AN INVESTIGATION INTO THE DESIGN, DEVELOPMENT, PRODUCTION AND SUPPORT OF A WILDLIFE TRACKING SYSTEM BASED ON GSM/GPS TECHNOLOGIES

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Table Of Contents

Abstract

The wildlife tracking market can be regarded as a niche market in the worldwide tracking industry. The methods considered for RF wildlife tracking are limited to techniques that can be reconciled with the cost, size and power consumption limitations required by this application. For this reason the primary method of wildlife tracking till recently was still based on an RF beacon transmitter fitted to the animal and a mobile manually operated tracking device that is equipped with a RF receiver. This method of tracking is very time consuming, as the animal is tracked by physically searching for it in the wild, which mostly limits the tracker to focus on one animal at a time. Another method that found limited use in wildlife tracking is GPS positioning combined with communication by means of satellite telemetry. This method of tracking is very expensive, the physical size of the tracking device limits the usage of this system to large animals, and there are to date not an efficient power source to drive this system for a desired period of time without putting undesired stress on the animal.

Recent advances in the world of wireless communications resulted in the widespread use of RF tracking based on mobile transceivers that communicate not with a mobile tracking device or with satellites but with the beacons of a fixed installed wireless network. The primary method of positional tracking used in this industry is GPS location based on triangulation, with data communication by means of GSM or an alternative network of fixed RF transmitters.

Using the communication capabilities of GSM networks as basis for wildlife tracking enables a level of efficiency, flexibility and cost-effectiveness that cannot be matched by the earlier approaches. As this new approach to wildlife tracking has not been applied in practice before as an integrated part of wildlife management systems, the need existed to investigate the design, development, production and support of a wildlife tracking system that is based on these advances in technology.

The results of this method of tracking opened up a whole new dimension in wildlife tracking for research, security and wildlife management, based on the fact that GPS is a global means of determining positional data and GSM is a globally accepted means of data transfer that is expanding each day.

Opsomming

Die wildopsporingsmark kan beskou word as 'n nis mark in die wêreldwye opsporingsindustrie. Die metodes wat oorweeg kan word vir RF wildopsporing is beperk tot tegnieke wat versoen kan word met beperkings op koste, grootte en kragverbruik wat benodig word deur die toepassings. As gevolg van hierdie redes was die primêre metode van wildopsporing tot onlangs nog steeds gebaseer op 'n RF-sendermontering aan die dier en 'n mobiele handbeheerde opsporingstoestel wat toegerus is met 'n RF-ontvanger. Die metode van opsporing is baie tydsintensief omdat die dier wat opgespoor word fisies gesoek word in die wildernis, wat meestal die opspoorder beperk om te fokus op een dier op 'n slag. Nog 'n metode met beperkte gebruik in wildopsporing is GPS posisionering gekombineerd met kommunikasie deur middel van satelliet telemetrie. Die metode van opsporing is baie duur, die fisiese grootte van die opsporings eenheid beperk die gebruik van die sisteem tot groot diere en daar is tot op hede nie 'n effektiewe kragbron om die sisteem aan te dryf vir die verlangde periode van tyd sonder om onnodige stremming op die dier te plaas nie.

Onlangse vooruitgang in die wêreld van draadlose kommunikasie het tot gevolg dat die uitbreidende gebruik van RF-opsporing, gebaseer op mobiele senders en ontvangers wat kommunikeer, nie met 'n mobiele opsporingseenheid of met satelliete kommunikeer nie, maar met bakens of met vaste draadlose netwerke. Die primêre metode van posisionele opsporing in die industrie is GPS lokasie gebaseer op driehoeksmeting met datakommunikasie deur middel van GSM of 'n alternatiewe vaste RF-sender.

Gebruikmaking van die kommunikasievermoë van die GSM netwerk as basis vir wildlewe-opsporing, stel 'n vlak van doeltreffendheid, buigsaamheid en koste effektiwiteit wat nie gevind kon word by vroeëre benaderings nie. Deurdat die nuwe benadering tot wildopsporing nog nie van tevore prakties toegepas is as 'n integrale deel van wildbestuurstelsels nie, bestaan daar behoefte om ondersoek in te stel aangaande die ontwerp, ontwikkeling, produksie en onderhoud van 'n wildopsporingstelsel wat gebaseer is op die vordering in tegnologie.

Die resultate van die metode van opsporing het 'n hele nuwe dimensie geopen in wildopsporing vir navorsing, sekuriteit en wildbestuur, gebaseer op die feit dat GPS 'n globale metode is vir bepaling van posisionele data en GSM globaal aanvaar word vir data oordrag en wat daagliks uitbrei.

Abbreviations

$	US Dollar
2D	Two Dimensional
3D	Three Dimensional
AM	Amplitude Modulation
ARGOS	Advanced Research and Global Observation Satellite
BOM	Bill Of Materials
BTS	Base Transceiver Station
DGPS	Differential Global Positioning System
EM	Electro Magnetism
EN	Enable
ESD	Electro Static Discharge
FIFO	First In First Out
FM	Frequency Modulation
Fri	Friday
FRS	Functional Requirement Specifications
FTA	Full Type Approval
GEO	Geographical
GLS	Global Location Sensing
GMT	Greenwich Mean Time
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HH	Hand Held
i.e.	It Est (That Is)
I2C	Inter-Integrated Systems
ID	Identity Document
ISO	International Organization for Standardization
kByte	Kilo Byte
km	Kilometers
km/h	Kilometer per hour
LEO	Low-Earth Orbiting
MHz	Mega Hertz
mA	Milli Ampere
ms	Milli Seconds
mV	Milli Volt
NE	North East
NO	Number
NOAA	National Oceanic and Atmospheric Administration
NW	North West
PC	Personal Computer
PCB	Printed Circuit Boards
PM	Post Meridian
RF	Radio Frequency
RTC	Real Time Clock
sec	Seconds
Sep	September
SMS	Short Message Service
Temp	Temperature
URS	User Requirement Specifications
US	United States
uS	Micro Seconds
USA	United States of America
UV	Ultraviolet
VHF	Very High Frequency

List Of Figures

List Of Tables

Chapter 1

Introduction

1.1 Background to the needs of the wildlife industry

"The need to preserve our natural heritage is very important to man kind and wild life researchers all around the world. A good example of a nature reserve which requires active management resulting from the impact of the restricted conservation area on wildlife behavior is the Pilanesberg National Park, the flag ship nature reserve of the North West Parks and Tourism Board which spans over 500km². This ancient volcano exists as an isolated island of biodiversity in a sea of human development. As a result of Pilanesberg being enclosed, active management of all populations is required in order to maintain the diversity, health and vigor of the various species and the system as a whole. In an effort to understand the impact that various species have on the natural functioning of a savannah eco-system, some populations require extensive monitoring. It is vital to the understanding of these populations that each individual and its relationship with all other individuals within the reserve are understood. Such detailed knowledge of entire populations is unheard of in most other natural systems. It provides unique opportunities for biologists to study a number of questions, which have been very difficult, if not impossible to answer until now. Collaborative research with both local and overseas academic institutions is on going and some excellent results are being achieved. In order to achieve the resolution of data required to develop and maintain an understanding of the various aspects of the eco-system, a wide variety of monitoring tools are used. Field rangers traverse the entire area on foot patrols, reporting both animal sightings and potential security threats while specialist monitoring personnel utilize VHF radio collars and directional antennae as their primary form of animal monitoring. The topography of Pilanesberg however makes radio tracking a laborious, frustrating and costly endeavor. The development of modern technology is providing the potential for more effective and reliable animal tracking. Pilanesberg is in the process of developing "real-time" monitoring systems rather than paper-based systems that presently are updated monthly or even quarterly and are limited in their ability to cope with the increased demands for information." (Van Dyk, 2003)

Mr. Gus van Dyk is one of the world leading researchers in the canine field (lions, leopards, wild dogs, cheetahs etc.). He clearly states in the above reference that there is a definite need for an alternative method of animal tracking. This was one of the main driving forces behind the state of the art approach to wildlife telemetry as studied in this thesis. The primary problem in the wildlife tracking market is that the leading technology that supplies positional data (satellite tracking) is very expensive and physically too big to be used in the tracking of smaller wildlife species. The alternative tracking technology that is less expensive (RF tracking) and that can be fitted on smaller animals does not give positional data and is very time consuming to use.

1.2 Benefits of conbining GPS and GSM

The primary problems in the wildlife tracking market at this moment are the following.

- Conventional RF methods of tracking are very time consuming. Most of the time available for tracking is spent to locate the wild animal that need to be tracked, and sometimes these animals are not located at all. The tracker can also only focus on the tracking of one specific animal at a time (except where there are more than one animal that needs to be tracked in a herd or group).
- State of the art GPS/satellite based tracking telemetry is very expensive. Only well funded research organizations, well established game reserves and selected game farms can afford to use this type of telemetry. It is physically impossible to fit this type of tracking telemetry on smaller animals such as wild dogs, leopards or cheetahs due to the size of the tracking unit.

Against the above background it is clear that a totally new paradigm is required to arrive at new generation RF tracking systems for the wildlife industry. From an initial market survey it was evident that the optimal support of integrated wildlife management requires a tracking system that combines the following capabilities:

- The tracking device fitted to the animal must be small enough to be used on a variety of species, including medium-sized animals like wild dog and baboons.
- The tracking telemetry must have an operational life of several years to limit the cost and disruption resulting from regularly physically capturing the animal to replace the unit.
- The system must provide continuous tracking information for a large number of animals, which is not possible using a concept based on manually operated tracking.
- The system must allow field support and upgrading of functionality while in use to allow the underlying management concept to be adapted over time.

A survey of state-of-the-art positioning and communication technologies clearly indicated that the above set of functionalities requires the combination of GPS positioning with the communication capabilities of a fixed installed wireless network. The only wireless network offering close to ubiquitous covering combined with small size and low cost is GSM (Global System for Mobile Communications), based on its widespread and increasing use for voice and data communications. The obvious choice was therefore to research the possibilities of combining these two technologies for use in wildlife tracking.

The functionality that will make the required wildlife tracking system a state of the art tracking solution can be summarized as follows:

- The low power consumption of the unit.
- The small physical size of the unit.
- The relatively low price of the tracking system.
- The capabilities to determine parameters such as speed and direction of animal movement and the temperature of the animal.
- The fact that the tracking unit is remotely programmable.
- The management capabilities of the tracking software.

A GPS/GSM wildlife tracking system will enable a tracker to focus on various animals simultaneously. It will be less expensive than satellite telemetry, it will be small enough to be fitted on smaller animals such as wild dogs and there are suitable power sources available to drive this system for a desired period of time (at lease two years) without putting undesired stress on the animal.

1.3 Problem statement

The focus of this study is the development of a knowledge base to support the design, development, production, support and deployment of a new generation wildlife tracking concept. This tracking concept is based on the most appropriate set of positioning and communication technologies. It is important to note that this study was conducted in close co-ordination with a related study. This related study focused on the market needs and the design of a commercial strategy to deploy this technology in practice.

Prior to the commencement of this study, no comprehensive study has been published that describes the needs for wildlife tracking against the background of what state-of-the-art wireless networking technology can support. The first element of the problem statement was therefore to conduct a study of detailed functional requirement specifications of a wildlife tracking system that can satisfy the wildlife tracking needs.

No operational systems that could overcome the limitations of manually operated RF telemetry and of satellite tracking existed before this study was commenced. The second element of the problem statement was therefore to conduct a detailed survey of the functional, maintenance and support requirements for a wildlife tracking system to allow the cost-effective deployment and support of the system over its intended lifespan, as well as of the technologies that can support such a system.

The third element of the study was the design of a system that will satisfy the support requirements of a wildlife tracking system. The first aspect that needs to be addressed to overcome these challenges is the question of supportability, maintainability and manufacturability of the tracking system. Supportability refers to the characteristics of design and installation that enables the effective and efficient maintenance and support of the system throughout its planned life cycle. A maintenance support structure needs to be established to facilitate the ease with which the software system or component can be modified to correct faults, improve performance or other attributes, or adapt to the changed environment in which the whole system functions. Design for manufacturability has required additional effort early in the design process.

Once the maintenance and support requirements for a wildlife tracking system were known, the next problem to address, forming the fourth element of this study, was the formulation of a design that will satisfy both the functional, packaging, size, lifespan and support requirements for a wildlife tracking unit. This set up the fifth element of the study namely the development process that should be followed to develop a prototype system but also evaluate it in practice to allow market feedback to be designed into improved versions.

The sixth part of this study focused on the processes that should be followed to allow the detailed evaluation of the functional and support capabilities of a wildlife tracking system. This should included categories of system and component testing as well as quality testing.

The final phase of this study involved the practical evaluation of the prototype system to determine whether the needs of the market were correctly interpreted, whether the capabilities and limitations of the chosen technologies were correctly understood and whether the practical implementation of these technologies would survive practical testing in a very difficult environment.

These practical evaluations were conducted over a variety of conservation areas, including game parks and game farms in South Africa and in other countries such as Botswana, Costa Rica, Zambia, Cameroon, Tanzania, Uganda and Kenya. The results of this part of the study can therefore be viewed as representative of the global wildlife industry.

1.4 Approach

This thesis addresses the engineering management problems that were faced during the design, development and early stage implementation of this system. Focus points of this thesis are the design of the tracking system, the supportability, maintainability and manufacturability of the system as well as testing and implementation of such a system into the wildlife market.

When designing a new product or system, the first objective is to determine the market needs. This is the first and one of the most important factors to keep in consideration in designing any product or system, and must result in the specification of the functional requirements of the system. If a product is designed without proper market research, a lot of unnecessary work will be done. This can be very expensive for a company and a lot of time will be wasted in the design process.

Secondly, it is very important to determine what technology is available, on and off shelve, for developing the product to fulfill all the market needs. After a thorough knowledge of the available technology has been gained, that knowledge must be integrated and reconciled with market requirements to determine how the functional requirements of the product or system will be satisfied.

As soon as the functional requirements have been determined and the key technologies have been selected, a study must be conducted about the supportability, manufacturability and maintainability of the product or system. The results of this study must be incorporated with the functional requirements of the product or system after which the system level design can be performed, followed by the detail design of functional elements.

When the detail design has been completed, a prototype must be developed and tested in a laboratory environment. Once all design faults have been corrected in this environment, a more advanced prototype must be developed for thorough field-testing over a specified period. During this detail design phase, the production plan must be initiated in co-operation with a production house to ensure that the product can be produced and rolled out once all laboratory and field test were accomplished successfully.

Against this background, the following aspects will be addressed in this thesis.

1. The user requirements specification for the GPS/GSM wildlife tracking system.
2. Key functional requirements for the GPS/GSM based tracking system.
3. System level design of the wildlife tracking system.
4. How the functional requirements will be met using a combination of off the shelve and newly designed functional modules.
5. Designing the wildlife tracking system to achieve easy supportability for units in the field (e.g. remote software upgrades)
6. Designing towards manufacturability, based on the expected manufacturing volumes, required manufacturing cost, etc.
7. Designing to support maintainability at a low cost within the expected operational domain and the skill levels of typical end-users.
8. Design of interfaces with other elements of the total system, including collars, transmission stations, wireless networks, etc. aimed at limiting the reliance of the system on external suppliers.
9. Practical evaluation of the complete system in typical application environments.

This study will describe the holistic approach to product development and establishing an operational manufacturing and support capability, against the background of the requirements set by the business opportunity and the industry environment.

The above-mentioned issues will be addressed in the following chapters

Chapter 2: The user requirement specifications for a wildlife tracking system
Chapter 3: The technology environment.

Chapter 4: Functional requirement specification.

Chapter 5: Supportability, manufacturability and maintainability.

Chapter 6: System level design.

Chapter 7: Detail design.

Chapter 8: Laboratory testing, field testing and production.

Chapter 9: Summary and conclusion

1.5 Summary

The wildlife market is a fast growing industry and for these markets monitoring and tracking of wildlife is of utmost importance to conserve and manage these industries. This thesis will provide an overview of the current needs of the wildlife tracking market as well as the need for a new tracking system that will address specific wildlife management problems in the industry. A description will be provided of the process that was followed to develop a knowledge base which could be used to design, implement and practically evaluate a new generation wildlife tracking system, based on the combination of GPS and GSM technology.

Chapter 2

The user requirement statement for a wildlife tracking system

The second chapter of this document explores the industry in which wildlife tracking is an essential requirement to support daily operations. The research question addressed in this chapter is defined as follows: what set of user requirements is representative of the needs of the wildlife management market for a tracking system that will not only satisfy the functional needs but that will also prove to be supportable and maintainable in the field? The market for wildlife tracking consists of research institutes, private game owners, game lodges and game reserves. This market is analyzed and the user requirements for wildlife tracking in this market are explored.

2.1 The target market

YRLess International (Pty) Ltd investigated the possibility to design a tracking solution that will satisfy the needs of the wildlife tracking market.

Before any user requirement specifications of a product can be described, the potential target market of the product must be defined and studied. In the case of the development of a wildlife tracking system, the target market can be divided into segments as demonstrated in Figure 2.1. The envisaged solution will be developed against the background of the different needs for animal tracking of the various segments of the wildlife market.

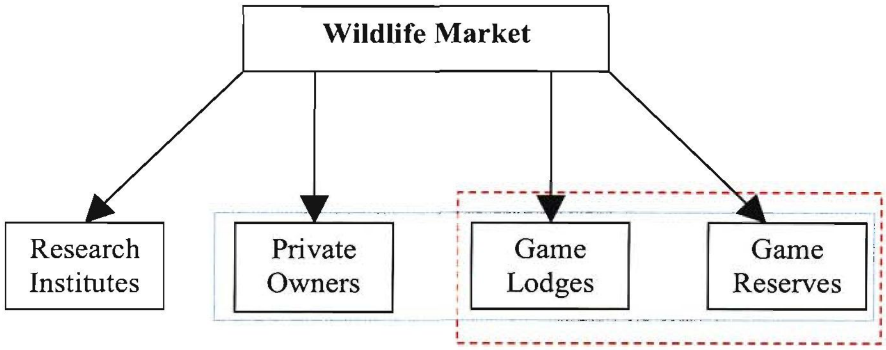


Figure 2.1 – Wildlife Tracking Market

The needs for wildlife tracking of the various segments of the wildlife market differs from each other in various ways. In the following short description, the various needs for tracking in the market segments are described.

2.1.1 Research institutes

The main objectives of research institutes are the collection and interpretation of data relating to the movement and behaviour of animals. The required data consists of environmental, position and migration data to support the research that is done on animals, the way they habitat the land, their relationship with other species, what affects their numbers, and how human activity affects them. Research institutes thus use tracking telemetry to support them in obtaining this information.

2.1.2 Private owners of game farms and estates

Private owners view wildlife as an asset or an investment. Normally the private owner's interest in the wildlife market is to purchase, breed and resell profitable species of wildlife. Typical species included in these breeding projects are animals such as lions, black and white rhinos, elephants (not primarily used because of the huge area needed to maintain these animals) and endangered species such as sable, wild dogs and cheetahs. Private owners will mainly use tracking for security reasons.

A good example is found in the breeding of rhinos. Rhinos don't normally breed in captivity except when they matured in captivity. This means that the private owner must make use of a minimum of 60 hectares of land, depending on the vegitation, for these animals to breed. The value of a breeding pair of white rhino is about $ 125,000.00 and the black market price of a rhino horn is $ 1,500.00. (Marcela, R. 1996)

Rhinos and elephants are the number one target for poachers both in South Africa and in the rest of Africa. For a private owner it is of utmost imporance that the location of the animal is known at all times. This is a typical example of the wildlife tracking needs for private wildlife owners.

The private owner sometimes may use the wildlife on his estate or farm as a tourist attraction. On these farms tourists can get the opportunity to view animals up close in a cage and the private owner will also entertain tourists on this premises. Tracking systems would not be used for these purposes, but only for security as stated above.

2.1.3 Game lodges

Game lodges and game reserves fall in the same categorie (shown in Fugure 2.1) in which the main line of business is tourism. National and international tourists pay large amounts of money to visit game lodges and the objective for the management of these lodges is to provide a sufficient level of customer satisfaction to guarantee repeat visits and positive recommendations to friends that may become future customers. To ensure that tourists enjoy their stay, lodges provide excellent service, food, entertainment and accommodation. Another way is to ensure that these tourists have the opportunity to view all the wild game they came to see. With tracking systems fitted on key animals, a game lodge can ensure that tourists view all the game they want to see within a limited period of time.

One problem with this approach is that when tourists visit a game lodge or reserve, they do not prefer to view animals that is fitted with a collar. This gives a damper on the "African experience" they seek in visiting these lodges and reserves. However, if the visitors are told that the collars are needed for research of an endangered species, they would normally not mind the collaring of the animal.

Another application for tracking systems in game logdes is the management of big game such as elephant and rhino that consume huge amounts of vegetation and are known to break out of fenced areas. Tracking systems enable game lodges to monitor these activities and to accurately manage their vegetation and habitat resources.

2.1.4 Game reserves

Game reserves also use tracking in the management of their wildlife and for tourism as previously mentioned. Most of the research done by research institutes on wild animals is done in reserves because it is most similar to the natural environment and habitat of wild animals. Thus, game reserves has the combined needs for wildlife tracking of wildlife research institutes and game lodges.

2.2 System requirements of the tracking market

Two different research methods were applied to establish the system requirements of the wildlife tracking market.

- Method 1: A company (Company A) that supplies wildlife tracking telemetry (radio transmitters and satellite tracking solutions) for the past 24 years, was contacted. According to Company A, there was a definite need for an alternative tracking system. Company A is situated in Pretoria, South Africa. They were contracted to do a survey on wildlife tracking requirements. Company A has a database of over 150 clients that uses tracking telemetry and their clients consists of research institutes, private owners, game lodges and game reserves. Through contacting their clients and knowledge gathered over the past 24 years, Company A compiled a list of requirements for the alternative tracking solution.

- Method 2: YRless International (Pty) Ltd contacted a few international research institutes. Some of these institutes such as 'Save the Elephants' visited our offices.

Researchers, rangers and park managers of game reserves and lodges such as Pilansberg, Phinda, Addo and Kruger National Parks were also contacted or visited. In the same time some private owners in the Hoedspruit area (Sabi Sands etc) were visited. During these visits, YRless International (Pty) Ltd did their own survey on the requirements of an alternative wildlife tracking solution.

The results of method 1 and 2 were thorougly studied. A document containing the system requirements of a wildlife tracking was created and distributed to Company A and a few research institutes, private owners and game reserves and logdes. A final requirements document was created based on our own research and the previous surveys. This document is discussed below.

The wildlfe tracking requirements of the wildlife market can be divided into four categories of functional requirements that are again subdivided into sub-categories as illustrated in Figure 2.2.

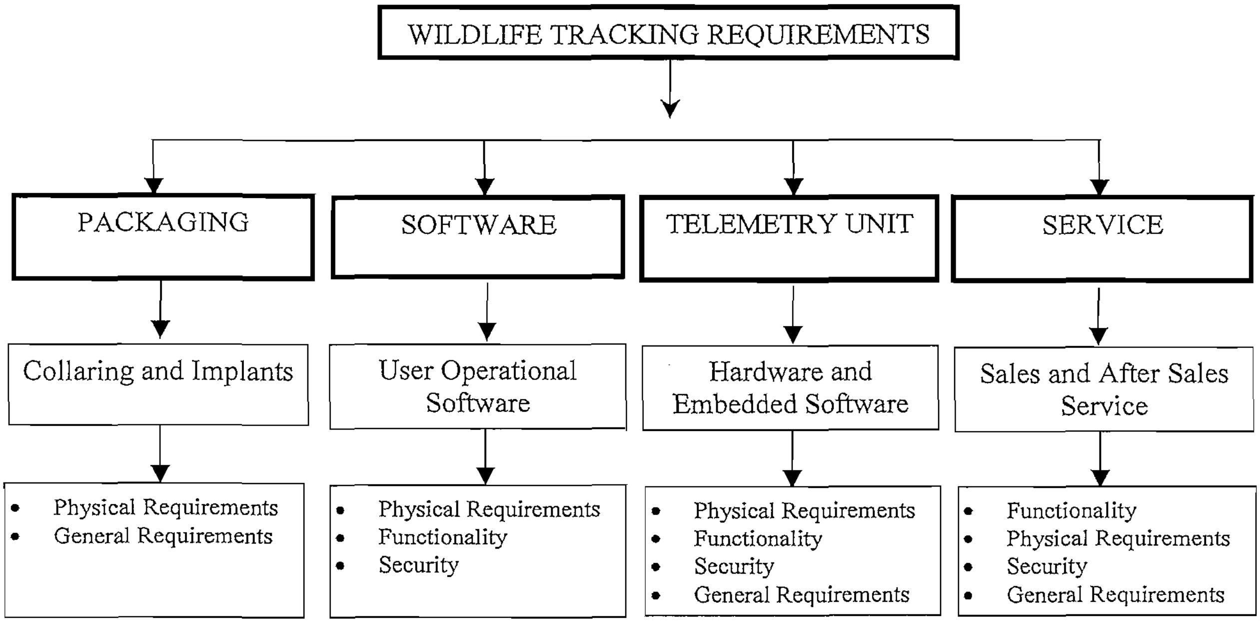


Figure 2.2 – Wildlife tracking requirements

2.2.1 Packaging

The packaging of the unit is a integral part of the successfull implimentation of the system into the market. If the packaging fails, the sytem fails. This packaging must withstand harsh environmental and mechanical stresses for a period of two to three years.

The table below gives a summary of the packaging user requirements as given in appendix A

Packaging user requirement specifications	
Physical requirements	• It should be robust to withstand the elements of nature (extreme temperatures, humidity and climatic changes) for up to three years. • It must be able to withstand mechanical stress caused by typical animal behaviour. • The appearance of the packaging should blend into its environment. • The tracking solution must be easy to mount or fit onto a wild animal. • The packaging must not put the animal in any discomfort or handicap the animal in any way.
General requirements	• The material and solutions that is used to manufacture the packaging must be readily available to minimize the delay time for the manufacturing of the packaging. • The packaging must also be low cost to ensure that the cost of the tracking system is kept as low as possible.

Table 2.1 – Packaging user requirement specifications

2.2.2 Software

The user operational software interface the client will use to view and analyze the tracking data, must give the client easy access and full functional control over the tracking system.

Table 2.2 gives a summary of this department in appendix A .

User operational software user requirement specifications	
Functionality requirements	• The software should display all data visually. This data must contain the animal's position on a specific time and date, the speed and direction that the animal is travelling, and ambient temperature. This data must be accurate and easily updated at user specified intervals. The data that is displayed must be accurately GEO referenced (i.e. data must be shown and plotted on a geographical map) and be updated on user demand. • The user must be able to add Geo-fenced regions on the maps of the software. The user must be notified if an animal moves into or out of this GEO-fenced area. • It must have the capabilities to export all data parameters to an external program such as Excel. • The installation of the software must be easily done. • The user must be able to operate or manage the software even if the user has minimal computer background. • The software must empower the client to customise or configure the user interface to make the software more user-friendly. • It must satisfy the tracking needs of all the clients in the wildlife tracking market as illustrated in Figure 2.1.
Physical requirements	• The interface should be appealing to the client and neatly packaged with a professional appearance • It should contain a very well developed help file and menu description with 24 hour online support from a control room available if needed. • The "look-and-feel" of the software must be in line with well known user interfaces such as Microsoft Windows XP.
Security requirements	• The tracking software should supply the client with a secure tracking solution, meaning that all data is password protected. All data must be stored in a secure database, so in case a client should loose any tracking data for any reason, YRLess can supply the client with an up to date copy. It is the responsibility of the client to secure his computer systems against viruses or external hackers that may try to gain entry through the internet on intranet.

Table 2.2 – User operational software user requirement specifications

2.2.3 Telemetry unit

The tracking telemetry unit will be fitted into the packaging and onto the animal. All the tracking data will be collected by this telemetry unit and sent via a communication channel to the client. A summary of its requirements is given in table 2.3

Telemetry unit user requirement specifications	
Functionality requirements	• The unit should supply the client with accurate positional data and if possible temparature and environmental data. • It must supply the client with valid and accurate data at user specified time intervals. • The data collection intervals must be easily reprogrammable or updated in the field. • There should be an alternative backup tracking telemetry unit incorporated with the main unit in case the main unit malfunctions. • Data storage capability on the unit must be able to handle about 32,000 data readings.
Physical requirements	• The hardware platform should be compact enough that it can be fitted onto smaller species of animal such as baboon, wild dog and jackal. • The usable lifespan of the tracking telemetry unit must be two to three years while being exposed to the typical environmental and stress conditions while fitted to an animal. • The unit must be waterproof, shock proof and durable and be supplied with power for two to three years.
Security requirements	• The data that is sent to the user must be secured by means of encryption. • A secure communication channel between the user and the tracking unit must be used .
General requirements	• The telemetry unit must have a minimum power consumption to ensure that it is functional for as long as possible without replacement of the battery (two to three years).

Table 2.3 – Telemetry unit user requirement specifications

2.2.4 Service

The sales and after sales service that the client receives is another fundametal part of launching a system successfully into the market. Table 2.4 give a summary of the user requirement specification for sales and after sales service.

Service user requirement specifications	
General requirements	• Firstly all contact with the client must be professionally handled. Issues such as physical appearance, the manner in which client relations is handled, and all documentation must be professional and of good quality. • After sales service must be of the same quality as upfront marketing. • It is of utmost importance that the delivery time of the tracking system is minimized. • There must be a follow-up contact with the client within the first month after the tracking solution was delivered. • A service line must be available to provide general software support and guidance during working hours. • A 24 hour services line must also be available when emergency tracking (when an animal has broken through a fence and the tracking intervals must be changed) is needed. • All clients must be contacted at lease once a month as part of the after sales service. • A backup database service must be implimented. This service will enable the client to retrieve data that is lost or deleted. • Emergency alarming must be part of the service package. Emergency alarming is when an animal breaches a GEO-fenced region.

Table 2.4 – Service user requirement specifications

2.3 Summary

The target market has various requirements for a GPS/GSM tracking system. Some of these requirements overlap between the various market segments which make the design process easier, but some other requirements are specific to certain segments. It is important to determine which segment in target market will be the primary focus area, so that the initial system specification to be developed will satisfy the system requirements of this focus area. After this, the requirements specifications of the other segments of the target market must be added around the system requirements of the primary focus area in such a way that the system concept will satisfy all of these specifications.

Chapter 3

The technology environment

In order to fully understand the motivation for YRLess International (Pty) Ltd to design a new method for wildlife tracking and monitoring, the technology environment must be discussed and understood.

Firstly the key technologies used by other wildlife tracking systems in the tracking and monitoring market, including GPS, satellite communications, GSM, satellite tracking and VHF tracking will be discussed. This will be followed by the investigation of the most suitable technologies to support the development of a state-of-the-art tracking telemetry system in wildlife tracking market.

3.1 GPS and GPS functionality

A GPS (Global Positioning System) satellite transmits signals to equipment or telemetry devices on the ground. A GPS receiver passively receives satellite signals, but the receiver does not transmit. GPS receivers require an unobstructed view of the sky, so they are used only outdoors and often do not perform well near tall buildings or obstructions such as within canyons or deep valleys. GPS operations depend on a very accurate time reference, which is provided by atomic clocks at the U.S. Naval Observatory. As illustrated in Figure 2.1 there are at least 24 operational GPS satellites available in orbit at all times. Due to the fact that these 24 satellites are in orbit around the whole earth, not all 24 satellites are within view of one receiver at one specific moment. There are also backup satellites in orbit in case any of the other should malfunction. Each of these GPS satellites have atomic clocks on board.

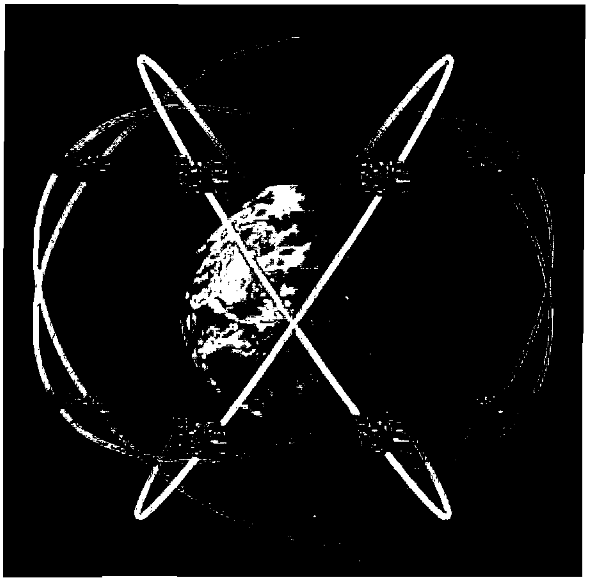


Figure 3.1 – Constellation of GPS satellites

A GPS satellite transmits data that indicates its location in orbit and the synchronized current available time. All GPS satellites synchronize operations so that these repeating signals are transmitted at the same instant. The signals arrive at a GPS receiver at slightly different times because some satellites are farther away than others. The distance to the GPS satellites can be determined by estimating the amount of time it takes for their signals to reach the receiver. When the receiver estimates the distance to at least four GPS satellites, it can calculate its position in three dimensions. If three GPS satellites are located by a GPS receiver, it can calculate its position in two dimentions.

The accuracy of a determined position with GPS depends on the receiver. Hand-held GPS units have about 10-20 meter accuracy. Other types of receivers use a method called Differential GPS (DGPS) to obtain much higher positional accuracy. DGPS requires an additional receiver fixed at a known location nearby. Observations made by the stationary receiver are used to correct positions recorded by the roving units, producing an accuracy better than 1 meter (Smithsonian Institution, 1998a).

3.2 Triangulation

Triangulation is a process and analysis by which the approxmate location of a radio transmitter can be determined by measuring one of the following .

- The radial distance of the received signal from two or three fixed points
- The direction of the received signal from the same two or three fixed points.

Triangulation is mostly used in cellular communications to determine the approximate geographic position of a user.

Figure 3.2 illustrates the fundamental principle of triangulation. In the top part of figure 3.2 the distance to the user is determined by measuring the relative time it takes the signal to travel from the user set to three different base stations.

In the bottom part of figure 3.2 directional antennas at two base stations can be used to determine the location of the cell phone. If three base stations are used, the location can be determined more successfully

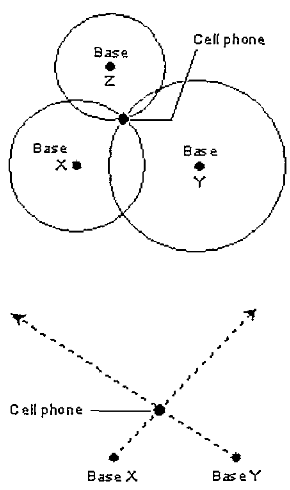


Figure 3.2 – Traigulation

In determining position through triangulation, the apparatus used can be confused by the reflection of signals from large objects such as buildings, mountains and other obstructions. Two independent triangulation determinations should be made to establish a more accurate position of the user. (Searchnetworking, 2006)

3.3 Satellite communications

Most satellite communication systems use a constellation of 48 Low-Earth Orbiting (LEO) satellites illustrated in Figure 3.3, to relay signals from over approximately 80% of the earth's surface, excepting the extreme Polar Regions and some mid-ocean regions. The satellites are placed in eight orbital planes of six satellites each, orbiting the earth every 113 minutes. Included in these constellations are a number of backup satellites that can be activated in the event of failure of any of the operational satellites.

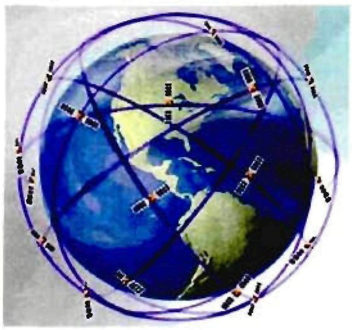


Figure 3.3 – Constellation of communication satellites

These satellites are not stationary, geosynchronous satellites such as those used with a precisely aimed satellite dish. The lower orbits (about 1440 km) have an advantage in that there is little or no echo or delay with voice and data communications.

The satellites use technology which keeps them simple, cost effective and reliable. There is minimal signal manipulation occurring on the satellites themselves; they act basically as reflectors or mirrors, bringing the signals down to earth stations that conduct all the digital signal processing. If the satellite communication device moves behind an obstacle, or the communicating satellite drops below the horizon, the signal is automatically handed to another satellite in view. This is a patented technology referred to as path diversity.

These communication devices do have their limitations. It does not work well inside buildings, behind trees and mountains, or in vehicles. The optimum condition is that of an open area, with no obstructions to the sky.

The second limitation is that the coverage pattern is not uniform around the globe. It is optimized for the major continental land masses. Thus coastal regions and offshore islands may actually be in fringe areas or have no coverage at all.

Another issue to take into consideration is that satellite communication is very expensive. There is also a chance that in densely populated areas a satellite communication device may not receive a communication channel due to a high usage rate that may occur (Aerohost Web Systems, 2003).

3.4 GSM

The first radio communication systems consisted of base stations that were installed on high positions, for example on hills, mountains or high constellations. They were able to cover a large territory (often more than 20 km radius from where the base station is situated). There were no capacity problems with these approaches, because there were not many customers. However, after a few years, the customer became more, and so it was necessary to increase the capacity of these communication systems. The cellular concept was introduced.

The idea of cell-based mobile radio systems appeared in the early 1960's, but they were not introduced until the 1980's. In a cellular system, the covering area is divided into cells. The frequency band allocated to the system is distributed over a group of cells and this distribution is repeated all over the covering area of the operator. The concept of those systems is to re-use the frequency. This means that the same frequency is used several times by cells that are located far from each other. If the transmitter power is low, the distance between two cells using the same frequency can be short.

Low transmitter power causes a small covering area. That is why in cities with a high population density, the covering area of a BTS (Base Transceiver Station) is very small. An important factor for cellular planning is the population penetration, because each cell must be able to support the traffic from the corresponding geographical zone.

The reuse of frequencies considerably increases the capacity of the cellular system The GSM system is therefore able to support millions of users using only 25 MHz bandwidth. The cells are grouped into clusters. A cluster consists of as much cells as the number of divisions of the frequency band allocated to the operator.

The following terms describe the cells of the GSM network.

- Macro cells - are large cells. They are used only in sparsely populated areas
- Micro cells - are used in areas where the system must support large quantities of traffic (cities). The transmitted power is low, so the distance between two cells using the same frequency can be short.

- Selective cells - some cells has a full coverage (360 degrees in terms of the coverage from the cellular tower). It is however not always optimal to use this type of cell. For example, when it is only necessary to cover a single house, the operator can use a cell with coverage of 120 degrees. Nevertheless, selective cells are also used in other ways. Sometimes, when a full coverage is needed, you can find three selective cells that offer full coverage (3 x 120 degrees).
- Umbrella cells - many micro cells obviously result in a high number of handovers. To solve this problem the concept of umbrella cells is introduced. An umbrella cell covers several micro cells. When the speed of the mobile is too high, the mobile is handed off to the umbrella cell. The mobile will then stay longer in the same cell, in this case in the umbrella cell. This will reduce the number of handovers and the work of the network (Scourias, J. 1997).

3.5 Satellite tracking

Weather satellites of the U.S. National Oceanographic and Atmospheric Administration (NOAA) circle the earth at about 850 km above the earth. This NOAA series of environmental satellites has ARGOS instruments attached. The ARGOS instruments can detect signals emitted by satellite transmitters when the satellite passes overhead. If they receive at least two messages during one pass, computers at the base station situated on earth can calculate a location for the transmitter. However, locations based on only two messages are not very accurate - there is a good chance that the satellite tracking device was within 1 km of the location calculated by the satellite. Ideally, locations should be based on four or more messages (Smitsonian Institution, 1998b).

3.6 VHF telemetry

VHF Telemetry is the technique of determining information about a carrier through the use of radio signals from or to a VHF device. "Telemetry" is the transmission of information through the atmosphere usually by radio waves, so radio tracking involves telemetry, and there is much overlap between the two concepts.

The basic components of a radio tracking system are

- a transmitting subsystem consisting of a radio transmitter, a power source and a propagating antenna, and
- a receiving subsystem including a "pick-up" antenna, a signal receiver with reception indicator and a power source. Most radio tracking systems involve transmitters tuned to different frequencies (analogous to different AM/FM radio stations) that allow individual identification. This gives the different signal strength of the transmitters and not a distance indication (Northern Prairie Wildlife Research Centre, 2002).

3.7 Modern tracking telemetry

To understand the full technology environment, a study must be done to identify the wildlife tracking telemetry solutions that are currently available in the wildlife tracking market. This study, in accordance with the user requirement specification and the previously discussings in the technology environment, is a very important part in the system level design.

Four distinct types of wildlife tracking are in use today:

1. very high frequency (VHF) radio tracking,
2. satellite tracking,
3. global location sensing and
4. Global Positioning System (GPS) tracking.

3.7.1 VHF tracking

Transmitting Systems

According to Northern Prairie Wildlife Research Centre (2002), a basic transmitting systems include a radio transmitter, a power source, a transmitting antenna, material to protect the above mentioned electronic components and other material to attach the system to the animal that is tracked. It is also stated that the size and mass of the total transmitting package, the type and strength of signal sent, and life of the unit vary considerably.

Transmitters

Each radio transmitter consists of electronic parts and circuitry, usually including a quartz crystal tuned to a specific frequency. Crystals come in different degrees of shock-resistance, and for animals such as wolves that lead aggressive lifestyles, high-shock resistant crystals are usually used.

Signals can be either continuous, which sounds through a speaker like a high-pitched whine, or pulsed, which sounds like a series of "beeps." Pulsed signals are usually used at rates of 30-120 per minute. Lower pulse rates yield longer transmitter life. Pulse widths can also vary, with 18 milliseconds being the minimum that is easily tracked. The narrower the pulse, the longer the life.

Transmitting frequency

Frequencies used in wildlife telemetry usually range from 27 MHz to 401 MHz. VHF transmitters typically give a ground-to-ground range of 5-10 km which is increased to 15-25 km when received aerially (Rodgers et al. 1996). Lower frequencies propagate farther than higher frequencies since they reflect less when traveling through dense vegetation or varying terrain (Cederlund et al.1979; Mech 1983). However, lower-frequency signals consist of longer wavelengths, which increase the size of the transmitting and receiving antennas necessary for detecting them. This has implications for feasibility and receiver portability.

The frequency ranges used for tracking by means of VHF telemetry are 148-152 MHz, 163-165 MHz, and 216-220 MHz. The higher frequencies bounce more (e.g. off mountains) but have the advantage of requiring smaller antennas. Whatever frequency is selected, individual transmitters are usually tuned ≥10 KHz apart to allow distinctiveness despite signal drift (1-2 KHz) due to temperature and battery fluctuations (Mech 1983).

Power supply

The principal weight of VHF tracking telemetry is determined by the battery used and the collar and protective material. The total weight and the life of the transmitter are determined by the battery.

Lithium batteries that supplies voltages between 2.9 V and 3.9 V are generally employed in VHF systems because due to the following reasons:

- they have longer shelf life;
- their energy capacity-to-volume ratio is twice that of mercury or silver oxide batteries.

Another power supply that is used in VHF systems is photovoltaic or solar cells. (Aucouturier et al. 1977; Snyder et al. 1989). During the day, the transmitter pack uses the solar battery to operate and to store additional energy in the NiCd rechargeable batteries. At night, the unit is powered solely by the NiCd battery. One disadvantage of this method is that rechargeable batteries can only be recharged a limited number of times.

Transmitter protection

Transmitters are usually coated with "potting". This is usually a resin-like material and is used to seal the electronic components included in the VHF transmitter system. These VHF systems are coated to protect the electronic circuitry and power supply against damage caused by animal behaviour (chewing, scratching, etc.) and by the environmental stress such as moisture, mechanical damage, etc. According to MacDonald (1978) the most common reason for transmitter failure is battery failure due to moisture exposure or shelf deterioration.

Transmitter attachment methods

There suggested five essential guidelines in selecting the ideal transmitter package and attachment for a particular project:

- minimum weight,
- minimum effect on the animal,
- maximum protection for the transmitter,
- permanence of the attachment, and
- maximum protection of transmitter from animal mortality factors such as predation and accident. Various attachment methods show varying effects on animals.

Pouliquen et al. (1990) states that collars have traditionally been used to attach transmitter systems on mammals with prominent necks, large ears or horns.

Another alternative is to use surgically implanted transmitters such as subcutaneous transmitters, abdominal transmitters, or rumen transmitters. With implants the signal strength of the transmitter broadcasts is greatly reduced (Samuel and Fuller 1996) and the animal must undergo veterinary procedures to implant the device. (Morris 1980).

VHF receiving systems

Receiving systems detect and identify signals broadcasted from transmitters fitted to animals. Receiving system consists of the following subsystems:

- a receiver,
- a receiving antenna,
- cables,
- a mechanical or human recorder and
- a human interpreter (Mech 1983; Samuel and Fuller 1996).

Receivers

The primary focus for receivers is to detect and distinguish between signals of specific frequencies. Normal receivers consists of a three-position power switch (internal or external power and off), dials for gain and channel, band, and fine frequency adjustments, jacks for an external antenna (UHF or BNC), headphones, a recorder, and external power.

For some receivers frequencies must be entered by dials while others are digitally programmable. Standard alkaline batteries are normally used to power receivers and will function for 8-12 hours. Receivers can also be powered externally from vehicle cigarette lighters.

Some receivers include a sweep option that allows the unit to search within 10 KHz of the tuned signal since signal can drift in the field due to battery and temperature fluctuations (Mech 1983). Other receivers are programmable and can automatically scan for several frequencies at intervals from as little as ½ second to as long as 10 minutes (Samuel and Fuller 1996). The researcher presets the search time and can stop the scanning to home in on a particular signal. This allows the researcher to locate more than one animal at a time.

VHF tracking methods

Through VHF telemetry animals in the field can be tracked through two main methods: homing in and triangulating. Passive remote tracking is accomplished through automatic tracking systems (Cochran et al. 1965).

Homing is the following of a signal toward its greatest strength. The signal increases as the researcher gets closer to the animal and the receiver gain must be reduced to further discriminate the signal's direction. The process of proceeding forward and continually decreasing the gain is repeated until the researcher sees the animal or otherwise estimates its location when sufficiently near (Mech 1983).

Triangulation is the obtaining of two signal bearings from different locations which then cross at the animal. In practice, it is better to take three or four bearings because antenna directionality is imprecise. When more than two bearings are plotted, the bearings form an error polygon on a map. This polygon theoretically contains the animal's location.

3.7.2 Satellite tracking

Satellite telemetry utilizes a platform transmitter terminal (PTT) attached to an animal. This PTT sends an ultra high frequency (401.650 MHz) signal to satellites. The satellites calculate the animal's location and sends this information to sites on the ground. These PTTs are attached to ground animals by means of collars, harnesses and subdermal anchoring (Taillade 1992).

PTTs are very powerful transmitters that transmits a signal to satellites orbiting 800-4,000 km away. Their radiated power ranges from about 250 mW to 2 W (Taillade 1992).

The data rate collection by satellites varies according to topography and latitude. Satellites are in polar orbits, that has to effect that more overhead satellite passes occur, yielding more data collection (Ancel et al. 1992).

Because early PTTs weighed several kilograms, satellite telemetry is only used on large animals such as elephants. The primary advantage of satellite telemetry is its ability to track animals over long distances and in remote areas.

Advantages and disadvantages of satellite telemetry

The greatest advantage of satellite telemetry is in tracking elusive and far-ranging species and minimizing the researcher's travel/field time requirements.

Satellite telemetry is less accurate than either conventional VHF radio-tracking or GPS radio-tracking that will be discussed laster in this chapter. Satellite telemetry frequently reports locations of which the accuracy varies from within 150 m to many kilometers (Keating et al.

1991). Fancy et al. (1989) found that approximatly 90% of satellite-based location estimates are within 900 m of the known location, with a mean error of 480 m.

With satellite-based tracking it is almost impossible to track the animal from the ground unless a VHF transmitter is built into the PTT.

3.7.3 Global location sensing

An alternative to satellite telemetry is the global location sensor (GLS) system. According to Northern Prairie Wildlife Research Centre (2002), a GLS system calculates the animal's position by changes in the ambient light intensity related to the season and time of day, and two fixes per 24-hr period are possible for up to 220 days. The GLS is appropriate only when large location error (150 km) is acceptable such as when studying migratory movements of far ranging, remote species like polar bears or wandering albatross. Although this system is even less accurate than satellite telemetry, it is much less expensive. The GLS unit costs only about $200, and there are no fees for data acquisition or processing. Additionally, the GLS unit weighs only 113 g. However, no data can be accessed until the GLS unit is retrieved. Thus if the GLS unit retrieval is not successful, all data are lost.

3.7.4 Global Positioning System (GPS) tracking

Global Positioning System (GPS) tracking of animals is the latest major development in wildlife telemetry. A GPS receiver is embedded in an animal collar to calculate and record the animal's location, time, and date at programmed intervals. These data is calculations is based on signals received from a special set of satellites that orbit the earth. Each satellite contains an almanac of all the other satellite positions, its current position, and the exact time.

The GPS system

With GPS telemetry these satellites function as transmitters and the animal's telemetry unit acts as a receiver for data transmitted from the satllites. This information is used by the animal's telemetry unit to calculate the animal's location based on the positions of satellites at that point in time and the time taken for the signal sent from each satellite to reach the animal's receiving unit.

According to Northern Prairie Wildlife Research Centre (2002), at least four GPS satellites are always in view from any position on ground level. This allows for 3D-position acquisition based on the four variables (latitude, longitude, altitude, and time/receiver clock bias). When line-of-sight to a particular satellite is obstructed due to, for example surrounding topography, a 2D position can be calculated using three satellites and three variables (latitude, longitude, and time/receiver clock bias). Altitude in a 2D fix is automatically calculated by either using the last known altitude from a 3D fix or by averaging a subset of the recent known altitudes (Rodgers et al. 1996).

Data retrieval for GPS tracking

There are currently three methods of data storage and retrieval in GPS telemetry:

- on-board storage for later collar retrieval and subsequent downloading,
- remote downloading to a portable receiver,
- remote relaying through the Argos satellite system.

On board storage capabilities minimize the effort of the researcher. The collar is attached to the animal and later retrieved. This retrieval can be through an automatic or remotely triggered drop-off mechanism or if the animal is captured. The data are recovered by simply downloading it from the collar. If the on board storage method is used, the collar is relatively smaller in size. Store-on-board collars contain comparatively smaller circuitry and are less complex than other types of GPS collars and thus can carry heavier (longer lasting) batteries for the same overall collar weight. These collars are also less expensive than other GPS telemetry methods.

The main disadvantage when using a store-on-board-only GPS unit is data loss. If a GPS collar fails to release, all the data are lost unless the animal is found, captured and the unit recovered.

GPS data downloaded to a portable receiver ensures data recovery will occur even if the collar fails to release from the animal. With this method, data are downloaded directly to the researcher. The collar is preprogrammed to transmit data through a VHF signal (some systems use FM-relay devices or a UHF modem) to the researcher's receiver at user defined intervals. This timely retrieval of data allows biologists to supplement the location information with field data.

A vital feature with this type of GPS unit is long-term data retention following remote data transmission. Units that follow data transmission with a complete memory sweep are undesirable because often reception of the transmitted reports may not be successful.

Disadvantages with this method of tracking include the relative increase in complexity and weight of the unit that is fitted on the animal as well as for the receiving equipment. This also has the effect that this method is more expensive. Apart from the added cost of the equipment itself, it takes additional labor to retrieve the intermediate data reports.

GPS data relayed by satellite uses the Argos satellite system to relay data reports. The researcher therefore needs neither to be in the field to collect the data reports, nor to maintain special receivers or other additional equipment.

Disadvantages include the bulk and weight of the animal's telemetry unit. This added weight limits the size to animals that can tolerate this type of GPS unit. The researcher must also pay Argos to relay data information through its satellites.

Advantages and disadvantages of GPS tracking

Moen et al. (1997) states that Global Positioning System (GPS) tracking allows the researcher to obtain accurate data (within 5 m) on animal location as frequently as every minute or as infrequently as once per week.

Per data point, the costs of GPS tracking can be cheaper than for conventional VHF radio-tracking (see below). This is because for a given unit of researcher labor, GPS radio-tracking can gather much more location data.

Cost of GPS telemetry systems

A single GPS collar usually ranges from $3,000 to $4,500, about 10 times that of a VHF collar for mid-sized mammals.

Although GPS systems cost much more than VHF systems, this does not mean they are less economical. When cost/location is considered, as opposed to cost/animal, GPS collars can be the cheaper alternative and also save personnel costs since the study may be less labor intensive.

3.8 Summary

Taking into consideration the advantages and disadvantages of the types of telemetry used for wildlife tracking, it is clear that the user requirements stated in chapter 2 can be satisfied by a combination of the telemetry techniques described in this chapter. The main reason for designing this new method of wildlife tracking, is to incorporate the latest technology available to comply to the user specification and introducing it successfully into the wildlife industry.

Chapter 4

Functional requirement specification

In this chapter the next research question is addressed, i.e. which set of functional requirement specifications for a wildlife tracking system based on GPS/GSM technologies will satisfy the user requirements statement developed in chapter 2. The requirements can be divided into three categories namely the requirements for the tracking unit itself, for the data gate way by which the data is received from the tracking unit and distributed to the client and for the method by which the client can view and analyse the tracking data.

4.1 Functional requirements for the tracking unit

The user requirement specifications for the tracking unit itself can be summarized as illustated in the figure below.

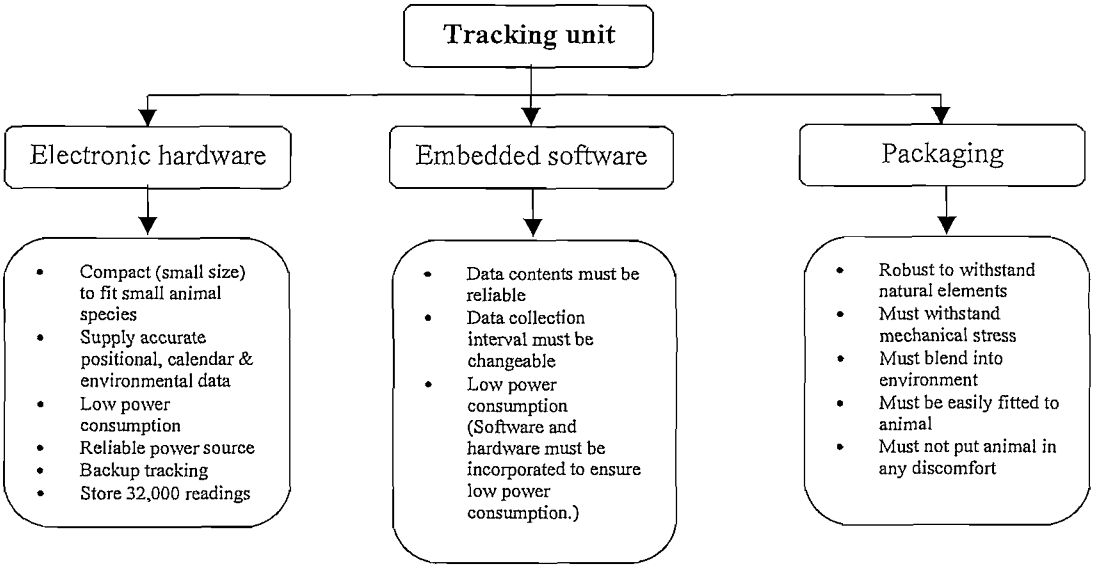


Figure 4.1 - URS of tracking unit

The user requirement specifications is used to determine the functional requirement specifications. Functional requirement specifications are basically the criteria that must be satisfied by the product design.

The functional requirement specifications of the tracking unit can be given as follows.

4.1.1 The tracking hardware

The tracking hardware consisting of electronic components must comply with the following criteria:

- The tracking unit must be compact enough to be fitted on smaller animals such as wild dogs, baboons and aardvark.
- The tracking unit must deliver accurate position data. This data must be made available in an internationally accepted format.
- The positional data must be linked to the date and time when the data was collected.

- Motion data must be collected. This data must include the velocity and direction that the tracking unit is traveling at the specific time and date that the positional data was collected
- Accurate temperature detection data must be supplied.
- The unit must have a very low power consumption to enable the tracking unit to collect data for a duration of two to three years
- A backup tracking telemetry function must be available if the main tracking unit malfunctions.
- The tracking unit must be capable to store 32,000 data parameters
- The power source that drives the tracking unit must have the capacity to deliver enough enegry to drive the tracking unit for a minimum of two years for a minimum of five tracking readings (including position, motion, activity, time and date and temperature data) per 24 hours.
- One of the functional requirements of the tracking unit hardware is that it must be small enough tho be fitted on smaller animals. This requirement also applies for the power source of the tracking unit.

4.1.2 The embedded software

The software that controls the tracking hardware must consist of the following functional requirement specifications:

- The integrity of the data that is collected must never be in dispute, meaning that the data must be accurate, correct and reliable. To ensure this, measures must be incorporated to verify data that is collected and send through to the user at the required interval.
- The unit must be remotely reprogrammable. These remotely upgradable functions include the changing of the following parameters:
    1. unit reporting schedule,
    2. the specified time slot to collect al the data variables and
    3. the number of data readings to be sent to the control room.
- The embedded software must ensure that the tracking unit has a minimum power consumption.

4.1.3 The packaging

The functional requirement specifications of the packaging in which the tracking hardware and the power source is assembled are as follows:

- The packaging must withstand harsh environmental conditions, physical treatment and mechanical stress for a periode of two years.
- The packaging that is fitted to the animal must fit into the animal's natural environment in terms of its physical appearance.
- The packaging must by easily fitted onto the animal within a short period of time while the animal is dozed and must not put the animal in discomfort

4.2 The user operational software

A summary of the user requirement specifications is given in figure 4.2 below

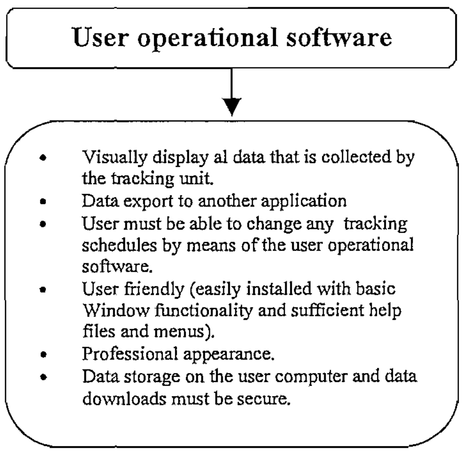


Figure 4.2 – URS of user operational software

The user operational software is the method the user uses to view and analyse the tracking data. This interface will determine if the user will utilize the tracking system to its full potential. The user interface must comply to the following functional requirement specifications:

- The interface must allow the user to view the tracking data visually on a geograhically referenced map. All data parameters such as date and time, positional information, movement information and environmental information must be visable. The map interface must enable the user to zoom in or zoom out for a more or less detailed map.

- The user must be able to export tracking data to other software applications such as Microsoft Excel. It must have the capabilities to import other tracking data into the interface.
- The appearance of the user operational software must be professional and modern.
- The interface must enable the user to change or add the following parameters
  1. The tracking schedule
  2. The number of tracking data readings to be sent every time the tracking unit reports to the control room
  3. The specified positional data collection time slot.
  4. Add vital animal information to the interface. This information may contain the age of the animal, its gender, number of young, tribe name ect.
  5. Activate or deactive the backup beacon transmitter
- The interface must enable the user to securely protect tracking data on the computer where the user operational software is installed. The channel used to download new data into the user operational software must also be secure.

4.3 Summary

This chapter is a basically an outflow of the user requirement specifications in chapter 2 and provides a detailed desricption of the required system functional specifications. The detailed requirements described in this chapter will be the driving force behind the system design. The system design will only be successful if all these functional requirements are met and sustained during the life span of the system.

Chapter 5

Supportability, manufacturability and maintainability

In an increasingly competitive world, product design and customer service may be the ultimate way to distinguish a company's capabilities. In this chapter the next research question is addressed: what are the supportability, manufacturability and maintainablility requirements of a wildlife tracking sytem that can ensure that not only the needs of end-users as described in chapter 2 can be fulfilled, but that it can also be backed up by the required customer service to ensure that product functionality is sustained. This is a very integral part of any product development, as without these capabilities it will not be possible to sustain the functional capabilities of the system during its operational life cycle.

5.1 Supportability and maintainability

Supportability refers to the characteristics of design and installation that enables the effective and efficient maintenance and support of the system throughout its planned life cycle. It is closely related to maintainability in that good supportability requires the incorporation of reliability and maintainability characteristics in the design. This is why supportability and maintainability are discussed together and not seperately.

Supportability is an integral part of the design process to ensures that supportability requirements are incorporated in the design and that logistics resources are defined to support the system during the operating life of the system. Without a supportability infrastructure, it is inevitable that as soon as a product is deployed in the field and a problem occurs, it will take an indeterminite time to address the fault or problem. Another reason why a supportability structure is incorporated is to ensure that a there are efficient client service available for any situation or query that may arrise.

Support resource requirements in this case include the skills, tools, equipment, facilities, spares, techniques, documentation, data, materials, and analysis required to ensure that a tracking system maintains its integrity over its intended lifespan. For instance, when the performance of the tracking system is compromised, (i.e. loss of designed functionality), the damaged system must be restored quickly and at low cost.

Customer requirements can dictate the maintenance philosophy, materials availability, and repair capabilities that a design team must incorporate throughout the design process. In the case of most new companies such as YRless International (Pty) Ltd, with a relatively young design team, the first objective is always to finalize the design of the tracking system to such a state that the product can be sold. It was only when the first products started to fail and were returend to the workshop that a plan for supportability was designed. This was due to the fact that not one of the design team members have previously been involved in any development up to the deployment phase of a product. Starting with the design of the support system at this stage only is much too late, as it is either impossible or very expensive to alter the underlying design at this stage. It is therefore of utmost importance that a maintainability structure is developed in co-ordination with the design. This maintainability stucture must be finalized before a product is released. In any future product development it will be easier to develop a supportabiblty and maintainability structure in co-ordination with the product design due to the fact that it is easier to determine where and how supportability and maintainabilty will be needed. This is because as a design company grows in expertise, there is better understanding of where supportability and maintainability are needed.

Designing of the tracking system should provide for the aspect of inspectability for potential damage. The methods chosen for inspection may be restricted as it is very difficult to inspect electronic components.

A variety of inspection techniques are utilized as inspection tools for process-related defects of the tracking unit itself. No single inspection technique can locate and isolate all defects in the tracking unit itself.

It is of utmost importance for any design team that all inspections to be performed are practical and useful to detect damage or defects. YRless International (Pty) Ltd have designed the inspection procedure in such a way that when a tracking system is returned to the workshop due to some kind of failure, it can be attached to a computer interface and terminal to enable error coding software to determine the cause of failure. For 95% of the first 20 comebacks, the cause of failure and defects where human error. It is also important to notice that when components were picked an placed by machines, the failure rate of the tracking unit decreased. This highlights the fact that when a human does a task such as placing and soldering components, the chance of failure increases.

The elements of supportability can be divided as illustrated in Figure 5.1

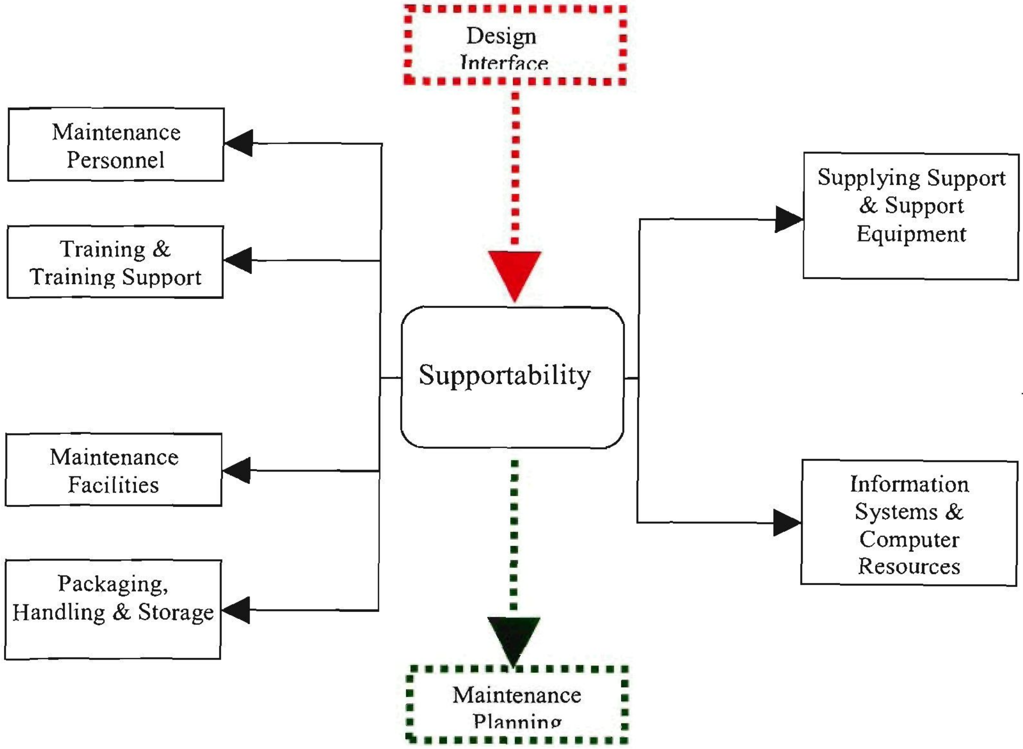


Figure 5.1 – Elements of Supportability

As adapted from Figure 5.1 (Blanchard & Fabrycky, 1998:493) the supportability of a product flows out of the design elements of the product and system. If the supportability system is in place, the maintenance plan can be implemented.

Maintainability is the ease with which a software system or component can be modified to correct faults, improve performance or other attributes, or adapt to a changed environment.

There are two different categories of maintenance activities that must be taken into account when designing the product and maintenance concept: corrective maintenance and preventative maintenance.

5.1.1 Corrective maintenance

This is unscheduled maintenance accomplished, as a result of failure, to restore a system or product to specific level of performance. This includes the possible ongoing modifications to

software to bring is to the proper operational state in the event that it has not achieved the desired level of maturity when the system is delivered to the customer.
(Blanchard & Fabrycky, 1998:402)

Corrective maintenance was relevant in three areas namely the tracking unit, the control center and the user operational software.

Corrective maintenance on the tracking unit happened when the tracking unit was delivered to the organization that collared the unit. It so happened that the seventh unit that was collared malfunctioned. Because the collaring organization is situated in Pretoria, a person had to drive to Pretoria to repair it. The problem with this unit was a static discharge from a worker to the unit and it had to be replaced. A counter for any future failures was to supply the collaring organization with additional spare units in case something malfunctioned. The malfunctioned unit would then be sent back to establish the cause of failure.

Another situation when corrective maintenance is needed on a tracking unit is when the unit is already collared to the animal. In this case, a replacement collar would be send to the client. The animal would be captured and the collar replaced. The malfunctioned collar would be retrieved to establish the cause of failure.

Corrective maintenance on the control room happened when a network link was inactive, there were a power failure for longer that 12 hours or when the communication link between the tracking unit and the control center was inactive.

In the case of the user operational software, corrective maintenance had to do with the client's network connection to the control center, the anti-virus software installed on the client's computer that blocked the user operational software or firewall settings that blocked any data transfer between the control center and the client's computer.

5.1.2 Preventative maintenance

Preventative maintenance is scheduled maintenance accomplished to retain a system at a specific level of performance by providing systematic inspection, detection, servicing, or the prevention of impending failures through periodic item replacements. (Blanchard & Fabrycky, 1998:402)

Preventative maintenance of the tracking unit, the control center and the user operational software is an ongoing process. When a new user requirement is discovered and it was feasible, additional functionality would be added to the tracking units. Improvements on features such as power consumption would also be implemented. New improved security features and stability would also be implemented on the side of the control center and user operational software.

YRLess International (Pty) Ltd use six steps to determine whether maintainability is positively influenced by process improvement (including the testing and production processes).
(Huffman Hayes, J. & Jefferson Offut, A. 2000)

1. The specific process or product activity of interest would be chosen, e.g. for unit testing. The theory here is that certain unit testing techniques may lead to improved maintainability. This can happen in one of two ways:
   - When designing test cases for the unit, the developer can discover better ways to design or code the unit, thus improving maintainability;
   - When executing the tests, defects will be uncovered, the design/code will be modified, and maintainability will be improved.
2. Second, a null hypothesis would be developed, for example: "Software units that have been subjected to unit tests achieving 100% branch coverage exhibit maintainability that is no better than software units that have not been so tested."
3. A study would be set up to examine a variety of unit testing methods. These methods should be selected with care to ensure that the focus is only on the differences in maintainability.
4. An empirical study would be set up to examine a variety of testing.
5. The complexity of the modules would be determined prior to unit testing.
6. Branch tests would be developed and executed.

Maintainability would be measured after the introduction of a new testing method to see if maintainability was impacted. Maintainability was basically measured by evaluating the following three steps during a corrective or preventative maintenance procedure.

- Firstly the turn around time during a corrective and preventative maintenance procedure is evaluated. It is essential that the turn around time is kept as short as possible to minimize the discomfort it may have caused the client.
- Secondly the resulting outcome of the maintenance process is evaluated. The procedure that was followed during corrective or preventative maintenance must address the direct cause of failure and correct it.

- Thirdly, an evaluation must be done to determine if the corrective steps or actions during the maintenance process will not be the cause of any other future failure in the product or system.

If the outcome of the evaluation of the above mentioned point is positive, the maintenance was successfully handled and accomplished.

5.1.3 Maintenance personnel

In the case of YRless International (Pty) Ltd, maintanance personnel needs to be allocated in all the departments as illustrated in Figure 5.1. YRLess International (Pty) Ltd has a 24 hour support line. All these maintenance departments always has one person on standby 24 hours a day should a client contact the support line. This support line must be active 24 hours a day due to the fact that YRLess International (Pty) Ltd has international clients that may need support and assistance.

5.1.4 Training and training support

This department in the supportability structure must assist clients and users in operating the software package received to analyse the tracking data. This is a very crucial part in the support system. If a client does not understand how to use the software, or all the capabilities of the tracking system, the client or user may have the impression that the system malfunctions. In the chapter that discussed user requirement specifications, it was stated that if a client or user purchases a tracking system, it is crucial that the client or user is visited to demonstrate the system and give in depth training in the full functionality of the system. The people allocated to this part of the supportability department must always have good people skills and patience due to the fact that not all users and clients have extended computer skills or knowledge. It is important that people that is working in this department have proper training facilities, resources, training aids (mockups, simulators and software), training procedures and manuals at their disposal to assist the client or user.

Another training department in the supportability structure is an internal training department. This department must train new employees in the company in the various department in YRless International (Pty) Ltd.

5.1.5 Maintenance facilities

These facilities includes all facilities required to support scheduled and unscheduled maintenance actions at all levels of maintenance. In the case of the tracking sytem on the hardware side, this is not very complex. YRless International (Pty) Ltd supplies the tracking unit to an external company at one central point to collar the units before it is supplied to the client. A stationary maintenance facility and mobile maintenace facility is required. The reason for this is as follows:

- When a tracking unit is collared and it malfunctions before it is supplied to the client, the collar has to be opened. This is a time consuming and delicate process to ensure that the tracking unit is not damaged and has to be done at the stationary maintenance facility. When a tracking collar malfunctions in the field, it also has to be brought back to the stationary maintenance facility.
- A mobile maintenance facility is needed when a tracking unit malfunctions before or during the collaring process. It is the easier to do maintenance on the unit in this phase of production at the stationary collaring plant situated in Pretoria than to bring it back to stationary maintenance facility in Potchefstroom.

5.1.6 Packaging, handling and storage

This category covers the initial and sustaining transportation requirements to support the distribution of tracking system. YRLess International (Pty) Ltd is reponsible for distributing all tracking units to the collaring plant. If nessasary a courier service is used. When a tracking collar is completed, the collar is supplier to the client by means of a courier service, or the client collects the collar, or it is delivered by the training department. The training department must visit the client to provide the client with software and system training. In circumstances when a client is not situated in South Africa, he normaly collects the collar himself (this gives the training department an opportunity to guide the client through the software and system) or it is couriered to the client. If this is the case, the training department guides the client through the software and system by phone or through a net meeting.

Operational system software is normally couriered to the client two weeks before the client receives the tracking collar.

5.1.7 Supplying support and support equipment

This equipment includes all tools, condition monitoring equipement, special test equipememt and special handling equipment required to support all scheduled and unscheduled maintenance actions. As stated above in the maintenance facilities, YRLess International (Pty) Ltd has two maintenance facilities, namely a stationary and a mobile maintenance facility.

At the stationary facility, all tools, monitoring, test and handling equipment are set up for any required maintenance. A desktop computer is also assigned for these purposes. In the mobile facililty, all tools, monitoring, handling and test equipement are placed in a professional toolbox setup. This mobile facility can operate at any given time from a 12V vehicle battery and all software needed to perform monitoring and tests are installed on all maintenance personnel laptops. This ensures that maintenance can be done on a tracking unit in all typical operational locations.

5.1.8 Information systems and computer resources

This part of the supportability structure includes all installation, maintanance, inspection, design (hardware schematics and software flow diagrams) and supplier information and instructions. This is implemented through a software file on each of the maintenance computers as well as a hard copy if it is needed. It is also crucial that there are persons on standby if they are needed. For instance, if something is questionable in the software or hardware structure or design, the mobile maintenance personel must be able to contact the software or hardware designer if it is necessary any time of the day or night.

5.2 Manufacturability

Design for manufacturability (DFM) is the process of proactively designing products to (1) optimize all the manufacturing functions: fabrication, assembly, test, procurement, shipping, delivery, service, and repair, and (2) assure the best cost, quality, reliability, regulatory compliance, safety, time-to-market, and customer satisfaction.
(Anderson, D.M. 2004)

Design for manufacturability may require additional effort early in the design process. However, the integration of product and process design through improved business practices, management philosophies and technology tools will result in a more producible product to better meet customer needs, a quicker and smoother transition to manufacturing, and a lower total program/life cycle cost.

As adopted from (Ransey, G. 2004.), the design for manufacturability process can described as illustrated in figure 5.2.

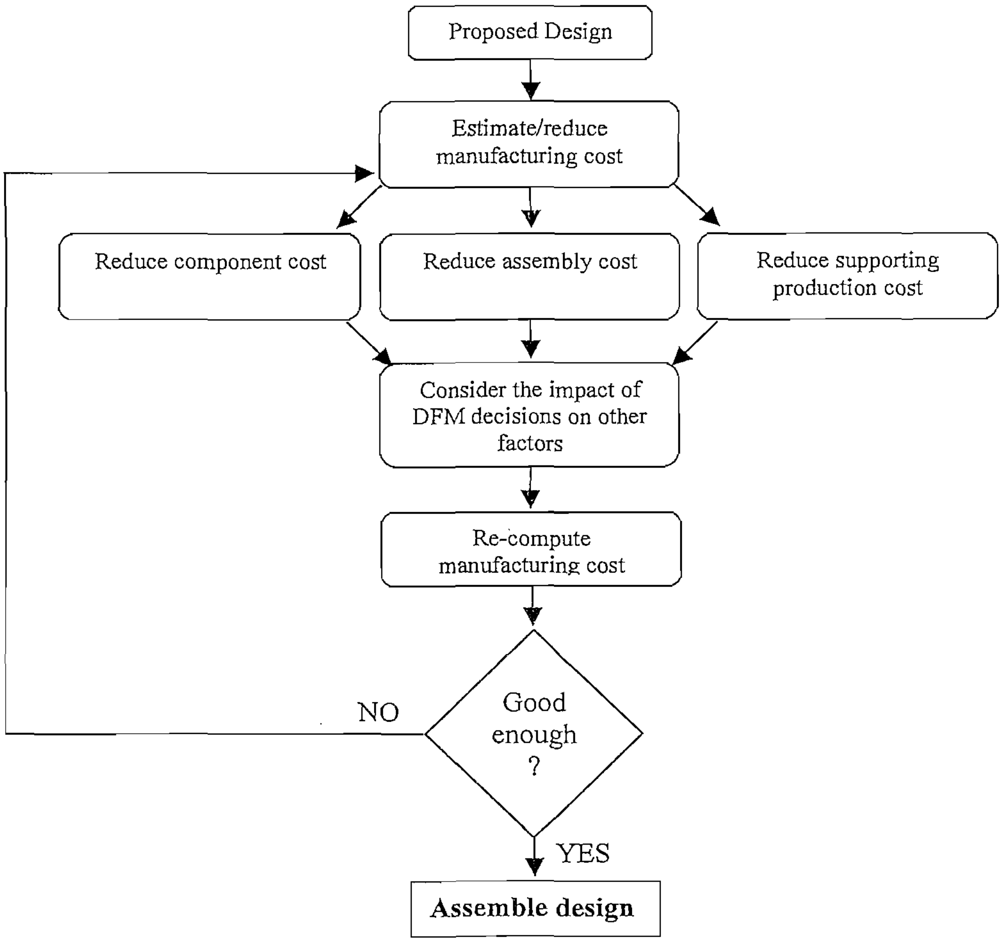


Figure 5.2 – Deign for Manufacturability

5.3 <u>Summary</u>

Because of the growing importance of product manufacturability and field maintenance, design for manufacturability and maintainability concepts are critical for successful product deployment. It is the key to achieving and sustaining a competitive advantage through the development of a high quality, highly functional tracking system effectively manufactured through the synergy of integrated product and process design.

In summary, maintenance is a very important area of engineering and design. The integration of product and process design activities has been used in improving quality, productivity, budget and schedules. Practical studies of these activities are required to investigate their merits for improved maintenance.

Chapter 6

System level design

In this chapter, the research question that is addressed is to determine which system level design will satisfy the functional, form and fit requirements for a wildlife tracking system as described in the chapters 3 and 5, using the technologies selected in chapter 4. The different hardware and software subsystems will be discussed and it will be motivated why each subsystem forms an important part of the system design. The figure below demonstrates the basic functionality of the tracking system as a whole.

Figure 6.1 – Construction of the tracking system

6.1 Operational concept

In chapter 2 the user requirement specifications were discussed. A functional requirement specifications document was developed in chapter 4. This chapter forms the backbone of the system design that follows. The system designed for wildlife tracking can be divided into five subsystems:

- The tracking unit.
- The control room that receives all tracking data parameters.
- The user interface by which the client view and analyse the tracking data.
- The communication method used to transmit and receive data between the tracking unit and the control room (Communication Method 1).
- The communication method used to transmit and receive data between the client and the control room (Communication Method 2).

This can be described as in Figure 6.2

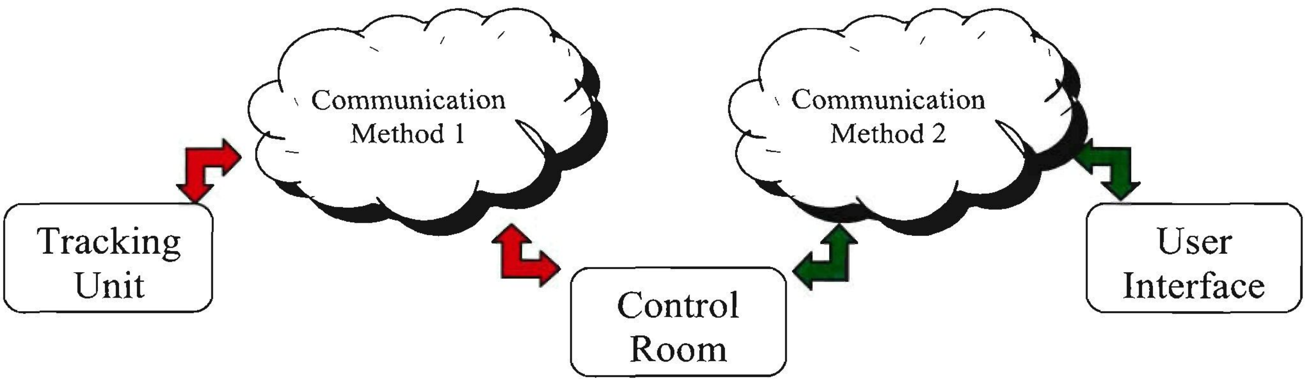


Figure 6.2 – Basic System Operational Concept

6.1.1 The tracking unit

The tracking unit is fitted by means of a collar around the animal's neck.

A collar was chosen as packaging due to the following reasons.

- It is easy to fit a collar on the animal.
- A collar does not harm or put the animal in discomfort.
- The collar and can be painted to fit into the natural environment of the animal.
- The collar is durable and can withstand harsh environmental and mechanical stress for long periods of time.

The tracking collar is made of durable industrial conveyer belt. Conveyer belt is strong and can withstand environmental and mechanical stress.

The tracking unit and power source is molded into the collar with dental acrylic. Dental acrylic is strong, water resistant and can also withstand environmental and mechanical stress.

This tracking unit consists of electronic circuitry, a printed circuit board and a power source.

In the following paragraphs the motivation for the implementation of the electronic components is discussed.

- Micro controller: An event driven tracking unit was designed. For this purpose, a micro controller was chosen to be the "brain" for the application. The micro controller controls the communication between all the other components and drives the tracking unit. The micro controller is only activated when tracking data is collected, stored and transmitted. For the remainder of the time the micro controller is deactivated or put into "sleep". It is then activated at a user specified time interval by another component of the tracking unit.
- Global Positioning System module (GPS): To develop a tracking solution, the positioning information and other data that is provided to the user must be accurate. This is why a GPS receiver is implemented in the design. The GPS receiver can calculate position (longitude, latitude and altitude), speed, velocity and direction of movement very accurately in a relatively short time. It can calculate all the above-mentioned data variables anywhere on the globe within a non-obstructed view of satellites. The module that is used is also very lightweight, small, low in power consumption and not expensive. Another method that was researched for collecting positional data is triangulation via a RF network. The problem with triangulation is that the data parameters are not as accurate as a GPS.
- Global System for Mobile Communications module (GSM): In the development of the tracking unit, a means of data transmission was sought. The final choice was to use a GSM module. GSM is a defined protocol that is used throughout the globe. In the previous decade, the GSM market has increased dramatically. As mentioned, it is an

internationally defined protocol, so this opens up an international market. This also means that no external infrastructure must be developed for data communication. Another point to consider is that the communication cost for GSM is not expensive if based on Small Message Service (SMS).

- Non-volatile memory: All data that is collected is stored on this memory. It works on a FIFO (first-in-first-out) principle if all memory banks are used. This memory module was also added to the design to ensure that no data was lost in certain scenarios. One of these scenarios is when the unit is outside GSM coverage for a period time and no data transfer can occur. The tracking data is stored on this memory until data transmission is accomplished. The size of the memory is 4096 Kbytes and enables the tracking unit to store approximately 4,000 data readings.
- Real time clock (RTC): The RTC is the part of the design that enables the tracking unit to have low power consumption. The RTC interrupts the micro controller when the tracking unit is inactive (sleep). These interrupts occur at user-defined intervals.
- Beacon transmitter: The beacon transmitter is incorporated in the design as a backup method of tracking. It is based on the RF tracking described in chapter 3.
- Negative temperature coefficient thermistor: The thermistor is basically a resistor that changes its resistance as the temperature changes. From of these changes the temperature can be determined

A 3.6 V primary lithium thionyl chloride spiral D-size cell battery was selected as a power source. The advantages of this type of power source is the following:

- The power source has got a high capacity of 13Ah. The maximum recommended pulse current this power source can deliver is 4500 mA and the maximum continuous current is 1800 mA. Two of these batteries are normally used in a lion collar and one cell is used in smaller animals such as wild dogs and cheetahs.
- The cells are a very stable over the lifespan of the power source.
- The battery has got a high discharge voltage and low self-discharge rate (less than 3% after one year of storage at +20°C).
- The primary voltage of the cells is 3.6V. All the electronic components used in the tracking unit functions from this voltage.

6.1.2 The control room

The control room consists of a controller PC that intercepts all SMS's that the GSM modem receives that is connected to this PC. This controller PC then analyses this SMS and stores it in a database on a server PC that is connected to the controller PC. This server PC is connected to the Internet. It is possible to receive these SMS's through a direct service provider (Vodacom, MTN or Cell C) link. The only problem with this is that the cost for this link can only be justified by high quantities of incoming and outgoing SMS's. At the moment a modem costs about $130.00 once off and a Viacom Messenger contract about $5.00 per month. The monthly cost for a direct service provider link is about $400.00. The SMS's through a direct link and through a contract SIM card is the same.

6.1.3 The user operational software

In the detail design, a user operating in Thick Client mode receives a software program and a tracking password with which they can view and analyze all their tracking data on their PC. This tracking data can be updated through the Internet. Users also receives an Internet address at which they can view tracking data in Thin Client mode on any other PC that is not running a tracking software program, but that is connected to the Internet.

Another method the user can use to collect their data is by means of a SMS that the controller PC forwards to them. This SMS contains the newest tracking data available of the animal fitted with the tracking collar. Another function is that the user may request data with an SMS. This SMS is sent to the control room and the control room will reply to the user with an SMS with the relevant data.

The operational concept is described visually in Figure 6.3

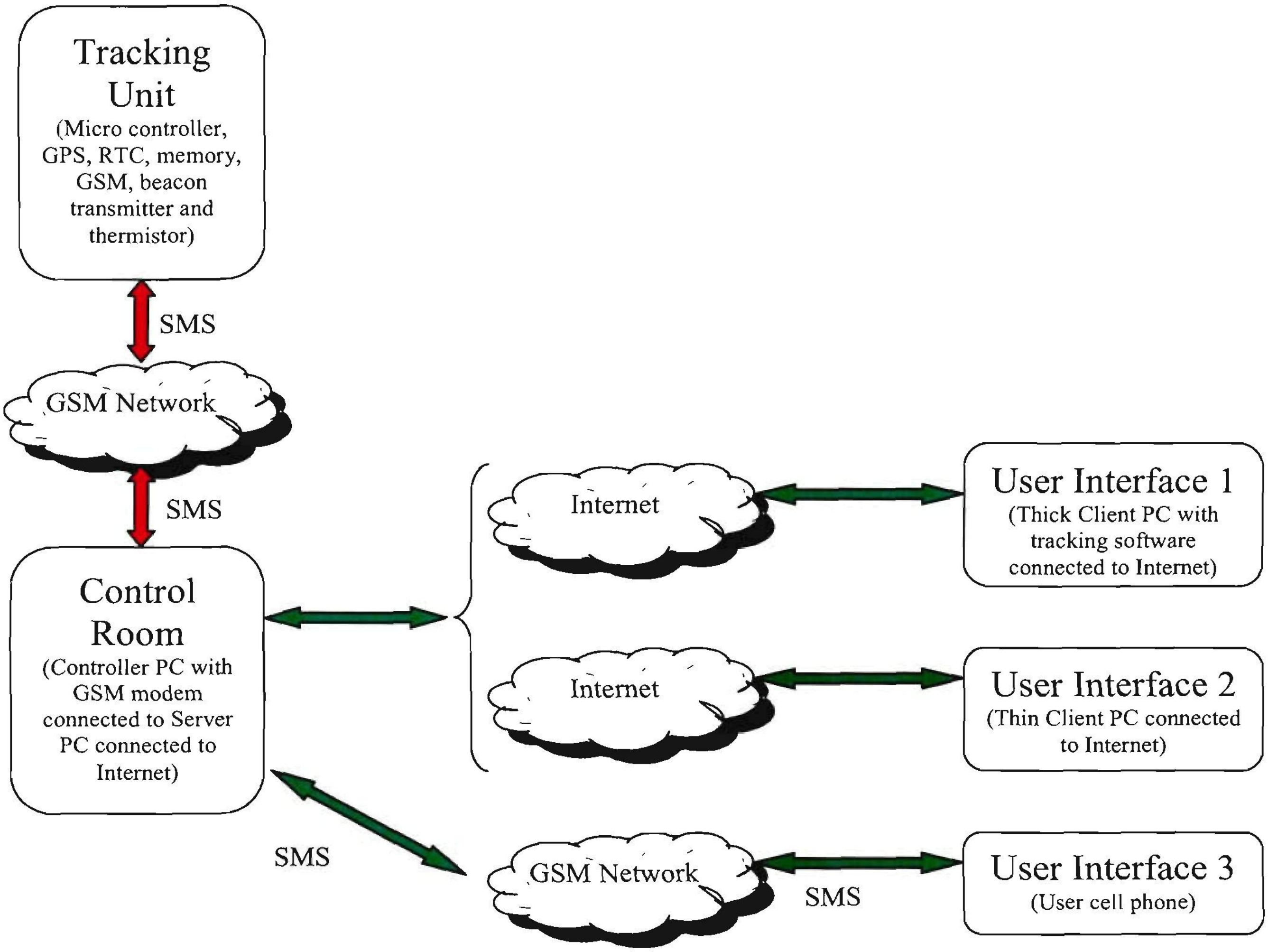


Figure 6.3 – Operational Concept

6.2 Summary

The animal tracking system concept that was designed to satisfy the functional requirements involves the following key elements:

- A tracking unit is mounted on an animal of the user's choice.
- This tracking unit collects specific data that is transferred via the GSM network by SMS to a local control center.
- The relevant data is collected by this control center and stored in a secure database on a secure server.
- The user that wants to gain access to the tracking data utilizes data interpretation software to study the relevant data.

Chapter 7

Detail design

A complete description of the detailed design of the system is beyond the scope of this thesis. In the previous chapter the system level design was discussed. This chapter discusses specific guidelines that assisted the design team of YRLess International (Pty) Ltd in designing the hardware, embedded software and the user interface of the tracking system. In the process a further research question was addressed: which approach to design will best enable the reduction of the overall cost of implementing the design? The impact of manufacturability, maintainability and supportability requirements on the design will also be described.

7.1 Introduction

Products are designed to provide particular capabilities and meet identified performance objectives and specifications. Given these specifications, a product can be designed in many different ways. As a designer, the first objective was to optimize the functionality of the product design.

The first objective is to design the product to satisfy functional requirements in laboratory situations. In the second phase, this functionality must be achieved in non-ideal operational situations. Thereafter the other market needs must be fully satisfied. That is why thorough market research, including not only functional requirements but also aspects like support requirements, must be done as described in Chapter one.

One of the main goals in designing a product is to design it in such a way that the production of the product takes the minimum effort. When the design engineers and manufacturing engineers work together to design and optimize the production processes, it is known as integrated product and process design. The designer's consideration of design for manufacturability, cost, reliability and maintainability is the starting point for integrated product development.

In this case, the best approach to hardware design was to base the design on existing components and subsystems that can only be minimally modified and that are already in production. This is done as part of the system engineering process. This approach ensures that the key components used in the design are already tested and approved. Existing GPS modules, GSM modules, RTC components and microprocessors were used in the hardware design.

Research has shown that decisions made during the design period determine 70% of the product's costs while only 20% of the product costs could still be decided on in the production process. Further, decisions made in the first 5% of product design could determine the vast majority of the product cost, quality and manufacturability characteristics. This 5% can therefore have a big impact on a company's success and profitability.
(Crow, K. 2001)

This just emphasizes how important it is to have consensus in the decision making during the design of a product to ensure that costs that are committed to during the design process are focused on meeting market needs. This is a very important statement and guideline to follow. If a product is designed with no clear goals aimed at satisfying market needs, unnecessary time, design efforts and production costs are spent.

While the design of a custom part or selection of a new part may be the most optimal approach to meet product requirements from the designer's point of view, it may not be the best overall approach for the company. Product cost and quality may be negatively affected by the proliferation of specialized items that require specialized capabilities or prevent efficient manufacture and procurement.

Minimizing the number of active or approved parts through standardization not only simplifies product design, but can also result in operational efficiencies and lower inventories. Management should therefore provide directions to designers in the form of a formal policy of parts standardization and emphasis on use of parts from an approved parts list for certain commodities.

In addition to standardization, simplification of part and product designs also offers significant opportunities to reduce costs and improve quality. Designers need to evaluate if there is an easier way to accomplish the function of each part. Product complexity can be further reduced by utilizing a modular building block approach to designing products. Through standard product modules, a wide variety of products can be assembled from a more limited number of modules, thereby simplifying the design and manufacturing process. By simplifying and standardizing designs, establishing design retrieval mechanisms, and embedding preferred manufacturing processes in the preferred part list, design and production efficiencies are enhanced.

7.2 Product design guidelines

According to (Crow, K 2001), a number of general design guidelines have been established to achieve higher quality, lower cost, improved application of automation and better maintainability.

Examples of these are as follows:

- Reduce the number of parts to minimize the opportunity for a defective part or an assembly error, to decrease the total cost of fabricating and assembling the product, and to improve the chance to automate the process
- Foolproof the assembly design so that the assembly process is unambiguous

- Design verifiability into the product and its components to provide a natural test or inspection of the item
- Avoid tight tolerances beyond the natural capability of the manufacturing processes and design in the middle of a part's tolerance range
- Design "robustness" into products to compensate for uncertainty in the product's manufacturing, testing and use
- Design for parts orientation and handling to minimize non-value-added manual effort, to avoid ambiguity in orienting and merging parts, and to facilitate automation
- Design for ease of assembly by utilizing simple patterns of movement and minimizing fastening steps
- Utilize common parts and materials to facilitate design activities, to minimize the amount of inventory in the system and to standardize handling and assembly operations
- Design modular products to facilitate assembly with building block components and sub-assemblies
- Design for ease of servicing the system.

In addition to these guidelines, designers need to understand more about their own company's product development system, i.e., its capabilities and limitations, in order to establish company-specific design rules to further guide and optimize their product design with respect to the company's production system.

According to (Anderson, D.M. 2004) the importance of good product development are the following.

- Good product development is a potent competitive advantage.
- Product design establishes the feature set, how well the features work, and, hence, the marketability of the product.
- The design determines 80% of the cost and has significant influence on quality, reliability and serviceability.
- The product development process determines how quickly a new product can be introduced into the market place.
- The product design determines how easily the product is manufactured and how easy it will be to introduce manufacturing improvements like just-in-time and flexible manufacturing.

- The immense cost saving potential of good product design is even becoming a viable alternative to automation and offshore manufacturing.
- True concurrent engineering of versatile product families and flexible processes determines how well companies will handle product variety and benefit from Build-to-Order and Mass Customization.

7.3 Evaluation of design alternatives

With the traditional approach, the designer would develop an initial concept and translate that into a product design, making minor modifications as required to meet the specification. The designer started this process by considering various design concept alternatives early in the process. At this point, little has been invested in a design alternative and much can be gained if a more effective design approach can be developed. Only through consideration of more than one alternative is there any assurance of moving toward an optimum design. Using some of the previous design rules as a framework, the designer needs to creatively develop design alternatives.

Design automation tools can assist in the economic development of multiple design alternatives as well as the evaluation of these alternatives. YRLess International (Pty) Ltd used a number of design tools in the production of this GSM/GPS based tracking solution. These design tools include computer-aided design (in this case CADINT), computer-aided engineering (PIECESPICE) and solids modeling. CADINT and PIECESPICE aided the designers in cost effectively developing and analyzing design alternatives. CADINT can utilize manufacturing guidelines to develop producible designs. Solids modeling helped the designers visualize the individual part; understand part relationships, orientation and clearances during assembly; and detect errors and assembly difficulties.

In addition to these design productivity improvement tools, there is a variety of analysis tools to evaluate designs and suggest opportunities for improvement. These can be used to analyze design symmetry; ease of part handling, feeding and orientation; and the number of parts. They can also analyze assembly operations, evaluate designs against design practices and analyze tolerance requirements.

Once the designer has acquires a basic background in design principles, the designer must learn to work more closely with manufacturing engineers and others who can provide him with feedback on design issues. This is a very practical and important statement.

7.4 Tracking unit hardware and embedded software

This part of the chapter will give the reader a broader view into the hardware design of the GPS/GSM tracking system, why certain components were used and how this fits into the whole system.

The tracking unit consists out of a micro controller (μ-controller), a Global Positioning System module (GPS), a Global System for Mobile Communications module (GSM), a real time clock module (RTC) and a non-volatile Memory module as previously mentioned.

In Chapter six the functionality of each component was discussed. The tracking unit is designed to be activated at certain user specified time intervals. The main reason for this is to ensure that the power consumption of the tracking unit is kept as low as possible. Between these time intervals, the unit is not active except for one component embedded in the hardware design. This component is the real time clock.

The Real Time Clock enables the tracking unit to have minimal power consumption during these non-active stages of the tracking unit. Before a tracking unit goes into this low power mode, the micro controller changes the schedule of when the tracking unit must be activated again.

As soon as it is time for the tracking unit to be activated, the real time clock interrupts the micro controller. Because of this, the micro controller is in sleep mode during the non-active state of the tracking unit. When this interrupt occurs, the micro controller goes through its event driven software program to give the unit its tracking functionality.

Another component that is in a sleep mode is the GPS module. The GPS module has a backup voltage function that is activated when the GPS module goes into sleep. During this process, the GPS stores its previous valid reading and almanac that enables the GPS module to search for GPS satellites without needing to download the almanac from the satellites first. This must be done in order for the GPS to get a faster location fix of the tracking unit's position. The GPS is able to calculate a 2D or 3D position coordinate. It is always better to get a 3D fix because a 3D fix is more accurate than a 2D fix.

This location reading is then stored on the non-volatile memory. This memory has the capacity to store about 32,000 location readings. Other data is also stored on this memory. This data is for instance temperature data, time of location reading and error codes to supply information about the functionality of the other components embedded in the hardware design.

After a number of these readings are taken, they are transformed into a SMS to the control center along with this temperature and error coding data. This non-volatile memory can also be downloaded, setting and requests can be done, settings that include the log time of the GPS can be altered, the control center number can be changed and the number of readings per SMS and the time schedule can be changed.

Backup features on the tracking unit include two alarms on real time clock, an active watchdog timer, reset on 15-second timeout (for get character procedures) and SMS reset feature.

The hardware construction of the tracking unit is illustrated below. As previously mentioned, this tracking unit is mounted on a wild animal by means of a collar and must have a useful life of approximately two years.

Note that there is bi-directional communication between the micro controller and all the other components as the micro controller controls all procedures on the tracking unit.

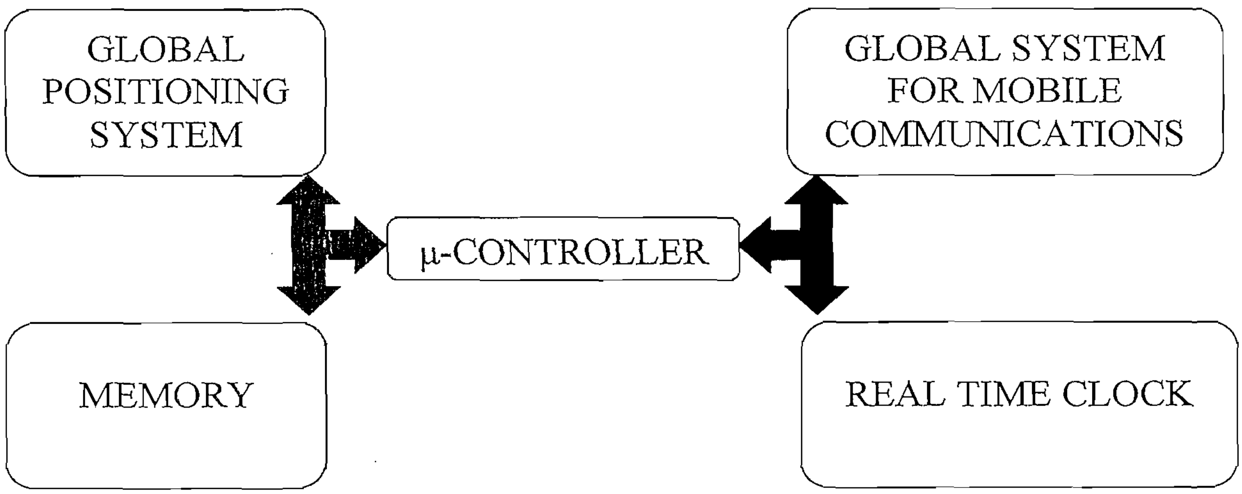


Figure 7.1 – Basic design of the tracking unit

The process flow of the logical operation of the unit will now be described. Firstly, the RTC becomes fully active at a user specified time and interrupts the micro controller to begin the tracking process. The first procedure executed by the micro controller is to activate the GPS.

The GPS has a certain user specified time slot to determine the position of the animal, the direction of movement and the speed at which the animal is moving. As soon as this data is determined, the micro controller stores this data in the memory. During the third procedure, the micro controller activates the GSM module that registers on the local GSM network. As soon as this is accomplished, it sends an SMS via the GSM network to the control room containing all the GPS data as well as other data such as activity status of the animal and temperature of the animal. Finally, the micro controller activates or deactivates a backup beacon transmitter in the fourth procedure. The user can choose between three transmitter settings. The transmitter can be permanently on, permanently off or on automatic. If the transmitter is set to automatic mode, the transmitter is activated if the tracking unit is not in a GSM coverage area and deactivated if the unit enters a GSM covered area. The reason for this is that when the tracking unit is not in a GSM covered area, the user will still be able to find the tracking unit if needed by means of a Yagi antenna and RF receiver. After this last procedure, the unit goes into low power mode. These operations are illustrated in figure 7.2.

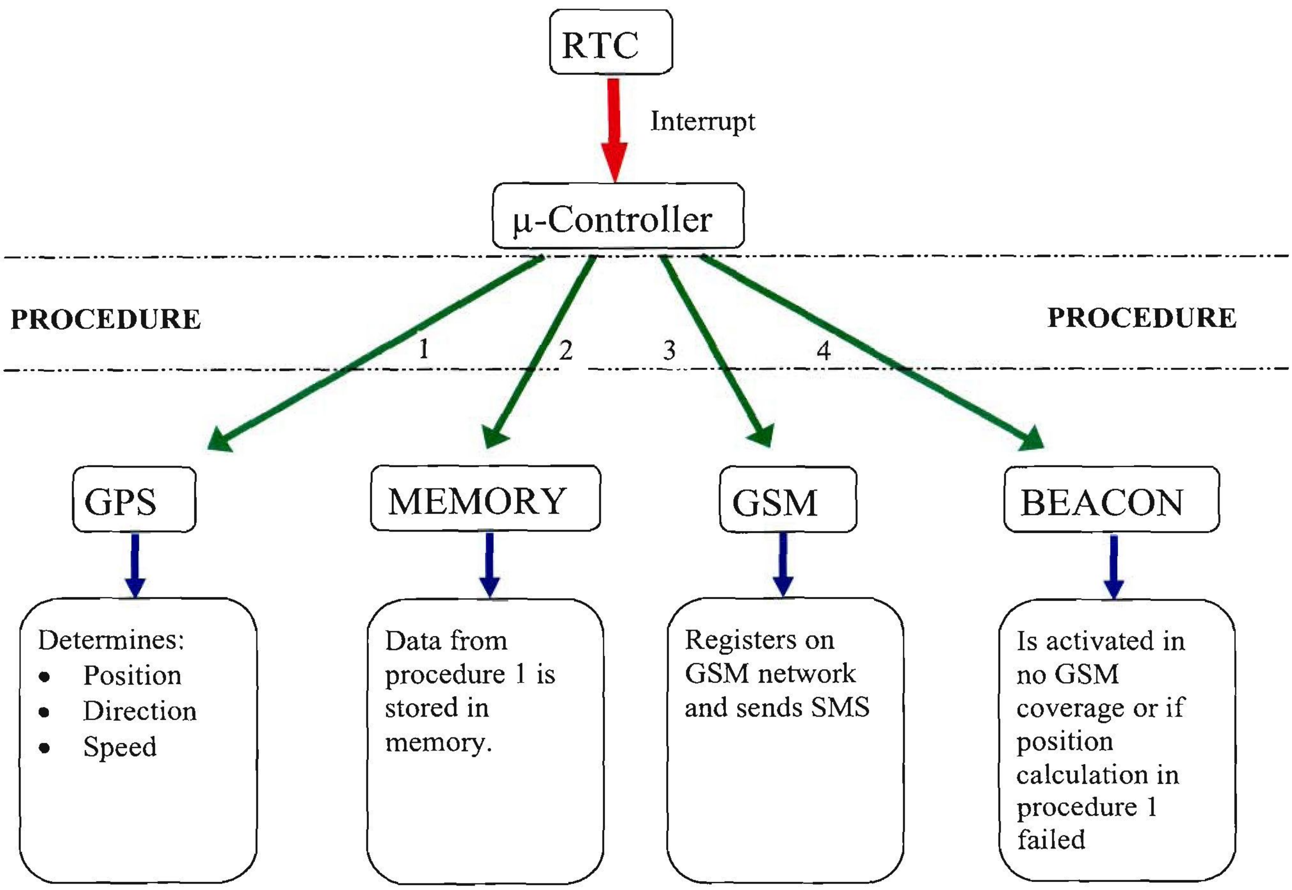


Figure 7.2 – Basic Tracking Unit Operational Concept

The embedded software on the unit is developed with an event driven system in mind. As illustrated in Figure 7.1, the tracking unit consists of a GPS module, a GSM module, a micro controller, a non-volatile memory chip and a real time clock. In the sequence below the basic embedded software program is discussed. Table 7.1 below gives the sequence of the embedded software that is programmed on the unit.

STAGE	STAGE INDICATOR	STAGE DESCRIPTION
1		RTC interrupts the microprocessor at the user specified interval to start the event driven program.
2	A	GPS is activated and initialized.
3	B	The GPS is queried: Determine the position and velocity of animal.
4	C	The GPS is queried: Determine the time and date.
5	D	Save data of stage B and C in the non-volatile I2C memory.
6	E	The GSM engine is activated.
7	F	The GSM engine is initialized.
8	G	First stage of GSM internal activation sequence. Internal GSM error checking and activation sequences.
9	H	GSM engine is requesting to be registered on local GSM network.
10	I	The Status of GSM network registering is received.
11	J	GSM engine waits actively for a period to receive SMS's.
12	K	The SMS that is received is analyzed for any queries or changes. These queries and changes can include the following •Schedule changes •Downloading of all data or just a certain period's data •Query the local cell information •Query the global cell information •Change the number of GPS readings to be sent in on SMS •Change the time period for the GPS to gather its data •Change the number or ID to where the data must be sent •Query all settings of the unit
13	L	All SMS's are deleted. Verifies if GSM engine is registered on GSM network
14	N	Downloads all GPS and unit data from I2C memory of this sequence schedule and sends it via SMS to controller computer.

15	O	Sends settings request via SMS to controller computer if it was queried in stage K
16	S	Sends local cell information via SMS to controller computer if it was queried in stage K
17	U	Sends global cell signal strength via SMS to controller computer if it was requested in stage K
18	V	Sends all data that could not be sent in previous sequences due to any reason via SMS to controller computer
19	X	Again delete all SMS's
20	Y	End all activity on the unit. End of loop
21	Z	Timer initialized. Unit goes into low power mode (sleep)

Table 7.1 – Embedded Unit Software Sequence

7.5 The control centre

The control center is a very integrated part of the tracking system. The basic architecture of the control center can be illustrated as in Figure 7.3.

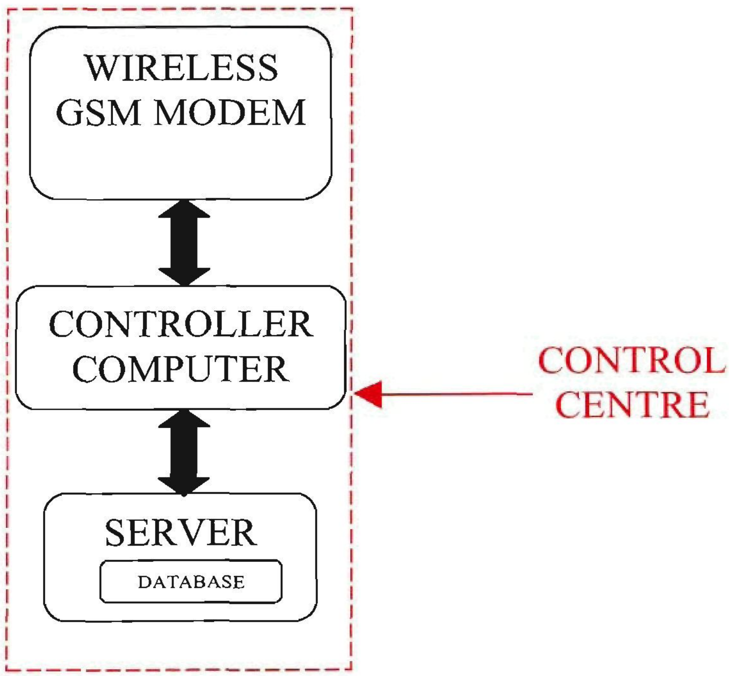


Figure 7.3 – Basic design of the Control Centre

The control center consists of a number of wireless GSM modems, a number of controller computers, an extensive database and a server.

Firstly, the wireless GSM modems receive the data from the tracking unit. Thus, the wireless GSM modem is the link via the GSM network between the tracking unit and the control center. The wireless GSM modem is also the link for changing features and schedules remotely on the tracking unit. If a large number of units are active in the field, it will become necessary to use a higher bandwidth connection between the control room and the GSM network.

The controller computer has a Windows Operating System and has controller software installed. This controller software receives the raw data from the tracking unit via the wireless GSM modem. It filters, decodes and analyses this data and stores it in a database.

All this data is secured and regular backup methods are applied to ensure that all data is securely stored. This database is situated on the server.

The server is a separate computer with a Linux Operating System installed. Linux has been chosen based on three reasons.

- Firstly, Linux is a much more secure operating system than Windows.
- Secondly, Linux is more stable than Windows.
- Thirdly, in Linux the operator has more control over the operating system than in Windows. Linux can be changed to fit the needs of the operator.

Many people will differ from this point of view, but this choice was based on the requirements of the control room system, as well as on experienced gained working with both operating systems.

7.6 User and Tracking Software

In this part of the design chapter the tracking software used by the client is discussed. The figure below illustrates the options available for users to analyse their tracking data.

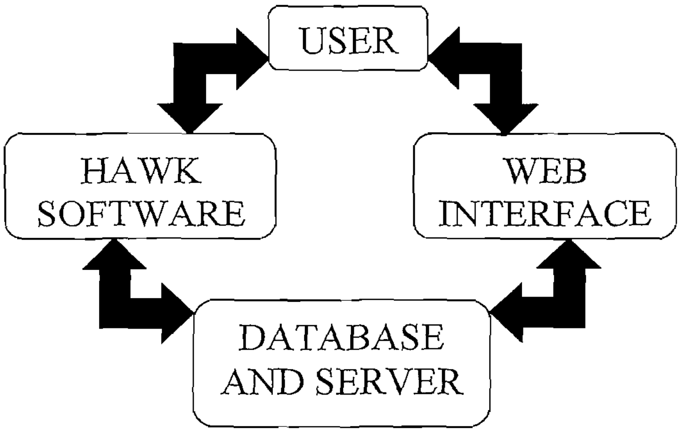


Figure 7.4 – Basic illustration of user and tracking software options

The user and tracking software consists of two parts. For both parts, the user needs an Internet link.

For the first option called a "thick client" interface the user receives a software package. This software enables the user to receive data from the server with all the tracking information needed by the user. The user can analyze this data in a visual and user-friendly program. The data that the user receives is connected to the user password. This ensures that no user can download another user's data. A user can also export this data to other programs such as Microsoft Excel.

The other option is a "thin client" interface. This user and tracking software is web based. This enables a user to access his tracking data through a website. The user receives a website address and a password for his data. The user then can access his data anywhere through a web interface. This method of data analysis is not so advanced as when using the Hawk software package, but the inclusion of this method of analyzing data gives the user a wider choice in tracking accessibility.

Another method of collecting data that is not illustrated in Figure 7.4 is by means of the user's cell phone. The user can only view tracking data such as longitude, latitude, speed and so forth. At this stage the user can't use a cell phone to view and analyze data, but it will be possible using a cell phone with Internet capabilities through the website as discussed above.

The "thick client" interface illustrated below show the design on user level of the tracking and monitoring software. This software enables the user to view and analyze all the data collected from the tracking unit fitted on their animals. The functionality of the tracking software is described below.

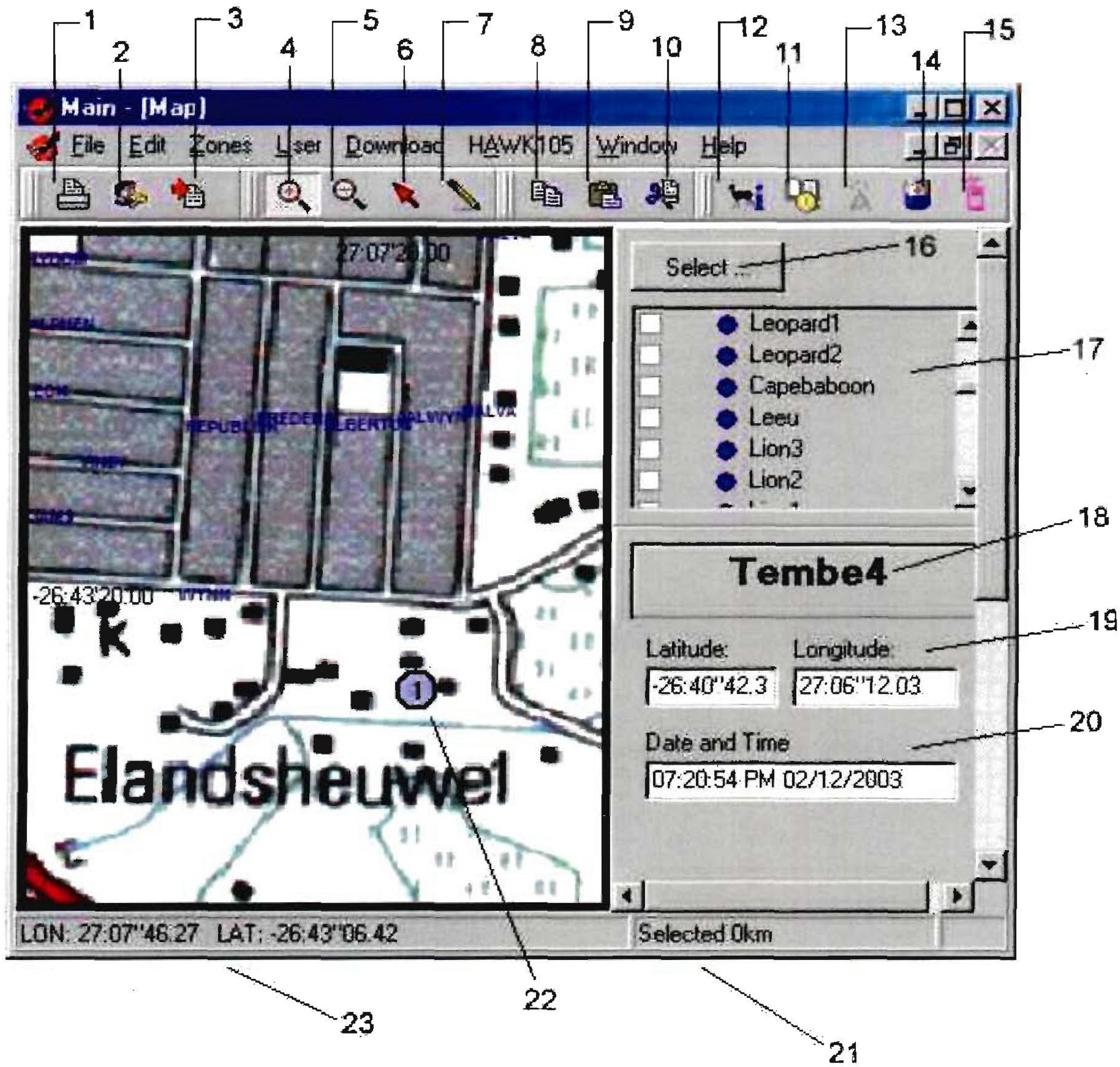


Figure 7.5 – User and Tracking Software

1. Print the current page.

This function enables the user to print a page with the data visible on the screen.

2. Enter secret password.

As stated previously, all data is secured by a secret password allocated to every user. This button lets the user type a password that allows the software to connect with YRLess Control Room. Without this password, the user is not allowed to download any data.

3. Download data from YRLess Control Room.

After the secret password is entered at button 2, the user can download all data available on the YRless database connected to the specific user password. To enable the download, the user must be connected to some sort of Internet connection.

4. Zoom into the current map.

This button enables the user to zoom in on the map shown on the Hawk software.

5. Zoom out of the current map.

This button enables the user to zoom out on the map shown on the Hawk software.

6. Selection tool.

With this tool, the user can select certain data points on the screen. This tool also enables the user to select a position or move the map around

7. Pencil to calculate distance (see point 21).

This tool enables the user to determine the distance between points. A user can for instance select one point with this tool, and select another point. The distance between the points will be shown at note 21. If a user selects a third point, the total distance from point one to point three through point two, will be shown.

8. Copy positions to another application.

If a user wants to view data in another application such as Microsoft Excel, the user will use this tool to copy such data. A user will for instance select the data date span as shown in note 16, and copy this data into the application as shown in the diagram below. This data contains the position reading number, date of the position reading, the exact position time, the longitude and latitude, the speed the animal was moving at that precise date and time, the direction the animal was moving at the precise time, the temperature at that point in time and if the animal was within GSM coverage.

	A	B	C	D	E	F	G	H	I
1	No.	Date	Time	Longitude	Latitude	Speed	Direction	Temp	Coverage
2			(GMT+2)	(Degrees)	(Degrees)	(km/h)	(Degrees)	(oC)	
3	0	7/7/2004	5:39:33 PM	32.34109904	-27.73940023	0	0	21.3203125	Y
4	1	8/7/2004	5:38:47 PM	32.32646077	-27.82315063	0	314	23.59229279	Y
5	2	9/7/2004	5:41:14 PM	32.38236084	-27.73685099	20.92147255	156	23.96777153	N
6	3	10/7/2004	5:38:50 AM	32.3327006	-27.79522909	0	0	13.7841177	Y
7	4	11/7/2004	5:40:57 AM	32.28838094	-27.89603068	0	201	16.63806725	Y
8	5	17/07/2004	5:38:20 AM	32.3566508	-27.69585978	0	0	15.42832279	Y
9	6	12/8/2004	5:34:23 PM	32.28400065	-27.88415934	0	168	25.08980179	N
10	7	12/8/2004	5:38:24 PM	32.28392944	-27.88393962	0	0	25.08980179	Y
11	8	13/08/2004	5:34:49 AM	32.33661906	-27.7413798	0	0	10.36608505	N

Table 7.2 – Copy positions to another application

9. Paste positions from another application.

This tool can be used to past data from another application such as Microsoft Excel or ARCVIEW. This data can then be viewed by means of the Hawk software.

10. Cut positions to another application.

This function is the same as the copy function in note 8, but this function also removes the data points from the database that is kept on the users computer. If the user loses these data points for any reason, the user can apply for such data and YRLess International (Pty) Ltd will supply these points to the user. YRLess international (Pty) Ltd keeps backups of all data.

11. View the current time schedule of the unit.

This function enables the user to view the time schedule that the tracking unit reports to the control room. This function also enables the user to change this schedule.

12. View information about current selected animal.

The user can add and remove information regarding the animal. This can be updated and stored on the PC of the user.

13. Change the status of the backup beacon transmitter.

All units are fitted with a beacon transmitter. The beacon transmitter is just a backup method of tracking the animal fitted with the GPS/GSM tracking solution. This beacon transmitter can be switched on, switched off or switched to automatic. Automatic means that if an animal fitted with tracking unit is inside GSM coverage, the beacon transmitter is switched of, but when an animal moves outside GSM coverage, the beacon transmitter is switched on. This the user can change remotely from his personal computer.

14. Check the estimated status of the battery life on the unit.

Every time the tracking device collects data, the battery life decreases. This function enables the user to view the estimated battery life left on the tracking device. This calculation is done by the control center. It is an accurate calculation taking in consideration the log time of the GPS, the number of reading send in a SMS, the number of position readings taken per day and the period the beacon transmitter is active.

15. Check the status of the "Forwarding", "Where is" and "Zones" functions.

This distribution channel enables the user to distribute data to other users on their cell phones in real time when the control room receives it. This function enables the user to distribute data to other users in the field where there are no technology available to collect, view and analyze the data. It is one of the most widely used functions in the system. The user can receive the following data remotely.

- **Zone violations:** This violation occurs when an animal leaves a certain region, enters a certain region or moves from one region to another region. The picture below shows a zone where the animal must always be inside the boundaries. The red dot is activated when the animal leaves the zone and the user is immediately notified by SMS about the behavior.

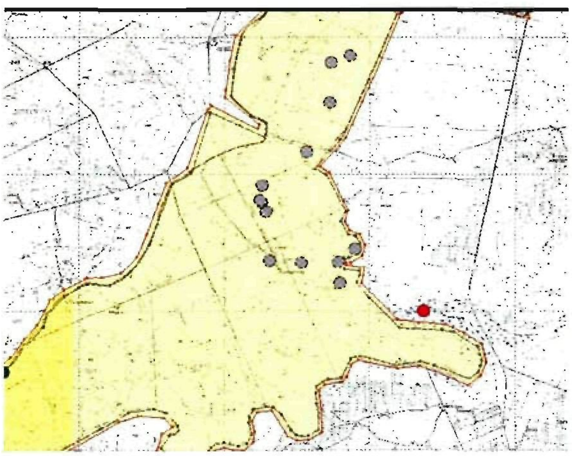


Figure 7.6 – Zone violation

- **Forward coordinates:** The user will receive an SMS with the animal's coordinates in longitudes and latitudes as well as the date and time as soon as the control room receives the relevant data from the animal.
- Another feature is what YRLess calls "Where is" polling. The user can SMS the following message "Where is Pilanesberg_Elephant22" to one the control room numbers. The control room will SMS the user with this similar message

"Pilanesberg_Elephant22 is 78.5 meters NW of Manyeni Gate and 23 meters NE of Crossing 7 on 7/7/2004 at 5:39:33PM". A user can use this function only if he has placed GEO-beacons in the area within which the animal moves. In the previous SMS Manyeni Gate and Crossing 7 are such GEO-beacons. The date and time is the last position received by the control room.

16. Select an animal to view in the map area.

The user can select the animal or animals to be viewed in the HAWK software package.

17. View all your units.

When a user enters the user password as stated I note 2 and downloads the animals linked to the password as stated in note 3, the animals the user has access to will appear in this box.

18. Name of the selected animal

This box contains the name of the animal that is being viewed and analyzed.

19. Position of the current selected position.

The longitude and latitude of the animal selected is shown in this space. The location shown is always a 3D location reading. In some circumstances, a tracking unit cannot determine a 3D location reading in the allocated time frame and only a 2D location reading is determined. This 2D reading is also sent to the control room, but it will show on the customer software that the reading is a 2D reading and not a 3D reading.

20. Date and time of selected position.

This box gives the date and time of the point that is selected.

21. Distance as drawn with pencil (see point 7 above).

If the function in note seven is used, the distance is shown in this space.

22. Position in map area.

This dot on the map shows the current selected position of the animal.

23. Current position shown by cursor.

If the cursor is moved on the map, the longitude and latitude of the cursor point is given.

7.7 Summary

This chapter describes the approach that was followed to ensure that the cost of implementation of the detailed design is optimized. The discussion regarding the detail design can be divided into three parts namely the tracking unit itself, the control room setup and the user software interface. All of these parts were designed separately, but with a standard data protocol to enable these three parts to function as an integrated tracking system. Without any one of these parts, the system would be incomplete. Through the selected detailed design all user requirements were met.

Chapter 8

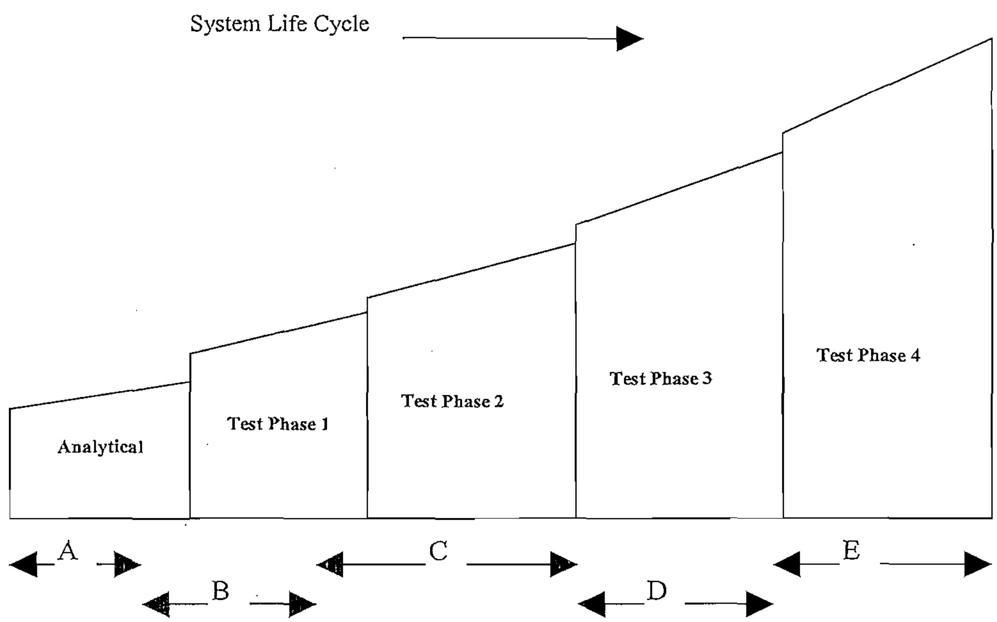
Laboratory testing, field testing and production

In this chapter the final research question is addressed: will the wildlife tracking system design as described in chapters 6 and 7 provide the required functionality when operated in the field? Various categories of system and component testing that was utilized to verify this are identified and discussed. This phase of the system development process can be the most crucial and time consuming part due to the fact that all aspects of the system must be implemented and tested. If this phase of the system development is neglected, it will result in many failures and comebacks that will compromise the integrity and the quality of the product.

8.1 Categories of system and component testing

Various categories of system/component testing can be identified. In the following figure, the different phases of system/component testing is illustrated. Please note that the effectiveness of the evaluation effort increase when progressing through testing phases 1, 2, 3 and 4 (Blanchard & Fabrycky, 1998:124).

As adopted from Blanchard & Fabrycky (1998), the testing phases are illustrated in figure 7.1.



- A – Conceptual Design
- B – Preliminary System Design
- C – Detail design and development
- D - Production
- E – System utilization and life cycle support

Figure 8.1 – System/component testing phases

8.1.1 Analytical

This is the evaluation of the testing using design workstations and analytical modules such as CAD, CAE, CAM and CALS programs. This is a very theoretical test phase and gives a reasonable idea of how the product/components will function in various situations and circumstances. YRLess International (Pty) Ltd used the following programs:

- *CADINT*: This program is generally used in PCB designing, but has the functionality to provide the user with reports containing the following data:

  -Impedance Calculator: The Impedance Calculator dialog box displays the characteristic impedance of a transmission line based on the dimensions and permittivity specified for the selected configuration. This is very helpful when designs around RF components are done.

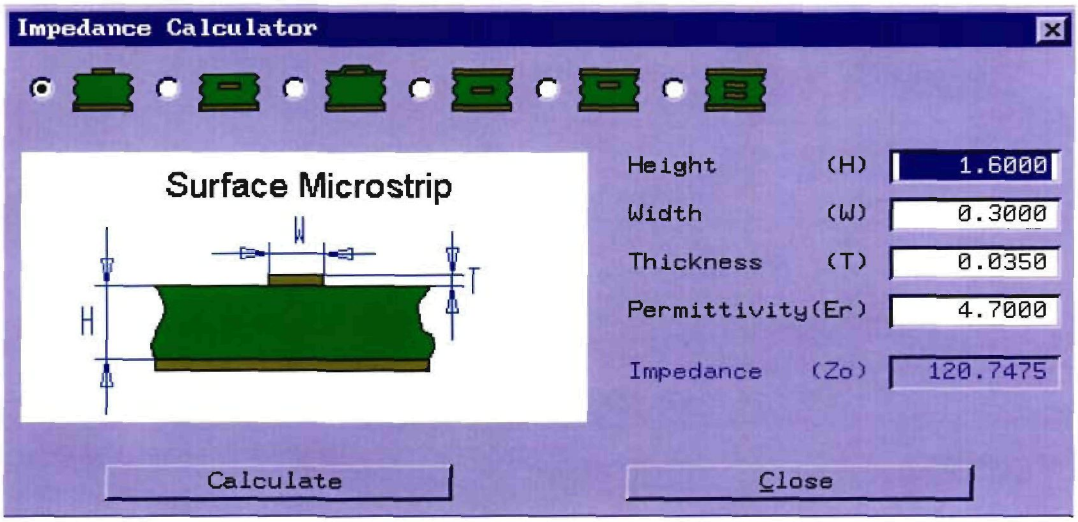


Figure 8.2 – Impedance Calculator

-Clearance Checks: This is also a very helpful tool. In the program, the user can set certain clearance parameters. If these parameters are breached, the program points out these points to be corrected. If the clearances between data, clock, Vcc and Ground planes are too small, interference on these lines are possible and can cause major problems.

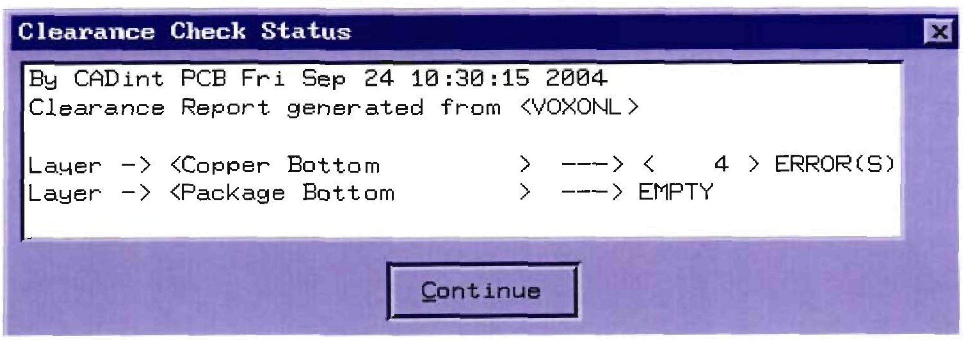


Figure 8.3 – Clearance Check

8.1.2 Test phase 1

The first phase is the evaluation of engineering and service test modules, system components, breadboard evaluation, mockups testing and the testing of rapid prototypes of the system.

8.1.3 Test phase 2

The second test phase consists of the evaluation of prototype and production models (production sampling).

Formal testing was accomplished during the latter part of the detail design when the pre-production prototype equipment and software were available. Prototype equipment is similar in functionality to production equipment, but it is not fully qualified for production.

The Test Phase 2 program contained the following tests:

Performance tests

The HAWK110 Wildlife tracking system consists of various components. These components are sensitive with respect to environmental parameters such as temperature, humidity and vibration. It is thus of utmost importance that all components and all parts of the tracking system must be thoroughly tested en verified for performance under all environmental conditions.

Environmental tests

Tests in this category determine if the product will withstand harsh and extreme environmental conditions. As there is a small but non-zero probability that the HAWK110 tracking system will be exposed to these extreme conditions, it is necessary to verify that the product will perform satisfactorily under such conditions.

Temperature tests

Environmental tests were conducted in different circumstances. The first test that was conducted was a temperature test. A spreadsheet of the rated temperatures of all the components was assembled. Through this spread sheet a theoretical operational temperature was determined.

Five Temperature tests were conducted, each test repeated three times. Before these tests were done in the testing oven, the oven temperature was calibrated.

Temperature test 1:

The unit was tested at 10 °C below its theoretical maximum operating temperature. The maximum theoretical operating temperature for the YRLess International (Pty) Ltd is 70 °C. The units were set on a 5-minute schedule and the temperature was increased by 12 °C / hour. This was done so that the tracking units could be monitored with every one degree temperature increase. The temperature was slowly increased until the unit malfunctioned. This test was conducted 3 times with two (2) similar tracking units. After every test, the units were left for a couple of hours to restore to normal room temperature (± 25 °C).

	Starting Temperature	Temperature Increase/Decrease	Rate of change	Malfunction Temp 1	Malfunction Temp 2	Malfunction Temp 3
Unit 1	45 °C	Increase	12 °C / hour	72 °C	73 °C	72 °C
Unit 2	45 °C	Increase	12 °C / hour	73 °C	74 °C	73 °C

Table 8.1 – Temperature Test1

All the malfunctions in this test started at the GSM module. At the above stated temperatures, the GSM module did not send a SMS.

Temperature test 2:

The unit was tested 10 °C above its theoretical minimum operating temperature. (- 20 °C) The temperature was slowly decreased until the unit malfunctioned. This test was conducted 3 times with two (2) similar tracking units. The unit was kept on a 5-minute schedule and the temperature decreased by 12 °C for the same reasons as in Temperature test 1. The temperature was this time decreased until the units malfunctioned. The units again were left for a couple of hours to restore their temperature.

	Starting Temperature	Temperature Increase/Decrease	Rate of change	Malfunction Temp 1	Malfunction Temp 2	Malfunction Temp 3
Unit 1	-10 °C	Decrease	12 °C / hour	-22 °C	-21 °C	-22 °C
Unit 2	-10 °C	Decrease	12 °C / hour	-21 °C	-22 °C	-22 °C

Table 8.2 – Temperature Test 2

Again, the units started to malfunction at the GSM module. The reason for malfunction was the same as in Temperature test 1 when the GSM modules stopped to send SMS's.

Temperature test 3:

The unit was tested 5 °C below its maximum operating temperature as determined in Temperature test 1 for a period of 12 hours or until the unit malfunctioned. This test was conducted one time with two (2) similar tracking units. The temperature was chosen at 67 °C. During this 12 hours of testing, not one of the units malfunctioned.

Temperature test 4:

The unit was tested 5 °C above its minimum operating temperature as determined in Temperature test 2 for a period of 12 hours or until the unit malfunctioned. Before this was done, the units were left for 4 hours after Temperature test 3 was finished. This test was conducted at – 17 °C for one time with two (2) similar units. Once again, the units did not malfunction during these 12 hours.

Temperature test 5:

The unit was tested at 5 °C below its maximum operating temperature from Temperature test 1 for a period of one hour. The temperature was then decreased rapidly over a period of 20 minutes to 5 °C above its minimum operating temperature. The temperature was kept stable for one hour and then rapidly increased to 25 °C. This test was conducted two times with two (2) similar units to determine if a tracking unit will restore to full functionality if rapid temperature increases and decreases occurred.

The temperature was decreased at a rate of 252 °C per hour from 67 °C to –17 °C in 20 minutes. Both units malfunctioned when exposed to this rapid temperature changes. This happened between – 12 °C and –17 °C.

It seems as if the tracking unit can't handle these rapid temperature changes. Although the chances that these scenarios will happen in the field are virtually zero, it is still important to determine the limits within which the units can be operated before they are deployed in the field.

GSM antenna tests

The GSM antenna was tested. The first test was a theoretical test done with a software program called NECWIN. The USA defense force and research programs in the Arctic use this program for antenna design. It was decided to use a whip antenna rather than a helical or loop antenna. This is due to the fact that a whip antenna is less expensive than a loop antenna and when field tests were done, there wasn't much difference between the performance of the whip and the loop antenna. What made the choice very difficult was that the tracking unit is mounted on various kinds of animals. This means that if one unit is mounted on an elephant and a similar unit is mounted on a leopard, the ground plane of the unit and thus the GSM antenna will change.

The next test on the GSM antenna was done in a Faraday RF enclosure. This enclosure functions in such a way that no RF signals penetrate this enclosure. A criteria was established where a very poor cellular signal strength was generated. These tests where done to determine the minimum GSM signal strength needed for the tracking unit to communicate with the control room. During these tests, it was measured that the tracking unit can communicate via SMS with a relative GSM signal strength of 4 out of a possible 60. This measurement is done by means of the GSM module that is used in the tracking unit. A command is sent to the GSM module, which replies with the signal strength. This measurement is given out of a total of 60 with 60 the strongest and 1 the weakest signal.

Structural tests

These tests are done to determine the structural capabilities of the product. Tests must be done to determine material characteristics relative to stress, strain, fatigue, bending, torsion and general decomposition that the product can handle.

Various structural tests were performed. Only one structural test was done during temperature test 5 where components were put under stress by rapid temperature changes. When a tracking unit is mounted in a collar, it is potted in dental acrylic that is very stable during temperature fluctuations and which is a very strong potting. This has to effect that the tracking unit is efficiently protected from structural damage in the field.

Most tracking systems undergo another structural test. Some of these tests are done on vibration tables. A tracking unit is fitted on a vibration table to determine the vibrating stress it can handle. This is not a test needed in animal and wildlife tracking due to the fact that wildlife tracking system are not exposed to significant vibration. If a vehicle tracking system was designed, these tests must be done because there are high levels of vibration present in vehicles.

Reliability tests

Reliability tests are performed on one or more system elements. The crucial and most sensitive components on the HAWK110 hardware PCB are the RTC and the micro controller. If one of these components malfunctions, the whole tracking solution malfunctions. The micro controller is dependant on the RTC and micro controller crystal, and the RTC is dependant on the RTC crystal. The crucial part on the HAWK110 hard PCB is thus the crystals that drive these components. To ensure the reliability of the HAWK110 tracking unit, a software watchdog was implemented to insure that the micro controller does not malfunction and a backup RTC and backup RTC crystal were implemented in the design process.

Another aspect of reliability is the data that is supplied by the unit via the control room to the client. The various data aspects of the tracking unit were tested as described below.

Position reliability

Two points can be viewed in Figure 8.4. Point 1 is the green dot and is the exact position of the tracking unit when it was tested (Exact position meant within a 7 meter radius). This position (longitude and latitude) was verified with two different kinds of handheld GPS modules (HH GPS1 and HH GPS2). The second point (red) is taken from the same tracking unit only 20 seconds before point 1 (green) was taken. The only difference between these points is that point 1 (green) is a 3D location reading and point 2 (red) is a 2D location reading. The difference between these two points is 27 meters. This may not seem to be a huge difference, but if a tracking unit is placed in a zoned area, this 27 meters may be the difference between an animal being inside or outside this zoned area. This drift only happens when a 2D location reading is determined. To correct this drift only 3D location reading that is calculated by the GPS is sent to the control room. To ensure integrity of position data, all tracking units are placed on exactly the same testing point during final testing. This test point was only compared with the hand held GPS modules. The position data received by the control room is then compared to the longitude and latitude of the test point to ensure this integrity. Another precaution that is taken to ensure the integrity of position data is that only the third 3D location reading calculated by the GPS is sent to the control room.

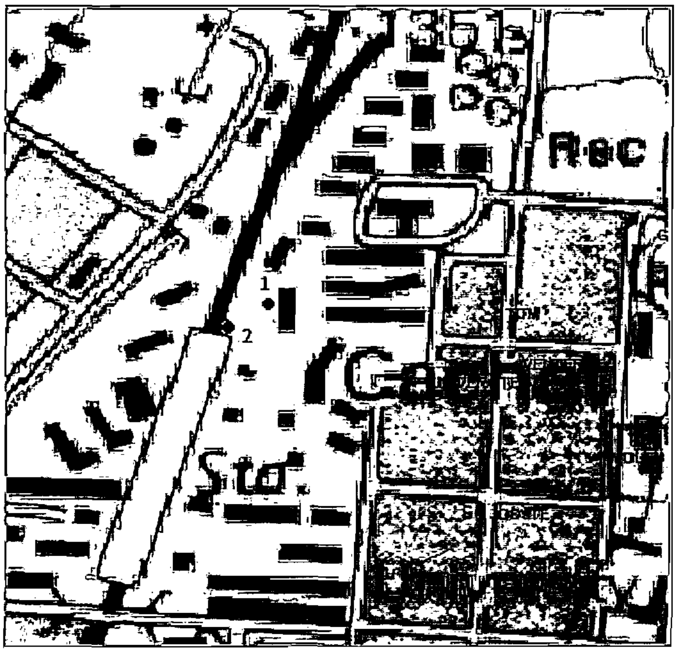


Figure 8.4 – Position reliability

Time, date, speed and direction reliability

Together with position data received by the GPS, the time and date of the position data, the speed at which the GPS is traveling and the direction of movement is given. These parameters were verified with the same two handheld GPS modules (HH GPS1 and HH GPS2) as stated previously. Some of these verifications are given in Table 8.3. No other non-GPS based technique was used as reference for the measured speed.

	Time 1 (GMT +2)	Speed 1 (Km/h)	Direction 1 (Degrees)	Time 2 (GMT = 2)	Speed 2 (Km/h)	Direction 2 (degrees)
Tracking Unit	13:52:33	78.27	151	14:12:55	113.54	34
HH GPS1	13:52:33	78.27	151	14:12:55	113.54	34
HH GPS2	13:52:33	78.28	151	14:12:55	113.55	34

Table 8.3 – Time, Date, Speed and Direction Reliability

Various of these tests were done over a number of days and all the results corresponded after a 3D location reading was received by the GPS on the tracking unit.

Temperature reliability

These tests were performed during the temperature test described earlier in this chapter. As mentioned, the tests were done in testing ovens that were calibrated for these tests. During the temperature tests, the oven temperature and the temperature given by the unit via SMS was compared and verified with each other. Some of the results are give in Table 8.4

	T1 (°C)	T2 (°C)	T3 (°C)	T4 (°C)	T5 (°C)	T6 (°C)	T7 (°C)
Unit 1	-5.19	-1.50	5.29	11.16	20.48	35.70	49.55
Unit 2	-5.20	-1.50	5.30	11.17	20.49	35.71	49.56
Oven	**-5.24**	**-1.55**	**5.34**	**11.21**	**20.55**	**35.76**	**49.64**

Table 8.4 – Temperature Reliability

It can be seen that the temperature of the testing units were a little lower than that of the given oven temperature. When the oven temperature rises above 20 °C, the error became more significant as seen at T6 and T7. This could be due to the fact that the resistance that is part of the thiristor circuit that determines the temperature, changes a little with a temperature increase. To minimize this error, high temperature resistors were used in the final product to bypass this problem.

8.1.4 Test phase 3

Test phase three includes the testing of production models evaluated at designated test sites. In theory, all products in the GSM bandwidth range must undergo certain approval tests. A FTA (Full Type Approval) test must be done to determine if the product complies with standards and if the radiated power of the design is within the specified limitations. The practical problem is however the high costs associated with these tests. The cost to conduct compliance testing on one design ranges between $5,000.00 and $10,000.00, and in addition there are currently no accredited FTA test facilities in South Africa. The distributor of the GSM modules also advises its clients that these tests must be done in their laboratories in France. Two units must be tested at these facilities and these units must be accompanied by a hardware engineer for a period of one to two weeks. This makes it an even more expensive test to be done, but because YRLess International (Pty) Ltd is linked to the North West University, the distributors of the GSM module agreed to evaluate the YRLess hardware designs free of charge and to make some suggestions regarding the design.

Before the design was sent to France, YRLess International (Pty) Ltd received a detailed hardware specification sheet from the GSM distributors containing all the important hardware specifications needed for a design to pass the FTA process. Comparing these notes with our hardware design, it was clear that the hardware was from the start designed in compliance with these specifications. This meant that the Gerber files of the hardware as well as the schematic and BOM (Bill of Materials) could be sent for inspection to France.

About two weeks after these files were sent to the FTA testing facilities, a reply from France was received with only a few minor suggestions regarding the hardware design. Not one of them was a critical change that would influence the FTA process, but only a few recommendations to consider should we want to use other functions of the GSM module in the future.

When evaluating the critical components of the hardware design, a list could be compiled of all the tests the individual critical components passed. These tests are the following:

Test	Applied Standard
Stress Test	Thermal shocks IEC 68-2-14.
Vibration Test	Sinusoidal vibration IEC 68-2-6.
Vibration Test.	Random vibration IEC 68-2-36
Shock Test	IEC 68-2-27.
Bump Test	IEC 68-2-29.
Humidity Test	Corrosion test IEC 68-2-3.
Warehouse Test	Low temperance IEC 68-2-1.
Warehouse Test	High temperature IEC 68-2-2.
High temperature	IEC 68-2-2.
Light Test1	UV radiation and temperature EDF HN60E03.
Fall Test1	IEC 68-2-32.
Electro Static Discharge Test	IEC 1000-4-2.
Salt Mist Test	IEC 68-2-11
Atmosphere Test	Flowing mixed gas corrosion. IEC 68-2-608-2-60
Marking Test	EN 60 950

Table 8.5 – Tests and Applied Standards

8.1.5 Test phase 4

This test phase is the continuous evaluation of the system in operational use. Because the product is fitted onto an animal, it is not practical to retrieve the product in order to subject it to a calibration sequence to determine if the product is fully functional. The only way to evaluate the tracking unit is to generate a report on the incoming data received by the control center from the tracking unit. With this report all data can be analyzed and through this analysis the functionality of the system can be determined to a certain point.

Another method to evaluate the system is through feedback received from clients. If a client is questioned about the performance of the system, the system can be evaluated based on the client's response.

8.2 Quality testing

8.2.1 Quality during component selection

The selection of components is one of the most crucial parts of product or system design. A balance must be determined between the cost and the quality of a component. Reliability, availability and the record of accomplishment of components must be used to ensure that the product is reliable and of suitable quality. For products that require a high level of reliability, it is important to rather select a more expensive component, well known for reliability, than a less expensive component of unknown reliability.

Environmental specifications of components are another quality feature that is important. Through product and market research, it can be determined to which set of specifications a product must comply. This will determine if the selected components must be of normal, industrial or extended quality to withstand the expected environmental conditions.

8.2.2 Quality assurance during supplier selection

It is essential that a supplier with a good record of accomplishment in the following departments is selected:

- Well priced to ensure that your components costs stay low.
- Fast and on time delivery times is essential. When your production increases, it is essential that you could determine the delivery date of components.
- Supplier of high quality components.
- Company must be stable to ensure predictable supply.

8.2.3 Quality assurance during manufacturing

Manufacturing can be divided into four parts.

- PCB Manufacturing
- Component Placement

- Product Assembly
- Final product testing and packaging

PCB manufacturing

Firstly, the PCB's must be manufactured. It is of utmost importance that the company that manufactures the PCB's is ISO 9000 certified. According to ISO Management Systems (2002), the ISO 9000 and ISO 14000 families are among ISO's most widely known standards. ISO 9000 and ISO 14000 standards are implemented by some 610 000 organizations in 160 countries. ISO 9000 has become an international reference for quality management requirements in business-to-business dealings.

The ISO 9000 family is primarily concerned with "quality management". This standard describes what the organization must do to fulfill:

- the customer's quality requirements, and
- applicable regulatory requirements, while aiming to
- enhance customer satisfaction, and
- achieve continual improvement of its performance in pursuit of these objectives.

Another important factor in PCB manufacturing is that that the company that manufactures the PCB's received a component placement protocol from the company that is contracted to place the components on the PCB's. If the PCB manufacturing protocol does not agree with the component placement protocol, the PCB's are not suited for placement.

Component placement

Secondly the components must be placed (pick and placed) on the PCB's. It is of utmost importance that the company that pick and place the components on the PCB's is also ISO9000 certified. Most of these placement companies also assembles and tests the products.

In most circumstances a component placement company would provide the following options:

- The component placement company could do the component placement and supply the components.
- The component placement company could just do the component placement and the client supplies the components.

In the case of YRLess International (Pty) Ltd, the prototypes of the HAWK110 were manufactured by hand. This means that all components were placed and soldered by hand. After sufficient prototype testing, the manufacturing of the ISO certified boards were moved to an ISO 9000 certified placement company.

Product assembly

Thirdly, the product must be assembled. The assembling and testing of products were done by YRLess International (Pty) Ltd. It is of utmost importance that the personnel assembling products are highly qualified in their line of work. These personnel should also have a good understanding of how the product functions and of component sensitivity to heat, moisture, ESD (Electro Static Discharge) and EM (Electro Magnetism).

It is furthermore important that internal workshops are held at lease once a month to introduce new methods of product assembling and to receive feedback from personnel on issues regarding work environment, productivity and personnel growth and relations. At these workshops a summary of the last month's production statistics, fall-out rate of products, cause of fall-outs and effects of fall-outs can be addressed. These workshops can also be used to set goals for the next month and a possible bonus if these goals are reached. This will give the personnel a feeling of purpose in the company and will improve the personnel relations and quality of the work.

Final product testing and packaging

In the HAWK110 final product testing, all the components on the hardware PCB are individually tested for functionality. All these individual test results are inserted into a log file and saved for future reference. The tracking device is then reprogrammed with the HAWK110 embedded product software. The software is verified and the HAWK110 tracking system is tested as a unit for full functionality. These test results are linked to the individual component test results and saved for future reference.

The tracking unit is then assembled in the relevant collar. These collars differ for each type of animal and it is necessary that each unit be tested in the relevant setup. The tests that are conducted includes the validation of the data sent to the control room (positional data, temperature data and activity data), the reporting schedule intervals of the unit, the GSM signal strength in various GSM coverage areas and the power consumption of the unit during active and non active phases. These procedures test all the hardware components for functionality as well as the entire system functionality.

The tracking unit is then potted with dental acrylic. After the acrylic has cooled down, the entire test procedure as stated above is conducted again in case any software or hardware has been corrupted during the potting procedure.

8.3 Field testing

Field testing included the introduction of six wildlife tracking collars into the field in various geographic locations. Two of these collars were fitted on leopards on the planes near Ghanzi in Botswana, one was fitted on a baboon in the Cape Peninsula, two were fitted on sables in the south western regions of the Kruger park and one on an elephant in Kenya as a part of the Save the Elephants research project. The elephant-tracking unit supplied about 9,000 position readings during two years and the baboon collar supplied about 1,500 position readings during two months on one C cell battery. One of the sable collars stopped functioning after a few months and could not be retrieved to allow the reason for failure to be established. The other collar functioned for the expected lifespan. The two leopard collars were employed in a vast area with weak GSM coverage. They did not report very frequently, but all data was recovered during these data bursts when the units entered GSM coverage areas.

An interesting application that was reported involved a private detective using one of these collars (before it was fitted on the allocated animal and without the prior knowledge of YRLess International (Pty) Ltd) in one of his cases. The client of the private detective suspected her husband of being unfaithful and the detective placed the collar behind the seat of the husband's vehicle and tracked the suspect to the residential address of his mistress. Luckily, this was the last we heard regarding this interesting application.

8.4 Summary

The testing phase in any design is very time consuming, but certainly one of the most important activities before a product can be launched with the required level of confidence. The test report must address all design requirements, and if a design requirement is not met, the design must be altered to address this requirement. It is always good design criteria to contract an external test facility that is also ISO accredited, to test a new product to verify test results and findings that are done by the designers. The tests that were conducted verified that the final design of the different subsystems used in the wildlife tracking system, as well as the complete system as a whole, complied with the design criteria.

Chapter 9

Summary and conclusions

9.1 Summary

The wildlife market is a rapidly growing industry, based on the increased importance of conservation and eco tourism. This has the effect that the wildlife tracking industry is also expanding. This industry mostly consists of research institutes, private game owners, game lodges and game reserves. The current tracking telemetry options available in the tracking industry are RF telemetry and satellite telemetry. Both of these telemetry technologies have advantages and disadvantages in practical tracking applications. The problem is that these forms of telemetry do not fulfill all of the requirements of the wildlife tracking industry. That is why a GPS/GSM tracking solution was designed. This solution can fill the gaps in the different tracking segments provided that a thorough business concept is designed around this technology.

The product that was developed opened up new possibilities for wildlife tracking which have never been researched in detail before. Using the communication capabilities of GSM networks as basis for wildlife tracking enables a level of efficiency, flexibility and cost-effectiveness that cannot be matched by the earlier approaches.

A part of this business concept is the manufacturability, supportability and maintainability of the product in the field. These requirements are an integral part of the product and system design. If this part of the design is neglected the system will fail as a practical solution.

The tracking system that was developed consists of three parts. The first part is the tracking unit. To ensure that the tracking unit is introduced successfully into the tracking market, the unit must comply with certain criteria. These criteria include that the tracking unit must be physically small, have low power consumption, economically priced and provide valid positional and other telemetry data. Positional data is provided by means of a GPS. Other data that is supplied is temperature and activity. The unit uses GSM as a method of communication.

This data is sent to a control room. This control room consists of a controller PC with GSM modem connected to server PC connected to the Internet. The GSM modem intercepts the SMS sent by the tracking unit and stores the SMS data in a database. This data is then made available to the user through the Internet. The user can analyze the data through a software program or through a web interface. The software program enables the user to do a thorough analysis of the tracking data, while the web interface supplies the user with basic tracking facilities.

The system underwent four phases of laboratory testing. The first phase involved the evaluation of engineering and service test modules, system components, breadboard evaluation, mockups testing and the testing of a rapid prototype of the system. The second test phase consisted of the evaluation of prototype and production models. This test phase included performance, environmental, temperature, structural and reliability tests. Test phase three included the testing of production models evaluated at designated test sites such as FTA facilities and standardization test facilities. The fourth test phase was the continuous evaluation of the system in operational use. This evaluation was based on the continuous data that was received from the tracking unit and through the feedback received by clients regarding the system functionality and operation.

Another area of testing that was conducted throughout the entire design and production phases was quality testing. This continuous process of quality assurance was applied throughout the complete development process during components selection, supplier selection, manufacturing, component placement and final product assembly.

9.2 Conclusions

This development was the first study conducted by YRLess International (Pty) Ltd. The study covered a wide field. Intensive market research was done to determine the user requirements of the wildlife tracking market. An investigation into the design, development, production and support for a solution for these requirements were undertaken. It coved hardware development in conjunction with embedded programming, system engineering, high level programming such as web design and the development of the user interface software and database development. The hardware design had to ensure that the unit was physically small enough to be fitted on smaller species of animals. The hardware and embedded software development had to ensure that the power consumption of the unit was kept to a minimum to ensure that the tracking collar could be employed in the field for a minimum of two years. The development team consisted of three engineers and one programmer with no previous experience in this field of development.

In spite of these obstacles, the first tracking collar was deployed in the field after one year of development and testing.

During a period of two years after YRLess International (Pty) Ltd introduced the GPS/GSM tracking system to the wildlife industry, 156 tracking collars were deployed in the field. Out of these 156 units, there were 11 comebacks of which six failed because of moisture that penetrated the dental acrylic through cracks in the molding. Because the collaring and potting of the tracking unit is done by an external company, only five of the failures were linked to the product supplied by YRLess International (Pty) Ltd. This gives a fall out rate of only three percent for a product that was employed in very harsh environments.

It can be concluded that all of the research objectives that were established have been achieved. The level of product acceptance provides conclusive proof that the user requirements according to which the system was developed, sufficiently represent the real needs of the market. The functionality provided by the system satisfies the needs of most end-users, based on practical feedback received from a representative set of user. The design approach that was followed resulted in a robust product that not only complied with the set of functional criteria derived from user requirements, but also sustained this level of performance within the actual end-use environment over the required period of time.

The product that was developed was successfully introduced to the wildlife tracking industry and the market has accepted the principle of GPS/GSM based tracking. Like all products, a new system must prove itself in the industry where it being applied. Eighty percent of first time users returned with new orders after they have used the tracking system. Many suggestions received from clients regarding the improvement of the system as well as other features have been added to the design. A new version of the tracking system is already in the design phase. This new version will include an extended onboard memory and a herd tracking feature that will enable the user to monitor the activity of a whole herd through one GPS/GSM tracking unit by means of additional RF telemetry.

It has been practically demonstrated that the application of the fundamental principles of systems engineering resulted in the successful development, production and implementation of a technologically advanced product in a very demanding environment.

Appendix A

The requirements collected for this report were gathered in two different manners.

- AWT has a database of over 150 end users that uses tracking telemetry and these end users consists of research institutes, private owners, game lodges and game reserves. Through contacting these end users and knowledge gathered over the past 24 years, AWT compiled a list of requirements for an alternative tracking solution.
- YRless International (Pty) Ltd contacted a few international research institutes. Some of these institutes such as 'Save the Elephants' visited their offices in South Africa. Researchers, rangers and park managers of game reserves and lodges such as Pilansberg, Phinda, Addo and Kruger National Parks were also contacted or visited. In the same time some private owners in the Hoedspruit area (Sabi Sands etc) were visited. During these visits, YRless International (Pty) Ltd did a survey on the requirements of an alternative wildlife tracking solution.
- The results of the above mentioned methods were thorougly studied and a combined document concisting of requirement specifications were generated. This document is discussed above.

Survey report – Requirement specifications for an alternative wildlife tracking system. A combined effort by Africa Wildlife Tracking CC and YRLess International (Pty) Ltd

Africa Wildlife Tracking is a South African company based in Pretoria. The company specializes in manufacturing satellite and radio tracking equipment for wildlife.

AWT integrates technology to give individuals and organizations the power to manage and protect wildlife resources effectively. With commitment to research and development of up-to-date technologies, including the use of satellites and wireless communications, the company has advanced systems which enable clients to monitor and track their wildlife.

Some of the tracking options include: Satellite / VHF combined: use of satellite unit to relay GPS, real time and historical data.

- Satellite: collars, glue-on and backpacks
- VHF: collars, implants for rhino horn or abdominal cavity of most mammals.

Radio and satellite technologies can be used to track animals on land. There are various choices available for each type of terrestrial tracking system. VHF radio collars and implants will allow you to track your animals manually with the help of a receiver and antenna whilst satellite collars will enable you to do it from a PC. With radio collars it is imperative to remember that terrain, vegetation and power lines will have an effect on the reception. Dialogue between clients and AWT is essential in order to ensure that clients are issued with the correct equipment to suit their specific needs.

AWT has a database of over 150 clients that uses wildlife tracking telemetry on a daily basis. Knowledge gathered over the past 24 years and extensive research into new tracking telemetry enables AWT to be one of the most diverse and advanced global tracking telemetry providers.

AWT and YRLess International (Pty) Ltd has worked together since 2001 to introducing a new method of animal tracking into the animal tracking market segment. The development and deployment of this telemetry into the market has undergone various developments over the past few years. With AWT's in depth knowledge of the wildlife tracking market, its segments, the requirements of the various tracking segments, combined with the electronic and system development skills of YRLess, these two companies has worked in coalition in developing this new method of tracking.

Tracking Market

Through the client database and the knowledge that were gathered over the past 24 years, a definite animal tracking market could be identified. The segments of the wildlife tracking markets include

- research institutes and wildlife foundations,
- private owners of game farms,
- game lodges and
- game reserves.

The need for wildlife tracking of the various segments of the wildlife market differs from each other in various ways.

The combined user requirements for the different tracking market segments

The various segment of the tracking market has different tracking requirement needs. These needs could however be incorporated into a single requirement specification protocol that will satisfy the different needs for the different market segments. These requirement specifications can be subdivided into four categories that are important to the end user. If these needs are met with excellence, a milestone will be reached that was never satisfied in the past.

These requirements categories are as follows.

- Packaging of the tracking telemetry unit.
- The tracking telemetry unit that is fitted to the wild animal.
- The software interface forming the link between the tracker and the telemetry unit.
- The service the end user receives as foundation in order to utilize the tracking system succesfully.

Packaging of the tracking telemetry unit.

All the tracking telemerty units must be package in some means in protection material to ensure that the unit is not exposed to the different elements that could cause the telemetry to malfunction or worst of all, fail! This packaging must be able to withstand harsh and sometimes unexpected environmental and mechanical stresses for a period of two to three years. This two to three year operational period is sufficiant for the different target market segments. The packaging method of the telemetry unit thus forms an integral part of the successfull implimentation of the tracking system into the market.

The user requirement specifications of the packaging of the telemtry unit can be sub-divide into two segements.

Physical requirements of the packaging of the tracking telemetry unit.

1. As previously mentioned, the construction of the packaging of the telemetry unit and the materials used to package the unit must be robust to withstand the different elements of nature. These elements includes extreme temperatures, humidity, moisture, drastic climatic changes and ultraviolet radiation. The period for which these element must be endured is two to three years.
2. The packaging must be able to withstand mechanical stress caused by typical animal behaviour. These behaviour include chewing of the packaging and scratching.
3. It is nessasary that the packaging of the telemetry should blend into the animals natural environment to ensure that the animal is not adversely affected in natural behaviours such as hunting or grazing.
4. When the wild animal is captured to employ the tracking unit, the packaging of the telemetry unit must enable easy and quick fitment or mounting on the animal. The capturing of wild animals is very traumatic to them and the period the animal is physically handled, must be kept as short as possible.
5. The design of the packaging of the tracking telemtry and the fitment of the device must not put the animal in any discomfort or handicap the animal in any way.

General requirements of the packaging of the tracking telemetry unit.

1. Putting the manufacturing process of the packaging under scope, the material and solutions that is used to manufacture the packaging of the telemtry unit must be readily available to minimize the delay time for the manufacturing of the packaging.
2. The packaging must be low cost to ensure that the cost of the tracking system is kept as low as possible. There is however a line between quality and price of material and the end user will invest more in the packaging if it ensures the successful employment of the tracking unit.

The tracking telemetry unit

The tracking telemetry unit is packaged and fitted or mounted on the animal. All the tracking data must be collected by this telemetry unit and sent via a communication channel to the end user to analyse this data on operational software.

The user requirement specifications of the tracking telemetry unit can be sub-divide into four segments.

Functional requirements of the telemetry unit.

1. The unit should supply the end user, via the operational software, with accurate positional data, temparature and environmental data.
2. The data collection must be at user specified time intervals. This data must be accurate.
3. The data collection intervals must be easily reprogrammable or updated in the field.
4. There should be an alternative backup tracking telemetry unit incorporated with the main unit in case the main unit malfunctions.
5. Data storage capability on the unit must be able to handle about 32,000 data readings. This will give the end user access to approxamitly 30 data readings per day for a period of 3 years.

Physical requirements of the telemtry unit.

1. The hardware platform of the tracking unit should be compact enough to enable fitment onto smaller species of animal such as baboon, wild dog and jackal.
2. The usable lifespan of the tracking telemetry unit must be two to three years, while being exposed to the typical environmental and stress conditions, while fitted to an animal.
3. The unit must be waterproof, shock proof and durable and be supplied with a power source for an operational period of two to three years.

Security requirements of the telemtry unit.

1. The data that is sent to the user must be secured by means of encryption. This will ensure that no data is hacked in data transfer between the tracking unit and the operational software.
2. A secure communication channel between the user and the tracking unit must be used.

General requirements of the telemtry unit.

1. The telemetry unit must have a minimum power consumption to ensure that it is functional for as long as possible without replacement of the power source (two to three years).

The tracking software

The tracking software is basically the only link that the end used has with the employed tracking telemetry unit. This interface the end user will utilize to view and analyze the tracking data supplied by the telemetry unit. The software must give the client easy access and full functional control over the tracking system.

The user requirement specifications of the operational software of the telemtry system can be sub-divide into three segments.

Functional requirements of the operating software.

1. Data received from the employed telemetry unit should be displayd visually on the PC of the end user. This data must contain the animal's position on a specific time and date, the speed and direction that the animal is travelling, and ambient temperature. The data must be accurate and easily updated at user specified intervals. The data that is displayed must be accurately GEO referenced (i.e. data must be shown and plotted on a geographical map) and be updated on user demand.
2. The user must be able to add Geo-fenced regions on the maps of the software. The user must be notified if an animal moves into or out of this GEO-fenced area. This is mostly for security reasons when an animal breaks out of fenced areas or moves into urban areas.
3. The software must have the capabilities to export all data parameters to an external program. Researchers moslty use programs such as Microsoft Exel or ARCview to do indepth analysis of data.
4. The installation of the software must be easily done.
5. The user must be able to operate or manage the software even if the user has minimal computer background.
6. The software must empower the client to customise or configure the user interface to make the software more user-friendly.
7. The operational suftware must satisfy the tracking needs of all the end users in the different wildlife tracking market segments.

Physical requirements of the operating software.

1. The interface should be appealing to the client and neatly packaged with a professional appearance that the end user is used to.
2. The software should contain a very well developed help file and menu description with 24 hour online support if needed.
3. The "look-and-feel" of the software must be in line with well known user interfaces such as Microsoft Windows XP.

Security requirements of the operating software.

1. The tracking software should supply the client with a secure tracking solution, meaning that all data is password protected. All data must be stored in a secure database, so if an end user should lose any tracking data, a copy of this data can by supplied to the end user. It is the responsibility of the end user to secure the computer systems against viruses or external hackers that may try to gain entry through the Internet on intranet.

Service

The sales and after sales service that the client receives is another fundametal part of launching a system successfully into the market. The service the end user receives will be the foundation in order to utilize the tracking system succesfully.

The user requirement specifications of the services offered can be sub-divide into one segment.

General requirements for service.

1. Firstly all contact with the end user must be professionally handled. Issues such as physical appearance, the manner in which user relations is handled, and all documentation must be professional and of good quality.
2. After sales service must be of the same quality as upfront marketing.
3. It is of utmost importance that the delivery time of the tracking system is minimized.
4. There must be a follow-up contact with the user within the first month after the tracking solution was delivered. This month will give the user efficiant time to get accustomed with the tracking system.
5. A service line must be available to provide general software support and guidance during working hours.
6. A 24 hour services line must also be available when emergency tracking (when an animal has broken through a fence and the tracking intervals must be changed) is needed.
7. All users must be contacted at lease once a month as part of the after sales service.

8. A backup database service must be implimented. This service will enable the user to retrieve data that is lost or deleted.
9. Emergency alarming must be part of the service package. Emergency alarming is when an animal breaches a GEO-fenced region.

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