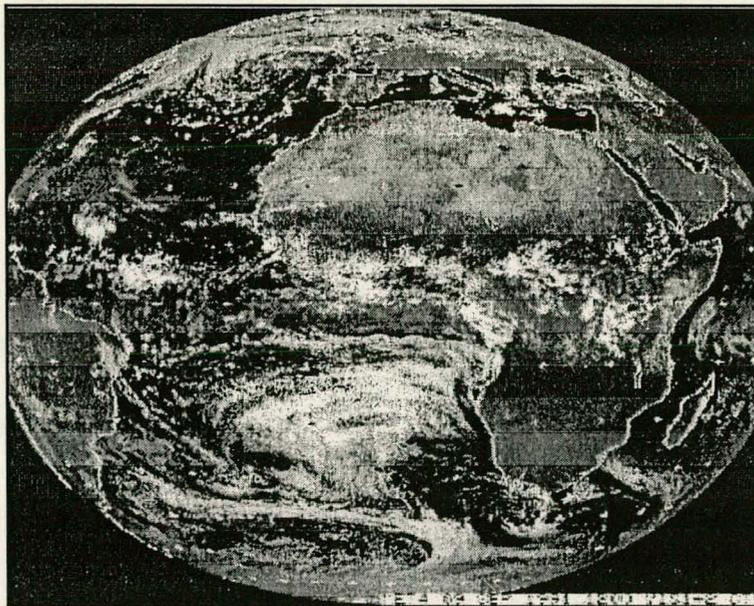
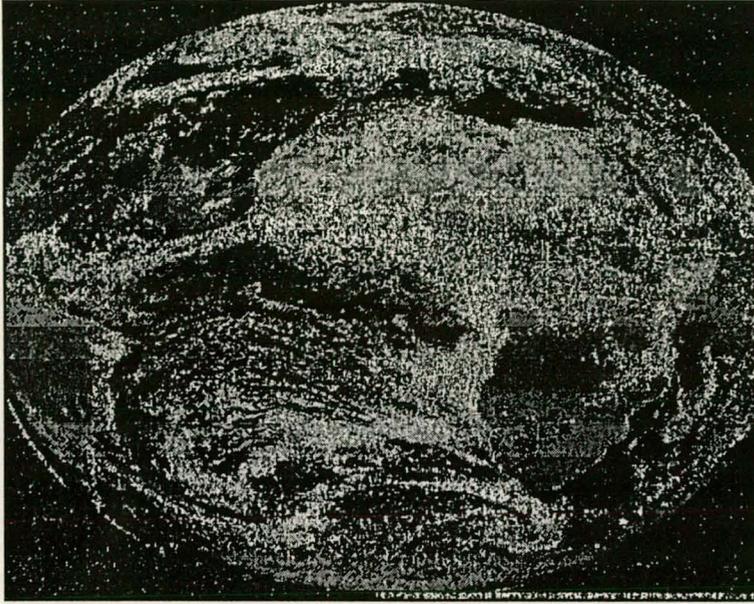


Figure 5.4: Sixteen colour METEOSAT image

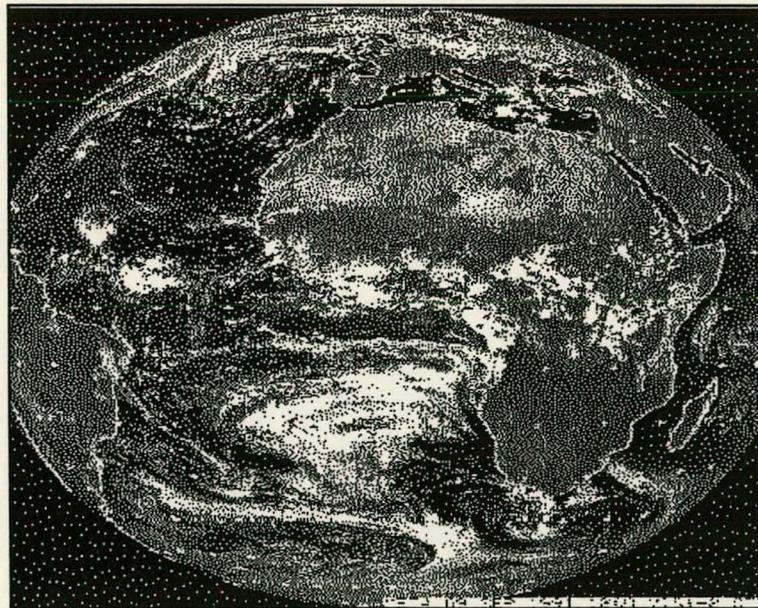
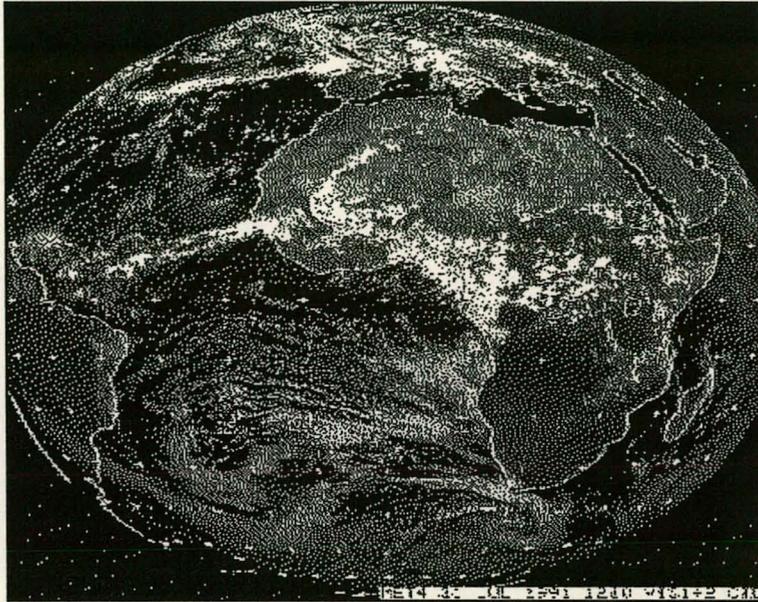


Figure 5.5: Two colour METEOSAT image

of a person. RIMS would automatically provide this link by matching the correct reference data with the correct field.

5.6 SUMMARY

In this chapter the development of some of the key issues of an operational real-time fire incidence management system were described, as identified by the objective oriented functional analysis (appendix B). The analysis has helped to construct a functional structure for RIMS and identified the most important data and events (i.e. event partitioning) associated with each of those functions.

Building an Entity-Relationship model of the system and the later steps of the systems development life-cycle such as data normalization (Rennhackkamp, 1990; Yourdan, 1989) were attempted but not described, as the conceptual nature of this study is not aimed at such level of detail.

The concept of event driven processing at the application level ensures a natural co-existence with operating systems such as Windows NT or DESQview 386 in the longer term (appendix A).

The reasons why MS-DOS 5.00 was used as a development platform is explained in appendix A and elaborated in chapter 8.

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CHAPTER 6 : TOWARDS REAL-TIME MANIPULATION OF IMAGES FOR A PC

In a real-time system the efficient and fast manipulation of maps and other images such as satellite pictures is essential for a successful system. The reasons, problems and requirements have been discussed in chapters 2, 3 and 4. It is essential to note that high quality graphics are expensive in monetary and processing terms and the equipment is not really suitable for portability in the harsh environment associated with forest fires. This chapter therefore describes the development of a more elementary, affordable but fast approach to the graphical requirements of central operations control, which also provides the necessary portability by making use of the standard video equipment associated with most commercially available laptop computers. For this purpose a special image database structure was developed which allows for rapid retrieval from disk to screen and uses a minimum disk space.

The maintenance of images and data is coupled to the operational activity while using RIMS. This minimizes lengthy update exercises and creates the impression of being 'burden-free'.

Basic problems were solved as follows:

- a) selecting and testing methods for inputting images of different kinds (e.g. maps and photographs);
- b) designing, developing and testing methods to display images at speeds suitable for the real-time environment;
- c) designing, developing and testing routines capable of translating co-ordinates to map grids and *vice versa*;
- d) developing and testing routines for the calculation of areas from map co-ordinates and
- e) investigating and testing suitable methods of exchanging data and images with a GIS on a network and applications level.

6.1 SCANNING AND IMAGE STORAGE PROCEDURES

Image scanning is a rapidly developing technology and the use of such equipment is a cost-

effective way of entering image data such as maps and photographs into a computer system as the service can be rented (as opposed to buying) from companies who specialize in high quality image scanning. For the purposes of this study the scanning hardware and software listed in appendix A were used. The capability of the PC software product could be described as 'poor to average' compared with the software running on the Apple Macintosh or the more expensive commercially available alternatives. Unfortunately the Apple Macintosh environment is not available on the network at Stellenbosch and therefore all development had to be done on the PC product.

The scanning process did not present a problem but it was necessary to correct the image in terms of a skewed placement on the scanner. Correcting skewness and storing images for high speed retrieval from disk are discussed below.

6.1.1 Storing an image for highspeed retrieval

Maps are regarded as a resource within RIMS and are therefore stored in association with descriptive data to facilitate processing. For example, to show the resources used at a particular fire using an image of the area where the fire is burning as background, the data in table 6.1 represents the image firstly as a resource and secondly provides reference data for further processing (refer to appendix B for clarity on structure).

The image received from the scanning software was stored in TIFF¹ format. This is a versatile format for general purposes, but has to be adapted for the highspeed retrieval of an image which was achieved by reformatting the image into a format directly compatible with the VGA² hardware. By doing so, high retrieval speeds are obtained, but the image database has to be restructured if other display hardware is used. This can be ignored as operational environments tend to be stable and it is relatively elementary to provide a set of restructuring programs (e.g. VGA and Super VGA).

¹ Tagged Image File Format (TIFF).

² Video Graphics Array (VGA).

Map images stored as a resource
Resource ID number Resource type = 'Map image' Resource sub-type = 'Area background image' List: ID numbers of allocated fires using the particular image
Image reference data
<p>Note: Other resources are associated with the image via the data below</p> Map image file name Region ID: Refer to reference data (appendix B) Sub-region ID: Refer to reference data Map density (e.g. 300 d.p.i.) Number of colours (e.g. 16) Width (pixels) Height (pixels) Pixellength (represents mapscale in meter) Central meridian (Gauss) List: Known pair of X co-ordinates (Gauss) (m) List: Map X correction factor List: Known pair of Y co-ordinates (Gauss) (m) List: Map Y correction factor

Table 6.1: Image storage

Tests were done with a 16 colour VGA card (640x480 pixels) with a limited 256 colour (320x200 pixel) capability (Wilton, 1987). The 256 colour mode performed slightly faster to the observing eye due to the bitplane selection which had to be done in 16 colour mode.

6.1.2 Correcting an image scan for skewness

The process of correcting a map after being scanned skewly is shown in figure 6.1. The user is prompted to select points 1, 2, 3 and 4 of which 1 is on the Gauss Y grid¹, 2 is at the intersection of the central meridian, 3 is on the Gauss X grid and 4 is the point of rotation. The system can now calculate the angle Θ and store

¹ Note the exchange of the X and Y axis on the Gauss grid.

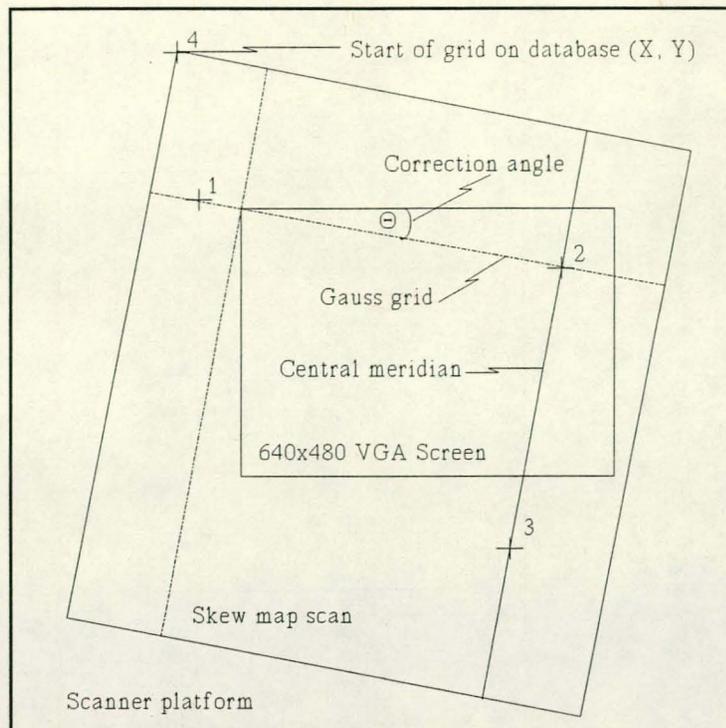


Figure 6.1: Scanning skewness

the image after correcting for the angle. Storing the image squarely allows for fast retrieval from the image database.

To rotate a single point around the origin:

$$x = x * \cos(\Theta) - y * \sin(\Theta)$$

$$y = x * \sin(\Theta) + y * \cos(\Theta)$$

Another problem is that fire incidence management could be active over more than one map, bearing in mind that a mapping system such as the Gauss Conformal (section 6.3.1), is more distorted towards the left and right sides of the central meridian. As this level of detail would distort the study objectives, it was ignored. However, table 6.1 does provide for this situation by listing correction factors, each corresponding to different segments of the highspeed retrieval structures developed for RIMS. Adequate mathematical manipulation of this problem is also described by Lauf (1983).

6.2 MAPPING FUNCTIONS AND AUTOMATIC EVENTS WITHIN RIMS

The manually selected mapping functions were briefly described in the previous chapter and the associated data were shown in table 6.1. Several background (automatic) services were identified and tested, for example:

- a) backing up screen images to disk after updates and
- b) monitoring and updating positional data on the image in real-time.

6.3 MAP CO-ORDINATES

The use of a map as a background to real-time operations where objects are added, moved or placed, requires translating co-ordinates to map grids and *vice versa*. For this purpose the Transverse Mercator Projection was chosen, adapted to provide for problem factors (e.g. stretched paper or digitizing inaccuracies), implemented in a program and tested.

6.3.1 Mathematical implementation

The Transverse Mercator Projection was originally developed by the mathematician J.H. Lambert and later redeveloped by C.F. Gauss as a particular case of his general theory on conformal transformations (ITESSA, 1972; Lauf, 1983; Williams, 1975). The Gauss Conform System is extensively used in South Africa where it forms the basis for a mapping series starting with the 1:50 000 map compiled by the Surveys and Land Information (Kuus, 1992). The South African projection is organized in two degree strips with reference to a central unevenly numbered meridian (e.g. 23° is the central meridian between 22° and 24°).

For the purposes of RIMS the 1:250 000 scale was chosen and the mapping co-ordinates and grid values were calculated with the aid of a C program. The formulae were adapted in terms of Xc and Yc to correct for small deviations caused by physical distortion or map production errors. The mathematics used within the test program is explained in the subsequent paragraphs.

a) Grid co-ordinates in terms of geographical co-ordinates

$$X = Xc \left(m + \frac{1}{2} \omega^2 \nu \sin \phi \cos \phi + \frac{1}{24} \omega^4 \nu \sin \phi \cos^3 \phi (4\psi^2 + \psi - t^2) + \right. \\ \left. \frac{1}{720} \omega^6 \nu \sin \phi \cos^5 \phi [8\psi^4 (11 - 24t^2) - 28\psi^3 (1 - 6t^2) + \right. \\ \left. \psi^2 (1 - 32t^2) - \psi 2t^2 + t^4] \right)$$

$$Y = Yc \left(\omega \nu \cos \phi + \frac{1}{6} \omega^3 \nu \cos^3 \phi (\psi - t^2) + \frac{1}{120} \omega^5 \nu \cos^5 \phi \right. \\ \left. [4\psi^3 (1 - 6t^2) + \psi^2 (1 + 8t^2) - \psi 2t^2 + t^4] \right)$$

where:

$$m = \int_0^\phi \rho \, d\phi = \int_0^\phi c(1 + e^2 \cos^2 \phi)^{-\frac{3}{2}} \, d\phi$$

Xc = X correction factor represented as a deviation from 1.0

Yc = Y correction factor represented as a deviation from 1.0

b) Geographical co-ordinates in terms of grid co-ordinates

$$\phi = \phi_1 - \frac{1}{2} y^2 \frac{t_1}{\rho_1 \nu_1} + \frac{1}{24} y^4 \frac{t_1}{\rho_1 \nu_1^3} [-4\psi_1^2 + 9\psi_1(1 - t_1^2) + 12t_1^2] -$$

$$\frac{1}{720} y^6 \frac{t_1}{\rho_1 \nu_1^5} [8\psi_1^4 (11 - 24t_1^2) - 12\psi_1^3 (21 - 71t_1^2) +$$

$$15\psi_1^2 (15 - 98t_1^2 + 15t_1^4) + 180\psi_1 t_1^2 (5 - 3t_1^2) + 360t_1^4]$$

$$\omega = y \frac{\sec \phi_1}{\nu_1} - \frac{1}{6} y^3 \frac{\sec \phi_1}{\nu_1^3} (\psi_1 + 2t_1^2) + \frac{1}{120} y^5 \frac{\sec \phi_1}{\nu_1^5}$$

$$[-4\psi_1^3 (1 - 6t_1^2) + \psi_1^2 (9 - 68t_1^2) + 72\psi_1 t_1^2 + 24t_1^4]$$

where: ϕ_1 = Footpoint latitude

c) Constants of the South African grid system

Williams (1975) supplies the constants for the modified Clarke 1880 ellipsoid as:

$$a = 6378300.819203 \text{ m} \quad \text{Semi-axis major}$$

$$b = 6356566.464516 \text{ m} \quad \text{Semi-axis minor}$$

d) Derived constants of the South African grid system

Let ρ and ν be the *principle radii of curvature* of the spheroid. They are respectively in the plane of the meridian and the prime vertical. From the geometry of a spheroid:

$$\rho = c/V^3 \quad \text{and} \quad \nu = c/V \quad \text{where,}$$

$$c = a^3/b \quad \text{and} \quad V^2 = 1 + e^2 \cos^2 \phi$$

$$\psi = \nu/\rho = V^2 \quad \text{and} \quad t = \tan \phi$$

x = Grid latitude

y = Grid longitude

ϕ = Degrees latitude

ω = Degrees longitude

$$f = (a-b)/a = 1/293.466307656 \quad \text{(Flattening)}$$

$$e^2 = (a^2 - b^2)/a^2 = 0.006803481018843$$

$$e'^2 = (a^2 - b^2)/b^2 = 0.006850085445147$$

The implementation proved to be successful for the purpose of representing information accurately enough for real-time managerial purposes, as the calculation is accurate to within a meter. If 1:50 000 or 1:250 000 maps are used for image backgrounds, this accuracy is better than the expected map error (section 6.3.2).

6.3.2 Expected map errors

Commercially available maps tend to stretch, and although a production system would not use image scans of such maps, the above formulae were adapted as described in section 6.3.1.

The expected theoretical error introduced by equipment and digitizing procedures on a scale of 1:250 000 map is:

$$\sqrt{25^2 + 0.625^2 + 62.5^2 + 25^2} = 67.320362 \text{ m}$$

where:

plotter accuracy:	0.1 mm = 25 m
digitizer accuracy:	0.025 mm = 0.625 m
digitizing accuracy:	0.25 mm = 62.5 m
scanner error:	0.1 mm = 25 m

At a scanning resolution of 98 pixels/cm, 1 pixel = 25.51204 m and the accuracy drops to 71.991677 m (from 67.320362) (1 mm = 250 m on 1 : 250 000).

At a scanning resolution of 118 pixels/cm, 1 pixel = 21.18644 m and the accuracy drops to 70.575465 m (from 67.320362).

Kuus (1992) reports that the manufacturing process of the 1 : 250 000 map produces an average accuracy of far better than the accepted 200 m. The accepted manufacturing accuracy of the 1 : 50 000 map series is in the order of 15 m. In terms of incidence management this is acceptable and therefore is a low-cost alternative to high-precision mapping.

6.4 EXCHANGE OF DATA AND IMAGES WITH A GIS

The exchange of data and images between RIMS and a GIS system is of mutual benefit to both systems and was tested on a network and applications level.

Two files were exchanged with ArcInfo in TIFF format for testing purposes (Duckworth, 1992). A C program, which unpacks and displays the GIS corrected image in Tagged Image File Format (TIFF) was written and found to be acceptable provided the image was pre-converted to the number of colours which can be supported by the PC video system (i.e. 16 colours for this project). It was later established that code for reading TIFF headers exist in the public domain and this can be used and adapted to undertake projects of this nature in future. Detailed specifications for TIFF revision 6.00 is available (Aldus Corporation, 1992).

On the network level RIMS must be able to open a session *via* its own network software with the underlying network system of the machine on which the GIS is implemented. Based on the work presented in the previous chapter, this exchange can be regarded as being solved.

Another and more formal method available for the exchange of data is the National Standard for the Exchange of Digital Geo-referenced Information of which a copy was obtained from the Chief Directorate of Surveys and Land Information (Lester, 1992). A copy of the data could not be obtained in time for direct experimentation. The manual, however, provides an in-depth description of the exchange standard. The required interface program for extracting the data is regarded as technical detail.

6.5 SUMMARY

The graphical operations discussed in this chapter are part of a basic set of functions specifically selected to suit the relatively slow PC environment. RIMS in a portable form (appendix B) requires laptop technology but the video display hardware of these machines are still slow in comparison to a standard desktop PC. The implementation described in this chapter will ensure optimal speeds for application in real-time fire incidence management.

The positional placement of resources, fire perimeters and cadastral information were demonstrated in terms of the mathematical implementation and argued to be accurate enough for managerial purposes. The decision making process during fire incidence management does not require absolute accuracy from a manager's point of view but *post mortem* reports, however, must be relatively accurate, i.e. at least as accurate or even better than the maps used by a particular organization, as it could be used to update the Annual Plan of Operations, update mapping information or serve as evidence in court.

The exchange of data and images with a GIS has the benefit for RIMS of being able to use high quality maps with the associated map data as a background to ongoing real-time operations.

The GIS in turn benefits by being updated (kept current) as the result of data, for example the co-ordinates of burnt areas, are available soon after the fire has been extinguished.

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CHAPTER 7 : COMMUNICATION SYSTEM

The value of a good communication system to support fire-fighting has been discussed by several authors over many years (Le Roux, 1988; Luke, 1960). Several problem areas however still exist and have been identified in previous chapters. Given the realities of the South African rural area communication system, this chapter presents a network model developed for FIN¹ and ESN² which is capable of providing integrated services:

- a) between RIMS and the FTU;
- b) between RIMS and the ESU;
- c) between RIMS and the internal and external telephone system and
- d) for inter-connecting regional forestry and FFA LAN's³.

The model is technically supported by the knowledge and insight gained during the development of communication services for production purposes in several campus projects at the University of Stellenbosch, i.e.:

- a) LAN terminal services using TCP/IP⁴ on Arcnet and Ethernet using the Novell ODI⁵ drivers;
- b) LAN terminal services using Novell TES⁶;
- c) home terminal services for the administrative staff of the University of Stellenbosch (RS-232) which are compatible with ADABAS/NATURAL requirements and
- d) a real-time terminal with a magnetic card interface for the student meal-booking system on campus.

¹ Forest Industry Network (FIN).

² Environmental Sensor Network (ESN).

³ Local Area Network (LAN).

⁴ Transmission Control Protocol / Internet Protocol (TCP/IP).

⁵ Open Data Interface (ODI).

⁶ Terminal Emulation Services (TES) in VAX Netware for VMS.

The TCP/IP system from the National Center for Super-computing Applications (NCSA) was used as the initial base for this work and then adapted to fit the specific requirements of the University. The C code for KA9Q was studied and analysed. This code was written by Phil Karn (Horzepa, 1989) for amateur packet-radio TCP/IP services and it includes support for the KISS link-layer non-protocol serial interface as well as the AX.25 protocol.

At the beginning of 1991 the information required to develop a TCP/IP packet driver (appendix F) for the Novell ODI system on Arcnet, was not available in South Africa. A specification accompanied by the necessary hardware was sent to Mr. D. Lanciani (1992) in Boston, who developed the code under local guidance. The project was a unique achievement in that it was the first¹ packet driver available, for the Novell ODI system on Arcnet. This packet-driver has been installed on approximately 600 PC's at the University of Stellenbosch and is in constant use for all terminal and file transfer services to the central computing facilities.

The TES communication drivers, initially developed at the University of Stellenbosch, were unstable due to the lack of technical information on the internals of Netware. After studying the protocol, these communication drivers were re-designed and re-written in March 1991. This second generation drivers are still used on campus by all PC's containing the older Technetics 1050 Arcnet Network Interface Cards and are also used in all real-time mealbooking terminals (barring two remote terminals).

During large fires it may be necessary to set up several networks on various mediums (e.g. telephone and radio). These networks may be a command network to link fire management, a tactical network to link ground forces, a ground-to-air network to provide positive control of air and/or ground forces, an airband network for aircraft control (e.g. spotters directing bomber attacks), a supply network to link supply orders to operational control, as well as a fire-camp network to link supply lines with the supply officers. Normally these networks do not exist until they are required.

¹ Determined via international Electronic Mail requests to suppliers and universities.

By introducing a voice-mail server, a multiplexer, a bridge and a VOX¹ to the existing telephone PBX² system and LAN present in most forestry organizations and the FFA, the concept of integrated services with reference to fire incidence management was studied (Fourie, 1988).

Complex processing triggered by elementary and physically small network events is introduced as a concept of maximizing low bandwidth usage. A relatively inexpensive method of using satellite technology for data communication and the collection of weather images, is briefly evaluated and described.

Imminent and longer term trends in the development of international communication technology was analyzed and applied to the model. The physical and logical structures of FIN and ESN were evaluated and presented with reference to experiments and implementations to clarify crucial aspects.

This chapter therefore contributes to the process of setting up several networks in a fully integrated and dynamic manner in real-time.

7.1 TRENDS IN COMMUNICATION SERVICES

Modern trends in communication services have many advantages and should be exploited for the necessary functionality. International and local Public Telecommunications and Telephone³ (PTT) networks are currently upgrading their services by installing digital transmission equipment commonly referred to as ISDN⁴ (Waldron, 1992). This equipment will allow the transmission of telephone and computer traffic, whether it be video, data, telephone conversations or computerized graphics, over the same network in a digital format

¹ Voice Operated Switch (VOX).

² Private Branch Exchange (PBX).

³ The South African PTT is represented by an organization called Telkom.

⁴ Integrated Services Digital Network (ISDN).

(Cashmore, 1992). Novell has recently released WAIDNet¹ which allows remote computers to dial into LAN services using ISDN S-Bus protocols which are transparent to protocols such as IPX/SPX, SNA, TCP/IP, X.25 and X.75. For each of these protocols, Novell has released gateway routers (Hypercom Systems, 1992).

ISDN was originally designed as a 64 Kb/sec. service, but popular demand as a result of technological progress in the areas of video, faximilee and images, has made it obvious that this bandwidth is inadequate. International telecommunication giants (e.g. Siemens) have therefore started the evolutionary process of implementing cost-effective networks which should be operating at speeds of 2.5-10 Gb/sec. by the turn of the century (low-cost broadband ISDN). Broadband ISDN can be seen as a supplement for normal ISDN. This process has been endorsed by the acceptance of the *de jure* SONET² or SDH³ 150 Mb/sec. transmission standard, which is already being implemented and expected to be dominant as the European operational standard by 1995 (Baur, 1991).

The technology allows the automation of many office procedures such as customer services, credit verification, directory services, shared access to company databases and resource ordering (Pawlita, 1991). Many of these digital services are already utilized in private networks using digital ISDN PBX systems combined with leased lines for remote circuits.

It is already common practice to replace the answering machine with a voice-mail computer which is capable of providing sophisticated services such as auto-attending the company telephone system, operating the company mailing system or providing access to the company database (Univoice, 1992). Mail-inboxes can be checked by using DTMF⁴ telephones or Toni devices.

Voice recognition is still a problem but is receiving close attention by the computer industry.

¹ Wide Area Integrated Digital Network (WAIDNet).

² Synchronous Optical Network (SONET).

³ Synchronous Digital Hierarchy (SDH).

⁴ Digital Tone Multiple Frequency (DTMF).

Voice-mail systems with limited voice recognition services are however available. The words '0-9' as well as 'Yes' and 'No' can be recognized, therefore a remote menu system can be operated using voice (Digital, 1991).

Satellites are able to deliver large volumes of information to very wide areas. Today the Intelsat satellites that serve Southern Africa are responsible for transporting the bulk of international telephone and television broadcast traffic and relay most cross-border computer traffic. It is expected that satellites will form the hubs of wide-scale cellular mobile networks. These services are currently artificially limited to high premium applications such as car phones, because of the huge investment made in traditional cable networks. Europe and South Africa are, however, considering smaller radio-based networks, known as Radio In The Loop (RITL) for remote areas (e.g. the Sabie telephone system) as a means to overcome the backlog in telephone applications (Baur, 1991; Cashmore, 1992).

7.2 BUSINESS ADVANTAGES OF MODERN COMMUNICATION SYSTEMS

The advent of the Value Added Networks (VAN's) had far-reaching implications world-wide. Organizations such as ISM, First National Bank, Standard Bank, Vanco and J-Net have taken advantage of local legislation by forming companies that add value to the existing local PTT (Telkom) services. These companies are well placed to provide services such as the rerouting of electronic mail, distributing customer on-line information, providing Electronic Data Interchange (EDI) services as well as the management of Information Services on behalf of other organizations. As a result, organizations can cut costs by saving on manpower, hardware, software and technical support (Cashmore, 1992).

Electronic Data Interchange (EDI) is a technology that allows different organizations to exchange standardized documents such as invoices and orders. The growing use of EDI is having a major impact on improving company efficiency and cutting administrative costs. In the current economic climate, South African subscribers are benefiting by the access this technology provides to overseas markets (Cashmore, 1992).

7.3 INTEGRATED FORESTRY NETWORK

Given the background described in the previous sections, a physical and a logical communications model is presented in figure 7.1 and 7.2 respectively. This network model is a suitable platform for interconnecting all the endnodes identified in table 3.1 (chapter 3) in a transparent manner. It also allows for technological growth with the minimum of changes within the emerging international trends discussed previously.

7.3.1 FIN communication controller

It is the task of the FIN communication controller to manage all data transmitted over the network associated with the FTU and the ESU. It can be regarded as a special software unit capable of encoding/decoding network events, but more specifically it:

- a) passes incoming FTU (or other sensor types) events to RIMS, the voice-mail server, the database or the GIS by using a table of available services (refer to table 7.1¹ for examples);
- b) routes outgoing messages from the destinations mentioned in (a) back to the FTU;
- c) does similar tasks for the sensor network and associated ESU's;
- d) provides standardized data format mappings for the different ESU types for ESU database updates;
- e) provides a queuing system for event traffic bottlenecks or when a mobile station moves into an area of radio shadow (this technique guarantees delivery as soon as the station is visible as opposed to a voice session where the caller may have become busy) and
- f) provides a network event traffic monitor for management purposes.

To do this dynamically and efficiently, the concept of the RIMS event scheduler discussed in chapter 5, is also applicable to the FIN controller. The source, destination, network codes and descriptions presented in table 7.1 should be updatable in real-time in a production system to dynamically provide for new requirements.

¹ The lengthy transmission codes are only for clarity as the encoding process could be improved for a production system.

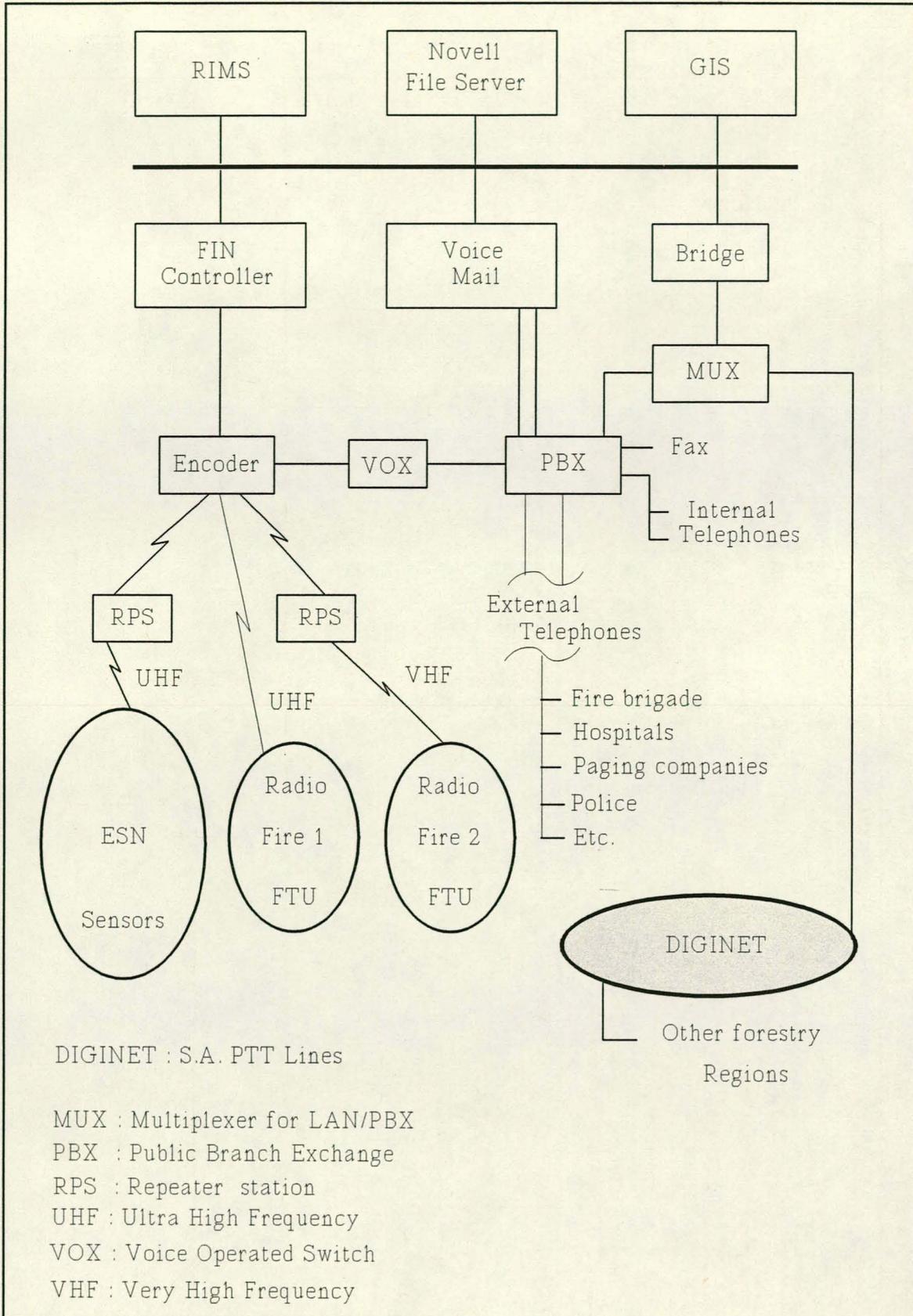


Figure 7.1: Physical network model

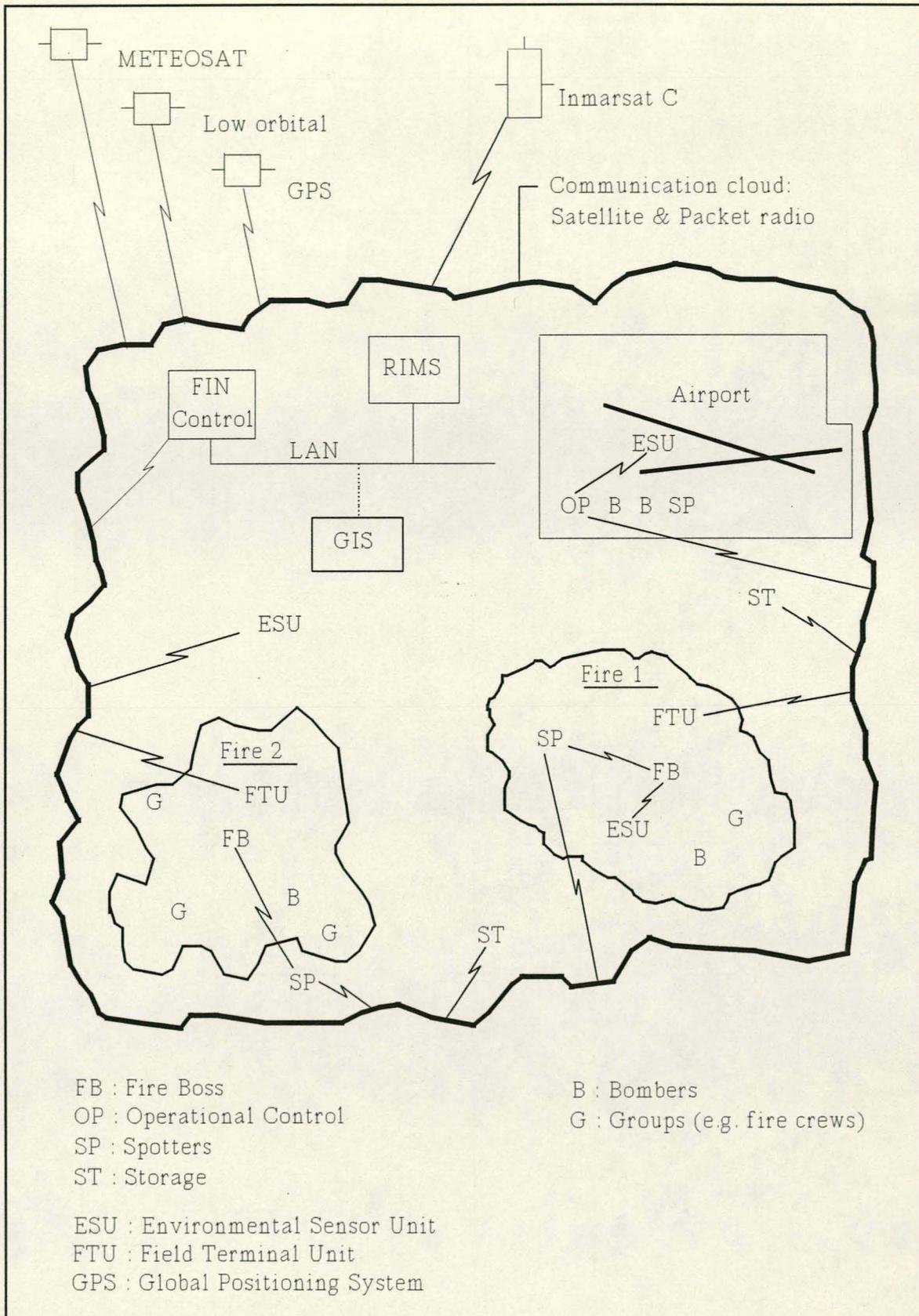


Figure 7.2: Logical network model

Received FROM	Routed TO	Network code	Code description
<u>Pilot FTU</u>	RIMS	0	Confirm position of a fire
<u>Fire boss FTU</u>	RIMS	0	Attention - Urgent
	Voice-mail	1	Call hospital for ambulance
	RIMS	2	Digitize the fire perimeter
	Database	3	FDRI rate of change
	Database	4	FDRI 10h00
	Database	5	FDRI 10h00 with 14h00 forecast
	RIMS	6	Message to operations manager.
	RIMS	7	Request spotter support
	RIMS	8	Request bomber support
	GIS	9	Request property owners from current GPS position
	GIS	10	Request plantation value from current GPS position
	GIS	11	Request plantation areas from current GPS position
Database	12	Wind direction	
<u>Lookout FTU</u>	RIMS	0	Electronic alidade check
	RIMS	1	Fire sighted + direction
	RIMS	2	Smoke sighted + direction
<u>Finance FTU</u>	Database	0	Read Smart Card
	Database	1	Write Smart Card
<u>Special FTU</u>	RIMS	0	Airfield watertanks full
	RIMS	1	Airfield watertanks at minimums
<u>Output</u>	Admin	0	Route to administration printer
	Database	1	Route to database
	FTU Screen	2	Route to FTU screen
	FTU Printer	3	Route to FTU printer
	RIMS	4	Route to operations control
Voice-mail	5	Route to the voice-mail server	
Note: Operators will be prompted for additional information where necessary, for example, the operator will be prompted for the direction (from the current GPS position) in which he wants an analysis made.			

Table 7.1: Examples of FIN controller services

7.3.2 Inter-regional LAN

The connection of the LAN via a bridge, multiplexer and diginet to other regions provides for:

- a) the exchange of data and information from one RIMS system to another, for example the transfer of resources (chapter 5) and
- b) continued operation in the event of a fileserver failure in one region via a product such as Novell SFT III¹.

7.3.3 Inter-regional PBX

The connection of inter-regional PBX systems over the same link allows for multiple telephone connections without the added cost of a separate connection via the lines of the PTT. The real benefit for forestry is that field personnel using radio can be connected to regional and inter-regional personnel on the normal telephone network using VOX connections. This service could later in this decade be modernized by Radio In The Loop (RITL) or cellular radio technology.

7.3.4 Radio network

Modern radio encoder systems allow for the integration of many services. Figure 7.1 indicates that the ESN sensor network is integrated to the more general purpose forestry FIN network. Besides the incoming data from the sensors at different time intervals, forestry personnel can therefore perform a variety of operations on the sensor network (e.g. reset the internal clock of an ESU).

The fire and sensor networks (figures 7.1 and 7.2) were intended for voice and low bandwidth (1200-2400 bits/sec.) data communication. The reason for the indicated slow data

¹ Novell SFT III provides a transparent real-time switch to another server in the event of a file server failure (Novell, 1992).

communication speed is that it may still be several years before the latest highspeed satellite technology will be available in rural areas. For the interim period UHF¹/VHF² radios are cost-effective solutions, while C-band (only 600 bits/sec.) satellite terminals are usable as an access method to problem areas. Transceivers placed on commercial aircraft for the purposes of servicing a real-time fire-weather network, is another option which should be investigated once a strategy for a sensor network has been formalized.

Modern sensor networks typically link 255 ESU's on a single radio frequency using an unspecified protocol provided by the supplier. The line-of-sight range (i.e. without a repeater station) is approximately 40 km (Campbell Scientific Inc., 1990).

7.3.5 Voice-mail server

Placing a voice-mail server between the LAN and the telephone services provided by the PBX provides for:

- a) the ability to answer incoming calls with data from the central database in voice (e.g. the FDRI³ of the day);
- b) the relief of personnel from answering telephones during the hectic activity of operational fire control and
- c) the ability to place telephone calls to any of the endnodes identified in chapter 3 to transmit event messages generated by RIMS (e.g. 'FFA Nelspruit requires an ambulance at airport' or a paging message).

7.4 SATELLITE COMMUNICATION AND IMAGING

The large scale satellite communication systems such as the VSAT system used in Europe

¹ Ultra High Frequency (UHF) 406-512 MHz.

² Very High Frequency (VHF) 130-174 MHz.

³ Fire Danger Rating Index (FDRI).

and America, are still relatively unknown in South Africa. Available professional satellite communication systems are expensive, for example the current price of an Inmarsat C terminal is approximately R40 000/terminal (Van der Watt, 1992).

Fortunately, there are satellites in the public domain that are presently usable with very small capital outlays in terms of hardware and software. These satellites could make an important contribution towards fire incidence management, given a higher low orbital satellite density.

7.4.1 Global Positioning System (GPS)

GPS is a well known satellite system used on a worldwide scale for aircraft navigational systems, police, fire brigades and many other applications. Commercially available systems give an accuracy of approximately 20x20m on the surface of the earth, but can be corrected to within centimeters if used in conjunction with another unit placed on known coordinates (Auspace Ltd., 1991b; Auspace Ltd., 1991c; Magellan Systems Inc., 1991a; Magellan Systems Inc., 1991b).

Besides sealed units (approximately R4 500.00), it is possible to buy the GPS electronics (approximately R2 000.00) which in turn can be inserted into an electronic design of choice (Auspace Ltd., 1991a; Magellan Systems Inc., 1991c). This principle, as a function of fire incidence management, is exploited in conjunction with the FTU project described in chapter 8.

7.4.2 Meteorology (METEOSAT)

Usable METEOSAT images of approaching weather systems are transmitted at 8h14, 11h14, 14h14 and 17h14 each day. All images start with an infrared image followed by a normal digital image (chapter 5). The 8h14 transmission includes an image on water vapour.

The antenna (approximately R3 000.00), PC board and software (approximately R700.00)

as well as the receiver and pre-amplifier (approximately R1 500.00) operating at 1691.0 and 1694.5 GHz are commercially available (Malan, 1992).

7.4.3 Other low orbital satellites

A higher density of low orbital satellites will provide real-time communication prospects for fire incidence management in South Africa towards the end of this decade. Current low orbital satellite densities are useful in 'store-and-forward' applications. The University of Stellenbosch plans to launch SUNSAT during 1994 for experimental purposes while other organizations are planning similar exercises for 1995.

To be useful in real-time applications, there must always be a visible satellite on the horizon. This implies a new RIMS processing element which keeps track of usable, low orbital satellites by predicting their appearance on the horizon. This software is available in the public domain, interfaces can be written to it and the principle can be demonstrated.

7.5 SELECTION OF PROTOCOLS

Transmission Control Protocol / Internet Protocol (TCP/IP), Novell IPX/SPX as well as more elementary protocols such as XMODEM and KERMIT were evaluated in projects over the past two years.

It was found that TCP/IP provides the best integration service over virtually any communication medium including radio and satellite. The option is made even more attractive from a development point of view, because the source code for the communication stack is available in the public domain (e.g. NCSA and KA9Q). In terms of the fire incidence network TCP/IP would function as:

- a) routing protocol in the FIN controller;
- b) Novell fileserver access protocol;
- c) voice-mail access protocol;

- d) GIS access protocol;
- e) RIMS access protocol and
- f) FTU access protocol.

Unfortunately the ESU's on the sensor network cannot use this protocol. Besides the fact that the TCP/IP protocol stack will be too large for most units, manufacturers of the equipment usually supply it in a 'as-is' fashion. This problem leaves two alternatives:

- a) specify the format in which the data should be and then allow the supplier to connect his system to the LAN and
- b) develop special driver programs for the FIN controller in collaboration with the supplier.

7.6 APPLICATION LAYER FUNCTIONALITY

Given the above technical network background and the examples of identified encode/decode services provided by the FIN controller, it is now possible to solve the problems identified in chapter 3 by providing solutions to the requirements identified in chapter 4.

With the help of table 7.1 some of these services will be presented in chapter 8 where the FTU will be discussed. An attempt will be made to associate the specialized processing available on a FTU, with the more generalized functionality of a Laptop/Notebook computer system.

The same can be done for sensor units, but this would be more difficult (and costly), as the full co-operation from suppliers are needed.

7.7 SUMMARY

It was found that a communications platform suitable for integrating the multiple functions

of fire incidence management, can be obtained by:

- a) doing modest updates to the hardware of existing telephone systems (PBX) present in most forestry organizations;
- b) connecting the organizational LAN and the telephone system to other regions *via* a multiplexer;
- c) implementing a voice-mail server;
- d) developing the software required for the FIN controller and
- e) giving this controller the application layer routing intelligence presented (partly) in table 7.1.

Voice communications will always play a vital role in fire incidence management, therefore the task of computer services should be directed at those services which have the potential of overloading voice channels (e.g. lengthy explanations), where the nature of the service is complex or where the activity requires digital recordkeeping (e.g. for possible court cases or financial implications).

The development of unique communication requirements where needed (e.g. the FIN controller) can be made a reality within approximately three months of intensive programming if the existing base of public software is exploited. This effort has been demonstrated to be feasible and reliable in several campus communication projects.

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CHAPTER 8 : FIELD TERMINAL UNIT (FTU)

This chapter presents the development of the essential functional characteristics of the Field Terminal Unit (FTU). This has the purpose of showing how an integrated service for fire incidence management can supply operational staff with sophisticated functionality by using an elementary user interface, given the technology and developments explained in the previous chapters.

8.1 OVERVIEW OF THE PHYSICAL AND FUNCTIONAL STRUCTURE

Appendix A indicates the experimental hardware on which the experimental system was implemented. Figure 8.1 gives an overview of how it was constructed. GPS and radio modem functionality could be integrated directly into the FTU for portability reasons, or alternatively be linked to equivalent external units (with subsequent loss of portability). The GPS equipment installed as a navigational aid in modern aircraft is an example of an external unit which could be linked via a RS232 port to the FTU instead of the internal GPS boards discussed in chapter 7, section 7.4.1 (Cloete, 1992; Fourie, 1992b).

As in the case of RIMS, the problem with a new development is to establish the essential functions the system must support, to identify the events that drive the system as well as what data are applicable to the functions of such a system. The objective oriented functional analysis presented in appendix D served the purpose of identifying functions, events and data for the FTU (Viljoen, 1990). The combined analysis presented in appendices B, C, D was in turn used as an aid in developing the necessary integration between all system elements, and incorporates a consideration for slow (1200-2400 bits/sec.) radio networks. In the rest of this chapter the following operational aspects of the FTU are noteworthy:

- a) the acceptance of the necessity of voice communications allows for experimentation with a smaller keyboard (which would be more acceptable to field operators);
- b) the intuitive and easy way in which direction from an operator's current GPS position can be selected;

- c) the elimination of lengthy voice explanations over the radio during crisis situations (a concept used by e.g. most modern police forces);
- d) the simplistic way in which complex processing on the central computer systems (FIN, RIMS and GIS) can be initiated;
- e) the identified requirements (chapter 4) and the subsequent analysis (appendix D) allow better use of network bandwidth through the process of encoding (the development could be regarded as a forestry oriented analogy to the well-known American APCO-10 code system) (Chandler *et al.*, 1983);
- f) the different hardware and software configurations of the unit allow for a FTU specifically adapted to a task (and therefore variable cost of ownership) and
- g) the unit is virtually useless without network availability, a directly coupled sensor unit and/or a connected GPS (which underlines the importance of an integrated systems approach).

8.1.1 Development of keyboard selectable functionality

The development of manually (i.e. by keyboard) selectable functions for the FTU is summarized in table 8.1. These functions assume the hypothetical hardware configuration in figure 8.2. To identify these functions a series of simulations between the FTU, a PC and a VAX mini computer were developed and tested. The PC functioned as the FIN controller or GPS and the VAX functioned as RIMS or a GIS. The conducted tests included, for example:

- a) initiating complex compressing from the FTU by requesting graphical summaries on the VAX;
- b) scheduling keyboard selected urgent, important and standard priority events originating from the FTU into the RIMS scheduler, e.g. an urgent request for attention;
- c) initiating the display of a graphical image, e.g. a lookout reporting a fire, by means of a single keyboard event and
- d) demonstrating the initiation of the digitizing process using GPS (simulated), e.g. digitizing a fire perimeter.

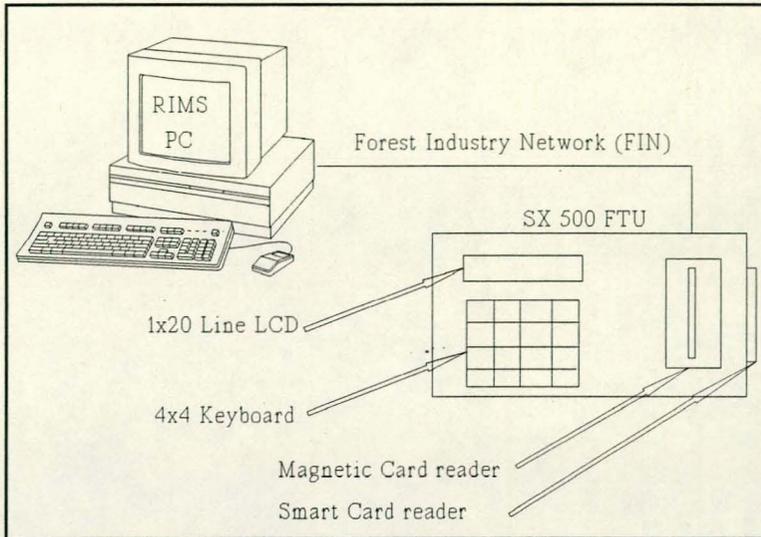


Figure 8.1: Experimental FTU system

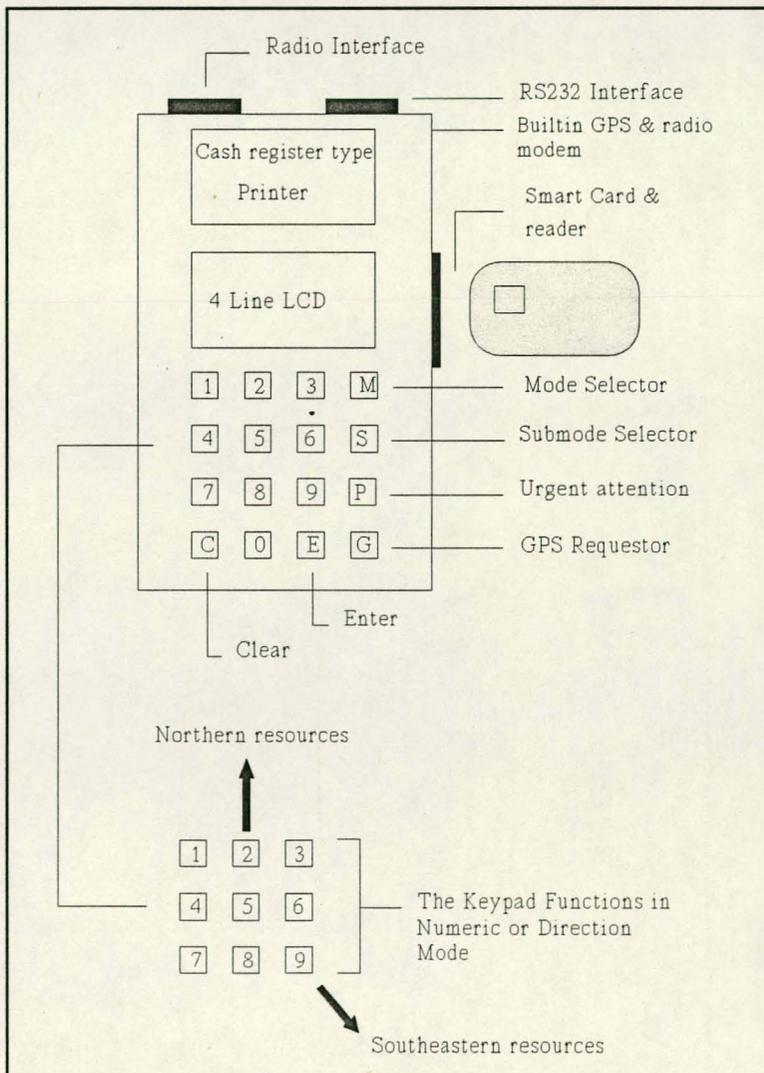


Figure 8.2: Fully configured FTU

FTU main functional structure

<u>Fire-fighting</u>	<u>Lookout functions</u>	<u>Specialized functions</u>	<u>Financial functions</u>
FDR1	Check electronic alidade	Monitor airport water level	Log aerial mission data
GPS functions	Confirm a fire	Monitor aircraft data	
Mail functions	Report smoke		
Reports	Request urgent attention		
Requesting services			
System configuration			
Weather			

Functional structure : Level 2

<u>FDR1</u>	<u>GPS</u>	<u>Reporting</u>	<u>Requesting services</u>
10h00	Confirm position of fire	Allocated resources	Request:
14h00	Digitize (e.g. flying):	From current position:	- ambulance
Area	- an area	- Plantation areas	- bomber aid
Forecast	- a burnt area	- Plantation values	- equipment
Region	- a point	- Property owners	- fire-fighters
	- backburn perimeter	- Sensitive areas	- rapattack aid
	- fire perimeter	- Vegetation types	- spotter aid
	- position of fire-fighters	Weather map	- urgent attention
	- starting point of backburn		
	- starting point of fire		
	Transmit FTU position to RIMS		
<u>Mail functions</u>	<u>System configuration</u>	<u>Weather</u>	
Enter:	Download:	Area	
- destination	- configuration	Region	
- message	- data		
Transmit:	Load:		
- digitized data	- configuration		
- message	- allocated resources		
	Set:		
	- date/time		
	- scan depth (km)		
	- scan width (km)		

Functional structure : Level 3

Note: At this level the detail (where necessary) about the requested function is established (e.g. selecting: 'Request more fire-fighters', is followed by the question: 'How many?'). Below are some examples.

Digitize

- Case: No objects of this type:
- Request number -> Store as: 'ObjectTypeNumber' (e.g. FIRE01 or BACKBURN02)
 - Escape to cancel
- Case: Existing objects of this type:
- Select an object to re-digitize
 - Select the 'ADD' object to add a new object
 - Escape to cancel

Mail

- Case: Mail to destination:
- Enter encoder or telephone number
- Case: Mail message:
- Select by code
 - Select by reference data (appendix D)

Esc/Return = 'CLEAR' button | Scroll UP = '1' button | Scroll DOWN = '7' button | Select = 'ENTER' button

Table 8.1: Functional structure for the FTU

8.1.2 Development of automatic functionality

The FTU is constantly executing some functions in a transparent (automatic) manner, especially when coupled to a WAN¹ network. In the situation where it is not coupled to the WAN, the system is:

- a) monitoring for keyboard input;
- b) updating the date and time and
- c) monitoring for 'trigger' events, e.g. the battery is running down.

If a GPS and/or a portable weather station is added, the previous functions are extended as follows:

- a) evaluating and storing incoming data from the weather station;
- b) calculating new averages for the FDRI, temperature, windspeed and direction at changeable time intervals (table 8.1);
- c) monitoring 'trigger' events, e.g. a change in position (GPS) or a shift in the wind direction, by means of changeable parameters and
- d) responding appropriately to 'trigger' events, e.g. blowing the car hooter² for attention, by means of changeable parameters.

When the unit is connected to the WAN and can therefore communicate with RIMS, weather stations as well as other electronic facilities, the automatic functional responsibilities are again extended by providing for:

- a) evaluating and storing incoming data from the specific remote weather stations allocated by RIMS;
- b) monitoring extended 'trigger' events, e.g. wide area wind shifts in progress;
- c) responding to 'are you there' polls from FIN;
- d) routing network traffic to other FTU systems not directly visible from FIN (i.e. functioning as a Digipeater (Horzepa, 1989);
- e) temporarily storing own internal and routable messages if contact is lost, e.g. the

¹ Wide Area Network (WAN).

² This is a standard facility provided for radios mounted in vehicles.

- current position of the FTU is in a radio shadow;
- f) transmitting position reports to RIMS on request and
- g) acknowledging data receipts to transmitting source.

8.2 FTU PROCESSING EXAMPLES

On receiving network traffic from the FTU (or another type of sensor), the FIN controller will immediately acknowledge receipt of the request, and then proceed with evaluating the requests according to the principles explained in the previous chapter¹. Depending on this evaluation, the request will then be routed to the appropriate server unit which could be the central RIMS controller, the GIS for specialized requests, direct requests to the database or a request for voice-mail services. Note that FTU requests can be answered back in three ways, i.e.:

- a) displayed on the FTU screen;
- b) printed on the FTU printer (if attached) and
- c) transmitted in voice using the voice-mail server.

The transmission of data through a medium is subjected to a propagation delay which depends on the type of medium. An average loss for the type of network described is in the order of 0.5×10^{-8} seconds (Halsall, 1988). For all practical purposes this will be ignored.

8.2.1 Digitizing the growing fire perimeter

In chapter 5, section 5.3, an example of a spreading fire perimeter was presented. By making use of a spotter aircraft or helicopter, the fire perimeter can be flown and roughly digitized using the GPS functionality of the FTU. The accuracy of this operation will depend on factors such as the quality of the equipment, the speed of the aircraft and the number of GPS satellites above the country at that time. Using spotter aircraft, the point accuracy error

¹ Refer to the examples presented in table 7.1.

should not exceed 60 meters (Auspace Ltd., 1991b). Table 8.1 indicates that the digitizing of objects (e.g. the fire perimeter) presents the problem of selecting either a new object to 'ADD' (table 8.1) or an existing object to re-digitize. This selection process is a possible source of error during field operations but cannot be avoided.

Absolute accuracy during the active stages of the fire is not regarded as very important, as the exercise merely serves the purpose of operational management and reporting. After the fire, the FTU could be used to obtain a more accurate perimeter by walking, driving or slow flying by helicopter. Table 8.2 presents the digitizing process from the viewpoint of a series of events, given that an aircraft is used to overfly the fire perimeter. The data which are eventually transmitted over the network, the network addressing scheme as well as an estimate of the network travel time are also presented. This task, which has been identified to the FIN controller as a pilot/observer request type '0' in table 7.1, will be routed to RIMS for processing.

Given the implementation of a production RIMS system, the digitizing of fire perimeters could aid the initial correcting of fire behaviour models by adjusting predicted behaviour with actual behaviour as the fire develops.

8.2.2 Requesting GIS support during a fire

In this example the fire boss has noticed that the wind is pushing the fire in a northwesterly direction, and he wants the centrally based administration officer to contact the property owners in the path of the fire. This task, which has been identified to the FIN controller as request type '9' in table 7.1, will be routed to the GIS for processing. Table 8.3 presents the events and data.

The fire boss receives an immediate acknowledgement via his FTU that the request has been received and that processing has started. He is also notified when processing has been completed. The whole process as detailed in table 8.3 was initiated by three keyboard inputs from the fire boss or his assistant.

Sequence of network and system events	Task responsibility
<p>Request type: 1. Digitize the fire perimeter.</p> <p>Inputs: 1. Start digitizing process. 2. Digitize a point where necessary. 3. End digitizing process.</p> <p>FTU events: 1. Interrogate GPS 2. Transmit request types and inputs.</p> <p>FIN events: 1. Receive FTU requests and data. 2. Route to RIMS. 3. Acknowledge action to FTU.</p> <p>RIMS events: 1. Receive FTU requests and data. 2. Acknowledge action to FIN. 3. Plot the point (screen and database). 4. Acknowledge completion to FIN.</p> <p>FIN events: 1. Acknowledge completion to FTU.</p>	<p>Pilot/observer</p> <p>Pilot/observer</p> <p>FTU/GPS FTU</p> <p>FIN</p> <p>RIMS</p> <p>FIN</p>
Data transmitted on network	Data size (Bytes)
<p>AX.25 header</p> <p>Fire ID number</p> <p>Request type = 12</p> <p>Request subtype : 0 = start digitizing 1 = digitizing 2 = end digitizing</p> <p>X GPS coordinate (Gauss)</p> <p>Y GPS coordinate</p> <p>Packet 16 bit CRC</p> <p>Packet end flag</p> <p>Total bytes transmitted:</p> <p>Transmit time at 2400 bits/sec.: 0.12 seconds</p>	<p>17 (minimum)</p> <p>1</p> <p>1</p> <p>1</p> <p>4</p> <p>4</p> <p>2</p> <p>1</p> <p>31</p>

Table 8.2: Events and data for digitizing the fire perimeter in real-time

Sequence of network and system events	Task responsibility
<p>Request types:</p> <ol style="list-style-type: none"> 1. Produce a list of property owners, addresses, telephone and FAX numbers. 2. Print at the desk of the administration officer after completion, requesting to contact these people. <p>Inputs:</p> <ol style="list-style-type: none"> 1. Direction of information scan: NW. (figure 8.2) 2. Scan depth: Current position for 10 km. 3. Scan width: 5 km. 4. Current position <p>FTU events:</p> <ol style="list-style-type: none"> 1. Transmit request types and inputs. <p>FIN events:</p> <ol style="list-style-type: none"> 1. Receive FTU requests and data. 2. Route to GIS. 3. Acknowledge action to FTU. <p>GIS events:</p> <ol style="list-style-type: none"> 1. Receive FTU requests and data. 2. Acknowledge action to FIN. 3. Process request. 4. Print the list. 5. Acknowledge completion to FIN. <p>FIN events:</p> <ol style="list-style-type: none"> 1. Message to Admin officer: 'Contact property owners'. 2. Acknowledge completion to FTU. 	<p>Fire boss</p> <p>Fire boss</p> <p>Fire boss System default System default GPS</p> <p>FTU</p> <p>FIN</p> <p>GIS</p> <p>FIN</p>
Data transmitted on network	Data size (Bytes)
<p>AX.25 header</p> <p>X GPS coordinate (Gauss)</p> <p>Y GPS coordinate</p> <p>Request type = 9</p> <p>Direction (e.g. NW)</p> <p>Output redirection (e.g. 1 = Admin officer)</p> <p>Packet 16 bit CRC</p> <p>Packet end flag</p> <p>Total bytes transmitted:</p> <p>Transmit time at 2400 bits/sec.: 0.13 seconds</p>	<p>17 (minimum)</p> <p>4</p> <p>4</p> <p>1</p> <p>2</p> <p>1</p> <p>2</p> <p>1</p> <p>32</p>

Table 8.3: FTU requests for complex processing aid from GIS

8.2.3 Enhancement of the lookout service

When a lookout reports the initial sighting and direction of a fire, this has to be confirmed by a spotter aircraft¹ using a FTU, or another lookout must establish a cross-bearing. Confirmation by another lookout contains the possibility that this secondary lookout has more than one fire, or a single but different fire in sight. This could lead to a false position calculation by RIMS which can only be adjusted by the FTU in the spotter² as it overflies the position of the fire.

By using a limited configuration of the FTU in the lookout, which has the capability of doing the functions listed in table 7.1, the central operations manager can be provided with a digital image (photograph) of the area which is not transferred over the network, but is centrally stored so that a 360° view of each lookout in the region is available.

The graphical techniques explained in chapter 6 can be used to display a 16 colour photograph. The results showed reasonable and recognizable area images and requires 153600 kilobytes of storage capacity per photograph. The number of photographs required to cover 360° per lookout will depend on the photographic lenses used. Given a production system, the RIMS computer should support a 256 colour graphical card for excellent photographic images (as opposed to the 16 colour system used in the experiments). This places the operations manager in a position to visually compare the fire/smoke reports from different lookouts and thus eliminate fire confirmation errors. In knowing the exact appearance of the terrain, the operations manager is also helped in the efficient application of fire-fighting resources.

The transmission of data over the network as well as the occurrence of events and subsequent function activation, are similar to the previous sections.

¹ Refer to the pilots request type = '0' in table.7.1.

² Confirmation by the spotter overrides any initial lookout positioning.

8.2.4 Monitoring water levels at remote airstrips

While visiting the FFA in Nelspruit, a fire occurred in an area called Kruisfontein. The bombers which were sent to this fire, used one of the nearby specially prepared unmanned airstrips as a base, but found that the water supply was at a minimum. Another airstrip had to be used which resulted in a prolonged period before the fire could be controlled. The reasons for this problem were that the groundcrew had to be transported to a new airstrip, the pilots were waiting for support and when the operation finally got underway, the longer flying times meant fewer waterloads dropped per hour.

Using the FTU as conceptual basis in a limited, solar powered configuration, the waterlevels at remote airstrips could be monitored on a constant basis throughout the fire season. If a fire occurs in an area, the operations manager could interrogate the waterlevels at the airstrip in advance before scheduling the bombers.

8.3 LAPTOP/PALMTOP TECHNOLOGY AS OPPOSED TO THE FTU

The alternative solution to a FTU would be to provide field personnel with separate pieces of equipment consisting of a laptop/notebook computer, a GPS unit, a radio modem and a radio interface. Both approaches have advantages and disadvantages as shown in table 8.4.

Laptop and palmtop combined with operating systems such as MS Windows NT¹ with Pen Extensions should dominate computing trends in forestry towards the middle of this decade (Kessell, 1990) as the performance of developing hardware platforms are increased. However, for the immediate future it should be noted that:

- a) a real-time computer system cannot go down for long periods as important data will be lost;
- b) if the system does go down, booting procedures should be short;
- c) current hardware platforms (especially lap and palmtops) combined with systems such

¹ New Technology (NT).

as Windows 3.x or Windows NT are slow in reacting and slow to boot in comparison to MS-DOS and DESQview 386;

- d) Windows 3.x provides no task protection and therefore a misbehaving task will influence all tasks (Microsoft Corporation, 1990) and
- e) real-time computer systems cannot be general in nature as shown by the special data terminals developed for emergency services in countries such as America and South Africa (e.g. Police mobile terminals).

It is for these reasons (besides development practicality) that MS-DOS 5.00 was chosen as an initial development platform. There is also evidence that changes in computer vendor alliances¹ are resulting in very powerful opposition to the MS Windows environment.

FTU	Laptop/Notebook
<u>Advantages</u>	<u>Disadvantages</u>
<ul style="list-style-type: none"> a) Different FTU configurations provide task specific solutions and a price advantage. b) Integrated and compact. c) Price is attractive. d) Robust. e) Simple human interface for field operators. 	<ul style="list-style-type: none"> a) Different PC configurations are limited. b) Not integrated. c) Highly priced. d) Not robust. e) Human interface is more generic in nature.
<u>Disadvantages</u>	<u>Advantages</u>
<ul style="list-style-type: none"> a). Functionality limited to the implementation. b) Non-standard hardware. c) Requires knowledge of the C programming language. 	<ul style="list-style-type: none"> a) Functionality generic in nature. b) Industry standard hardware. c) Any programming language can be used.

Table 8.4: FTU versus Laptop/Notebook

Both technologies have a place in fire incidence management, for example the

¹ For example the IBM, Novell, Apple and Digital Research alliance is opposing Microsoft Corporation.

Laptop/Notebook could be applied as a portable central control system (RIMS), while the FTU could be applied for direct use in the rough field operational area. None the less, for comparative purposes a cost analysis is presented in table 8.5.

1992	FTU	Laptop/Notebook
Unit	2 400	7 000
Radio modem	1 000	1 000
GPS	2 000	4 500
Printer	800	800
Total	R 6 200	R 13 300

Table 8.5: FTU and Laptop cost comparison

8.4 REPORTING

Reporting on a FTU 'cash-register' type printer will be primitive but able to supply enough information for a decision to be made. Figure 8.3 presents a simplistic report on lightning and frontal activity which can be requested from RIMS over FIN to, for example, decide whether or not to light a backburn.

8.5 SUMMARY

The concept of a FTU which is developed specifically for fire incidence management was described and demonstrated. The FTU contains the necessary functions to be part of a network, it monitors and processes real-time input from environmental sensors and requests data from a GPS. The role of different unit configurations in relation to the various aspects of fire incidence management was also discussed. The concept was critically evaluated in terms of Laptop/Palmtop technology. Both technologies may have a place, for example:

- a) Laptop/Palmtop technology could be used in a co-ordinating capacity close to the fire as a RIMS processor (or a smaller derivative system) and
- b) The FTU could be used in harsher or specialized conditions, or where the operators of the unit are not trained to handle more sophisticated technology.

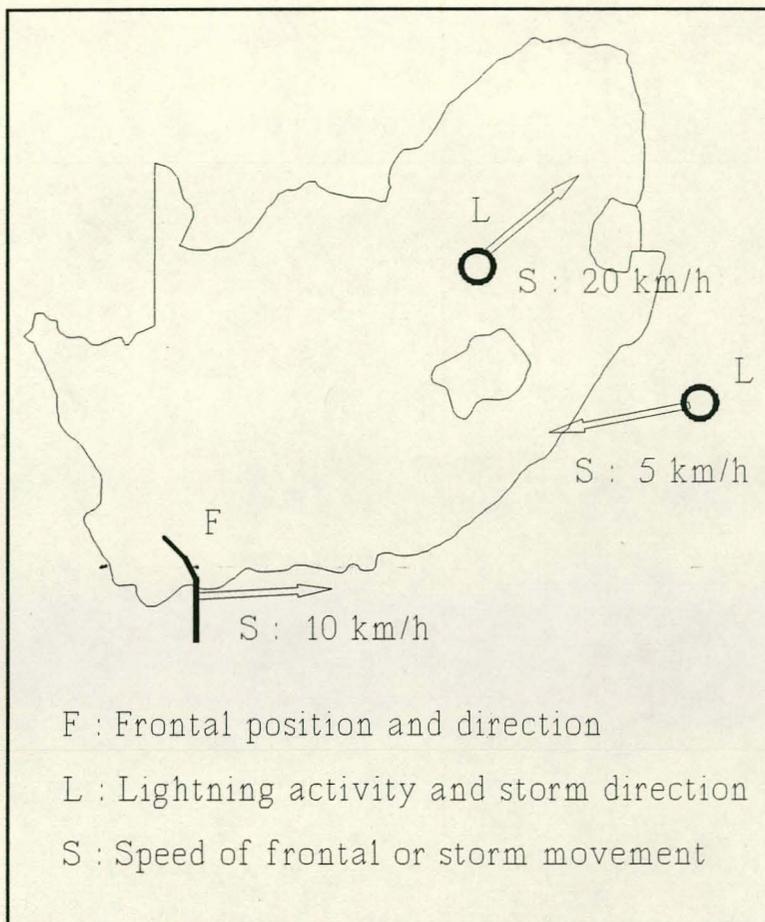


Figure 8-3: FTU elementary reporting

Developments in America, Australia and Canada (discussed in previous chapters) as well as correspondence with Lee (1992) at the BIFC and Tithecott (1992) in Canada, indicate that the idea is functional. Canadian forestry is currently experimenting (Tithecott, 1992) with a Laptop/GPS combination for elementary mapping purposes. Their project is very new and few details are available other than that similar capabilities to RIMS, FIN and the FTU are being investigated. This dissertation therefore makes an early contribution by specifying the functions required for improved remote fire incidence management in South Africa.

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CHAPTER 9 : CONCLUSION

The applications model for fire incidence management was developed after an intensive and broad national and international analysis of current problems, operational methods and stated requirements. This information combined with structural and functional development, event identification and partitioning as well as the identification, structuring and description of data present within the system, is a unique approach to fire incidence management in South Africa.

This applications model can be seen as a prototype and provides an initial and formal platform on which to build more complex systems. In support of this statement, several international experts agree that the computerization of the operational level is a successful avenue towards studying higher level problems related to technologies such as Artificial Intelligence (AI) and Geographical Information Systems (GIS) (Schildt, 1990; Yourdan, 1989). The practical experience and reality of similar systems in America and Canada confirm this (German, 1988; Lee, 1992; Tithecott, 1992).

9.1 THE SOUTH AFRICAN STRATEGIC FORESTRY PLAN

Escalating economic pressures and the identified need for closer scientific support on environmental issues, demand the inclusion of Information Technology (IT) in the Strategic Forestry Plan¹. One of the subsets of the IT plan should facilitate the upgrading of the current radio and telephone communication systems to support data and voice capabilities (Fourie, 1992; Van der Zel, 1992). More futuristic capabilities for rural area networks, such as video (e.g. for training on a national scale) should also be addressed in the Strategic Forestry Plan because the technological capability has been developed, but not yet deployed on an international scale.

¹ Information Technology is currently not part of the Strategic Forestry Plan.

Enormous technical, managerial and economic advantages are to be gained from the converging of voice, video and data technologies to a common digital format as well as integration of the telephone with data processing. The forestry industry will benefit by adopting these available and proven technologies, especially where field communications are still based on voice and paper.

9.2 TECHNOLOGICAL ADVANCEMENT IN FIRE INCIDENCE MANAGEMENT

The integrated systems approach of this study has indicated how existing software technology, equipment and telecommunication structures can be used and extended in functionality to assist fire incidence management in South Africa. Besides being technically feasible, it has been shown that:

- a) a flexible reporting system can be developed by using the file structure and print drivers of a commercial word processor;
- b) communication flexibility amongst central personnel, field personnel, databases and the GIS, is achieved by using the programming interface (API) provided by most commercial voice-mail servers (e.g. broadcasting a weather forecast);
- c) data messages generated by the system can be routed in voice to any outside organization via the voice-mail server and the telephone system (e.g. an urgent call to a hospital);
- d) event scheduling at the applications level in a real-time system have substantial advantages (e.g. using smaller computers);
- e) low bandwidth rural area radio networks are better utilized by implementing event-driven methods;
- f) personnel temporarily not available (e.g. a radio shadow) can be polled until available or until the message is cancelled (i.e. 'Time to live') by the central system;
- g) the automatic logging of data and images on fire progress in the format of a common word processor, enhances the quality and speed of reporting;
- h) the concept of the FTU could be applied to different applications by changing the hardware configuration and applicable software, e.g. a terminal for the fire boss or a specialized unit for a lookout;

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- i) Smart Card technology can be advantageous for the security of financial data and can be used as mediator in the flow of data to a point where network access can be obtained;
- j) the progress of a fire as well as an approximation of area burned can be centrally monitored using networked GPS facilities and
- k) the speed of the control system (RIMS) allows the operations manager to rapidly multiplex amongst active fires, greatly reducing the possibility of forgetting information just received in an audio mode.

The Americans and Canadians have proved that the accurate assessment of fire weather for real-time purposes can only be achieved by networking applicable environmental sensors (Forest Technology Systems, 1990; German, 1988). Unfortunately every vendor of environmental sensors have different designs which make integration difficult. This study provides the solution to this problem by using the FIN controller as a real-time interface. The FIN controller is responsible for:

- a) re-formatting different data formats (from different vendors) to a single standard and
- b) resolving peculiarities in communication design parameters (e.g. RS232 or RS422).

9.3 OTHER USES OF THE SYSTEM

If the necessary software functions are added as separate but integrated elements, then RIMS could be used for:

- a) detection planning (e.g. manning the lookouts and aircraft routing);
- b) fire behaviour training;
- c) prevention planning (e.g. warning the public);
- d) prescribed fire planning and execution strategies;
- e) providing real-time correction of fire-behaviour models and
- f) simulating suppression tactics and strategies.

The study proposals should also have positive influences on distantly related aspects such as:

- a) keeping the Annual Plan of Operations (APO) updated by using it as a real-time

database (Stander, 1992);

- b) providing a common national reference basis for environmental data, by using available network technology, for the use of fire managers, foresters and researchers;
- c) shortening lengthy technology transfer times from research to management because research can contribute new functions (e.g. FDRI calculation) to the real-time system (this results in better answers with little or no training input (Grey, 1990; Tew, 1990));
- d) the provision of an effective processing and communication platform for operational requirements, improves medium- and long-term planning accuracy and
- e) the provision of organizational aid in times of natural disasters.

9.4 ECONOMICAL BENEFITS

Stocks (1990) reports that increases in the effectiveness of the Canadian fire suppression system are unlikely without large budget increases. In South Africa this statement is even more true due to the economic realities of the foreseeable future. This study reflects that situation by:

- a) providing a task-specific design which effectively increases throughput on low-cost hardware;
- b) providing a network design which utilizes current infrastructure;
- c) reducing the complexity of the maintenance effort on the system databases as opposed to the general approach of non-task-specific software and
- d) the use of single inter-regional lines for voice and data purposes reduces overhead costs.

If RIMS is implemented and operated within the parameters of developing international and national telecommunication trends, changes in the national telecommunications infrastructure will not adversely affect the computer system (because of adherence to standards) by causing re-development, and therefore escalating costs in the communication areas of the system.

Besides the managerial and scientific advantages, there is evidence to show that large cost

savings can be achieved by networking environmental sensors especially in terms of maintaining these units in remote areas (Lee, 1988).

9.5 FURTHER STUDIES

The work presented in chapters 5 to 8 has the potential of developing into extensions of the present study. For example:

- a) the development of the RIMS real-time resource scheduler into a system supported by Expert System technology (Kourtz, 1987);
- b) the development of a real-time weather forecasting system which is supported by Expert System technology (Dyer, 1987);
- c) the development of a real-time fire behaviour model placed within the RIMS application model and based on the Rothermel BEHAVE system (Rothermel, 1991) and
- d) the development of the FIN communication system parallel to the rapid development of communication technology.

9.6 CONCLUDING REMARKS

This study presented the development of the conceptual structure for an applications model which has the objective of improving the efficiency and effectivity of fire incidence management in an elementary and cost-effective way. Specific problem areas to this approach were addressed and the results show the concepts to be feasible and therefore implementable.

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APPENDICES

APPENDIX A : HARDWARE AND SOFTWARE

1.0 PERSONAL COMPUTER (PC) HARDWARE

Development and testing was conducted on a standard PC 386 SX with a 25 MHz motherboard, 4 megabyte of RAM¹, a 150 megabyte disk and a standard Paradise VGA card allowing the following configurations (presented in column, row format):

- a) 80 x 25 Monochrome, 16 colour;
- b) 640 x 200 Monochrome, 16 colour, 2 display pages;
- c) 640 x 350 Monochrome, 16 colour, 2 display pages and
- d) 640 x 480 Monochrome, 16 colour, 1 display page.

The card also allows a 320 x 200 (256 colour) mode but this particular screen resolution was regarded as insufficient for practical use. After some experimentation the 640 x 480 (16 colour) mode was selected for the purposes of this study.

The image scans were made on a Microtek Colour/Gray scanner. The unit was alternatively connected to an Apple Macintosh as well as a PC to test the scanning software in the two environments.

2.0 FIELD TERMINAL UNIT (FTU) HARDWARE

The SX500 Smart Card reader from Sybertronix (Pty) Ltd. was used as a hardware platform for the FTU. This unit contains a Motorola 6811 processor, 128 Kb memory, 4x4 keypad, 1x20 line LCD, a Smart Card reader as well as a normal swipe action magnetic card reader.

The hardware configuration can be changed to suit the requirement.

3.0 PC SOFTWARE

The Turbo C 2.0 compiler was used for developmental purposes on the PC (Borland, 1989a; Borland, 1989b; Borland, 1990a; Borland, 1990b) while the Micro Series 68HC11 C-Compiler V2.31B/MD2 cross-compiler was used for developing code for the FTU.

Software for the FTU was transferred via CROSSTALK 3.61 to the unit.

The scanning software used for the PC was the MS-Windows product Imagestar 2.1 and Adobe Photoshop was used on the Apple Macintosh.

Image conversions were done with a public domain product called Alchemy Mindworks 6.1.

WordPerfect 5.1 and the WordPerfect 5.1 Development Kit were used for experimentation.

Novell BTRIEVE 5.00a was used as Database Management System (DBMS). The product

¹ Random Access Memory (RAM).

is primitive by modern DBMS¹ standards, but was proven to be very fast and very reliable for real-time applications.

4.0 OPERATING SYSTEM

All tests and development work for this dissertation were done with MS DOS 5.0 (Duncan, 1986), but the technical demands of an operational real-time fire incidence management system will require the support of a more advanced operating system. In general, the main characteristics which make an operating system suitable for a real-time system such as fire incidence management is speed, stability and multi-tasking with task protection. The operating system must also reset (boot) quickly to ensure minimal downtime in the case of a problem (e.g. a power failure). This choice can only be made when all the technical and financial parameters have been evaluated in a further study, but likely candidates are:

- a) DESQview 386 for the central and portable RIMS;
- b) MS Windows 3.1 for the portable RIMS and
- c) Windows NT² for the RIMS central control system.

The reasons for these choices could be found in the inherent functional versatility and internationally recognized longterm future of these products (Davis, 1989; Microsoft Corporation, 1990a; Microsoft Corporation, 1990b; Microsoft Corporation, 1990c; Fourie, 1992).

DESQview 386, MS Windows (3.1) or MS DOS (5.0) systems could be used in a supportive role as an applications platform for facilities such as the monitoring of incoming weather images, financial management and word processing.

Unix combined with X-Windows was ruled out as unsuitable for the central RIMS system as it requires an extensive systems support effort and because it is not really earmarked as a portable environment. Many voice-mail systems do however run under a limited version of Unix which only needs to be monitored for basic parameters, e.g. disk space (Univoice, 1992).

oooOOOooo

¹ Database Management System (DBMS).

² New Technology (NT).

APPENDIX B : REAL-TIME INCIDENCE MANAGEMENT SYSTEM (RIMS)

1.0 INTRODUCTION

The analysis presented is a shortened version of the original document and contains the most important physical and functional characteristics of RIMS (Rennhackkamp, 1992; Viljoen, 1990). Examples of how events were partitioned per function as well as the associated data are presented. Commonly used data were identified and classified as shown below.

The operational fire incidence management objectives in terms of wildfires and the resulting objectives of the necessary computer system have been identified in chapter 1. More detailed objectives for the computer system were identified in chapters 2, 3 and 4, which in turn were used to:

- a) develop the physical structure of RIMS;
- b) develop the functional structure of RIMS;
- c) identify the events leading to, or generated by these functions and
- d) identify the data in the system.

2.0 PHYSICAL STRUCTURE

During the fire season, fires can usually be controlled from a central point but situations such as: (a) a fire in a remote and awkward area or, (b) a breakdown in the communication system, may require the central system to be physically structured as:

- a) regional central control and
- b) portable central control.

This relatively simple breakdown introduces subtle changes in required functionality as shown below.

2.1 REGIONAL CENTRAL CONTROL

In a regional central control system, the physical breakdown in terms of equipment is:

- a) a workstation or Personal Computer (PC) capable of executing the functional characteristics;
- b) backup services;
- c) connectivity to:
 - a Geographical Information System (GIS),
 - a Global Positioning System (GPS) (attached for correcting mobile field values),
 - a Public Branch Exchange (PBX),
 - local and remote file server(s),
 - local and remote sensors;
- d) plotting services;
- e) printing services;
- f) Uninterruptable Power Supply (UPS) and
- g) voice-mail server.

2.2 PORTABLE CENTRAL CONTROL SYSTEM

In a portable central control system, the physical breakdown in terms of equipment is:

- a) a portable Personal Computer (PC) capable of executing the functional characteristics;
- b) connectivity to:
 - Geographical Information System (GIS),
 - Global Positioning System (GPS) (attached for corrective purposes),
 - Public Branch Exchange (PBX),
 - remote file server(s),
 - remote access to a Voice-Mail server,
 - sensor access;
- c) printing services and
- d) Uninterruptable Power Supply (UPS).

3.0 FUNCTIONAL CHARACTERISTICS

The functional characteristics strongly reflect the way in which the South African FFA/NFPA operation already functions, but the strengthening of computer control for fire incidence management, necessitates some adaptations. The main functions of RIMS are:

- a) operational control;
- b) communication services;
- c) financial services;
- d) reports;
- e) sensor services;
- f) system services and
- g) training.

Some of these functions are discussed below for demonstration purposes.

3.1 OPERATIONAL CONTROL

The physical act of co-ordinating the fire fighting process is defined within the following functions:

- a) fire management;
- b) group management;
- c) resource management and
- d) reference data management.

Fire management is discussed below as an example because most of the data are manipulated within this function. Those functions that are underlined indicate that only authorized personnel (e.g. the general manager of the FFA) may execute the function.

3.1.1 Fire management

The required functions are:

- a) add a new fire;
- b) complete this fire;
- c) join two or more fires;
- d) log real-time events;
- e) select another fire and
- f) split into more fires.

3.1.1.1 *Typical events associated with fire control in the operations room*

- 1 Undefined event
- 2 Added a resource
- 3 Added a group
- 4 Allocated a resource
- 5 Allocated a group
- 6 Allocated object co-ordinates
- 7 Completed a fire
- 8 Deleted a resource
- 9 Deleted a group
- 10 Deleted a registered loss
- 11 Digitizing an area
- 12 Digitizing a point
- 13 Map image written to disk
- 14 Paged a person
- 15 Registered a fire
- 16 Received an erroneous packet
- 17 Received a message (user)
- 18 Received a message (system)
- 19 Registered a loss
- 20 Transferred a resource
- 21 Transmitted a message (user)
- 22 Transmitted a message (system)
- 23 Updated a resource
- 24 Updated a group
- 25 Updated a registered loss
- 26 Updated the object co-ordinates
- 27 Updated resource allocation
- 28 Weather request in area submitted
- 29 Withdrew a resource
- 30 Withdrew a group

3.1.1.2 *Data manipulated by RIMS for fire control*

In this section the term:

- a) 'Lists' refers to a collection of elements of the same type (e.g. a set of co-ordinates) and
- b) 'Reference data' refers to the collection of commonly used data shown in section

3.1.2.

Data:

1. Fire data

Fire ID
Fire status
Fire name (area where fire started)
Short description of fire
Gauss X co-ordinate of fire starting point (m)
Gauss Y co-ordinate of fire starting point (m)
Date started
Date ended
Time started
Time ended
File name of last screen image copied to disk
FDRI in area
Name of person who takes responsibility for operation
Controller at FFA/NFPA
Fire boss at fire
Person/Company who reported fire
Probable cause of fire
Probable fuel in which the fire started

2. Resource data

Resources at a fire could be personnel, vehicles, aircraft, equipment, rations, weather and lightning stations. Each resource type was identified and described in terms of types and sub-types, i.e. specialization (Rennhackkamp, 1990).

Main data

Resource ID number
Organization ID number
Allocated group ID (0 = not allocated)
Resource type (e.g. personnel)
Resource sub-type (e.g. a manager)
Sharability amongst fires
List: Allocated fire ID's
Current X location (Gauss) (m)
Current Y location (Gauss) (m)

Sub-type data describing specific resource types

Data within each sub-type will differ according to the natural structure.

Type = "Aircraft"

Fire-fighting personnel refer to aircraft commonly as 'Bomber 1', 'Spotter 2' or 'Chopper 1'. This number is used as the key while the aircraft registration number (e.g. ZS-ZSI) is used only for positive identification.

Data common to all aircraft

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Registration number
Aircraft name (e.g. 'Cessna 210')
Colour (e.g. 'Yellow with white stripes')
Description of engine and power rating
Time for engine overhaul (hrs)
Time for 100 hour service
Current engine time (hrs)
Takeoff distance when full (m)
Takeoff distance when empty (m)
Load capacity (kg)
Hourly tariff (R)
Seating capacity (some bombers seat two)
List: Occupants

Bombers

Load capacity (litre)
Description of loading mechanism (e.g. 'side loading')

Helicopters

Load capacity (litre)
List: Equipment on board

Type = "Airports/airstrips"

Name of airport
Controlled airport?
Usable or not usable
Runway surface indicator: Reference data
Width of runway (m)
List: Runway directions (degrees magnetic)
List: Runway lengths (m)
List: Airport facilities (including water)

Type = "Channels"

List: Available channels
List: Channel descriptions

Type = "Equipment"

Data common to all equipment
Name of equipment

Clothing

Colour
Size of clothing (e.g. 'small, medium, large, xl')

Fire-fighting tools

Description of tool or set of tools

Hoses

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Pressure rating (KPa)
Description of size (mm)
Description of end fittings

Pumps (fuel)

Capacity (litre)
Description of operating mechanism
Fuel capacity (litre)
Fuel type (e.g. two-stroke)

Pumps (hand)

Capacity (litre)
Description of operating mechanism

Safety equipment

Description of equipment

Water trailers

Description of trailer hook mechanism
Capacity (litre)

Type = "Expendables"

Data common to all expendables

Units of measure (e.g. kg)
Quantity in stock
Maximum quantity stocked
Re-order level

Foam

Name of foam: Reference data
Description of foam

Fuel

Name of fuel: Reference data

Rations

Name of ration: Reference data

Retardent

Name of retardent: Reference data
Description of retardent

Type = "Frequencies"

Frequency (MHz)
Description of service

Type = "FTU"

FTU polling interval (seconds)

FTU event: Reference data

Type = "Groups/Teams"

Allocating resources on a single group ID eliminates most of the problems associated with the compound key necessary to identify every object (although initially necessary). The system should only check for a valid access status (e.g. 'resting') to allow an operator to re-allocate an object from one group to another. A group marked 'in transit' can be re-allocated, but safeguards must eliminate the possibility of anomalies (e.g. transferring a pilot while being in transit).

Group name (e.g. 'Sappi Proto 1')

Group Access Status

Type = "Lightning detector"

Flag a problem: Reference data

Type = "Lookouts"

Data common to all lookouts

Name of lookout point

Frequency

List: Personnel on duty

List: Co-ordinates of the area of visibility (m)

Lookout tower

Telephone number or call ring

List: Area photographs file names

Observation point

Description of observation point

Type = "Maps"

Image file name

Region ID: Reference data

Sub-region ID: Reference data

Map density (e.g. 300 d.p.i.)

Number of colours (e.g. 16)

Width (pixels)

Height (pixels)

Pixellength (represents mapscale in meter)

Central meridian (Gauss)

List: Known pair of X co-ordinates (Gauss) (m)

List: Map X correction factor

List: Known pair of Y co-ordinates (Gauss) (m)

List: Map Y correction factor

Type = "Personnel"

Surname

Name

Initials

Age (yrs)

Birthdate

Judgement factor (pessimist or optimist)¹

List of talents/skills

List of menu access rights

List of menu option rights

Type = "Radios"

List of frequencies (MHz)

List of channels

List of allocation ID's

ID of organization who will repair it

Type = "Radio repeaters"

Receive frequency (MHz)

Transmit frequency

ID of organization who will repair it

Type = "Roads"

Alternative road number (e.g. R150)

Average access time (km/hr)

Suitable for heavy traffic?

Road surface indicator: Reference data

List: Co-ordinates indicating poor surface conditions (m)

List: Co-ordinates indicating landing strips (m)

Type = "Satellites"

Name of satellite: Reference data

Receive frequency (MHz)

Transmit frequency (MHz)

Flag a problem: Reference data

Type = "Talents/skills"

Qualified/licensed?

Description of talent

Type = "Vehicles"

Vehicle name: Reference data

Vehicle roof number

ID of organization who will repair it

Engine serial number

Engine displacement (cc): Reference data

¹ The judgement capability of a manager expressed as a fraction, was successfully applied to development projects using a planning package for example, a pessimistic manager will always judge longer than necessary project completion times.

Power rating (Kw)
Time for next service (km)
Load capacity (kg)
Tank capacity (litre)
Tariff (R/km)
Seating capacity
List: Occupant ID number(s)

Type = "Waterpoints"
Waterpoint capacity (litre)
Minimum capacity (litre): Warning

Type = "Weather"
Name of weather station
Flag a problem: Reference data

3. Cadastral (e.g. places)

The cadastral database refers to all items not regarded as resources for fire-fighting (e.g. describing farms or places such as towns)

Cadastral ID
Cadastral item name
Cadastral item description
Cadastral item type
List: Co-ordinates (m)

4. Organization

Organization ID number
Organization name
Organization type
Organization internal status
List: Telephone numbers
List: Faximilee numbers

5. Plantation

Plantation ID
Plantation name
Organization ID number
List: Plantation co-ordinates (m)

6. Plantation blocks

Block ID
Block name
Plantation ID
Organization ID number
List: Block co-ordinates (m)

7. Plantation compartments

Compartment ID

Block ID
 Plantation ID
 Organization ID number
 List: Compartment co-ordinates (m)
 Species in compartment
 Age of trees (yrs)

3.1.2 Reference data management

The management of reference data by computer is elementary but the task of finding and classifying it, is substantial. The reference data identified are also described in terms of specialization. The second level functions are (chapter 5, table 5.1):

- a) Browse and select a type and sub-type resource and
- b) Select type and sub-type by key.

Typical events generated by administrative functions are:

- a) added reference data;
- b) deleted loss data;
- c) deleted reference data;
- d) retrieved reference data from disk to memory;
- e) saved the reference data updates to disk from memory;
- f) transaction unsuccessful;
- g) updated reference data and
- h) registered a loss.

The reference data were extracted from many sources and the exercise served the purpose of identifying and classifying commonly used data in the real-time system. By doing this it is now possible to:

- a) encode network traffic between RIMS and the FTU and thus save network bandwidth¹ on slow radio links;
- b) allow the central RIMS operator to select data by mouse rather than type data;
- c) minimize data redundancy;
- d) apply better integrity control and
- e) place this data in memory for greater speed advantages (e.g. data decoding).

Each category of reference data has an 'Undefined' value which, if selected, will allow new values to be added. The reference data are tabled below.

1. Action verbs

Undefined

activate	activated	activating
airlift	airlifted	airlifting
are	at	is

¹ Chapter 8.

attack	attacked	attacking
bomb	bombed	bombing
burn	burned	burning
by	from	to
cause	caused	causing
confirm	confirmed	confirming
commence	commenced	commencing
dispatch	dispatched	dispatching
divert	diverted	diverting
drop	dropped	dropping
found	lost	.
had	has	have
inbound	outbound	,
land	landed	landing
load	loaded	loading
locate	located	locating
operation	:	;
report	reported	reporting
request	requested	requesting
return	returned	returning
serviceable	U/S	%
spread	spreaded	spreading
standby	standdown	+
start	started	starting
taking off	took off	-
use	used	using

2. Action nouns

Undefined

aircraft

airport

airstrip

bakkie

bucket

bambi bucket

bomber

car

ETA

ETD

fire

fire boss

fire-fighter

foam

fuel

gravity feed

helicopter

lorry

observer

oil
pilot
pressure pump
rapattack
retardent
runway
spotter
water

3. Activity status

Undefined
Active
In transit from
In transit to
Off duty
Resting
Standby
Unreachable
Unserviceable
Withdrawn

4. Causes of fires

Undefined
Arson
Bee hunting
Cause unknown
Firebreak burning
Lightning
Flare-up of old fire
Negligence
Slash burning

5. Conditions (in a general sense)

Undefined
Bad
Good
Poor
Reasonable

6. Displacement (engines)

Undefined
50 cc
500 cc
1000 cc
1100 cc
1300 cc
1600 cc
2000 cc

2100 cc
3000 cc
4100 cc
5000 cc

7. Resource types

Undefined
Aircraft
Airports/airstrips
Channels
Equipment
Expendables
Frequencies
Groups/teams
Lightning
Lookout
Maps
Personnel
Radios
Radio repeaters
Rations
Roads
Satellites
Talents/skills
Vehicles
Water points
Weather stations

8. Resource sub-type = "Aircraft"

Undefined
Bombers
Helicopters
Spotters
Transport

9. Resource sub-type = "Airports/airstrips"

Undefined
Grass
Gravel
Tarmac

10. Resource sub-type = "Channels"

Undefined
Alpha
Bravo
Charlie

11. Resource sub-type = "Equipment"

Undefined
Clothing
Fire-fighting tools
Hoses
Pumps (fuel)
Pumps (hand)
Safety equipment
Water trailers

12. Resource sub-type = "Expendables"

Undefined
Foam
Fuel
Rations
Retardent

13. Resource sub-type = "Frequencies"

Undefined
Airband
Satellite
UHF
VHF

14. Resource sub-type = "Groups/Teams"

Undefined
Administration point
Bomber
Helicopter
Labour
Lightning
Lookout
Observation point
Proto
Spotter
Transport
Unimog
Water
Weather

15. Resource sub-type = "Lightning"

Undefined
Data format 1
Data format 2
Etc.

16. Resource sub-type = "Lookouts"

Undefined
Lookout tower

Observation point

17. **Resource sub-type = "Maps"**
 - Undefined
 - Area background maps
 - Aeronautical
 - Fire-fighting airstrips
 - Lookout area photo
 - Road access map
 - Water points

18. **Resource sub-type = "Personnel"**
 - Undefined
 - Admin
 - Management
 - Other
 - Planning
 - Technical

19. **Resource sub-type = "Radios"**
 - Undefined
 - Mounted (encoder)
 - Mounted (no encoder)
 - Portable (encoder)
 - Portable (no encoder)

20. **Resource sub-type = "Radio repeaters"**
 - Undefined

21. **Resource sub-type = "Roads"**
 - Undefined
 - Gravel
 - Gravel/soil
 - Gravel/tarmac
 - Soil
 - Soil/tarmac
 - Tarmac

22. **Resource sub-type = "Satellites"**
 - Undefined
 - Geostationary
 - Low orbital communications
 - Low orbital communications and imaging
 - Low orbital imaging
 - Weather

23. **Resource sub-type = "Talents/skills"**
 - Undefined

Mechanic
Bulldozing
Dynamiting
Handy man
Heavy duty license
Helicopter pilot
Mechanic
Pilot

24. Resource sub-type = "Vehicles"

Undefined
Bakkie 4x2
Bakkie 4x4
Bicycle
Bulldozer
Grader
Motorbike
MotorCar
Truck 4x2
Truck 4x4
Watertruck 4x2
Watertruck 4x4

25. Resource sub-type = "Waterpoints"

Undefined
Gravity feed
Pump feed

26. Resource sub-type = "Weather"

Undefined
Data format 1
Data format 2
Etc.

27. Fire Fuels

Undefined
Felled trees
Fynbos
Grass
Gums
Indigenous forest
Pine
Slash
Sugar cane
Wattle

28. Loss reason

Undefined

Burnt out
Crashed
Stolen

29. Organization types

Undefined
Farmer
FFA / NFPA
Fire Brigade
Hospitals
Paging companies
Private
Sawmiller
Timber grower
Timber Grower / Farmer
Timber grower / Sawmiller

30. Organization internal status types

Undefined
Headquarters
Private
Regional
Station

31. Rations

Undefined
Coffee
Cooldrink
Energy bars
Milk / Powdered milk
Soup
Sugar
Tea
Tinned food

32. Retardent

Undefined

33. Regions

Undefined
Eastern Cape
Eastern Transvaal
Natal Midlands
Northern Natal
Northern Transvaal
Orange Free State
Southern Cape
Southern Natal

South-eastern Transvaal
Tsitsikamma
Western Cape
Western Transvaal
Zululand

34. Sub-region = "Eastern Transvaal"

Undefined
Nelspruit
Piet Retief
Warburton

35. Satellite names

Undefined
SunSat (University of Stellenbosch)

36. Status of fire

Undefined
Contained
Dead
Jumped
Out of control
Under control

37. Title types

Undefined
Admin
Management (FFA/NFPA)
Management (Forestry)
Other
Planning
Technical (FFA/NFPA)
Technical (Forestry)

37. Title sub-type = "Admin"

Undefined
Admin Control Officer
Assistant Clerk
Clerk
Editor : Inferno
Senior Clerk
Secretary/Telephonist

38. Title sub-type = "Management (FFA/NFPA)"

Undefined
Administration Manager
Aircraft Manager
Airport Controller

Airstrip Controller
Board Chairman
Branch Chairman
Branch Committee Member
Duty Officer
Executive Committee Member
FFA Director
FFA General Manager
Flight Operations Manager
Manager
NFPA Manager
Operations Manager
Project Manager
Senior Manager
Services Manager
Supervisor

39. Title sub-type = "Management (Forestry)"

Undefined
Administration Manager
Assistant District Forest Officer
Assistant Forester
Board Chairman
Branch Chairman
Branch Committee Member
Chief Forester
Control Forester
Duty Officer
District Forest Officer
Executive Committee Member
Fire Boss
Forester
General Manager
Harvesting Manager
Induna
Manager
Management Forester
Operations Manager
Personnel Manager
Project Manager
Plantation Manager
Regional Director
Senior Manager
Services Manager
Senior Forester
Supervisor

40. **Title sub-type = "Planning"**
Undefined
Planning Officer
41. **Title sub-type = "Technical (FFA/NFPA)"**
Undefined
Air Crew
Aircraft Loader
Aircraft Mechanic
Aircraft Observer
Chief Flying Instructor
Control Officer
Crew
Driver
Duty Officer
Fire Tender Crew
Flying Instructor
Labourer
Loading Crew Member
Meteorological Personnel
Observer
Ops Co-ordinator
Ops-room Operator
Pilot
Radio Technician
Rapattack
Rapattack Trainer
Resource Controller
Staff Member
Senior Driver
Senior Foreman
Senior Labourer
42. **Title sub-type = "Technical (Forestry)"**
Undefined
Boss Boy
Centre Service Officer
Chief Driver
Chief Foreman
Conservation Officer
Control Officer
Crew
Driver
Duty Forester
Duty Officer
Extension Forester
Fire Crew
Fire Tender Crew

Foreman
Forest Guard
Harvesting Personnel
Information Officer
Labourer
Loading Crew Member
Lookout Personnel Member
Mechanic
Resource Controller
Staff Member
Senior Conservation Officer
Senior Driver
Senior Foreman
Senior Labourer
Silvicultural Personnel
Storeman

39. Title sub-type = "Other"

Undefined

Dr.

Farmer

Mr.

Mrs.

Ms.

Miss.

Prof.

3.2 FINANCIAL SERVICES

The financial functionality within RIMS are limited to those functions generating data directly as a result of operational activities and requires a reporting structure from within RIMS, but also serves as an input to the official financial system of the FFA or forestry organization (e.g. the number of hours flown against a fire).

The financial data within the fire-fighting system have restricted access and are passed to the authorized bookkeeping system for verification. The required functions are:

- a) invoices;
- b) order placement and
- c) loss control.

The generation of invoices will be taken as an example.

3.2.1 Invoices

Generating invoices via computer is elementary but the process of collecting the required data over a wide area in a real-time system presents a problem. Pilots for example, move over

wide areas during the day and here Smart Card technology can aid in the accumulation of aircraft data, which in turn can be loaded directly into RIMS on landing at an airport. This eases the administrative load on pilots as well as financial personnel. The necessary Smart Card drivers were developed and tested for this purpose. The major banks in South Africa have accepted the technology as being financially secure (Cashmore, 1992).

The required functions are:

- a) add a new invoice;
- b) add an invoice via Smart Card;
- c) browse and select an invoice and
- d) select an invoice by number.

3.2.1.1 *Examples of financial events*

- 1 Added an invoice
- 2 Cancelled an invoice
- 3 Client ID not found
- 4 Issued an invoice
- 5 Product ID not found
- 6 Transaction successful
- 7 Transaction unsuccessful
- 8 Updated an invoice

3.2.1.2 *Data examples*

1. **Orders**

Order number
Vendor ID Number (Organization database)
Date of order
List: Product ID (Product database)
List: Unit cost (R)
List: Quantity (Resource database re-order levels)

2. **Products**

Product ID
Vendor ID Number (Organization database)
Product description
Unit cost (R)

3. **Invoices**

Invoice number
Order number
Vendor ID Number (Organization database)
Date of invoice
Date of order
List: Product ID (Product database)

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List: Unit cost (R)

List: Quantity (Resource database re-order levels)

000000000

APPENDIX C : FORESTRY INDUSTRY NETWORK (FIN)

1.0 INTRODUCTION

The analysis presented is a shortened version of the original document and contains the most important physical and functional characteristics of FIN. Examples of how events were partitioned per function¹ as well as the associated data, where applicable, are presented.

2.0 PHYSICAL STRUCTURE

The developing physical structures of modern networks are tightly integrated with available and developing user functionality. Many organizations have approached the Department of Information Technology at the University of Stellenbosch for guidance on this matter, as it is difficult for the non-technical computer user in the general industry (who is trying to build a network) to distinguish between established and developing international communication trends from the available pool of technology.

The capabilities and benefits of developing networking trends, with special reference to the integration of telephonic and computer services, were regarded important enough to present as part of chapter 7 in a brief literature study.

3.0 FUNCTIONAL CHARACTERISTICS

The FIN controller evaluates the network status and routes in and outgoing network traffic by using a reference table to recognize the server containing the appropriate service. The following functionalities are required:

- a) monitor, log and report network events;
- b) monitor, log and report packet statistics;
- c) route network (user) traffic;
- d) route system events and
- e) provide a queueing mechanism for busy servers.

3.1 MONITOR, LOG AND REPORT NETWORK EVENTS

The network software constantly monitors events on all levels of the protocol stack for every active physical network and reports situations where necessary.

3.1.1 Network events

Typical events associated with this activity are described below in a way which demonstrates the partitioning of events for the different physical network elements as well as the protocol stacks.

¹ A function represents a logical sub-network with regard to FIN.

3.1.1.1 Physical link network event descriptions

- a) General
 - 0 Undefined
 - 1 Errors on line
 - 2 Line available
 - 3 Line connection intermittent
 - 4 Line not available
 - 5 Lost line connection

- b) Line Status Register
 - 6 Break interrupt
 - 7 Data ready
 - 8 Framing error
 - 9 Overrun error
 - 10 Parity error
 - 11 Transmitter line holding register empty
 - 12 Transmitter shift register empty

- c) Interrupt Enable Register
 - 13 Data available interrupt
 - 14 Modem status interrupt
 - 15 Receive line status interrupt
 - 16 Tx buffer empty interrupt

- d) Modem Control Register
 - 17 Data terminal ready
 - 18 Loopback test mode
 - 19 Master interrupt enable (actually OUT 2)
 - 20 Request to Send

- e) Modem Status Register
 - 21 Clear to send
 - 22 Delta clear to send
 - 23 Delta data set ready
 - 24 Delta Rx line signal detect
 - 25 Data set ready
 - 26 Ring indicator
 - 27 Received line signal detect
 - 28 Trailing edge ring indicator

3.1.1.2 Protocol level network event description

- a) General
 - 0 Undefined

- b) Internet Control Message Protocol (TCP/IP ICMP)
 - 1 Address mask request
 - 2 Address mask reply

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- 3 Destination unreachable
- 4 Echo reply
- 5 Echo request
- 6 Information request
- 7 Information reply
- 8 Parameter problem
- 9 Redirect
- 10 Source quench
- 11 Timestamp
- 12 Timestamp reply
- 13 Time-to-live exceeded

c) Destination Unreachable codes (TCP/IP ICMP)

- 14 Fragmentation needed and DF set
- 15 Host unreachable
- 16 Net unreachable
- 17 Port unreachable
- 18 Protocol unreachable
- 19 Source route failed

d) Time Exceeded codes (TCP/IP ICMP)

- 20 Fragment reassembly time exceeded
- 21 Time-to-live exceeded

e) Redirect message codes (TCP/IP ICMP)

- 22 Redirect for the host
- 23 Redirect for the network
- 24 Redirect for type of service

f) Radio AX-25 error events

- 25 ?already connected to that station
- 26 ?bad
- 27 ?call
- 28 ?clock not set
- 29 ?EH
- 30 ?not enough
- 31 ?not while connected
- 32 ?not while disconnected
- 33 ?range
- 34 ?too long
- 35 ?too many
- 36 ?VIA

g) Radio AX-25 status events

- 37 *** connect request to: X
- 38 *** connect request to: X (VIA X1, X2, ..X8)
- 39 *** CONNECTED to: x
- 40 *** CONNECTED to: x (VIA X1, X2, ..X8)

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```

41      *** DISCONNECTED
42      *** LINK OUT OF ORDER, possible data loss
43      *** retry count exceeded
44      *** X busy
45      bbRAM1 loaded with defaults
46      Cmd:
47      FRMR2 in progress
48      FRMR rcvd:
49      FRMR sent:
50      Link state is: CONNECT IN PROGRESS
51      Link state is: CONNECTED TO X
52      Link state is: CONNECTED TO X VIA (X1, X2,..X8)
53      Link state is: DISCONNECT IN PROGRESS
54      Link state is: DISCONNECTED
55      Too many packets outstanding
56      Was3

```

3.1.2 Event data

To follow, react and log the different events in the system, the subsequent data are kept.

3.1.2.1 Event log : Event type = "Network exception"

```

System date
System time
Network event type (e.g. link or protocol)
Network message description

```

3.1.2.2 Physical link network event descriptions

```

Physical line event number
Line event description

```

3.1.2.3 Protocol level (TCP/IP) network event description

```

Protocol event number
Protocol event description

```

3.2 MONITOR, LOG AND REPORT PACKET STATISTICS

Most modern networks transmit data in the form of packets and it is therefore relevant to

¹ Battery Backed Random Access Memory (bbRAM).

² Frame (FRM) Reject (R).

³ Indicates previous parameter value.

monitor the packets on a network for performance and problem statistics. This function is described as part of the FIN communication controller in chapter 7.

3.2.1 Data structures and variables

The data listed below have been identified.

3.2.1.1 *Event log : Event type = "Received erroneous packet"*

- System date
- System time
- Packet source address
- Packet destination address
- Packet type
- Packet description
- Packet error description

3.2.1.2 *Packet data structure (AX.25 unnumbered supervisory frame)*

- Packet start flag
- Packet call signs, source, destinations and digipeater addresses
- Packet control (i.e. frame type)
- Packet 16 bit CRC checksum
- Packet end flag

3.2.1.3 *Packet data structure (AX.25 information frame)*

- Packet start flag
- Packet call signs, source, destination and digipeater addresses
- Packet control (i.e. frame type)
- Packet layer 3 protocol type
- Packet data
- Packet 16 bit CRC checksum
- Packet end flag

3.2.1.4 *General variables*

- Packet cost
- Packetcost per day (at unitcost = packet)
- Packets (total) per day
- Packets (total) per hour
- Packets (total) per day per fire
- Packets (total) per hour per fire

3.3 ROUTE NETWORK TRAFFIC

The routing of network traffic will be the function of the network protocol stack.

3.4 ROUTE SYSTEM TRAFFIC

Routing system traffic refers to those events (or network packets) which need to be processed by the different system functions (distinguished by function ID's).

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APPENDIX D : FIELD TERMINAL UNIT (FTU)

1.0 INTRODUCTION

The concept of a FTU was introduced to investigate a suitable physical design as well as functionality applicable to fire-fighting operations. Similar, but general purpose units are for example used in the United States as a communication aid during disasters (Horzepa, 1989).

The analysis presented is a shortened version of the original document and contains the most important physical and functional characteristics of the unit. Examples of how events were partitioned per function as well as the associated data are presented.

2.0 PHYSICAL STRUCTURE

The hardware design criteria assumed are (testing was conducted on available and more elementary hardware):

- a) 16 key keyboard;
- b) 4x24 character LCD display;
- c) 128 kilobyte of RAM;
- d) GPS circuit board;
- e) radio modem circuit board and interface;
- f) RS-232 port;
- g) an optional Smart Card reader (e.g. for financial functions or system configuration) and
- h) an optional cash register type printer.

3.0 FUNCTIONAL CHARACTERISTICS

The functions of the FTU are purpose-specific and the main operating modes identifiable for fire-fighting are:

- a) fire-fighting functions;
- b) lookout functions;
- c) financial functions and
- d) specialized functions.

In the following sections, some of these modes are broken down until relevant functions and associated data are exposed. For the purpose of the discussion it will be assumed that the FTU is fully configured and that a portable weather station is connected to the RS-232 port.

3.1 FIRE FIGHTING

The fire-fighting mode is selectable using Key "A" on the FTU while Key "B" selects the sub-mode. In chapter 8, table 8.1 this physical selection process is mapped in terms of a selectable function (i.e. 'Key A' selects 'Level 1' while 'Key B' selects 'Level 2'). In both the remote and local modes, certain functions are continued transparently (automatically). The keyboard layout is presented in figure 1 and elaborated in chapter 8, table 8.1.

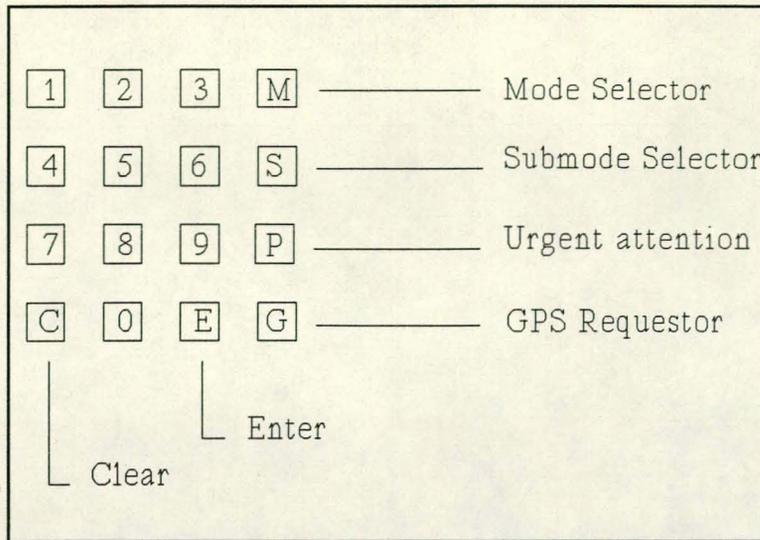


Figure 1: FTU Keyboard

3.1.1 Local functions

In local mode, i.e the FTU is not connected to a network or the network is out of action, the following functions are selectable, using Key "B":

- a) Fire Danger Rating Index (FDRI);
- b) Global Positioning System (GPS);
- c) system management and
- d) weather.

3.1.1.1 Fire Danger Rating Index (FDRI)

The FDRI can be calculated¹ in real-time using the attached weather station. The data used in this calculation are:

- a) drybulb temperature (°C);
- b) rainfall correction factor (table);
- c) relative humidity (%) and
- d) windspeed correction factor (table).

3.1.1.2 Global Positioning System (GPS)

The GPS function of the FTU requests the global coordinates of the FTU from the onboard hardware. If the FTU operator requested the service then the coordinates are displayed or printed but if the central controlling system requested the position, it is transmitted. The network events and the associated data are summarized in chapter 8, table 8.1.

¹ The current operational calculation of the FDRI is based on weather data only.

3.1.1.3 System management

The system management functions are the following:

- a) download data;
- b) set system date and time;
- c) set the scan¹ widths and depths (km) and
- d) upload data.

These functions are merely selected and executed. In the case of up or downloading data the correct format associated with the data has to be selected. The up and download function can be executed via a RS-232 cable or via the network.

In the situation where a fire is being controlled on that particular segment of the network, the FTU should not allow up- or download functions to proceed as this could cause network congestion.

3.1.1.4 Weather

The local weather can be read from the weather station attached via the RS-232 port.

3.1.2 Remote functions

In remote mode, i.e. the FTU is connected to a network, all the functions described under local mode as well as the following functions are selectable, using Key "B":

- a) electronic mail;
- b) reporting;
- c) requesting services and
- d) weather.

3.1.2.1 Mail

An elementary mailing system can be accomplished by using the verb and noun set described in appendix B and/or a forestry oriented adaption to the APCO-10 coding system. The APCO-10 codes below are most often used in forest fire communication and suitable for FTU encoding (Chandler *et al.*, 1983; Horzepa, 1989):

APCO-10 codes most applicable to forest fire communications:

Note: The text in single quotes indicate variable information fields. If an input is required it is implemented in the FTU as part of level 3 in the functional structure (chapter 8, table 8.1).

10-1. Unable to copy, change location

¹ The scan width and depth describes a strip measured from the current position of the FTU and the parameters are used in requesting complex processing from a central computer.

- 10-2. Signals good
- 10-3. Stop transmitting, you are interfering with emergency traffic
- 10-4. Acknowledgement
- 10-5. Relay (e.g. 10-5 'destination')
- 10-6. Busy - standby unless urgent
- 10-7. Out of service (i.e. supply location and/or telephone number instead)
- 10-8. In service
- 10-9. Repeat
- 10-12. Stand by (stop). Physical standby, remain alert
- 10-13. Weather and road report
- 10-18. Complete assignment quickly
- 10-19. Return to 'destination'
- 10-20. Location
- 10-21. Call 'person' by telephone
- 10-22. Disregard
- 10-23. Arrived at scene
- 10-24. Assignment completed, personnel and equipment back in service
- 10-25. Report in person to 'person'
- 10-28. Vehicle registration information
- 10-30. Illegal use of radio
- 10-33. EMERGENCY. Maximum priority, all other stations maintain radio silence
- 10-36. Correct time
- 10-41. Beginning tour of duty
- 10-42. Ending tour of duty
- 10-43. Information on 'subject' (request or supply)
- 10-50. Accident
- 10-52. Ambulance required
- 10-59. Convoy or escort
- 10-62. Reply to message
- 10-63. Prepare to make a written copy (e.g. park the vehicle and then respond with '10-4')
- 10-64. Message for local delivery (i.e. personally)
- 10-65. Obtain next unused message number
- 10-66. Message cancellation
- 10-67. All stations must copy message
- 10-68. Attempt to locate (e.g. a message)
- 10-69. Message received
- 10-70. Fire alarm
- 10-74. Negative
- 10-75. In contact with. (e.g. '10-75 11?' - '10-4 10-75 11')
- 10-76. En route
- 10-77. Estimated Time of Arrival (ETA)
- 10-88. Advise present telephone number

3.1.2.2 Reporting

Examples of the different report types required are summarized in chapter 8, table 8.1.

3.1.2.3 Requesting services

The request for assistance is a panic situation which will be placed in front of all events in the event queue of central control.

3.1.2.4 Weather

In addition to a locally attached weather station, area and regional real-time weather is available via RIMS.

3.1.3 Local and remote (transparent functions)

In both the local and remote modes the unit delivers standby type functions such as:

- a) responding to system and network events and
- b) routing traffic.

3.1.3.1 Responding to system and network events

In standby mode the unit is in a sleep mode (e.g. screen and printer off) but is scanning for the applicable events (subsequently listed), for example respond to a shift in the wind or an incoming message.

The algorithm for this function merely evaluates the services selected and responds with an appropriate response (e.g. a warning 'beep').

Typical events received and generated within the range of FTU functions are:

0. Undefined event
1. FDRI changing
2. Fire(s) in progress
3. GPS position report
4. Humidity shift
5. Incoming message
6. Message transmitted
7. Network down
8. Network not available
9. New message received
10. No active fires
11. Request acknowledged
12. Request completed
13. Request for FDRI in area
14. Request for GPS position
15. Request for humidity
16. Request for temperature
17. Request for wind direction
18. Request for wind speed

19. Requested assistance
20. Temperature decreasing
21. Temperature increasing
22. Wind direction shifting
23. Wind speed decreasing
24. Wind speed increasing

3.1.3.2 *Routing traffic*

The routing of traffic is a transparent function allowed by the networking protocol.

3.2 LOOKOUT FUNCTIONS

An example of how a specially adapted FTU could be used to enhance lookout functionality is described in chapter 8.

3.3 FINANCIAL FUNCTIONS

The use of Smart Card technology, the required functions and the associated data has been described previously (chapter 8 and appendix B).

3.4 SPECIALIZED FUNCTIONS

An example of using the FTU in a minimal hardware configuration for specialized functions, is described in chapter 8.

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APPENDIX E : RECONNAISSANCE LETTER

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Information Technology

**Private Bag X5018
University of Stellenbosch
Stellenbosch
7600**

**Tel: 02231-774341 (direct)
02231-774349 (secretary)
Fax: 02231-774102**

Re: Real-time Fire Decision Support Services in Forestry : Ph.D Study

After reading the combined reports of all the Task Groups as well as the papers delivered at the "Forestry Research '88'" symposium on technology transfer, I have noticed that the timber growing community has set a goal to double wood production by the year 2010 and that applicable modern technology is required to achieve this goal.

In contrast it has however also been stated that current technology transfer mechanisms with regard to implementing new techniques and research results are inadequate and many have failed for various perceived reasons. Therefore new ways for applying technology efficiently should be actively investigated. I am interested in applying the latest computer technology to Forestry in South Africa, as outlined in the brief project description below. The investigation is based on a working system in the American Forestry and Land Management context, with the exception that it is adjusted in terms of cost and functionality for the South African situation. The philosophy of the system is based on the belief that all levels of management should have real-time (e.g. changing weather conditions) inquiry and update access to any information applicable to his working sphere, not just in the office, but also in the field.

It would therefore be appreciated if you could help with the setting of a functional (and currently academic) requirement, by submitting inputs or sending information which may be of help.

Intended Contribution

The pilot study will be an attempt to provide field managers with a very elementary tool for

obtaining, requesting and/or updating information, crucial to their task, in real-time. You could imagine this service as something like an "Information Companion" with an interface that works as easy as a car dashboard (and which could in fact be mounted on a dashboard).

Extreme care should be taken to design for practical simplicity as the system interface is intended for direct use by managers. The system must also be relatively inexpensive yet powerful, in that it utilizes the latest trends in computer technology and communication.

As you read on, it should also become clear why I have chosen fire control as the pilot study and why I need the input of experienced Forest Officers in the matter.

System advantages (not exhaustive)

Some of the main advantages of such a system, given that it is "manager friendly", would be that:

- a) task specific information as well as system, database or model access would be at the managers fingertips no matter where he is, resulting in decisions based on a broader knowledge base,
- b) a platform would be provided for adding new services (i.e. electronic based technology transfer is taking place),
- c) managers would start to participate in formulating new ideas for using the platform (the US Forest Service and Bureau for Land Management reports that, contradictory to the expectation derived from the negative attitudes of managers before system implementation, an overwhelming response from managers after system implementation, placed them in a position of not being able to react fast enough on new, unthought of system requirements),
- d) field activities could almost be directly integrated with the APO (e.g. checking and updating the pruning schedule),
- e) data gathered during, for example logging operations, could be directly transferred to the office (or headoffice),
- f) substantial savings in dataprocessing (manually and/or electronically) could be expected (e.g. the US Forest Service has shown that the cost of producing and sending a single page letter has dropped to below 0.50c from a previous \$3.50 - \$5.00).

Technical implementation in SA conditions

In the field such a service could currently be achieved by interfacing to a standard portable or vehicle radio set (i.e. anywhere the radio works, data is obtainable on any defined subject, for example compartment registers). A more static service could also be obtained by using Smart Card technology especially in the finance area, as Smart Card technology has been accepted as "financially sound" technology by the banking community. This service will typically be maintained and backed up by the company planning office.

Rather futuristic you might say, but I can assure you that the technology for such a service has been in place (and therefore well tested) for at least the past 5 years and in fact could be

reasonably inexpensive if used with the already existing radio network present in most forestry companies.

You may also feel that your radio service is unreliable, especially under load in for example fire fighting circumstances, or perhaps the service is not available in many areas of your plantations. With this I have to agree but would like to point out that:

- a) one of the main reasons for the service becoming unreliable during peak usage times is due to heavier communication loads driving the weaker links in the radio system to failure and therefore, if computer technology is effectively applied for communication, a proportion of these loads could be controlled effectively,
- b) in joint ventures with other companies (e.g. fire fighting), the remarks made under (a) are emphasized even further, besides the fact that computer control can also now be used to integrate the operation in terms of the type of information exchange,
- c) in South Africa, commercially available, highspeed satellite communication infrastructure is currently being established at a much higher rate than expected due to the changed political climate and it provides significant advantages over radio links (the latest equipment is much improved and cheaper than the equipment which I demonstrated to Sappi Forests (Kwambonambi) in October 1990 in collaboration with Grinsat (Pty) Ltd).

Discussion

Technology is not the main problem, it already exists, it is constantly improved and is also becoming cheaper on a near daily basis. Writing computer programs is also not a problem (if backed up by sound analysis and design practices) and in most professional software environments the job of coding is done by junior staff under appropriate senior supervision.

The real problem lies in designing a system unique to the real-time information requirements of the timber growing community as well as projecting technology development trends against the design, for example:

- a) in order to control communication traffic via a computer it is necessary to know what sort of information is usually carried on the voice channels and then to filter out those discussions which could be computerized (e.g. a request for equipment),
- b) what information services does a field manager require (e.g. changes and predicted changes in wind direction during fire fighting),
- c) what sort of user interface will satisfy (i.e. be used) by a very busy and (usually) computer illiterate field managers (this is perhaps the most important question of them all),
- d) what is the best method for "plugging" the real-time system into existing company information systems, bearing in mind that each company has it's own network implementations and as well as ideas on the matter,
- e) how is information of common interest to the whole timber growing community going to be structured to ensure orderly transmit, receive, inquiry and update procedures.

To demonstrate this I have chosen "Real-time Fire Control" because this system inherently contains "chaos", "crisis" and "normal" management practices, as well as planning issues.

Project related personal experience

The discussion and examples given above, as well as many other technical and economic issues, need to be addressed in the design. I have managed to accumulate a substantial amount of information on real-time systems in forestry over the past three years and have been fortunate to have the opportunity to back this up with practical experience, some of which are described (briefly) below.

I have recently completed user interfaces based on the requirements of the University of Stellenbosch for the administration counter services, the library access service, the student mealbooking system as well as the general main computer access for Information Technology. One of the main requirements for all these interfaces was simplicity in order to encourage lesser experienced users (e.g. Faculty Deans) to use it.

I travelled to Europe (1991) and the USA (1988) in order to establish progress with real-time computer usage for forestry purposes and I have presented several lectures on the real-time fire control methods used by several agencies in the USA. I frequently receive updates on the US Forest Service and Bureau of Land Management system based at Boise in Idaho.

Another area in which I have gained extensive and detailed experience, is with Smart Card technology and during 1991 I was contracted by Syfrets to create a Smart Card Access Control system for their headquarters in Cape Town. This led to consultancy work for the Bank of Valetta on the island Malta in October 1991.

I have intimate knowledge of networks like Novell, SNA and TCP/IP and for example have the means to run TCP/IP over a radio network. This knowledge was obtained while working as a Communication Specialist for the University of Stellenbosch.

It may be of interest that I have SAASVELD training, currently hold a M.Sc in Forest Management (Stell) which includes subjects and projects to the level of Computer Science IV (Databases and Distributed Databases).

Request

I would have preferred to explain to you in person about the work I intend to do while at the same time gathering some of your thoughts on the matter. This is however not possible and I would therefore be grateful if you could perhaps help by for example (even if you have to imagine a little given a field communication device and system according to Utopian standards):

- a) supplying what sort of information a fire manager, planner, driver, foreman, etc. would find useful before, during and after a controlled or wild burn (e.g. how is the advancing weather front going to influence the wind direction in two hours from now),
- b) stating how the information that a manager requires, differs from that of the planning section or fire research,
- c) supplying some information on the fire season strategies of your company (e.g. how does changes in the Fire Danger Rating Index influence standby crews and

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- equipment),
- d) supplying some information on how you cooperate with other companies and/or organizations during the fire season (e.g. what sort of information do you exchange),
 - e) what sort of information do managers and planners require on a monthly, weekly, daily, hourly, etc. basis during the fire season (e.g. is Fire Danger Rating Index needed on a hourly or daily basis if measured by Utopian standards),
 - f) what sort of data and/or information are to be updated or monitored by managers and planners during the fire season or during a fire,
 - g) how is equipment, aircraft and personnel scheduled before, during and after a fire operation (especially in a multi-company operation).

If you have some (any) input, it would be appreciated if you could mail it to me at your earliest convenience. Faximilee or telephone calls are also welcome. There is no need to be formal and you could for example scribble your remarks down on the back of this document, perhaps pass on some minutes of meetings or even send a photostat of company strategy with regard to fire. If you need me to cover any costs for the reproduction of a document, I will do so.

With this study I could not possibly hope to provide the perfect answer in the quest for excellent Real-time Management Information using the latest available computer technology. The attempt would hopefully open new avenues and a basis from which to build.

Thank you very much for finding the time to read this lengthy letter.

Yours sincerely

Johan Fourie

**CHIEF : COMPUTER SYSTEMS SUPPORT
UNIVERSITY OF STELLENBOSCH
STELLENBOSCH**

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APPENDIX F : DEFINITIONS AND EXPLANATIONS

1.0 DEFINITIONS, EXPLANATIONS AND TERMINOLOGY

Asynchronous

Events occurring irregularly, independent of one another at unpredictable times, are asynchronous occurrences (Burroughs Corporation, 1985, p. G4).

Band

Indicates the frequency spectrum between a defined upper and lower limit (Burroughs Corporation, 1985, p. G5).

Bandwidth

The difference in hertz, between the upper and lower frequencies of a band (Burroughs Corporation, 1985, p. G5).

Baseband

The transmission technique where a single base frequency is used for all communications (e.g. different protocols) on a single physical service (e.g. a LAN type like Ethernet) (Novell Inc., 1986a).

Broadband

The transmission technique where a number of services (e.g. voice, video and data) are frequency-multiplexed through a medium (e.g. cable) with associated filters and amplifiers (Novell Inc., 1986a).

Data flow

A data flow is a movement of information or raw data amongst terminators, data stores or processes (Rennhackkamp, 1990).

Data store

A data store is a place in the organization which is used to keep a collection of data for a period of time (Rennhackkamp, 1990).

Environmental Sensor Unit (ESU) and Environmental Sensor Node (ESN)

An ESU is broadly defined as a permanently placed or a portable unit, designed for low power consumption and which contains:

- a) one or several sensors for example, temperature and windspeed and
- b) a data logger unit capable of sampling the attached sensor(s) and communicating with the outside world via a keyboard, a screen and/or a simplistic communication interface(s) (e.g. RS232-C).

An ESN is defined as an ESU which has been enhanced with a communication package, allowing the ESU to be introduced into a network as a participating ESN.

The communication package could for example be a software protocol stack operating over the RS232-C electrical interface on a cable or, it could be a software protocol stack (e.g. AX.25) operating over a more sophisticated radio or satellite transceiver system. It is important to note that all types of communication interfaces must provide all the functions

obtainable from the keyboard and screen interface. This allows:

- a) selecting a logger unit with a keyboard/screen interface, a network interface or both;
- b) manual operation via the screen/keyboard;
- c) operation in the immediate vicinity via a RS232-C port and a cable;
- d) remote operation via a network;
- e) operational savings by doing remote queries, adjustments and maintenance via the network interface and
- f) automatic software control via the network interface.

Field Terminal Unit (FTU)

A Field Terminal Unit (FTU) is defined as a small, portable computer system which is specially built for forestry purposes as implicated in this study or, alternatively could be related to the more sophisticated, commercially available laptop/notebook computers running forestry application software.

Packet driver

A packet driver is a small (usually assembler) program which interfaces a communication protocol stack (e.g. TCP/IP) directly to hardware (e.g. an Ethernet board) or to another communication stack (e.g. IPX).

Processes

A process is a function performed by the system to transform input data flow(s) to output data flow(s) (Rennhackkamp, 1990).

Terminators

A terminator is a logical class of person or object, which is the source or destiny of data. It is usually outside the boundary and interacts closely with the system. It could also be another system which interacts with the system under consideration (Rennhackkamp, 1990).

X.25

CCITT proposed international standard network access protocols for layers 1, 2 and 3 of the ISO/OSI¹ model. This set of protocols is collectively known as X.25 (Tannenbaum, 1981).

IBM developed SDLC (Synchronous Data Link Control) which is now used in SNA. This protocol was submitted to ANSI² for acceptance as the US standard and to ISO for acceptance as the international standard. ANSI modified it to become ADCCP³ and ISO modified it to become HDLC⁴. CCITT modified HDLC for its Link Access Procedure (LAP) as part of the X.25 network interface standard and modified it again (LAPB) to be more compatible with a later version of HDLC (Tannenbaum, 1981, p. 167).

¹ The International Standards Organization for Open Systems Interconnection.

² American National Standards Institute.

³ Advanced Data Communication Control Protocol.

⁴ High-level Data Link Control.

X.400

CCITT defined X.400 as a standard which will allow different computer vendors complying with the standard, to exchange mail over a X.25 based network (Du Toit, 1986).

XMODEM protocol

The XMODEM file-transfer protocol was composed in 1977 by Ward Christenson, a programmer who has contributed many useful programs to the public domain. XMODEM is an elementary send-and-wait protocol using a fixed-length data field (Campbell, 1987).

XODIAC

A proprietry network system developed by Data General Corporation.

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APPENDIX G : ABBREVIATIONS AND ACRONYMNS

1.0 ACRONYMNS

ADCCP	Advanced Data Communication Control Protocol
ALDS	Automatic Lightning Detection System
API	Advanced Programming Interface
APO	Annual Plan of Operations
BIFC	Boise Inter-agency Fire Centre
BLM	Bureau of Land Management
CFFDRS	Canadian Forest Fire Danger Rating System
CRC	Cyclic Redundancy Check
DBMS	Data Base Management Systems
DTMF	Dial Tone Multiple Frequency
EDI	Electronic Data Interchange
ES	Environmental Sensor
ESU	Environmental Sensor Unit
ESN	Environmental Sensor Node
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
FDRI	Fire Danger Rating Index
FDRS	Fire Danger Rating System
FFA	Forest Fire Association
FIN	Forestry Industry Network
FIREPLAN	Fire Planning Language
FISN	Forestry Industry Sensor Network
FOP	Fire Occurrence Protection system
FTU	Field Terminal Unit
GIS	Geographical Information System
GIMS	Geographical Information and Modelling Systems
GPS	Global Positioning System
GUI	Graphical User Interface
HDLC	High-level Data Link Control
IAMS	Initial Attack Management System
ISDN	Integrated Services Digital Network
ISO	International Standards Organization
LAN	Local Area Network
LAP	Link Access Protocol
LCD	Liquid Crystal Display
LFPA	Lowveld Fire Protection Association
NCSA	National Centre for Super Computing Applications
NFPA	Natal Fire Protection Association
ODI	Open Datalink Interface
OSI	Open Systems Interconnect
PBX or PABX	Private Branch Exchange
PC	Personal Computer
PREPLAN	Pristine Environment Planning Language
PTT	Public Telephone and Telecom
RAM	Random Access Memory

RAWS	Real-time Automatic Weather System
RIMS	Real-time Incidence Management System
RITL	Radio In The Loop
SDH	Synchronous Digital Hierarchy
SDLC	Synchronous Data Link Control
SNA	Systems Network Architecture
SONET	Synchronous Optical Network
SUNSAT	Stellenbosch University Satellite
TCP/IP	Transmission Control Protocol / Internet Protocol
TES	Terminal Emulation Service
TIFF	Tagged Image File Format
UHF	Ultra High Frequency
UPS	Uninterruptable Power Supply
VAN	Value Added Network
VGA	Video Graphics Array
VHF	Very High Frequency
VOX	Voice Operated Switch
VSAT	Very Small Aperture Terminal
WAIDNet	Wide Area Integrated Digital Network
WAN	Wide Area Network
WIMS	Wildlife Incident Management System

2.0 ABBREVIATIONS

bits/sec.	Bits per second
d.p.i.	Dots per inch
Kb/sec.	Kilobit per second
KB/sec.	Kilobyte per second
km/hr.	Kilometre per hour
Lat	Latitude
Long	Longitude
Mb/sec.	Megabit per second
MB/sec.	Megabyte per second
MHz	Mega Hertz
Gb/sec.	Gigabit per second
GB/sec.	Gigabyte per second

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