MASTER

Analysis aeronautical navigation service organisation in Tanzania : technology audit aeronautical fixed service provision via low-speed aeronautical fixed telecommunication network

Sturkenboom, Bas

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Author	Ing. Bas Sturkenboom
Supervision	
First supervisor Technology Development Science	Dr. P.E. Lapperre
Supervisor Telecommunication department	Prof. ir. G. Brussaard
Second supervisor Technology Development Science	Prof. dr. A.E. Szirmai

Directorate of Civil Aviation of Tanzania

ANALYSIS AERONAUTICAL NAVIGATION SERVICE ORGANISATION IN TANZANIA

Technology audit Aeronautical Fixed Service provision via low-speed Aeronautical Fixed Telecommunication Network

BOOK ONE: MAIN REPORT

10 June 1997

EXECUTIVE SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

Background

This report deals with the analysis of the Aeronautical Navigation Service (ANS) organisation within the Directorate of Civil Aviation (DCA) of Tanzania. If possible, an ANS organisation provides the four sub-services of the Aeronautical Telecommunication Service (ATS) which are: the Aeronautical Fixed Service (AFS), the Aeronautical Mobile Service (AMS), the Aeronautical Radio Navigation Service (ARNS) and the Aeronautical Broadcasting Service (ABS).[1] During the research, special attention was given to the way the Aeronautical Fixed Service (AFS) is provided via the low-speed Aeronautical Fixed Telecommunication Network (AFTN) in Tanzania.

Goal

The research goal is defined as: *present the Directorate of Civil Aviation of Tanzania with recommendations for the solving of the problems faced by the Aeronautical Navigation Service organisation and possible technological trajectories with respect to the enhancement of the present state of the Aeronautical Fixed Telecommunication Network and the organisation in which it is used.*

Due to lack of time and the extent of the last part of the research goal, the examining of the AFS provision via the AFTN is limited to the methodology for finding the shortcomings and causes of shortcomings of the service and the service provision.

Research questions

The research started with examining the aeronautical telecommunication sector, which is expressed in the first two research questions. With these questions, the technological environment is taken as a starting point and from there on all aspects in the direct environment of the equipment, which influence the functioning the equipment, are examined. This information is subsequently used to examine the ANS organisation in Tanzania in general and the AFS provision via the AFTN in particular, expressed in the last two research questions.

The main research questions are:

1. *Which aeronautical telecommunication equipment is presently used in air space control, how is this equipment used, maintained and how is it organised?*
2. *Which factors determine the level of quality of the provided Aeronautical Navigation Service?*
3. *How is the Aeronautical Navigation Service organised in Tanzania and which problems are presently encountered with the provision of the Aeronautical Navigation Service in Tanzania?*
4. *What are the prerequisites and necessary actions to enhance in the best way the present provision of the Aeronautical Fixed Service by means of the Aeronautical Fixed Telecommunication Network in Tanzania?*

Methodology: the ANS organisation in general

The described methodology applies to the first two research questions.

Aeronautical telecommunication equipment

Because of my professional background, a preliminary research was executed to get acquainted with the aeronautical telecommunication equipment as well as with the organisation responsible for the use and maintenance of the equipment. For this, relevant literature in this field was examined[2,3,4], interviews were held with various experts in the field of aeronautical telecommunication equipment and the first visits to the sites of the various

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1 International Civil Aviation Organisation, *Annex 10: Aeronautical Telecommunications - Volume II: Communication procedures* (Montreal, Canada: July, 1995, page 6).

2 International Civil Aviation Organisation, *Annex 10: Aeronautical Telecommunications - Volume I: Communication equipment* (Montreal, Canada: July, 1995).

equipment in Tanzania are also considered to be a part of the preliminary research. A model has been made to indicate the type of elements of the ANS organisation and the place of the elements within the organisation.

Quality factors Aeronautical Navigation Service
Beside an inventory of the relevant equipment and the way the equipment's control and maintenance is organised, also the quality of the aeronautical service provided with the equipment is important to examine, since it is the main measurement for the analysis of the ANS organisation at hand. To find the quality factors for the examining of every element within the ANS organisation, a literature survey[5,6,7] was conducted and several interviews were held with experts in the field of aeronautical telecommunication equipment.

Methodology: the ANS organisation in Tanzania
To describe the Aeronautical Navigation Service organisation in Tanzania, the above mentioned model, containing all elements with respect to the ANS organisation, is used. Also, the factors which characterise the functioning of all elements of the ANS department of the Directorate of Civil Aviation in the Tanzanian environment are described.
To gather the data, unstructured and structured observations have been made at three airports in Tanzania. These are Dar es Salaam International Airport (DIA), Kilimanjaro International Airport (KIA) and Arusha Airfield. Also, DCA employees, working in the Air Traffic Control (ATC), Communication and Maintenance sections, and engineers of the Electrical section of the Directorate of Aerodromes were interviewed. To get an idea of the level of knowledge of all mentioned employees of DCA, semi-structured interviews were held using questionnaires.

Methodology: the Aeronautical Fixed Service (AFS) provision via the AFTN in Tanzania
To be able to answer research question number four, the methodology of a technology audit was chosen. With the technology audit methodology, the shortcomings of a telecommunication service and subsequently of the telecommunication infrastructure are examined step by step. To come to a model for the technology audit, literature was consulted.[8] The technology audit methodology includes the examining of relevant literature[9,10,11], which has also been done to work out the methodology.

The Aeronautical Navigation Service (ANS) organisation
Basically, the ANS organisation consists of the following elements at the level where the ATS is actually provided:
1. aeronautical telecommunication equipment
2. auxiliary infrastructure
3. maintenance organisation
4. Air Traffic Control (ATC) organisation
5. aeronautical communication organisation
6. aeronautical training
7. Aeronautical Information Service (AIS) organisation

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3 Helfrick, Albert, *Modern aviation electronics* (Englewood Cliffs, United States of America: 1984).

4 Schreiner opleidingsinstituut, *Documentatie voor opleiding luchtmacht piloten nederlandse luchtmacht* (The Netherlands: 1988).

5 International Civil Aviation Organisation, *Annex 10: Aeronautical Telecommunications - Volume I: Communication equipment* (Montreal, Canada: 4th edition, 1985).

6 Mann, Lawrence, Jr., *Maintenance Management* (Lexington, Massachusetts Toronto, Canada, revised edition, 1976, 1983).

7 Tomlinson, P.D., *"The Maintenance Engineer", Plant Engineering* (July 10, 1980).

8 Lapperre, P.E., van der Ploeg, J., *Technology audit methodology for medium and small enterprises* (Eindhoven, The Netherlands: second draft August 1996).

9 International Civil Aviation Organisation, *Annex 10: Aeronautical Telecommunications - Volume II: Communication procedures* (Montreal, Canada: July, 1995)

10 International Civil Aviation Organisation, *Doc. 8259- AN/936: Manual on the planning and engineering of the Aeronautical Fixed Telecommunication Network* (Montreal, Canada: 5th edition 1991).

11 International Civil Aviation Organisation, *Doc. 7474/26: Africa - Indian Ocean Region Air Navigation Plan* (Montreal, Canada: 26th edition, 1989).

The auxiliary infrastructure consists of power supply, air-conditioning, buildings or cabins, cabling and security measures like fences.
The human resources, examined during the research, are confined to the employees of the ATC, communication and maintenance organisations.
The AIS organisation supplies aeronautical information to the communication and ATC organisations, but is not directly involved with the ATS provision and has not been examined thoroughly.

Other important elements with which the ANS organisation has to deal are:
1. pilots
2. other ATC centres
3. external aspects

Item three deals with external aspects, which influence the functioning of the ANS organisation and through that the ATS provision, but cannot be controlled or can be controlled with difficulty by the ANS organisation. The aspects are:

- national government
- national service industries (power supply and telecommunications)
- manufacturer aeronautical infrastructure
- international ATS counterparts

Quality factor elements
Of the quality factors concerned with all relevant elements, the factors, describing the characteristics of the aeronautical telecommunication equipment, are the most important, since they indicate the extent of functioning of the equipment. They also indicate the level of quality of provided ATS. The factors with the relevant equipment are the following:

- continuity of service (all aeronautical telecommunication equipment)
- integrity of service (navigation aids and surveillance equipment)
- transit-time (data communication equipment)

Other quality factors worthwhile to mention are the reliability of auxiliary infrastructure and national services, frequency of preventive and corrective maintenance and the skills and knowledge of the human resources.

Technology audit methodology
To identify shortcomings in the Aeronautical Fixed Service (AFS) provision via the low-speed Aeronautical Fixed telecommunication Network (AFTN) in Tanzania, a methodology is developed, which describes step by step the execution of a technology audit. The audit focuses in particular on the service characteristics from the viewpoint of the user and on the used technology. Only in the last step of the method, other aspects, which concern the direct environment of the technology, are examined to get a complete picture of all shortcomings and all causes.
The method is visualised in figure I.

Step 0 deals with the description of the service, since it limits the particular service and the particular form of implementation technology wise. This is necessary, since the service characteristics of other implementations differ and cannot be compared. For the description, the name of service, the elements of AFS provision via AFTN and the proposed functioning and usual application mode(s) of the service are important. In the Tanzanian case, the service provider is the Communication section of DCA, the users are Aeronautical Information Service (AIS) units and other aeronautical matters related administrations, the AFTN infrastructure contains land lines and manual controlled AFTN equipment and the communication procedures according to Annex 10 of ICAO.
Step 1 deals with the identification of shortcomings of the service by examining the service characteristics. Service characteristics as documented in ICAO documents and user agreements are compared with the status of the same characteristics in the Tanzanian situation. The relevant characteristics are *extent of service*, *speed of service*, *reliability of service*, *continuity of service* and *maintainability of service.*

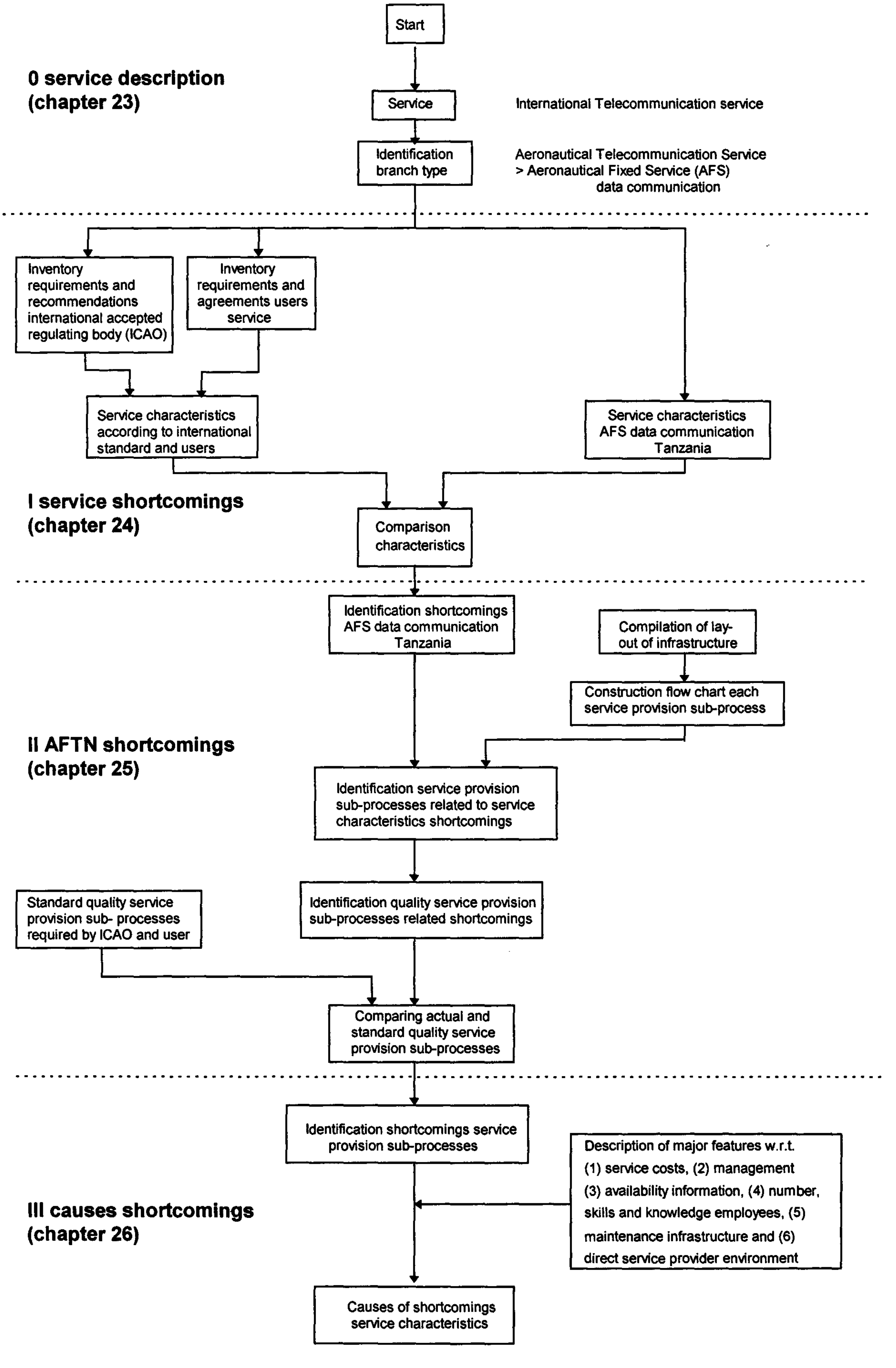

Figure I: schematic presentation technology audit AFS provision

Step 2 deals with the identification of shortcomings with the service provision, thus the AFTN. The identified service provision shortcomings are the causes of the service shortcomings. It comprises the following actions:
1. compilation of lay-out infrastructure
2. construction flow chart each service provision sub-process
3. identification relevant service provision sub-processes using identified service characteristics' shortcomings
4. identification required quality relevant service provision sub-processes
5. identification actual quality relevant service provision sub-processes
6. comparison actual and required quality relevant service provision sub-processes

The compilation of the **lay-out of the infrastructure** is done at two levels. First, the total network in the Tanzanian FIR is examined to be able to construct flow charts of each message transfer process from one station in the network to another station. Secondly, the lay-outs of the AFTN stations and communication centres with all equipment are compiled to be able to construct flow charts of the service provision sub-processes.
The general lay-out is subsequently divided into **AFS provision sub-processes**. The total AFS provision via the low speed AFTN can be divided into two or three types of series of sub-processes, depending on the type of AFTN station. The three series of sub-processes are the following along with the description of all parts:

The *transmitting series* consisting of:
1. processing of information into transferable message and printed form
2. transferring of message onto out-going circuit
3. conveying of message on out-going circuit

The *receiving series* consisting of:
1. transforming of incoming message into printed and torn-tape form

The *relaying series* consists of five parts:
1. transforming of incoming message into printed and torn-tape form
2. moving of torn-tape from teletypewriter receiver to processing part teletypewriter terminal
3. transforming of torn-tape into internal electronic signal and printed form
4. transmitting of internal electronic signal onto out-going circuit
5. conveying of external electronic signal on out-going circuit

Describing all sub-processes, for the entire lay-out of every station and centre, is an enormous job. Therefore, the **number of sub-processes** is **limited** by describing only those which concern parts of the network of which shortcomings are identified during the previous step.

To be able to compare the actual quality of the relevant sub-processes and the required quality of the relevant sub-processes, **features of the AFTN components are defined**. Basically, the AFTN infrastructure in Tanzania consists of AFTN circuits between teletypewriter equipment, controlled manually by operators, which also applies to the relaying of AFTN messages within a centre, which is the lowest degree of automation.

The features of an **AFTN circuit** with their indicators are:

1. capacity	(volume of traffic, number of channels and Baud rate)
2. transfer speed (Baud rate)	(ICAO: 50 Baud)
3. availability	(ICAO: 100%)
4. reliability	(ICAO: AFTN efficiency daily reliability per circuit 97%)
5. implementation	(simplex, duplex or two times simplex)

The features of **teletypewriter equipment** with their indicators are:

1. availability	(ICAO: 100%)
2. reliability	(manufacturer indications: MTBF and MTTR)
3. type of equipment	(amount of traffic; transmitters and receivers or transceivers)

The features of **operators** in a centre with their indicators are:

1. availability	(number of staff and volume of traffic)

2. speed of operation (handling time is considered here constant)

The feature of **relay equipment** with its indicator is:
1. speed of relaying (degree of automation)

The next action is the **comparison of the actual and required qualities of the sub-processes** with the help of the before mentioned features. This action **identifies shortcomings of the service provision**.

Step 3 identifies the causes of the shortcomings of the service provision and, because of that, the shortcomings of the service characteristics. This is done by examining the direct environment of the AFTN infrastructure to identify aspects which are not part of the infrastructure, but influence the functioning of the service provision and, through that, the level of the provided service. The main features are:
1. service costs
2. management
3. availability information
4. number, skills and knowledge of employees
5. maintenance AFTN infrastructure
6. direct service provider environment

CONCLUSIONS

ANS organisation in Tanzania

Aeronautical Telecommunication Service (ATS)
The ANS organisation in Tanzania provides the following sub-services out of the Aeronautical Telecommunication Service (ATS):
1. Aeronautical Mobile Service (AMS)
2. Aeronautical Fixed Service (AFS)
3. Aeronautical Radio Navigation Service (ARNS).

ad 1. **Aeronautical Mobile Service (AMS)** is provided for the following types of control along with the used equipment, application and location:

Type of control	Type of equipment	Application	Location	Remarks
Area Control	VHF radio communication	Upper airspace across Tanzania	Area Control Centre (ACC) DIA	• limited number VHF consoles at ACC • large work load controllers
	HF radio communication	Upper airspace borders FIR	ACC DIA	• limited HF radio communication
Approach Control	VHF radio communication	lower airspace Terminal Area (TMA) DIA lower airspace TMA KIA	ACC DIA Visual Control Room KIA	• co-located with Area Control and experiences same problems • experiences staff shortage
Approach Radar Control DIA	Radar equipment	lower airspace TMA DIA	DIA	• Radar system DIA is out of service • Air Traffic Control Officers cannot gain experience and relevant rating for promotion
Aerodrome Control	VHF radio communication	lower airspace Control Zones manned airports	All manned airports	• sufficient AMS provision
All types of control				• all used VHF radio equipment has sufficient coverage

ad 2. The **Aeronautical Fixed Service (AFS)** is provided via the following networks, types of equipment:

Type of network	Type of equipment	Location	Remarks
All types of networks			• all connections are TTCL land lines • lines are highly unreliable
AFTN	HF radio communication	AFTN communication centre DIA	• not done anymore
	teletypewriter equipment	AFTN communication centre DIA	• limited number of old, obsolete teletypewriters • limited number of connections • manual control messages by one operator per shift • unacceptable processing and relaying times
ATS/DS	specific telephone exchanges	all manned airports	• limited number of connections • poor availability lines
public telephone (TTCL)	public telephone exchanges	all manned airports	• only used, when other networks fail

ad 3. The **Aeronautical Radio Navigation Service (ARNS)** is provided by one ILS, five VORs, four DMEs and twenty-four NDBs.

Type of equipment	Application	Location	Remarks
ILS	precision approach	DIA	• incomplete • intermittent serviceable • no flight calibration for 5 years
VOR	terminal approaches and air route navigation	DIA, KIA, Mwanza, Mbeya and Tabora	• all VORs out of service or in bad state, except at KIA • no flight calibration for 5 years
DME	terminal approaches and air route navigation	DIA, KIA, Mbeya and Tabora	• all DMEs out of service or in bad state, except at KIA • no flight calibration for 5 years
NDB	most used for air route and airport navigation	twenty DCA and four private airports	• most of them in good state and serviceable

Power supply
The power supply at the airports of Tanzania is the responsibility of the Electrical section of the Directorate of Aerodromes. A power system consists of the following elements:

- power house (locating Tanesco power line entry, back-up diesel generators and switching mechanism)
- various transformers (powering aeronautical facilities)
- power cables

Most of the Tanzanian airport's power systems consist of old, deteriorated and obsolete equipment. The power supplies at both DIA and KIA have the possibility of complete break-down, which means unavailability of all facilities and services. Most of the Tanzanian airport's power supplies are faced with frequent Tanesco power failures and fluctuations.

Maintenance
The telecommunication section of DCA is responsible for the maintenance of the aeronautical telecommunication equipment, which is **organised** in a hybrid form between a centralised and decentralised form. The telecommunication section tries to meet objectives for daily, weekly, quarterly and yearly checks for **preventive maintenance**, but only meets weekly checks. Daily and quarterly checks are done by engineers and/or technicians stationed at the relevant airports. Quarterly and yearly checks are done by engineers of the Central Workshop in Dar es

Salaam, just like most of the **corrective maintenance**. The period in which equipment is unserviceable and cannot be repaired by resident engineers is prolonged, because of bureaucratic procedures and the means of transport of equipment and/or spare parts. Only some of the airports have **repair shops**, but the Central Workshop is the best equipped. The telecommunication section has only a limited number of **maintenance vehicles** for both preventive and corrective maintenance. A general **maintenance plan** is not present. All **statistical information** gathered during the routine checks is not analysed for management purposes.

Human resources
Most of the human resources, consisting of ATC Officers, Communication officers and Telecommunication Engineers and Technicians, are trained and refreshed at specific aviation **training** institutes. However, the overall training is experienced to be insufficient to carry out all the assigned tasks. Insufficient training is caused by unserviceability of equipment, hampering the practice of real-situation equipment. To train local DCA employees, the **Civil Aviation Training Centre (CATC)** was founded at DIA. The problems of the CATC are:

- staff shortage
- instructors who lack knowledge of the latest technologies
- insufficient test gears and equipment for real-situation practice

A **brain drain** of DCA is caused by leaving employees and caused a decrease in the level of knowledge. DCA employees are not paid sufficiently and experience a big **wage level** difference with the private sector. All employees experience difficulties with **promotion**, due to the inability of achieving licenses and ratings.

External aspects
The **Government of Tanzania (GoT)** influences the functioning of the ANS department by means of degree of ownership, Tender Boards and the national liberalisation policy. The ANS department relies on the **national companies** of Tanesco and TTCL for respectively power supply and telephone lines to provide the ATS. **Manufacturers of aeronautical infrastructure** influenced the functioning of the ANS department, when they were reluctant to assist with problems or acquisition of extra spare parts. The ATS provision was hampered, when **international counterparts** in an HF AFTN radio network or owning flight calibration units were not able to co-operate.

Airports in Tanzania
DIA is the main international airport of Tanzania. The airport's sites, containing aeronautical facilities, are the ACC - containing the Area Control Room, Equipment Room, Communi-cation Room and the AFTN Communication Room -, the Equipment Room in the Tower, the Transmitter Station - also containing an NDB -, the Receiver Station, the Localizer site, the Glide Path site, the Middle Marker site, the Outer Marker site - also containing an NDB - the NDB-DM site, the VOR/DME site and the Radar site. The power network at DIA has a ring construction for back-up purposes. **Kilimanjaro International Airport (KIA)** is the second largest airport and the airport's sites are the Visual Control Room, Equipment Room, the AFTN Communication Room, the D-VOR/DME site and three NDB sites. The power network at KIA has also a ring construction for back-up purposes. **Arusha Airfield** is a small airfield with relatively a lot of air traffic. The airfield's sites are the Visual Control Room, the AFTN Communication Room and the NDB-AR shed.

Technology audit methodology
The methodology shows, that the first three steps result in the technological shortcomings and causes, concerning the service and the service provision. Shortcomings with the AFS provision are shown on page VII, which are mainly focused on the Dar es Salaam AFTN communication centre. The remarks also show other aspects, which are, among others, dealt with in the last step of the methodology identifying the root causes of the service shortcomings. The aspects deal with problems in the fields of staff numbers, maintenance of equipment and the direct service provider environment. Another problem is the partial absence of statistical data, necessary to execute the methodology.

RECOMMENDATIONS

ANS organisation in Tanzania

Recommendations are shown in priority of implementation with the first recommendation as the most immediate.

With respect to **Aeronautical Fixed Service (AFS)**, the following recommendations should be implemented:

AFTN
- automation of message switching communication centre Dar es Salaam
- increase of communication operators communication centre Dar es Salaam

ATS/DS
- increase of number of links from Area Control Room Dar es Salaam to relevant domestic and international counterparts

With respect to **maintenance**, the following recommendations should be implemented:
- formulation of standardised maintenance plan, including all aeronautical telecommunication equipment
- improvement of facilities at repair shops other than Central Workshop
- establishment of contracts with foreign flight calibration units for yearly checks
- increase number maintenance vehicles to execute preventive and corrective maintenance properly
- more use of statistical information, concerning the functioning of aeronautical telecommunication equipment, for management and planning purposes

With respect to **power supply**, the following recommendations should be implemented:
- rehabilitation of power systems Dar es Salaam and Kilimanjaro
- installation of solar panels at all remote sites
- replacement of back-up generators which are beyond their technical life

With respect to **Aeronautical Radio Navigation Service (ARNS)**, the following recommendations should be implemented:
- replacement present VORs and DMEs which are in a bad state or unserviceable
- installation of VORs and DMEs at airports of Dodoma, Songea and Zanzibar

With respect to **human resources**, the following recommendations should be implemented:
- increase salary all DCA employees out of revenues
- upgrading CATC by acquiring more teaching materials and real-situation practice equipment
- improvement of level of knowledge of all ATC Officers, Communication Officers and Telecommunication Engineers and Technicians, including instructors CATC by periodical refreshment and upgrading CATC

With respect to **Aeronautical Mobile Service (AMS)**, the following recommendations should be implemented:
- rehabilitation VHF radio consoles within ACC at DIA for safer Area and Approach Control
- increase of number of controllers Dar es Salaam and Kilimanjaro

Technology audit methodology

The technology audit for determining the shortcomings and causes of the AFS provision via the AFTN in Tanzania requires many steps to be taken and the acquisition of enormous amounts of data. Due to lack of time, the technology audit has not been executed entirely. This means, that it is not entirely known to what extent the methodology works. Therefore, the technology audit should be executed to examine this. Since the final step of the audit is focused on the service costs, human resources, maintenance, management, availability of information and the direct environment of the service provider, it reveals the causes of the shortcomings of the service. Special attention should, therefore, be paid to this step. The total execution of the audit in the Tanzanian case also helps the Directorate of Civil Aviation with the encountered problems with the AFS provision via the AFTN.

PREFACE

Before you lies the report which is the result of my practical training for my Masters of Science degree for the study Technology Development Science at the faculty Technology Management at the University of Technology of Eindhoven in The Netherlands. My practical training took place in Tanzania, where I have done research with the Directorate of Civil Aviation.

Being a student in technology development science does not only gives you the opportunity to learn about various technologies and their impacts in society, but it also gives you the opportunity to discover and learn from other cultures.

In Tanzania, I lived in three different neighbourhoods and I experienced all aspects of Tanzanian life. I travelled with the same public transport as the Tanzanians do and I stood in the same rows for fetching water as Tanzanian house wives do. I also enjoyed the support of house help, who did my laundry and the cleaning of the house or room, as other ex-patriates do. It showed me the huge differences between these two 'lives' and a full picture of the Tanzanian society. What struck me most was the unlimited friendliness the Tanzanians express, despite their hardship. I sincerely hope, that their living conditions will improve, while their human nature will remain the same.

I also experienced the Tanzanian friendliness at work. Since naming everyone is impossible to do, I will only name some of them.
First of all, I would like to thank my direct supervisor with DCA, Mr. Mwamafupa, who has also been a mwalimu to me by enlightening me a bit the way Tanzanians live and specially the language they speak. He showed a tireless and inspiring effort to help me with my research, which I am very grateful for.
I also would like to thank Mr. Malisa for allowing me to do my practical training with DCA. Many thanks to Mr. Yomntonzi, Mr. Mpili and all the people, working in the Aeronautical Navigation Service department at Head Quarters. For the airport of Dar es Salaam, I would like to thank Mr. Ndatulu, Mr. Kataroki, Mr. Mgemela, Mr. Rwenyagira, all the CATC instructors and all the other people working there. For the airport of Kilimanjaro, I would like to thank Mr. Mgongolwa and the other people working there.
Thanks to all who are not mentioned here. I wish everybody with DCA all the best and I hope that their efforts in making the airspace and airports in Tanzania more safe will be recognised and rewarded.

Ninataka kuwasema watu watanzania asante sana na kwa heri.

I would like to thank my supervisors in The Netherlands for helping, supporting and guiding me from scratch to the point where they can judge the produce of my efforts.
First of all, I would like to express my gratitude to Prof. Szirmai for giving me other, refreshing angles to view the report and its subject. My thanks also stretches out to Prof. Brussaard for the advice and encouragement in the technical field.
I must confess, that throughout the past one and a half year, there have been numerous moments where doubts haunted my head and questioned the successful ending of my studies. However, every time I entered Paul Lapperre's room with these doubts, he always made me come out full of inspiration and new energy to proceed. Beside being a source of inspiration, his advice, remarks, criticism, stories of the good old days and assistance with the making of this report have been very valuable to me and for this I would like to thank him.

My heart goes out to those who have supporting me through the past one and a half year by just being a friend. Specially those who have send me letters and E-mail to Tanzania, I would like to thank most sincerely, since those threads with home kept me going all that time.

Finally, I would like to thank my brother Huib for his E-mails to Tanzania and support and my mother and father for their letters and support in every way before, during and after my stay in Tanzania. Without you, I would not have pull this off.

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PART I THEORETICAL FRAMEWORK

Before the Aeronautical Navigation Service (ANS) organisation is analysed, a theoretical framework is set up to have a basis for the research. Chapter 1 introduces the setting of the problem, which is the aviation sector of Tanzania in general and the Directorate of Civil Aviation (DCA) in particular. The latter incorporates the ANS department. To fulfil the research objective of presenting DCA with solutions or methologies to cope with the problems, four research questions are shown in chapter 2. Basically, the first two research questions are asked to be able to come up with an inventory of specific equipment used in the sector, its functioning and the way it is used by the ANS organisation and the last two research questions deal with the Tanzanian case of respectively the ANS organisation in general and the AFS provision via the AFTN in particular. Chapter 3 formulates the way the research questions are answered. A short contents of the rest of the report is given in chapter 4.

PART I THEORETICAL FRAMEWORK

1. PROBLEM SETTING

1.1 Tanzania: politics and economy

After the hey-day and subsequent collapse of the socialist experiment of Julius Nyerere, Tanzania has changed its economic policy towards a more free-market approach. Those elements of the public sector which have the potential to generate revenue, especially hard currency foreign exchange, are given the autonomy and flexibility to become self funding and self sustaining.
In this light, the government has constructed a Restructuring Program for the Civil Aviation Sector in general and the Directorate of Civil Aviation (DCA) in particular. It emphasises the significant contribution that has been made to the national economy, and the considerable potential that exists for further national economic growth, through commercial development of the sector. By increasing the quality of the aviation sector, the government hopes to attract more tourists to Tanzania, who will bring more hard currency into the country.

1.2 Tanzania: civil aviation sector

The plans stated in the national development objective for the Civil Aviation Sector are as follows. A Tanzania Airports Corporation (TAC) will be formed to own, maintain, operate and manage the nation's international and major airports. The existing DCA, divested of its airport operational and management role, will become streamlined to focus specifically on the monitoring, regulation and licensing of Tanzania's air transport industry, and will ultimately become a Civil Aviation Authority. In the long term, this body may be divided into a largely self-financing National Authority for Civil Aviation (NACA) and the TAC, who's job will be to manage, operate and maintain the major airports which are expected to become financially self-sustaining in the near future[1].

1.3 Today's problems of major airports around the world

One of the factors, that helped globalizing the world by making distances shorter, was and still is the exponential growth of the commercial aviation sector.
With the growth, problems arose for the sector and for the major airports in particular.
Due to the increase of the traffic density, especially at the larger airports, the need for more advanced navigation aids arose. The more planes come to an airport, the better and the more flexible the navigation aids must be to ensure the safest handling of all incoming and departing aircraft.
A major problem, especially for the major airports, is that technological improvement does not go hand-in-hand with actual implementation. One of the prerequisites for applying new technology on international airports is that it has to be standardised and certified by the International Civil Aviation Organisation (ICAO). The ICAO is an international regulating body, which sets up International Standards and Recommendations for every activity in the field of aviation[2]. The ICAO also specifies the signal formats, equipment performance levels and assigned frequencies for aeronautical telecommunication systems at an international level.
An example of this problem was the proposed total replacement of a navigation aid, the Instrument Landing System (ILS), by the technologically more advanced Microwave Landing System (MLS) as an International Standard of the ICAO by the end of this century. According to experts, this will never take place, because the airline companies believe it is too expensive and because the governmental financial support for the research, which

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[1] Thornburn Coquhoun Ltd., *Civil Aviation Sub-Sector Restructuring Study, Inception Report* (Dar es Salaam: December, 1994).

[2] Hop, Pascal, *Information Management Aspects of ATS Route Planning, Now and in the Future* (Eindhoven: October, 1996, pages 12 - 13).

lasted at least ten years, has been stopped. The implementation of MLS is now done in only a few countries.

To be able to cope with the increased traffic density, the Aeronautical Navigation Service has to be organised tightly. The provision of an Aeronautical Navigation Service stands or falls with the flexibility and capacity of the aeronautical telecommunication equipment and the implementation of telecommunication equipment, that is more flexible and have more capacity, stands or falls with the speed of the standardisation.

1.4 Introduction aeronautical telecommunication equipment

Two navigation aids have already been mentioned in the previous paragraph. To show what kind of aeronautical telecommunication equipment is available, a short presentation of the most common and most used aeronautical telecommunication equipment is given. The equipment's use is clarified by showing in which stage of the ANS provision it is used and the reason for its use.

The aeronautical telecommunication equipment can be divided into the following categories:

1. Communication equipment
2. Navigation aid (NAVAID)
3. Surveillance equipment

In figure 1, the general functions of the three types of equipment are shown.

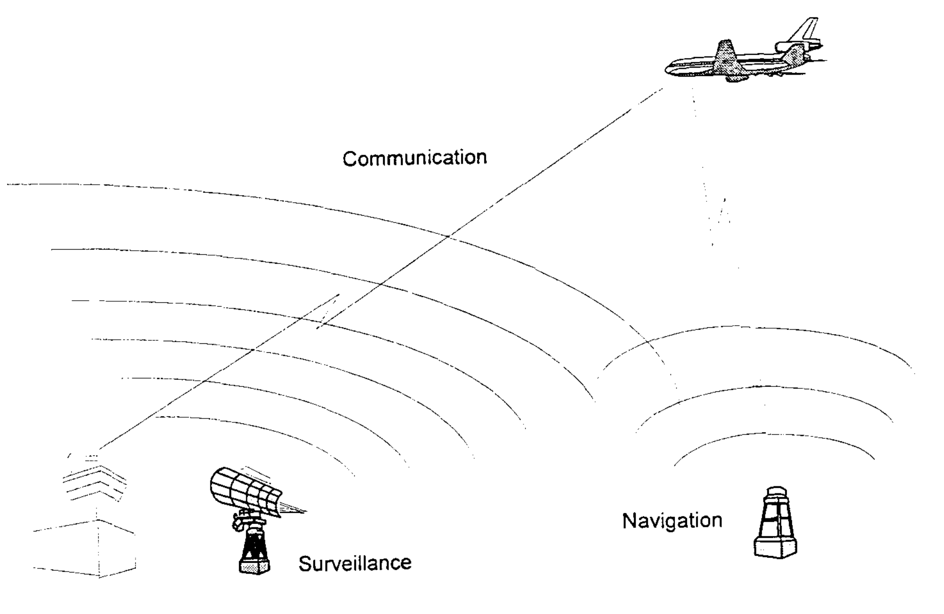

Figure 1: Functions aeronautical telecommunication equipment

Almost every modern aeroplane has a *Communication Radio* (*COM Radio*) on board. With this communication means, a pilot can communicate with a control tower, an approach control, or other planes. He can use it during any stage of the flying. With it, a pilot can gather information about the local weather conditions, the winds, and active runways at an airport or information about the conditions on the route.

For the information mentioned, the pilot can either use the *COM Radio* or a *Navigation Receiver* (*NAV Radio)* and obtain the information from the *Air Terminal Information Service* (*ATIS*) or from a *Flight Service Station* (*FSS*). The messages are recorded and transmitted from these stations to the aircraft.
An *Area Navigation* computer (*RNAV*) on board of a plane can be used to help the automatic pilot of a plane with the steering to an airport of which the co-ordinates have been put into the computer.
The *NAV Radio* can also be used by a pilot to tune to a *VHF Omni-directional Range (VOR)* Station. This ground station broadcasts a bearing with which a pilot can determine its position relative to the beacon. Almost every airport has such a station and there are also en-route ground stations. VOR ground stations are usually co-located with *Distance Measuring Equipment* (*DME*). A pilot can use this equipment to determine the distance to the station.
Position determination can also be done with the help of the *Non-Directional Beacon (NDB)*. The NDB is not a bearing beacon like the VOR, but a homing beacon. A pilot can tell whether he is getting closer to or moving away from the beacon, but he cannot determine his exact position relative to the beacon. To use this beacon, an aircraft has to be equipped with an *Automatic Direction Finder* (*ADF*). These systems are relatively less immune to propagation and atmospheric effects than the *VOR* system. With these two systems, one cannot calculate the distance other than indirectly. For that, one still needs *DME.*
Two systems which can fulfil both direction and distance calculations are the *Instrument Landing System* (*ILS*) and the *Microwave Landing System* (*MLS*). As with the *VOR*, an *ILS* transmits radials from the end of a runway. The radials make a path with their signals in such a way, that a plane can follow that path along a straight line to the beginning of the runway. The difference between *MLS* and *ILS* is that this path can be a parabolic line from either directions. Also *MLS* has more frequency channels, so that *MLS* is more flexible and has more capacity than *ILS*. Although *MLS* is better than *ILS*, it is not likely that it will be used world-wide. This is mainly because it has been technologically overtaken by satellite navigation, of which the *Global Positioning System* (*GPS*) is the most well-known system.
With the aid of four satellites, three for co-ordinates and one for time, *GPS* can give the pilot the exact location of his plane in the air, even with bad weather conditions. Where other systems are more likely to suffer from atmospheric or propagated interference, the satellite system signals will hardly be interfered. For use at international airports though, *GPS* has to be standardised and certified by an international body, in this case the ICAO. At the moment, ICAO is active in standardising the use of satellites in aviation in the next century.
To increase the flight safety, a controller on the ground can use surveillance systems to monitor and separate aircraft in a particular area. The most well-known system is the *Radio Detection and Ranging (Radar)*. The Radar transmits a rotating radio beam, which is reflected by every flying object in the vicinity of the station. Subsequently, the objects are shown as blips on a Radar screen. Each aircraft can transmit on request of the controller an identification code, which can be seen next to the blips with which aircraft can be identified and subsequently separated from each other.
Controllers also make use of communication networks to exchange flight information with controllers in adjacent Air Traffic Control (ATC) centres for the enhancement of flight safety.

In Appendix A, a hypothetical flight of a plane from one airport, via a small airfield to a major airport is portrayed to clarify further the use and functioning of the navigation and communication aids.

1.5 Tanzanian situation

Dutch experts in aeronautical infrastructure, who examined the state of the aeronautical infrastructure at the two international airports of Dar es Salaam and Kilimanjaro in Tanzania, showed that the major problems which DCA was facing were a lack of a proper maintenance system for the infrastructure and facilities at several airports, which as a result deteriorated[3],

[3] Poortvliet, van, Peter, *Civil Aviation in Tanzania Volume I* (Eindhoven: August, 1995, page 44).

and a lack of a proper information management system[4]. Solving these problems would improve the state of the Tanzanian airfields considerably, to begin with.

Within DCA, the Aeronautical Navigation Service organisation is responsible for the installation, control, maintenance and planning of all the aeronautical telecommunication equipment in Tanzania. The department can be compared with the Luchtverkeersbeveiliging (LVB) in The Netherlands.

During the research on the first of June 1996, the Directorate of Civil Aviation (DCA) made the transition from a fully governmental organisation to an autonomous agency of the government. This has meant changes particularly in responsibilities for the various departments. Besides that DCA has to become cost conscious, because the government does not finance DCA anymore. All costs made by DCA have to be paid with revenues received by DCA and the Department of Aerodromes. There is also an urgency for fund collecting activities.
After the financial year of 1993/1994, DCA already had gained financial control. The result was that the revenues nearly doubled in the new financial year. See table 1.

Revenues	Amount (Tsh.)
1993/1994	1,748,506,593
1994/1995	3,058,935,308

Table 1: Revenues financial years of 1993/1994 and 1994/1995

With the increased income, some rehabilitation and replacements of equipment and infrastructure could take place, like the implementation of full VHF Area cover and the purchase of a new Doppler-VOR and a new DME system for Kilimanjaro International Airport (KIA).
Besides financial control, DCA also hopes to get full freedom to form their own operational policy without interference from the Ministry of Communication and Transport. In advance, the middle and higher management of DCA has organised trips to airports and airfields in the country to make an inventory of all the problems and to listen to what the people on the work floor have to say about the fulfilment of their jobs.

1.6 Research goal

To present the Directorate of Civil Aviation of Tanzania with recommendations for the solving of the problems faced by the Aeronautical Navigation Service organisation and possible technological trajectories with respect to the enhancement of the present state of the Aeronautical Fixed Telecommunication Network and the organisation in which it is used.

2. RESEARCH QUESTIONS

From the general goal, defined in the previous paragraph, the research questions can be derived. These research questions have been formulated on basis of my professional background as an engineer in the field of computer communication and on request of DCA to perform a research to the problems encountered by their Aeronautical Navigation Service organisation.

2.1 Main research questions and sub-questions

Because of my professional background as an engineer in the field of computer communication, the first objective for the research was to get acquainted with the equipment

[4] Hop, Pascal, *Information Management Aspects of ATS Route Planning, Now and in the Future* (Eindhoven: October, 1996, page 61).

used for the provision of an Aeronautical Navigation Service which is expressed by the first research question.

1. ***Which aeronautical telecommunication equipment is presently used in air space control, how is this equipment used, maintained and how is it organised?***

1.1 *Which navigation aids are used and how are they used?*
(Non Directional Beacon; VHF Omni Range equipment; Distance Measuring Equipment; Instrument Landing System; Micro-wave Landing System; Global Positioning System; other navigation equipment)

1.2 *Which communication equipment is used and how is it used?*
(High Frequency radio; Very High Frequency radio; Aeronautical Fixed Telecommunication Network; Air Traffic Service/Direct Speech telephone network; public telephone network; micro-wave radio; satellite voice communication network; satellite data communication network; other communication equipment)

1.3 *Which surveillance equipment is used and how is it used?*
(Primary Surveillance Radar equipment; Secondary Surveillance Radar equipment; other surveillance equipment)

1.4 *How is the maintenance of the aeronautical telecommunication equipment organised?*

1.4.1 *How is the maintenance team organised?*

1.4.2 *Is there a maintenance plan and if so how does it look like?*

1.4.3 *How does the level of maintenance of the aeronautical telecommunication equipment affect the functioning of aeronautical telecommunication equipment?*

1.4.4 *How does the level of the maintenance of the surroundings of the aeronautical telecommunication equipment affect the functioning of the aeronautical telecommunication equipment?*

1.4.4.1 *Does the lack of maintenance of the buildings in which the aeronautical telecommunication equipment is located, influence the functioning of the aeronautical telecommunication equipment?*

1.4.4.2 *Does the lack of maintenance of all other external aspects, necessary for the functioning of the equipment, influence the functioning of the aeronautical telecommunication equipment? (fence)*

1.4.5 *How does the functioning of auxiliary equipment influence the functioning of the aeronautical telecommunication equipment?*

1.4.5.1 *Does the lack of maintenance or lack of presence of air-conditioning influence the functioning of the aeronautical telecommunication equipment?*

1.4.5.2 *Does the level of quality and quantity of the energy supply influence the functioning of the aeronautical telecommunication equipment?*

1.4.5.3 *Does the functioning of auxiliary equipment other than mentioned above influence the functioning of the aeronautical telecommunication equipment?*

1.5 *How is the aeronautical telecommunication equipment monitored and how is this organised?*

1.6 *How is the Air Traffic Control organised?*

1.7 *How is the Communication Section organised?*

2. ***Which factors determine the level of quality of the provided Aeronautical Navigation Service?***

2.1 *Which factors determine the level of quality of the Aeronautical Navigation Service provided by navigation aids?*

2.1.1 *Which factors influence the functioning of the navigation aids?*

2.2 *Which factors determine the level of quality of the Aeronautical Navigation Service provided by communication equipment?*

2.2.1 *Which factors influence the functioning of the communication equipment?*

2.3 *Which factors determine the level of quality of the Aeronautical Navigation Service provided by surveillance equipment?*
2.3.1 *Which factors influence the functioning of the surveillance equipment?*
2.4 *Which factors determine the level of quality of the human resources who provide the Aeronautical Navigation Service within the Aeronautical Navigation organisation?*

3. *How is the Aeronautical Navigation Service organised in Tanzania and which problems are presently encountered with the provision of the Aeronautical Navigation Service in Tanzania?*

3.1 *Which aeronautical telecommunication equipment is used for the provision of the Aeronautical Navigation Service?*
3.2 *How is the aeronautical telecommunication equipment used and maintained and how is this organised?*
3.3 *What is the present level of the quality of the provided Aeronautical Navigation Service?*
3.4 *Which factors have influenced the present level of the provided Aeronautical Navigation Service negatively?*
3.4.1 *What are the reasons for the presence of these factors?*
3.5 *Which actions have to be undertaken to solve the problems as best as possible?*

4. *What are the prerequisites and necessary actions to enhance in the best way the present provision of the Aeronautical Fixed Service by means of the Aeronautical Fixed Telecommunication Network in Tanzania?*

4.1 *What are the present problems with the provision of the Aeronautical Navigation Service by means of the Aeronautical Fixed Telecommunication Network?*
4.2 *What are the prerequisites for the best possible provision of an Aeronautical Fixed Service by means of the Aeronautical Fixed Telecommunication Network?*
4.3 *Which actions have to be undertaken to fulfil the prerequisites as best as possible?*

3. METHODOLOGY

For each of the research questions, a methodology is presented to answer the questions.

Question 1
Because my professional background as an engineer in the field of computer communication differs from the field of aviation, a preliminary research was necessary to get acquainted with the telecommunication equipment used in that field as well as with the organisation responsible for the use and maintenance of the equipment. For this, literature surveys have been conducted in The Netherlands and in Tanzania. Also interviews have been held with various experts in the field of aeronautical telecommunication equipment, working for the Dutch company Luchtverkeersbeveiliging (Air Traffic Safety) and with engineers of DCA. The first visits to the sites of the various equipment in Tanzania are considered to be a part of the preliminary research, as they made clear the reasons for the use of the equipment and how they were used.

Question 2
To answer research question number two, a literature survey was conducted and several interviews were held with experts in the field of aeronautical telecommunication equipment.
The literature survey focused on the annexes of the International Civil Aviation Organisation (ICAO), because in these annexes all aspects in the field of Civil Aviation have been defined. This includes the definition of the Aeronautical Telecommunication Service (ATS). This is the technological term for the Aeronautical Navigation Service (ANS). This will be explained more profoundly in part two.
To describe the organisation, the aeronautical telecommunication equipment has been taken as a starting point. After that, all elements and aspects within and outside the organisation have been examined to find out what their relation is to the aeronautical

telecommunication equipment and their influence on the functioning of the equipment. Based on this method, a model has been made, which describes all the relevant elements.

The problems, encountered by the ANS organisation, are shown in a problem tree, which shows the relations between problems in various problem areas. With the tree, it is shown that there are two types of relations between problems possible. A problem has of course a direct cause. They are responsible for the level of quality of the provided ATS. The direct cause can have an underlying problem, which has its own cause. The root causes of problems have been examined in various problem areas.
Beside the direct cause, there can also be the situation where a problem is not solved, but due to circumstances it is prolonged. The causes for the prolongation of problems are examined, because they have also an effect on the level of the provided ATS.

Question 3
To describe the Aeronautical Navigation Service organisation in Tanzania, the model described in part two is used. The model of part two gives a general view on the functioning of the ANS organisation and the factors, which characterise the functioning of the ANS organisation. In part three, factors in the Tanzanian environment are described, which characterise the functioning of the ANS department of the Directorate of Civil Aviation (DCA) in Tanzania.

To gather the data in order to answer this research question, unstructured and structured observations have been made at various airports in Tanzania. Of these airports, Dar es Salaam International Airport (DIA) has enjoyed the most interest, because this airport contains the central control of the entire Tanzanian air space as well as the central control of all communication means. Also, unstructured interviews have been held with Air Traffic Control Officers, Communication Officers, Maintenance Engineers and Technicians working for DCA and engineers of the Electrical section working for the Directorate of Aerodromes to get an idea of the exact functioning of all the used aeronautical telecommunication equipment and auxiliary equipment. In order to mainly get an idea of the level of knowledge of all above mentioned employees of DCA, also semi-structured interviews have been held in the form of questionnaires. These questionnaires have been handed out at the airports, which were visited during the research.

Question 4
To be able to answer research question number four, the methodology of a technology audit has been chosen. With the technology audit, a methodology is defined with which step by step the shortcomings of a telecommunication service and subsequently of the telecommunication infrastructure are examined. The methodology is used to examine the Aeronautical Fixed Service (AFS) provision via the Aeronautical Fixed Telecommunication Network (AFTN) in Tanzania. To come to a model for the technology audit, literature in this matter has been read.
The used model has been derived from the technology audit methodology for finding the most promising manufacturing sector in a country, the most promising product and the most eminent shortcomings of this product by comparing it with the product of a local or an international market leader.[5] The methodology also includes the examining of the production processes of both the manufacturer at hand and the market leader.
The technology audit also includes the examining of relevant literature, which has also been done to work out the methodology.
For information about the way the AFTN in Tanzania is organised, interviews with responsible people of the Communication section within DCA have been held and observations have been made.

[5] Lapperre,P.E., van der Ploeg, J., *Technology audit methodology for medium and small enterprises* (Eindhoven, The Netherlands: second draft August 1996).

4. STRUCTURE OF THE REPORT

Part II

Part II deals with the first two research questions. The Aeronautical Navigation Service (ANS) organisation is described with the aeronautical telecommunication equipment as the core of the organisation. A description follows with respect to the auxiliary equipment and other infrastructure means, which are necessary for the proper functioning of the aeronautical telecommunication equipment. Subsequently, part II describes the way the equipment is used and by whom. Also the way the equipment is maintained and by whom is described. Part II ends with a description of the aspects which lie outside the ANS organisation, but which influence the functioning of the organisation or the aeronautical telecommunication equipment.

With all descriptions of the relevant elements, quality factors are defined which characterise the functioning of the elements with respect to the ANS organsiation in general and the aeronautical telecommunication equipment in particular.

Part III

Based on the description in part II, the ANS organisation in Tanzania is described.
From the description of the organisation and the known factors which influence the functioning of the aeronautical telecommunication equipment and the people who use and maintain it, the problems which are encountered by the Tanzanian ANS organisation are derived.
Based on the descriptions of the organisation and the problems, conclusions are drawn on which recommendations for improvement are based.

Part IV

This part deals with the technology audit of the Aeronautical Fixed Service (AFS) via the Aeronautical Fixed Telecommunication Network (AFTN) in Tanzania. It describes the step by step approach of finding the shortcomings of the AFS as well as those of the AFTN. It also gives indications for identifying the root causes of the shortcomings by looking at the organisational and environmental aspects of the AFS provider.

PART II AERONAUTICAL NAVIGATION SERVICE ORGANISATION

Part II describes all the elements which are either parts of the Aeronautical Navigation Service organisation or are aspects which influence the functioning of the ANS organisation. With each element, quality factors are defined which characterise the functioning of the element with respect to the ANS organisation. Before the elements are described, the Aeronautical Telecommunication Service (ATS) is described in chapter 5, since it is the service the ANS organisation provides. The most important element of the ANS organisation is the aeronautical telecommunication equipment. Chapter 6 describes the most used types of equipment with emphasis on equipment used in the Tanzanian environment. The other chapters describe elements which support or influence the aeronautical telecommunication equipment. Chapter 7 describes the auxiliary infrastructure, chapter 8 the maintenance of the aeronautical telecommunication equipment and chapter 9 the relevant human resources who use or maintain the equipment. Finally, chapter 10 describes external aspects which cannot be controlled or can be controlled with difficulty by the ANS organisation.

PART II AERONAUTICAL NAVIGATION SERVICE ORGANISATION

Within most of the Civil Aviation Authority (CAA) or Directorate of Civil Aviation, the department which is responsible for the provision of an Air Traffic Service is the Aeronautical Navigation Service (ANS) organisation. Examples of ANS organisations are the Luchtverkeersbeveiliging (LVB) in The Netherlands, the National Air Traffic Service (NATS) in the United Kingdom and the ANS department of the Directorate of Civil Aviation (DCA) in Tanzania.

Air Traffic Service is a generic term, meaning a service on the organisational level for the purpose of maintaining flight safety and orderly flow of air traffic. The ANS organisation is the organisation, that provides the Air Traffic Service by means of aeronautical telecommunication facilities. The control and maintenance of these facilities is the provision of an Aeronautical Telecommunication Service (ATS).

The provided ATS should be of sufficient level for the achievement and maintenance of the highest possible level of air navigation safety. The organisation works in a certain way to be able to provide the ATS of a certain quality level. Factors influencing the ANS organisation influence also the way the ATS is provided by the organisation and through that the level of the quality of the provided ATS.

An ANS organisation consists of various parts or sections, which each have their contribution in the ATS provision. Therefore, factors influencing these parts or sections influence also the level of quality of their contribution to the provided ATS.

Figure 2 shows all the elements that are involved in the ATS provision by the ANS organisation.

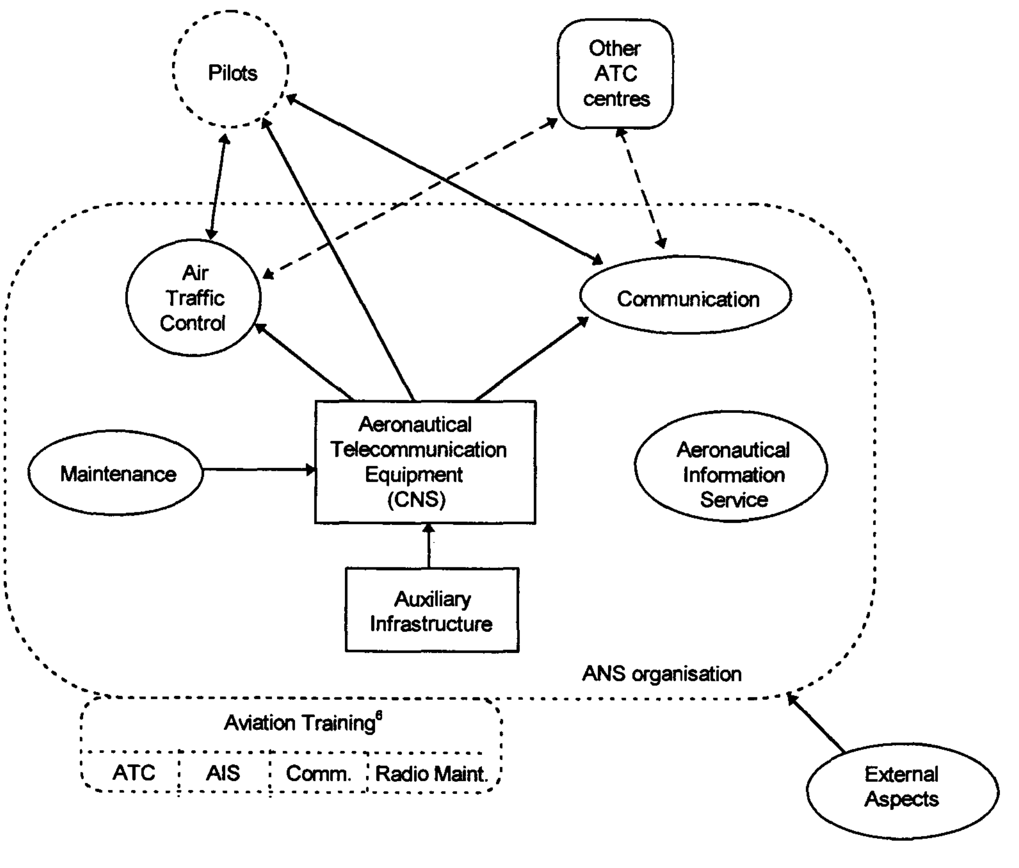

Figure 2: Elements Aeronautical Navigation Service organisation

[6] Comm. = Communication section, Radio Maint. = Radio Maintenance section

It should be noted, that a circle or ellipse indicates a section within the organisation and the square indicates equipment or any other kind of infrastructure.

With respect to the ATS providers, i.e. the ATC section, the Communication section and the Aeronautical telecommunication equipment, and recipients, i.e. the pilots and other ATC centres, the interrupted lines represent ground-ground interaction and the straight lines represent air-ground interaction.

Part two deals with all the elements shown in the figure, except for the *Aeronautical Information Service (AIS) section*, the *Pilots* and the *Other ATC centres*.
The AIS section is only mentioned, because it is not an executor of the ATS provision and has no influence on the actual ATS provision. Where necessary, its role within the organisation is described.
The icons of *Pilots* and *Other ATC centres* are merely shown for their positions with respect to the ANS organisation.

5. AERONAUTICAL TELECOMMUNICATION SERVICE (ATS)

An Aeronautical Telecommunication Service (ATS) can be called an International Telecommunication Service, when the service is provided to aircraft and/or aeronautical stations which are not in the same State as the State in which the service is provided.[7] For example, boundaries of the Flight Information Region (FIR) can coincide with the boundaries of countries. Communication by Area Control located in one country with aircraft flying in another country, but which are bound to cross the border between the two countries makes the ATS international.

The international ATS is divided into four parts:[8]

1. Aeronautical Fixed Service (AFS)
2. Aeronautical Mobile Service (AMS)
3. Aeronautical Radio Navigation Service (ARNS)
4. Aeronautical Broadcasting Service (ABS)

All types of services involve the use of aeronautical telecommunication equipment in some kind of way. To understand what kind of equipment is used for which service, all four services are described below together with one or more examples of aeronautical telecommunication equipment. A full overview of aeronautical telecommunication equipment and its use for a service is shown in table 2 of chapter 6.

Aeronautical Fixed Service (AFS) A telecommunication service between specified fixed points provided primarily for the safety of air navigation and for the regular, efficient and economical operation of air services.[9]
An example of AFS is the Aeronautical Fixed Telecommunication Network (AFTN), which is a world-wide telecommunications network to exchange messages like flight bulletins or updates of airport status.

Aeronautical Mobile Service (AMS) A mobile service between aeronautical stations and aircraft stations and between aircraft stations, in which survival craft stations may participate.[10]

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[7] International Civil Aviation Organisation, *Annex 10: Aeronautical Telecommunications - Volume II: Communication Procedures* (Montreal, Canada: July, 1995, page 2).
[8] International Civil Aviation Organisation, *Annex 10: Aeronautical Telecommunications - Volume II: Communication Procedures* (Montreal, Canada: July, 1995, page 6).
[9] International Civil Aviation Organisation, *Annex 10: Aeronautical Telecommunications - Volume II: Communication Procedures* (Montreal, Canada: July, 1995, page 1).
[10] International Civil Aviation Organisation, *Annex 10: Aeronautical Telecommunications - Volume II: Communication Procedures* (Montreal, Canada: July, 1995, page 1).

An example of AMS is the communication between an approach controller and the pilot of an aircraft, who is approaching an airport. The controller provides the pilot information about the runway and the up-to-date weather conditions. The equipment used with this service are all radio communication equipment.

Note: surveillance equipment like radar is used by controllers as an aid to get information about the positions of aircraft in airspace. Radio communication is used to instruct pilots of aircraft about their position in order to separate the aircraft for flight safety purposes. Therefore, surveillance equipment is considered to be part of the AMS provision.

Aeronautical Radio Navigation Service (ARNS) A radio navigation service intended for the benefit and for the safe operation of aircraft. With this service is meant, the provision of radio facilities with which aircraft can determine their position, velocity and other characteristics for the purpose of navigation.[11]
The aeronautical telecommunication equipment provided for this service are the NAVAIDs. Examples of ARNS are the provision of a VOR with which an aircraft can determine its relative position to the beacon and its route in the airspace and the provision of a DME with which an aircraft can determine its distance to the beacon.

Aeronautical Broadcasting Service (ABS) A broadcasting service intended for the transmission of information relating to air navigation.[12]
The information applies to up-to-date status reports of the weather and the situation on airports dealing with the facilities and the runway. An example of a system which is specially designed for this kind of information is the Automatic Terminal Information System (ATIS). It has its own frequency on which it broadcasts the pre-recorded information. The ATIS relieves a controller from some of his AMS duties, which is particularly useful in areas with a high traffic density.

This investigation deals with the first three types of services, since they are categorised by ICAO into Communication, Navigation and Surveillance (CNS) services, like it is indicated for example in ICAO's CNS/ATM Implementation Plan for the African - Indian Ocean region.[13] These services are provided by the corresponding types of equipment, as described in the examples. Where appropriate, the ABS provision and the equipment used for this type of service are described in general terms.

5.1 ANS organisation and the problems with ATS provision

As described before, the main objective of the ANS organisation is the provision of an Aeronautical Telecommunication Service (ATS) of a best possible level. The actors, which provide this ATS directly, are the ATC section, the Communication section and the aeronautical telecommunication equipment as shown in figure 2. Both sections make use of the aeronautical telecommunication equipment to provide the ATS directly.
The factors that characterise the performances of the sections and the equipment, may influence the level of the provided ATS. The factors are not only those belonging to the sections and equipment, but also those, which belong to the other sections, to the infrastructure and to external influences also shown in figure 2.
In case the factors are influenced or affected in a negative way, the way the ATS is provided is or may be affected negatively. This means that the ANS organisation has problems with the proper ATS provision. In other words, the problems have either a direct influence on the decrease of the ATS level or have a direct influence on the probability of a decrease of the ATS level.

[11] International Civil Aviation Organisation, *Annex 10: Aeronautical Telecommunications - Volume II: Communication Procedures* (Montreal, Canada: July, 1995, page 2).
[12] International Civil Aviation Organisation, *Annex 10: Aeronautical Telecommunications - Volume II: Communication Procedures* (Montreal, Canada: July, 1995, page 1).
[13] International Civil Aviation Organisation, *Doc. 003: CNS/ATM Implementation Plan - AFI Region* (Montreal, Canada: November 20th, 1995, appendix B to section III).

It means that the direct providers of the aeronautical telecommunication equipment are not able to provide parts of the ATS or provide parts of the ATS badly, which means not according to what is required. The probability of a decrease of the ATS level is brought about by the possible inability to provide an ATS and the possible further decrease in the bad provision of the ATS. The latter means that an insufficient provision of the ATS is likely to worsen further.

The cause of a problem that appears on the surface can have an underlying problem within the same or another problem area. The cause of this problem can have an underlying problem with its own cause and so forth. Every problem is examined for its cause, until the root cause has been found.

Furthermore, a distinction has to be made between the cause of a problem and the cause of the prolongation of the problem. The prolongation is a characteristic of the problem.
The direct cause of a problem is for example equipment that breaks down, due to a high voltage peak. The unserviceability (problem) is imputed fully to the high voltage peak (direct cause).
The prolongation of the problem is when a problem has occurred and action is not taken to solve it. The problem is prolonged due to a cause, that does not allow the action to be taken. For example, the equipment from the previous type of reason has become unserviceable (problem with direct cause), but it remains unserviceable because it was not replaced (cause of prolongation).

The example of the two above mentioned type of causes is shown in figure 3. The problem at the far left has a direct cause and a cause for the prolongation at the right. The relation between a problem and its direct cause is presented by an uninterrupted line and the relation between a problem and the cause of prolongation of the problem is presented by an interrupted line.

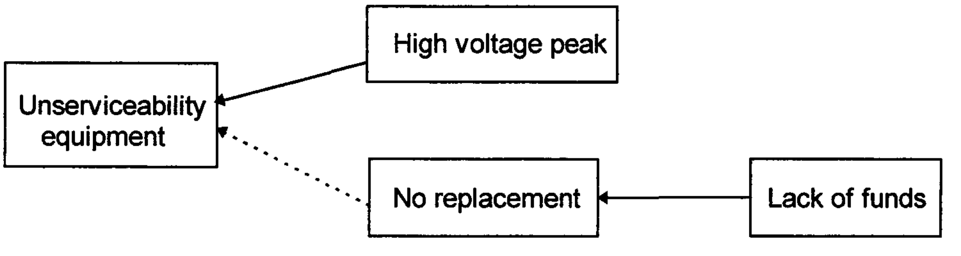
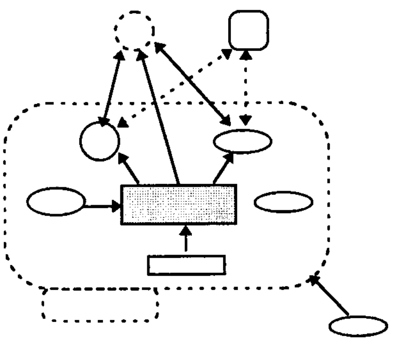


Figure 3: Example direct cause and prolongation

It should be noted that the scheme is not a time scale. The problem at first occurred, because of the high voltage peak, which is an occurrence at one moment in time. The problem is prolonged in time after the occurrence, because it is not replaced. It applies, however, to the same equipment.

When all the problems and all the relations between the problems and the causes have been identified, a problem tree can be made to have a full description of the problems, an ANS organisation is faced with.

6. AERONAUTICAL TELECOMMUNICATION EQUIPMENT



From figure 2, it is clear that the aeronautical telecommunication equipment is the core of the ANS organisation and that it is essential to provide the ATS. The equipment is used by the Air Traffic Control and Communication sections of the ANS organisation to provide their parts of the ATS. The pilots also make use of the part of ATS, which is provided directly by the equipment.
The aeronautical telecommunication equipment is supported by two elements. The maintenance section of the ANS organisation ensures the continuous and proper ATS provision by installing and maintaining the equipment. The auxiliary infrastructure supports the equipment, because it is constructed to ensure the continuous and proper functioning of the equipment.

Three types of aeronautical telecommunication equipment can be distinguished in aviation, according to the service they provide. The three categories are Communication, Navigation and Surveillance or CNS.
Table 2 shows all types of *aeronautical telecommunication equipment*. All equipment is a type of radio equipment, except for the first three communication systems which are fixed telecommunication networks. The networks are subsequently divided into a data network (AFTN) and a speech network (ATS/DS[14] and public telephone). In the second column, the *general application* of each piece of equipment or network is mentioned. The following column mentions the type of ATS *service* is provided by the use of the equipment. The column *components* mentions either the components of a system or a network or all possible applications of a system. For example, VHF radio can consist of a single transmitter and a single receiver or of a single transceiver which comprises both the transmitter and receiver. The division of a system into the different applications is done to be able to describe the *function* of each component clearly in the following column.
The last column contains the *major quality factors* that characterise the performance of the equipment. The factors consist of aspects, which can be influenced negatively. In that case, it has a negative influence on the ATS provision. The factors are described more profoundly in section 6.1.

With the description of all types of equipment, the emphasis is on equipment used in the Tanzanian environment.

Communication equipment	General application	Service	Components	Functions	Major quality factors
AFTN (data-network)	GG-COM[15] with other ATC centres	AFS	AFTN terminal[16]	relaying of messages	• continuity • transit-time
			AFTN-link	conveying of messages	• continuity • transit-time
ATS/DS (speech-network)	GG-COM with other ATC centres	AFS	ATS/DS telephone	speech terminal	• continuity
			ATS/DS-link	conveying of messages	• continuity
public telephone (speech-network)	GG-COM with other ATC centres	AFS back-up[17]	public telephone	speech terminal	• continuity
			public telephone link	conveying of messages	• continuity

[14] ATS in this case is Air Traffic Service and Aeronautical telecommunication Service
[15] GG-COM = ground-ground communication
[16] AFTN terminal can be either one message switching terminal or several transmitting and receiving terminals, where the relaying is done manually.
[17] The public telephone network as ATS/DS back-up is only used in some countries.

HF Radio	AG-COM[18] with pilots & GG-COM with other ATC centres	AMS & AFS	transmitter	transmits speech to aircraft or ground station	• continuity
			receiver	receives speech from aircraft or ground station	• continuity
			transceiver	transmits and receives speech from and to aircraft or ground station	• continuity
VHF Radio	AG-COM with pilots	AMS	transmitter	transmits speech to aircraft	• continuity
			receiver transceiver	receives speech from aircraft transmits and receives speech from and to aircraft	• continuity • continuity
Navigation aids	**General application**	**Service**	**Components**	**Functions**	**Major quality factors**
ILS	precision landing aid	ARNS	localizer glide path markers	transmits signal for horizontal position determination transmits signal for vertical slope position determination transmit upward signals for distance from threshold indication	• continuity • integrity • continuity • integrity • continuity • integrity
MLS	precision landing aid	ARNS	azimuth station (possible back azimuth station)	transmits signal for horizontal position determination	• continuity • integrity
			elevation station	transmits signal for vertical slope position determination	• continuity • integrity
			precision DME	DME is mentioned below more profoundly	• continuity • integrity
VOR	en-route and approach bearing beacon	ARNS	transmitter beacon	broadcasts signal for course determination aircraft.	• continuity • integrity
DME	en-route, approach and landing distance measuring station	ARNS	pulse receiver	receives identification pulses from aircraft	• continuity
			pulse transmitter	broadcasts identification pulses	• continuity • integrity
NDB	en-route and approach homing beacon	ARNS	transmitter beacon	broadcasts signal for determination of relative position aircraft	• continuity • integrity
GPS	precision en-route, approach and landing navigation	ARNS	Control and monitoring station	update navigation message and clock and monitor satellite transmissions	• continuity • integrity
			satellite transmitters	transmit its orbital co-ordinates	• continuity • integrity
			ground navigation equipment (only precision approach)	transmits co-ordinates of location	• continuity • integrity
Surveillance equipment	**General application**	**Service**	**Components**	**Functions**	**Major quality factors**
Primary Radar	detection of flying objects	ABS	transmitter	transmitting signal beam	• continuity • integrity
			receiver	receiving reflected signals	• continuity • integrity
			radar screen	showing objects within range Radar	• continuity • integrity
Secondary Radar	identification of flying objects	ABS	transmitter	broadcasts pulse to all aircraft within range Radar	• continuity • integrity
			receiver radar screen	receives identification and flight information aircraft showing identification and flight information of aircraft within range Radar	• continuity • integrity • continuity • integrity

Table 2: Aeronautical telecommunication equipment

Elaborate descriptions of the application, components and the functions of components of all the aeronautical telecommunication equipment can be found in appendix B.

6.1 Factors characterising the proper functioning of the ATS equipment

Every equipment has factors, that characterise the performance of the equipment. For each factor, aspects are examined which can influence these factors in a negative way.

[18] AG-COM = air-ground communication

Each category of aeronautical telecommunication equipment has the following factors as is shown in table 3.

Communication equipment		Navigation	Surveillance
speech	data	aid	equipment
Continuity	Continuity Transit-time	Continuity Integrity	Continuity Integrity

Table 3: Quality factors aeronautical telecommunication equipment

Since the emphasis with the aeronautical telecommunication equipment is on equipment used in the Tanzanian environment, the factors with respect to the AFTN are concerned with the low-speed AFTN used in Tanzania. The low speed AFTN makes use of teletypewriter circuits and the relaying of messages is done manually. Performance factors concerned with other types of AFTN are described and discussed more profoundly in part 4.

The factors continuity and integrity have been defined by ICAO for the Instrument Landing System (ILS) in Annex 10 which deals with aeronautical telecommunications.
Continuity is used for all aeronautical telecommunication equipment, since the ATS has to be provided continuously.
Integrity is used for NAVAIDs and surveillance systems of which the recipients are respectively pilots or radar controllers. One cannot speak of integrity for communication equipment, since the correctness of the information depends on human input and not on the equipment. The nature of the information transferred through communication equipment is constantly different, whereas the nature of the information of NAVAIDs and surveillance equipment stays the same. Section B.2.2 of Appendix B, dealing with aeronautical telecommunication equipment, goes deeper into the type of monitor systems and their functions.
The *transit time* applies only to data messages of the AFTN network. It is of most concern for the users of the network and can, therefore, be regarded as a performance factor of the AFTN. Because this factor is different from the other factors and is concerned with the AFTN only, this factor is discussed separately in section 6.1.3.

6.1.1 Continuity of the service

For the *Continuity Of The Service*, the ICAO defines the following for the ILS-system:

That quality which relates to the rarity of radiated signal interruptions[19].

The ILS, like any other NAVAID, has to radiate a signal continuously, so that pilots can rely on the fact that they can use the NAVAID at all times. This statement also applies to surveillance systems, used by Radar controllers, and to communication equipment, used by Communication and Air Traffic Control (ATC) Officers. Radar controllers should be able to rely on the fact that they can determine the position of an aircraft at all times and Communication and ATC Officers should be able to send a message at any required time, whether they use radio or fixed communication.

It is, therefore, important to know which aspects have an influence on the continuity of service.
The aspects are:
- reliability
- powering of equipment
- external aspects

19 International Civil Aviation Organisation, *Annex 10: Aeronautical Telecommunications - Volume I: Communication Systems* (Montreal Canada: fourth edition 1985, page 7).

Reliability

For a continuous service provision by equipment, the equipment should be reliable. The state which the equipment is in, has an influence on the reliability of the equipment and through that the reliability of the signals or messages. An indicator for the state of equipment is the availability. An indicator for the state of radio equipment is the range of the transmitted signal.

The availability of equipment during a time period indicates whether equipment has been unserviceable and the time period it has been unserviceable. The more time it is unserviceable, the less reliable the equipment is. With telecommunication networks, the availability also applies to the telecommunication links.

An indicator for unserviceability and deterioration of equipment is the age of equipment. When the unserviceability of an aeronautical telecommunication equipment or the range of a NAVAID has decreased and the age of the equipment is near or passed its technical life, it is very likely that the age is the reason for the unserviceability or deterioration. A possible consequence of deterioration is distortion of a signal in such a way that the conveyed information is useless. Decreased range of radio equipment also indicates possible deterioration of equipment. The range is expressed in Nautical Miles (NM).

In some countries, the reliability of the equipment is such that extra measures are helpful to enhance it. Such a measure is the duplication of a system. This means that a standby system takes over from the primary system in case that system breaks down or has to be shut down a considerable time for any reason. Although it is a measure of the reliability, it is not mandatory and it does not say anything about the ATS level in general.

Powering of equipment

Continuity of radiating or receiving aeronautical information means continuous and reliable powering of the aeronautical telecommunication equipment. Important aspects here are the means of powering, the safety measures taken in case the main power supply fails and the reliability of powering. Since power supply is an important auxiliary equipment for aeronautical telecommunication equipment, it is described more elaborately in section 7.1.

External aspects

External aspects with respect to continuity of service are environmental conditions, which can have an influence on the functioning of the equipment.

The state in which air-conditioning, buildings or cabins for the equipment, wires and cables and the security of the site are in and kept determine the level of protection for the equipment from environmental dangers. These can be extreme heat, flooding, high-voltage peaks and trespassers.

Also, the direct and indirect influence of other organisations on the functioning of equipment should be taken into account. Reliability of outside services, necessary for the eventual proper ATS provision, are important aspects. Because the services are provided by other organisations, they cannot be controlled or can be controlled with difficulty. Examples are reliability of power supply or reliability of hired telephone lines.

All the above mentioned aspects are described more profoundly in chapter 7, which deals with all the auxiliary infrastructure, and in chapter 10, which deals with external aspects.

The before mentioned aspects of the quality factors can be examined for each piece of aeronautical telecommunication equipment. There are, however, more aspects which influence the continuity of service, but can only be examined in a general perspective. These aspects are the way equipment is maintained and the way it is controlled.

Maintenance consists of preventive and corrective maintenance. Preventive maintenance is done to prevent equipment to become unserviceable and to maintain the continuity of service. Corrective maintenance is done to get faulty equipment serviceable as fast as possible and to restore the continuity of service as fast as possible. This implies proper management, sufficient maintenance facilities, sufficient and professional maintenance engineers and technicians other relevant maintenance aspects. The absence or bad state of these aspects can influence the continuity of the service negatively.

The maintenance aspects are dealt with in chapter 8.

Control of equipment by sections within the ANS organisation is done by the ATC and Communication sections. For continuity of service, sufficient, professional staff should be present. When there is insufficient staff, the service cannot be provided at the time it is needed. The staff should be professional, which means it should have knowledge and skills to be able to provide the service.
These aspects are dealt with in chapter 9.

6.1.2 Integrity of the service

For the *Integrity Of The Service*, the ICAO has defined the following for the ILS-system:

That quality which relates to the trust which can be placed in the correctness of the information supplied by the facility[20].

A pilot should be able to trust the received navigation information at all times to navigate safely through airspace and a radar controller should be able to trust the displayed aircraft position information on the radar screen at all times to separate aircraft in a safe manner.
In other words, the information should be accurate and it should be accurate at all times.

Therefore, two major aspects play a role with integrity of the information. These are:
- accuracy
- monitoring systems

Accuracy
Accuracy is the maximum permitted physical displacement or tolerance of a signal, while still yielding the same information for the recipient.
Therefore, to have the radiated signal of the equipment within tolerances, the equipment has to be calibrated first with installation. After installation and adjustment, regular calibration is necessary to maintain the signal between the tolerances and to maintain the accuracy of the facility.
Beside system measures, which calibration is, measures outside the system should be taken to minimise possible outside influences. These influences can be interference from other radiating equipment like radio stations and from its own signals, reflected by big objects in the vicinity of the facility. Both types of interference causes the signal to loose its accuracy. Also, extreme heat can cause the signal to drift out of tolerance. So, measures taken to prevent the signal from drifting have to be examined for their presence and state.

Monitoring systems
Calibration is a method to adjust the accuracy of equipment, but monitor systems are there to monitor the accuracy and through that the integrity of a system. Because the information should be correct at all times and the trust in the information should be present at all times, one or more monitor systems watch the equipment at the output and/or other critical points within the equipment constantly. The trust in information, radiated by an equipment, depends on the degree the signal is monitored. Thus, important is the presence of one or more monitor systems and the functioning of the monitor systems.

6.1.3 Transit-time low speed AFTN

The transit-time is defined by ICAO as *the elapsed time between instant of filing of a message with an AFTN station for transmission on the network and the instant that it is made available to the addressee.*[21]

[20] International Civil Aviation Organisation, *Annex 10: Aeronautical Telecommunications - Volume I: Communication Systems* (Montreal Canada: fourth edition 1985, page 7).

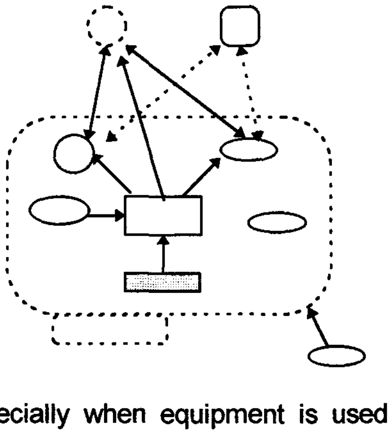
[21] International Civil Aviation Organisation, *Doc. 8259 - AN/936: Manual on the planning and engineering of the Aeronautical Fixed Telecommunication Network* (Montreal Canada: 5th edition, 1991, page 49).

Consider the example of a message send from an AFTN station to another AFTN station via an AFTN centre. This example indicates the three types of relay stations; the station where the message is filed and put on the network, the station which routes the message to the destination station and the destination station itself. The transit time here consists of all the relay times at the three stations, which makes the relay time the important aspect to be examined.

Relay time
The relay times of all the type of stations consist of the handling times at the stations, the transmission times on the links and the congestion delays, which occur at the stations.
The handling time is the time an operator needs to put a torn-tape with messages on an outgoing position or to retrieve it from an incoming position. This is an human aspect and depends on the skills of the communicator. For the sake of convenience, the handling time is considered as a constant and has no influence on the functioning of the AFTN as such.
The transmission times depend on the traffic speed capacity of the circuits and the volume of traffic the network must handle. In other words, the network must be able to handle the volume of traffic such, that the provided service is sufficient.
Except one, all congestion delays are caused by the waiting of a message on an operator to be handled. Therefore, it is important that each AFTN-station is staffed sufficiently to be able to perform all the tasks. Of influence is therefore also the number of connections going in and out of the station. The more connections there are, the more congestion delays can occur due to insufficient staff. The number of connections is determined by the number of stations concerned with the operation of aircraft.
The only congestion delay, which is not dependent on human performance is the delay while the torn-tape is waiting the availability of an outgoing circuit. The availability is already discussed with the reliability of systems or links with respect to the continuity of service in section 6.1.1.

Note: the importance of each AFTN station should be taken into consideration. The functioning of an AFTN centre with national and international connections has more influence on the total functioning of the network, than an AFTN station with only one terminal and one connection.

7. AUXILIARY INFRASTRUCTURE



Beside proper maintenance, also the presence and the proper state of auxiliary infrastructure influence the functioning of the aeronautical telecommunication equipment.
Of the auxiliary infrastructure, the power supply is the most obvious and the most important equipment and without it, the aeronautical telecommunication equipment cannot function at all.
Since aeronautical telecommunication equipment is electronic equipment, it should be well protected by environmental influences by means of proper housing. A bad state of the housing can influence the functioning of the equipment in a negative way, specially when equipment is used in countries with harsh environmental conditions like Tanzania.
Electronic equipment is guaranteed by the manufacturer to function properly up to a certain temperature. When it is likely that this temperature is exceeded, extra measures are needed to prevent equipment from overheating and improper functioning. Beside measures by the manufacturer of equipment like cooling elements, housing of equipment can be cooled by air-conditioning.
Since some of the aeronautical telecommunication equipment is located at sites which are at a reasonable distance from a control centre, cables between sites and the control centre have to be laid. The cables are power cables, monitor cables or control cables.
The remoteness of sites causes the sites to be more vulnerable to trespassing and in the worst case theft of equipment or parts of equipment. To prevent unserviceability of

equipment due to theft or damage by people, equipment or sites should be secured sufficiently.

7.1 Power supply

To be able to ensure, the continuity and with that the integrity of the aeronautical telecommunication equipment, the power supply must be continuous and of a sufficient level.

In order to meet these requirements, the power supply is constructed according to the following set up. Main power for the equipment is provided by the national power supply. Airports are supplied through special connections, which deliver sufficient power for the powering of all equipment at an airport. The power connection usually consists of several links with the power plant in the region, which supply high-voltage power. The high voltage is needed, because the power has to be distributed across the entire airport and even outside the airport's ground to the various sites with aeronautical telecommunication equipment and other electrical facilities. For example, some runway lights need a high power supply of 5 KV.
Main power supply for remote sites, which locate only one or two pieces of aeronautical telecommunication equipment, can consist of only a national power supply, but also of a generator, a number of batteries or solar power panels.

Since aeronautical telecommunication equipment needs to be functioning continuously, provisions should be made in case the main power breaks down for any reason. So, a back-up power system must be present.
The back-up power system must supply sufficient power for the most vital equipment at an airport. This means, that equipment like the aeronautical telecommunication equipment and the runway lighting is powered in any case.
Back-up power supply for the entire airport consists usually of large diesel generators. Back-up power for a site can consist of a smaller diesel generator, solar power panels or a number of batteries.
The power supply network at an airport has a certain topology, depending on the structure of the airport and the locations of various sites, which need to be powered. The main power enters the ground of an airport at a power-station. From there on, the power is transformed to lower voltages, if necessary, and subsequently distributed to the various sites via the network. The switching mechanism and the controls for the power network of the airport are also located at this power station. The switching mechanism switches from main power to back-up power in case main power fails. This has to be done automatically and almost instantaneously to ensure the continuous functioning of all the vital equipment, so sensors which detect power failure, activate the switching mechanism. Because continuous functioning of aeronautical telecommunication equipment requires not only continuous power supply but also continuous power of the same amount, sensors can also detect a significant and lengthy power fluctuation. This provision is made in countries where this is very likely to happen.

The configuration of the power network depends on the size of the airport.
Small airfields can suffice with a main power feed from an outside power source, a power station where the main power enters the airfield and where the back-up power, switching mechanism and power network controls are located and one-way connections to the various sites.
Large airports need to have built more security in their power network to remove possible failures. For this purpose, networks or parts of network, which power vital equipment, can be configured with a ring-construction. A power connection is distributed to various sites with various equipment and is lead back to the power station, which means that all sites have two connections. All sites can be powered via one connection, when the other connection is punctured.
A network can be equipped with more sub-stations to ensure the voltage level on all links of the network. The number of sub-stations depends on the number of vital sites to be

powered. Transformers may be present at these sub-stations to transform the high voltage of the power network to lower voltages, required by the equipment.
The cables of a network will be discussed in section 7.4.

7.2 Building, cabin or hut

The location of aeronautical telecommunication equipment depends on the function of each equipment. For instance, radio transmitters and receivers are located in special control rooms, like the Visual Control Room (VCR), because that is the place where they are used by the controllers. On the other hand, radio beacons are located at various sites at an airport or at sites along air-routes. The latter means, that they are located in urban or rural areas. The equipment, located at sites, is placed inside special cabins or huts.
The function of buildings, cabins and huts is to protect the aeronautical telecommunication equipment from environmental influences in such a way, it does not influence the functioning of the equipment in a negative way.

7.3 Air-conditioning

Manufacturers of electronic equipment guarantee the proper functioning of their equipment between minimum and maximum temperatures, mentioned in their manuals. Depending on the environmental conditions in various countries, there can be situations where the temperature of equipment are exceeded the threshold temperatures.
In case maximum temperatures can exceed, equipment need to be cooled to prolong its proper functioning. This can be done either by cooling-elements, which protect the most vulnerable electronic parts, or by air-conditioning of the room in which the equipment is located.
With aeronautical telecommunication equipment, it should be perfectly clear, whether air-conditioning is needed or not. When equipment has sufficient cooling elements, which ensure the functioning of equipment in harsh environments like the tropical environment, then air-conditioning is not needed. All other equipment need to be located in air-conditioned rooms.

7.4 Cabling

All the aeronautical telecommunication equipment is connected to one more or type of cabling or wiring. This can vary from power cables and control cables.

With power cables is meant the cabling of the power system laid out at an airport. Sites, which lie just in the vicinity of the airport, are usually supplied by power cables coming from the power station at the airport. Most cables at the airport are laid under the ground, but some of the outgoing power cables are strung between poles.

Control cables are one of the possible forms of establishing a link between a site with aeronautical telecommunication equipment and a control centre. For instance, the Instrument Landing System (ILS) consists of several equipment standing at either side of the runway. To check and control the entire system, remote control links are established.

Earthing of all cables is necessary to prevent strokes of lightning flowing to the sites with equipment with their damaging effect.

7.5 Security aeronautical infrastructure

Security of aeronautical telecommunication equipment and auxiliary infrastructure is necessary to ensure the proper functioning of aeronautical telecommunication equipment. The functioning can be effected by damage or theft of equipment or auxiliary infrastructure by people. Theft causes unserviceability of equipment and damage to equipment can cause unserviceability.

But not only direct human intervention can effect the functioning of aeronautical telecommunication equipment, also the crossing of monitor signals by people effects the functioning, because it can initiate the shut-down of the equipment. For instance, an Instrument Landing System (ILS) is equipped with several monitor systems to measure the integrity of the equipment and the radiated signals. This can include a near field monitor system, which monitors the direct output of the antenna. When people stand between the antenna and the near field monitor's receiving antenna, the monitor detects an integrity failure and automatically shuts down the equipment. This might be inconvenient, when an aircraft is just making its approach.

Theft of equipment or parts of equipment and crossing of signals are usually incidents and do not occur on a regular basis. But measures have to be taken to ensure the security of aeronautical telecommunication equipment as best as possible. Not only the buildings or cabins should be secured as was discussed in section 7.3, but also the sites or airport areas should be secured sufficiently.

7.6 Factors auxiliary infrastructure

This section deals with factors of auxiliary infrastructure influencing the proper functioning of the aeronautical telecommunication equipment.

7.6.1 Power system

Power supply is important for the functioning of the aeronautical telecommunication equipment without a doubt, so its reliability and the way it is maintained are worthwhile to examine.

Reliability of power supply
The reliability of the total power supply can be divided into the reliability of the main power, supplied by the national power company and the reliability of the back-up power system at each airport.
The reliability of the main power is measured by the number of power failures and the duration of power failures over a certain time period. The more power failures, the more the back-up power system has to be used and the more the switch gears endure wear end tear.
The reliability of the back-up power system depends on the state of the system. When generators are in a bad state and have deteriorated, the chance is there that they work intermittently. An indicator of the state of the equipment is its age with respect to the maximum technical life.
Not only the reliability of the power supply, but also the reliability of the power system can influence the functioning of the aeronautical telecommunication equipment negatively, when the equipment is in a bad state. Again the age with respect to the maximum technical life is an indicator of its state. Specially the switch gears, which change the power supply from main to back-up and back, and the control system are important parts of the power system. In this case not only main power failures, but also the number and length of main power fluctuations are important to examine, since they also trigger the switch gears when they are too long.
The reliability of the power supply for the aeronautical telecommunication equipment can also be examined by looking at the number of back-up measures for each equipment or group of equipment at a site. For example, beside main and central back-up power, a site can also have a separate generator or set of batteries in case the two first mentioned type of power supply fail. Another back-up measure is a ring-configuration of the network, which prevents sites to become unserviceable, as soon as a power link fails. The presence or absence of a ring-configuration should be weighted against the importance of an airport. A small airfield consisting of an airstrip does not require this back-up measure, since it is not adding substantially to the assurance of a proper ATS provision.

Maintenance
Regular maintenance of all parts of a power system and timely replacement of worn-out parts of the system ensure the proper functioning of the power system and through that the assurance of the continuous functioning of the aeronautical telecommunication equipment. Important to examine is the frequency of maintenance to all parts of the system.
As with the reliability, the age of the equipment with respect to its technical life is important to examine, since it also says something about timely replacement. In case this is not so and deterioration occurs due to wear end tear, the possibility of break down has increased.
The way the maintenance is organised with respect to the available facilities and the possibility of performing maintenance are furthermore aspects to examine.

7.6.2 Building, cabin or hut

In both cases, the building or cabin has to meet certain specifications to ensure the proper functioning of equipment. They have to have:
- proper insulation
- proper earthing
- proper security

Buildings or cabins have to be protected sufficiently to prevent entrance of rain water. Electronic equipment can be short-circuited, when it stands in a pool of water. This can damage the equipment enormously.
Buildings have to be grounded to protect equipment from strokes of lightning. The high-voltage of lightning can damage the equipment severely.
Buildings or cabins have to be secured sufficiently to prevent illegal entrance of trespassers. Not only to make sure that equipment is not stolen, but also to make sure that it is not damaged or shut down by accident. The security and security measures are also discussed in section 7.5.

State of building, cabin or hut
The state of building, cabin or hut in which aeronautical telecommunication equipment is located must be such that it does not interfere or is not likely to interfere with the proper functioning of the equipment. The age is an indicator for this, but also a description of any deficiency says something about the state.

7.6.3 Air-conditioning

To ensure continuous proper functioning of equipment in general and specially equipment, which has to function continuous, the air-conditioning should be in perfect working condition. It should cool the environment of equipment at any time it is needed.
Therefore, preventive maintenance should be executed regularly and an air-conditioning should be replaced as soon as its technical life is over.
A description of the state of the air-conditioning should indicate its functioning.

7.6.4 Cabling

To ensure the proper functioning of the equipment, all cables should be in perfect state and properly grounded. Insufficient earthing or insulation can cause damage to the cables or to the equipment to which they are connected in case of a high-voltage peak. Breaks in the insulation of cables can cause rusting of cables and earthing. When the earthing breaks because of rust, it cannot longer protect the cables and the equipment to which the equipment is connected from high-voltage peaks.

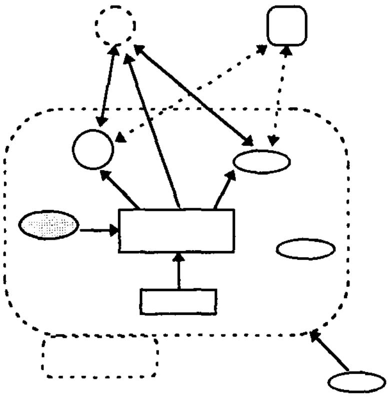
Regular maintenance should prevent worsening of the state of the cables and cables should be replaced after expiration of their technical life time.

7.6.5 Security

To ensure the proper functioning of all equipment and infrastructure, measures like fenced areas, locks on cabin doors and guards at remote areas should be taken.
Beside the actual measures, they also should be in a proper state and complement each other, when one of the measures is not sufficient. For instance, a guard can improve the security of an area or site, when the fencing of this area or site is inappropriate.

Beside taking direct security measures, security should be checked regularly and management should take action when the security is not sufficient. Any part of the aeronautical infrastructure, including auxiliary infrastructure, which cannot be secured sufficiently, should be considered to be implemented otherwise, when it appears that the functioning of the aeronautical telecommunication equipment is effected repeatedly.

8. MAINTENANCE AERONAUTICAL TELECOMMUNICATION EQUIPMENT



Equipment has a certain technical life, which starts basically with the installation of the equipment and ends when the equipment has deteriorated in such a way it is no longer economically or operationally feasible to maintain it. To ensure the proper functioning of the equipment during its technical life and the longest prolongation possible of the technical life, maintenance has to be performed.

Since maintenance of aeronautical telecommunication equipment deals with equipment concentrated at sites on airports in a Flight Information Region (FIR), which encompasses a large area or even a complete country, maintenance should be organised properly to keep a complete overview of the status of all equipment at all times. The vastness of the area in which maintenance has to be performed, the number of concentrated sites in the area, the importance of each site and the available human and other maintenance resources influence the way maintenance is organised.

8.1 Types of maintenance

Maintenance of equipment is divided into preventive maintenance and corrective maintenance.

Preventive maintenance is considered to be any maintenance that occurs before the quality or quantity of the equipment's product deteriorates.[22] The equipment's 'product' is in this case the provided ATS. The objective of the ANS maintenance organisation is to prevent the equipment to become unserviceable. Or in other words, the objective is to prevent the necessity of performing corrective or emergency maintenance.

Preventive maintenance consists of the regular monitoring of equipment to check its functioning, the execution of regular calibration to ensure the integrity of the equipment and minor adjustments if necessary and if possible. Also timely replacement of equipment before it breaks down is considered preventive maintenance.

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[22] Mann, Lawrence, Jr., *Maintenance Management* (Lexington, Massachusetts Toronto, revised edition, 1976, 1983, page 135).

The main objective of the maintenance organisation with **corrective maintenance** is to ensure that unserviceable equipment becomes serviceable as fast as possible. It is the repair or replacement of improper functioning or broken-down equipment.

8.2 Task proportion total maintenance

The ANS maintenance organisation is organised in such a way as to be able to achieve its contribution to the total maintenance in an FIR. The contribution of the ANS maintenance organisation differs from country to country and determines the range of the maintenance activities the organisation performs. The range of activities also indicates the level of contribution to the total ATS provision. The larger the range of activities is, the larger the contribution is to the ATS provision.

Some organisations perform all forms of maintenance, including the installation of the equipment. The occasions, when other organisations are involved, are the installation of completely new equipment which functioning is unknown to the local maintenance engineers and the repair of equipment for which the maintenance organisation has no facilities or knowledge.
Other maintenance organisations only monitor the equipment continuously and leave other maintenance aspects to the service department of the manufacturer. They only assist the manufacturer during installation of new equipment, since they are familiar with the local conditions, like for example radio signals which experience ground level reflections or reflections of near by large objects.

8.3 Maintenance plan or program

According to *Lawrence Mann, Jr.*, preventive maintenance programs yield numerous benefits. The more capital-intensive a plant is, the more it can benefit from a preventive maintenance program[23]. Since the ANS organisation provides the service in a highly capital-intensive way, some of the benefits also apply to preventive maintenance applied to equipment in the service sector. The benefits are:

- Minimum maintenance cost
- Maintenance performed when convenient
- Ability to contract maintenance
- Less downtime
- Minimum spare parts inventory
- Less disruption through emergency maintenance
- Less standby equipment needed
- Less overtime needed for maintenance personnel
- Increased safety with working with the equipment

A lot of these benefits materialize, when strict planning is done. To make the organisation work efficiently operationally and cost-effective wise and to minimise the occurrence of corrective maintenance, a maintenance plan or program is necessary. The emphasis must lay with a program which stipulates the way preventive maintenance should be done in order to prevent the necessity of corrective maintenance. In the plan all aspects and means are explained with which the maintenance organisation tries to achieve the objectives. When maintenance is delegated, the plan should indicate exactly which tasks are supposed to be done by the organisation itself.
The maintenance plan should at least contain the following items:

- Task proportion of ANS maintenance organisation

[23] Mann, Lawrence, Jr., *Maintenance Management* (Lexington, Massachusetts Toronto, revised edition, 1976, 1983, pages 136 - 137). N.B. the book deals with preventive maintenance of plants.

- Task distribution among maintenance personnel
- Frequency of each task
- Descriptions of procedures
- Way of recording and reporting of preventive maintenance data
- Distribution of resources and facilities
- Place of storage department within maintenance organisation

The preventive maintenance program covers the maintenance procedures as they are laid out in the service manuals delivered with the installation of the equipment by the manufacturer. The service manuals indicate the frequencies of the checks of all the parameters in order to have the best preventive maintenance according to the manufacturer.
The actual frequencies of checks and the actual points in time, when the checks are carried out, depend also on the way the equipment is used. Technologically complex systems used for servicing traffic of high importance require a more strict planning, than equipment rarely used or used for servicing air traffic, which consists of one aircraft per week. The maintenance planning of the last mentioned equipment knows more flexibility, than the maintenance planning of the other type of equipment. Also by the end of the technical life of equipment, the intensity of maintenance and thus the frequency of checks increases, because of the deterioration of the equipment.
These aspects have to be taken into consideration, when all the available resources and facilities are distributed among the various departments within the maintenance organisation.

This also applies to corrective maintenance of each and every equipment viewed in the whole of the maintenance. Broken-down equipment, normally used for high importance purposes like providing precision approach for landing aircraft at an international airport, has a higher interest of getting serviceable again than the unserviceability of a NDB at an airstrip in a remote part of the country.

8.4 Maintenance organisation

Organisation of maintenance can be done in three ways.

1. The maintenance can be organised centrally, where all repair is done in one workshop and personnel visits all the sites from the central maintenance station.
2. The maintenance can be divided completely into sub-stations each responsible for maintenance of equipment at their site. All repair of the equipment is done at the site where the equipment is located.
3. A hybrid form can exist, where for example maintenance personnel performing routine, preventive maintenance are stationed at the site, but the repair of equipment is done at a central workshop.

The maintenance organisation also consists of the storage department, which is responsible for the storage of spare parts or units and newly bought equipment, waiting for installation. It is important that the storage department falls under the authority of the maintenance manager, since preventive maintenance depends on the availability and the speed of retrieval of spare parts.
The way, the storage department is organised, depends on the way the maintenance is organised according to the above mentioned three forms.

Maintenance facilities are necessary to perform maintenance in the best possible way. This includes maintenance tools, available test data from service manuals, sufficient well-facilitated workshops, test gears and maintenance vehicles.

It is important to keep records for maintenance management and general ATS equipment management. Statistical data should be recorded to analyse performance of all systems for which the ANS organisation is responsible for. With this data, the quality level of the provided ATS should be determined and analysed and the information should be used for management and planning purposes.

Maintenance management is important to watch whether the objectives as stated in the maintenance plan are executed properly by the maintenance engineers. The management is also responsible for taking action in case the objectives cannot be met.

8.5 Factors maintenance of aeronautical telecommunication equipment

This section deals with the factors of maintenance of aeronautical telecommunication equipment influencing the proper functioning of the ATS equipment.

8.5.1 Preventive and corrective maintenance

Preventive maintenance
Preventive maintenance should be executed with regular intervals. When an organisation is not able to achieve the frequency, the chance is high that equipment becomes unserviceable sooner than it is the case when the organisation can achieve the frequency. The chance also exists, that equipment, which has become out of alignment, is not corrected on time. Like it is mentioned in section 6.1.2, the integrity of service is achieved by regular calibration.

Corrective maintenance
The essence of corrective maintenance is to get unserviceable equipment serviceable again as fast as possible, therefore the speed of making equipment serviceable again is the main factor here. The longer equipment stays unserviceable, the less contribution the maintenance section is giving to the overall ATS provision. As is already stated, the importance of the equipment should be taken into account.

8.5.2 Maintenance program

Because of the mentioned benefits in section 8.4, the presence of a maintenance plan or program is a factor, which influences the way the ANS maintenance organisation is performing the maintenance the most efficient.

8.5.3 Maintenance organisation

The degree of ATS provision assurance, provided by the maintenance organisation depends on the degree of responsibilities with respect to the type of maintenance to be performed.

Maintenance management
Good management should be able to cope with the limitations of the organisation and should be resourceful, when it comes to unusual situations. The latter means, that solutions of problems should be sought in other directions, when existing solutions are not possible.

Maintenance information of all aeronautical telecommunication equipment should be recorded properly and used for management and planning purposes.

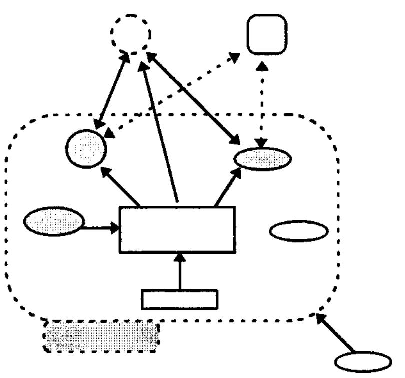
Maintenance personnel
Personnel should be sufficiently present to service all the facilities and perform all necessary corrective maintenance without disrupting the ATS provision. Furthermore, they should be properly trained and have sufficient skills to perform all the tasks they are

assigned to do. The maintenance engineers and their role with the ATS provision are discussed more profoundly in section 9.3.

Facilities
Facilities used to perform the maintenance, like vehicles, test gears, workshops, etc. should be first of all sufficiently be present in order to maintain all equipment as best as possible. Secondly, all facilities should be in a good state.

Accessibility to sites and equipment
To be able to perform both types of maintenance in such a way that the ATS provision is not endangered, all sites and equipment should be easily accessible. Any obstruction delaying routine checks can bring about the possible unserviceability of equipment. Any obstruction delaying timely repair or replacement of faulty equipment means, that the unserviceability of equipment and thus a lower level of ATS is prolonged.

9. HUMAN RESOURCES ANS ORGANISATION



To be able to provide an Aeronautical Telecommunication Service (ATS) according to ICAO requirements, an ANS organisation should not only provide the required facilities, but it should also provide these facilities at any time. This means that the facilities should be controlled and maintained in such a manner that these requirements can be met. Therefore, the human resources play an important role within the ANS organisation to provide the ATS.

The human resources within the ANS organisation, who are responsible for the actual implementation of the ATS, are the Air Traffic Control (ATC) Officers and the Communication Officers. The Maintenance Engineers have a supportive role in maintaining the aeronautical telecommunication equipment in such a way, that the other sections can use the equipment in the best possible way. The Aeronautical Information Service (AIS) Officers also have a supportive role, but they are not discussed elaborately, because they do not play a part in the actual ATS provision. Their role is discussed with the description of the Communication Officers in section 9.2.

9.1 Air Traffic Control (ATC) Officers

Basically an Air Traffic Control (ATC) Officer, responsible for a section of airway or a region of airspace, provides an ATC service to the pilots as part of the Aeronautical Mobile Service (AMS). They have to separate aircraft during various stages of flying to control and prevent collisions between aircraft. A controller also has to provide alerting and flight information service. The Air Traffic Control (ATC) service is provided with all types of control, which are Aerodrome or Tower, Approach and Area Control. In most countries, Radar Control is applied to separate aircraft.
For all types of control, air-ground communication (AG-COM) is used to monitor all air traffic in the airspace. VHF radio communication is most widely used for AG-COM. AMS is also provided via HF radio communication for Area Control, but this is done by Communication Officers (see section 9.2).
To exchange ATC information of immediate importance with other relevant ATC centres, the controllers use the Air Traffic Service/Direct Speech (ATS/DS) network as part of the Aeronautical Fixed Service (AFS).

Separation of aircraft is either based on time by using communication aids or based on distance by using surveillance equipment. The first method is called Procedural Control and the second method is called Radar Control.

With Procedural Control, a controller monitors the position, the speed and the direction of a particular aircraft flying along an airway known to the controller, when a pilot reports this information by radio every agreed period of time. With all the information of all aircraft in the area, the controller is able to separate the aircraft.

The most used surveillance aids world-wide are the Primary and Secondary Surveillance Radar (PSR and SSR). With the help of these aids, a controller won't have to calculate each position of each aircraft in a particular area to separate them. One look at the Radar screen can tell the controller exactly the distances between each aircraft within the range of the Radar installation. This type of control is called Radar Control and is used for Area and Approach Control. Radar equipment is also used for Aerodrome control, but it is never the basis of Aerodrome Control.
Implementation of Radar Control for a type of aeronautical control depends on the traffic density in an FIR. When the density is low, the separation by calculating the positions of aircraft is enough and can be easily done without jeopardising the safety of the aircraft. Radar control is in this case not required, but recommendable.

9.2 Communication Officers

The Communication Officers and Assistants provide the Aeronautical Fixed Service (AFS) which is done via the AFTN, the ATS/DS telephone lines and the public telephone lines. In some ANS organisations, they also provide a part of the Aeronautical Mobile Service (AMS). This is done via HF Radio communication for AG-COM with pilots flying near the border of the FIR. HF radio communication is, however, more and more replaced by satellite communication, which involves the ATC controllers.

Communication Officers are required to perform the following duties:

- Provide any information useful for the safe and efficient conduct of aircraft operations
- Communicate with other network stations for the exchange of weather information
- To maintain and expedite an orderly flow of aircraft operation within and outside the FIR
- Provide AFTN services or Global Telecommunications Services (GTS) at major international airports and telecommunication centres
- Perform traffic analysis duties on message handed by AFTN or GTS circuits in order to determine their efficiency in accordance with ICAO or World Meteorological Organisations Standards[24]

All information provided to the recipients by the Communication section is prepared and handed over to them by the **Aeronautical Information Service (AIS) section**. The AIS section collects all information concerning the flight safety within the airspace of the corresponding FIR. This information is issued in the form of Notice to Airmen (NOTAM). The NOTAM contains actual information on deficiencies of equipment of immediate importance for pilots flying to, from or over the FIR. The NOTAMs are send by AFTN to other ATC centres along the flight routes of aircraft. The AIS section also issues the Aeronautical Information Publication (AIP), which are three successive monthly summaries of NOTAMs. When a situation, described in an AIP, becomes a permanent situation, ICAO issues an amendment for world-wide AIPs.

The aeronautical telecommunication equipment used by the Communication section for the ATS provision are the following:

1. AFTN equipment and HF radio equipment for AFS
2. HF radio equipment for AMS

9.3 Maintenance Engineers

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[24] Government of Tanzania, *Scheme of Service for Communications Officers of the Directorate of Civil Aviation and Meteorology* (Tanzania: 1995, pages 34 -35).

The role of the Maintenance Engineer is described as follows:

The maintenance engineer is responsible for ensuring that equipment and facilities are properly installed, monitored for performance, and modified, if needed.[25]

The responsibilities mentioned before depend on the range of activities the maintenance organisation is responsible for, as is described in section 8.1. The range of activities also determine the contribution of the engineers to the ATS provision.

The main tasks of Maintenance Engineers differ per country or ANS organisation. In some countries, the trend of maintenance of equipment is more and more going into the direction of both preventive and corrective maintenance done by the manufacturer of the equipment. Maintenance employees of the ANS organisation are restricted to only monitoring of the equipment and even that is likely to be transferred to technicians of the manufacturer. Thus, the responsibility of the equipment stays with the manufacturer.
In other countries, the equipment is commissioned by the manufacturer and the ANS organisation after which the equipment is the full responsibility of the ANS organisation. The ANS organisation can only use the services of the manufacturer during the guarantee period. In the latter case, the engineers and technicians of the ANS organisation have to perform all the commissioning, installation and maintenance tasks.

Beside the main responsibilities as they are described above, being a Maintenance Engineer also involves the following:

- pre-installation checks of telecommunication equipment
- calibration of telecommunication equipment by ground checks
- spare parts procurement decisions
- on-the-job training of newly recruited personnel

On-the-job training is not done by Maintenance Engineers of all ANS organisations. This only applies to ANS organisations, which cannot afford to let engineers receive full practice at highly advanced training institutes, but which have to use local engineers to train students.

9.4 Civil Aviation Training

All human resources, working in the civil aviation sector, require specific training for the fulfilment of their tasks within the ANS organisation. For this purpose, Civil Aviation Training Institutes (CATI) have been founded to provide specific training courses. A difference, however, should be made between the basic training of ATC Officers and Communication Officers on one side and the Maintenance Engineers on the other. Although there are basic training courses for Maintenance Engineers at CATIs in various countries, basic training is also achieved at polytechnic schools or technical colleges with a telecommunications engineering branch.

As this prelude already indicates, a distinction is made between basic training and specific training. Basic training gives students the basics of their particular field in aviation. With this basis, students go further with specific training courses to become professional employees within the ANS organisation. The specific training courses are not only for broadening and deepening of the knowledge and skills of ANS organisation personnel to be able to perform all tasks as best as possible, but also to obtain better promotion possibilities.
Important with both types of training is the achievement of professional knowledge and skills.

For ATC Officers, the basic training consists of the basic courses of aviation law, basic control procedures and basic air navigation techniques.

[25] Tomlinson, P.D., "*The Maintenance Engineer,*" *Plant Engineering* (July 10, 1980, page 75).

Specific training courses widen the scope of control from Airport Ground Control to Area Control and provide knowledge and skills for the operational management of a control centre.

Communication Officers start their basic training with learning about the internationally accepted communication procedures and type of equipment used to provide the AFS.
Specific training involves courses necessary in order to broaden the scope from running the equipment to the running of a communication centre.

As said, Maintenance Engineers have a basic telecommunication training in which they are taught about the basic telecommunication principles, like analogue and digital transmission techniques. This training is done at either national technical colleges or at the aeronautical telecommunications engineering department of CATIs.
Specific training deals with the complete understanding of aeronautical telecommunication equipment, which includes installation and maintenance.

Training facilities are necessary to obtain skills and full comprehension of the operation of the equipment and to obtain sufficient promotion possibilities.

9.5 Factors human resources

This section deals with the factors of human resources within the ANS organisation influencing the proper provision of the ATS.

Although, the Maintenance section only plays a supportive role in the ATS provision, they ensure the provision of all aeronautical telecommunication equipment in an FIR with which the ATC and Communication sections directly provide the ATS. Therefore, all sections have to be dealt with equally with factors, characterising the performance of the employees with respect to the ATS provision.

Important with all sections are the knowledge and skills of each employee with respect to the control and maintenance of aeronautical telecommunication equipment and their motivation with respect to the job they are performing.

Although civil aviation training institutes can be found in almost all countries in the world, for an ANS organisation in a developing country it is convenient to send its future employees or employees to an institute in the country itself. This way travelling costs of students going abroad are saved and employees are sooner available for operational duties. Since training is mostly done at a CATI, it is important to examine the quality of the local institute.

9.5.1 Knowledge

Knowledge is gained through **training** which should have the following important aspects.
The **nature of the received training** which is expressed by the subjects of the courses should correspond to the tasks which have to be carried out. With respect to the ATS provision, the subjects of the training should correspond to the tasks to be carried out with respect to the equipment. To examine whether this is the case, a **job description** for each section should be known. The training is divided into basic training and the special training.
The **duration of the courses** should be sufficient, so that full comprehension of the subjects is possible.
The **number of refreshments** indicate the way the level of knowledge is maintained and updated, since the technology of equipment used in aviation has changed. Important here is whether the subjects given during training have been updated or expanded when the technology taught at training centres has changed.
Also important is to examine the way technology changes are watched and the level of distributing this knowledge among the relevant employees.

9.5.2 Skills

Besides knowledge, also skills, in the control and maintenance of the equipment is important to carry out the tasks as well as possible and the following relevant aspects should be taken into consideration.
Skills are first gained through **practical training** as part of the training courses. The duration of these practicals indicate the level of skills gained during training.
After training, skills are developed by **experience on the job**. The longer somebody is working in a particular field, the better the skills are developed.

9.5.3 Motivation

The motivation of the employees should be such that it won't effect the performance of the employees negatively. The motivation can be influenced by the following factors.
The **wage level** should be sufficient with respect to the number of tasks. When the received salary or compensating secondary conditions of employment are felt to be too low for the experienced work load, an employee can become demoralised and this can influence the way he or she is doing the tasks.
Another factor is the possibility of **promotion**. In some countries of which Tanzania is one, the wage level is related to the number of promotions.
The **relation between the received training and the number of tasks and their nature** also influences the motivation. When an employee has to carry out more tasks than stated in the job description and/or for the tasks has not been received any or proper training, the employee can become demoralised.
The number of tasks to be carried out within a section is related to the **number of staff** working in this section. The less staff is present, the more tasks an employee has to carry out and the more demoralised the employee can get.

9.5.4 Quality Civil Aviation Training Institute

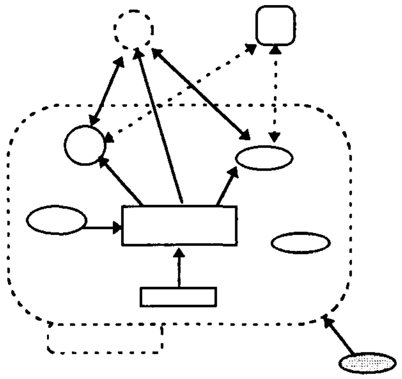
Training is given by qualified instructors which use syllabi to transfer their knowledge to the students and special training facilities to train the skills of students.

The **level of knowledge and skills of instructors** of the training institute with respect to technology used in the country or corresponding FIR should be sufficient in order to transfer it to the students. Beside that, they should maintain an update of changes of technology, which may be used in the near future or are already used by other ANS organisations in other countries.

The **training facilities** should be present, sufficient and well-functioning for full comprehension of the working of the equipment by students and the possibility to obtain experience by ANS organisation personnel, necessary for promotion possibilities.
The ATC section should have ATC simulators with which real life situations can be simulated and skills with performing all types of ATC. When simulators are not present or the number of students does not permit only the use of the simulators, possibilities should be present to practice with equipment in the corresponding control centres.
The Communication section should have at least processing terminals with which the making and processing of AFTN messages are simulated. In case the AFTN in the concerned country is implemented by use of teletypewriters, the equipment should also be available at the training institute in order to be able to practice with them. Also HF radio equipment should be available at the institute to train the skills with this type of equipment, which requires a certain amount of training with respect to the AMS provision as best as possible. Also possibilities of practising with equipment, actually used for the actual AFS and AMS implementation, should be available in order to get acquainted with the work stress.
The maintenance section should have at least a copy of all equipment used in the FIR, provided that the actual maintenance section is responsible for the total maintenance of all

aeronautical telecommunication equipment in the FIR. When this is the case, possibilities of practice with equipment in the field should be possible in case the training institute do not have sufficient facilities.

10. EXTERNAL ASPECTS TO ATS PROVISION



With external aspects are meant, inputs of institutions or companies outside the ANS organisation, which the ANS organisation has to rely on in order to provide the ATS properly. The aspects influence the functioning of the ANS organisation and through that the ATS provision, but cannot be controlled or can be controlled with difficulty by the ANS organisation. The organisation experiences a dependency towards the inputs. The proper functioning or reliability of the external aspects are the factors which the ANS organisation is dependent on.

An ANS organisation depends on the following institutions or companies for a proper ATS provision:
1. national government
2. national service industries
3. manufacturers of aeronautical infrastructure
4. international ATS counterparts

The dependency on the government applies only to ANS organisations, which are connected in any way to the government. There are ANS organisations, which close an entire airport when it is not paying.

With national service industries we mean above all, the national power supply company. The reliability of the supplied power to all airports is of major importance for the proper functioning of the aeronautical telecommunication and auxiliary equipment.
Manufacturers of aeronautical telecommunication equipment play a major part with timely delivering, proper installation and proper servicing of the equipment, according to the contract.
ATS counterparts are ATC centres, located in other FIRs or countries, which are connected with ATC centres, run by the ANS organisation at hand. Specially with the Aeronautical Fixed Service (AFS) where telecommunications networks connect telecommunications centres of different nationality, the functioning or reliability of the counterparts is important to be able to provide the ATS properly.

10.1 National government

In the past but also in the present, it appears that governmental policy towards the implementation of an ANS organisation has a significant impact on the functioning of the ANS organisation. Since the beginning of civil aviation, Civil Aviation Authorities (CAA) have been governmental institutions in every country in the world, since aviation was and still is a nation-wide phenomena. Later on, the internationally accepted International Civil Aviation Organisation (ICAO) was founded to make international air laws. The ICAO was and still is the regulating body, which sets up standards and recommendations for the safe guidance of air traffic in all air spaces.

Governmental interference
The actual provision of ATS has stayed with the governmental CAAs. During the late eighties and the beginning of the nineties, more CAAs or parts of CAAs privatised or became more independent from the government, like the Dutch ATC organisation Luchtverkeersbeveiliging (LVB) in the early 1990s. The privatisation positively effected the

efficiency, the financial situation, the general aviation strategic position and the strategic position with respect to contract negotiations of the ATC or ANS organisation, the productivity and motivation of ANS personnel and ATC's service fees.[26] Because of the improvement of the financial situation and the efficiency of the organisation, the ATS provision improved and through that the flight safety. There are, however, ANS organisations, which are fully or partially a governmental institution, which encounter governmental interference with respect to financial and/or operational policy.
Therefore, the level of governmental interference with respect to the policy of an ANS organisation can be regarded as an external aspect. The higher this level is, the higher the influence is on the functioning of the ANS organisation and on the ATS provision by the organisation. For example, the governmental policy of Tanzania towards aviation could be characterised as total neglect for a long time. In practice, it meant that all route and landing charges coming from airlines went straight to the treasury and only 30% to 50% came back. The implication was deterioration of airports and aeronautical infrastructure and a lower level of ATS provision.

Purchase control
A Government can also have a policy towards the operation of industry in certain sectors in general. Regulations and restrictions can influence the functioning of the aviation sector and the functioning of the ANS organisation in particular. Developing countries are often faced with a foreign exchange (forex) deficit. Therefore, purchases of local industries in foreign countries mean an outflow of forex out of the country. In order to control this forex outflow, some developing countries have governmental bodies whose task it is to examine coming purchases and their validity. This examination takes time, which means delay in the purchase of equipment and/or spare parts. This implies the prolongation or the becoming of the unserviceability of aeronautical telecommunication equipment and therefore the prolongation or becoming of a lower level of provided ATS.

Difference between public and private sector
Beside the direct influence on the functioning of the ANS organisation, governmental policy in general in a country can have an indirect influence on the functioning of an ANS organisation. When of two comparable industrial sectors in a country, only one is liberalised, the other sector is likely to encounter the impact of this situation. Wage level differences will occur and people may transfer from one sector to the other to increase their income. This is specially the case in developing countries, where wage level differences can be very high. The result can be a transfer of ANS organisation personnel to the private sector, which implicates a staff shortage within a lot of departments of the ANS organisation. Staff shortages can be such, that proper ATS provision is not possible anymore. It also means a work overload for the remaining employees, which can cause fatigue and demoralisation. These factors affect the proper functioning of these employees within the organisation, like it is discussed in section 9.5.3.

10.2 National service industries

Although the ANS organisation is fully responsible for the ATS provision, it is also dependent on the reliability of services provided by other organisations outside the ANS organisation. The services are necessary to provide the ATS properly.

National power supply
As mentioned before, the national power supply company is the most important outside company, which the ANS organisation is dependent on. The dependency on the power supply is expressed by the reliability of the main power supplied to the airports. This factor already has been discussed in section 7.6.1, whereas the power supply itself is described in section 7.1.

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[26] Hop, Pascal, *Information Management Aspects of ATS Route Planning, Now and in the Future* (Eindhoven: October, 1996, pages 70 and 74).

National Telecommunications company
Another major outside company, which provides a service to the ANS organisation for the ATS provision, is the national telecommunications company. The Communication section of the ANS organisation hires dedicated telecommunications lines to provide the AFS by means of the AFTN and the ATS/DS networks. Also, telecommunication links between VHF relay stations and an Area Control Centre (ACC) can be hired from the national telecommunications company.
Although, the Communication section and the Area Control section use the lines, the responsibility for the maintenance of the lines lies with the national telecommunications company. Therefore, the reliability of the lines depends on the way the telecommunications company maintains these lines and is, therefore, regarded as an outside influence.

10.3 Manufacturer aeronautical infrastructure

The degree of involvement with the ANS organisation's functioning by the manufacturer determines the degree of influence by the manufacturer on the ANS organisation.
When the manufacturer is restricted to delivering and installation of the equipment, the responsibility for the equipment ends with the commissioning of equipment to the ANS organisation. When the manufacturer also has to perform parts of or the total maintenance of the equipment, the ANS organisation is dependent on the functioning of the maintenance or servicing organisation of the manufacturer.
The influence of the manufacturer can even extent to the training of several local engineers, when this is stated in the contract of the purchase of equipment.

Beside actual responsibility, a good relationship between manufacturer and ANS organisation provides a good basis for smooth co-operation between the two organisations, when the manufacturer is requested to help with problems of the ANS organisation.

10.4 International ATS counterparts

A lot of the aeronautical facilities are set up to service pilots of aircraft directly without interference from other parties. Other facilities, though, require the participation of counterparts other than pilots of aircraft.

International telecommunication networks cross borders and involve foreign counterparts. Together they provide a part of the ATS, which is the international AFS.
This AFS provision is hampered when some or all of the counterparts can no longer participate in the network.
For example, when a counterpart in the AFTN network is omitted, the AFS between these counterparts is omitted which means a lower level of the general ATS.

Also, other ANS organisations provide services like flight calibration on which some ANS organisations depend to use since they do not have these services.

10.5 Factors influencing proper ATS provision

10.5.1 National government

Governmental interference
The degree of ownership or any involvement by a national government in an ANS organisation determines the degree in which the ANS organisation can determine its operational and/or financial policy. It should, therefore, be examined, together with the degree in determining the operational policy and the possibility of controlling its own budget.

Purchase control
For the degree of control of purchases by ANS organisation by a governmental institution, one examines the time required by the institution to decide upon purchases by the ANS organisation. Also interesting to examine in this context is the relationship between the ANS organisation and the institution with respect to smooth co-operation between the two. The better the co-operation from either side, the sooner purchases are granted by the governmental institutions.

Difference public and private sector
In case the ANS organisation personnel is paid by the government, the degree of difference between the public and a comparable private sector indicates the possible reason of ANS organisation personnel transferring to the private sector. For this, the wage level differences between the two sectors are examined. The higher the difference, the more likely it gives a motivation for ANS organisation employees to transfer to the private sector.

10.5.2 National service industries

National power supply
For the national power supply company, the factor which describes the influence of the aspect on the functioning of the ANS organisation is the reliability of the provided main power. Because this factor already has been described in section 7.6.1, it is not discussed here.

National Telecommunications company
The reliability of the hired telecommunication lines is described by the availability of the lines, as it is described in section 6.1.1.

10.5.3 Manufacturers aeronautical infrastructure

The dependence factors of the manufacturers of aeronautical infrastructure is hard to describe with quantitative information. The dependence of the ANS organisation on the manufacturers of aeronautical infrastructure can suffice with a description of the relation between the two and how this influences the ATS provision.

10.5.4 International ATS counterparts

Factor, which should be examined here, is the availability of the counterpart or counterparts on which the ANS organisation is depended to provide the ATS.

PART III ANS ORGANISATION IN TANZANIA

This chapter uses the model shown in part II to describe and analyse the ANS organisation in the Tanzanian environment. The emphasis is firstly put on the way the Aeronautical Telecommunication Service (ATS) is implemented in Tanzania. Organisational structures of all sub-services of the ATS are described and analysed along with the used types of aeronautical telecommunication equipment in chapters 11 and 12. All other elements, mentioned in the model of part II are described and discussed in chapters 13 to 16. Chapter 17 describes and discusses all the sites of three visited Tanzanian airports. Elements, concerned with the organisation, may encounter or cause problems and chapter 18 gives a general overview of all problems. Conclusions and recommendations with respect to the functioning of the ANS organisation are described in respectively chapters 19 and 20.

PART III ANS ORGANISATION IN TANZANIA

In June 1967, the East African Community (EAC) was founded by Kenya, Uganda and Tanzania. The community was established to have equalised currencies, free trade between the three countries, border-crossing employment possibilities and a mutual transport system.
In aviation, an East-African Directorate of Civil Aviation was founded, aeronautical infrastructure was established and financed by the three countries and the training of employees took place in Nairobi, Kenya and Soboti Uganda. The department of Aerodromes, which runs operations like passenger arrivals and departures at the airports, fell under the responsibility of the relevant governments.
In 1977, the EAC dissolved. All services had to be re-established by forming new organisations in each country.

In Tanzania, the Directorate of Civil Aviation (DCA) of Tanzania was founded to replace the DCA of the East Africa Community. DCA became responsible for the control of the airspace within the Tanzanian Flight Information Region (FIR), also established by ICAO in 1977.
The Tanzanian FIR encompasses the whole of Tanzania and a large area over the Indian Ocean. Besides that, the FIR encompasses also the upper airspace above Rwanda and Burundi. The lower airspace of these countries is controlled by the airspace control in the corresponding countries. Appendix C shows a map of the entire Tanzanian FIR with all the major airports, the two Terminal Areas (TMAs) of DIA and KIA and the major air routes.

The Directorate of Civil Aviation and the Aerodromes Department are governmental institutions since the foundation in 1977. The responsible Ministries provided direction on policy of operational implementations. Over the years, the responsible Ministry changed several times and with that the responsibility for a department. When the responsibility is with the Ministry of Communication & Works, Aerodromes is a department of DCA and otherwise a separate body. In table 4, one can see the numerous changes between the Ministries, responsible for the policies of respectively DCA and the Aerodromes department.

Period	Ministries
1977 - 1984	MoCT[1] and MoW[2]
1984 - 1990	MoCW[3]
1990 - 1993	MoCT and MoW
1993 - December 1995	MoCW
December 1995 to end of 1996	MoCT and MoW

Table 4: Ministerial changes

[1]MoCW = Ministry of Communication & Works
[2]MoCT = Ministry of Communication & Transport
[3]MoW = Ministry of Works

The frequent changes perpetuated administration problems and created conflicts, specially during the last six years. Also, the employees themselves were faced with continuing changes in the operational policies which inflicted confusion for their task implementations in all sections of both departments.

In 1996, DCA and the newly formed Directorate of Aerodromes fell under the responsibility of the Ministry of Communications and Transport. Co-operation between the two directorates stems from the original structure and is closely linked. For example, all incoming charges from airlines are divided among the two directorates.

Appendix D shows the organisational structure of DCA at Head Quarters' level. The figure shows all the departments within DCA, each headed by a Director. DCA is headed by the Director General of Civil Aviation.
As can be seen in the figure, Air Traffic Service (ATS) is one of the sections within the ANS department. With ATS is actually meant the Air Traffic Control (ATC) section. Chapter 17 deals with the ANS department at airport level. At that level, Air Traffic Service consists of the ATC, Communication, Telecommunication and AIS sections. This mixed use of the

same term caused confusion among DCA employees about the place of their own section in the organisation.

11. AERONAUTICAL TELECOMMUNICATION SERVICE IN TANZANIA

As mentioned in chapter 5, the Aeronautical Telecommunication Service (ATS) consists of four types of services.

In Tanzania, a large part of the AMS is provided by the ATC section and a small part is provided by the Communication section. AMS provision comes down to air-ground communication between controllers and pilots in all three types of control by means of VHF and HF radio communication. AMS provision by means of Approach Radar Control is not done anymore, since all Radar systems in Tanzania are out of service (see section 11.1.4).
The AFS or ground-ground communication between ATC centres is provided mostly by the Communication section by means of the AFTN. The ATC section provides a part of the AFS by means of the ATS/DS (see section 11.2.2). The Aeronautical Information Service (AIS) section provides the information for both the AFTN and the ATS/DS.
The ARNS in Tanzania is provided by the NAVAIDs NDB, VOR, DME and ILS (see section 12.2).
The ABS in Tanzania consisted only of the Automatic Terminal Information System (ATIS) service at Dar es Salaam International Airport (DIA), but it has never been operational.

Evolving from above, is the fact that the ATC and Communication sections are the actual users of aeronautical telecommunication equipment within the ANS organisation. They are the direct providers of the ATS in Tanzania. The Telecommunication section as well as the AIS section support these two sections with the ATS provision and are, therefore, the indirect ATS providers.

11.1 Aeronautical Mobile Service (AMS) in Tanzania

The provision of AMS is basically Air Traffic Control (ATC), which in general consists of Area Control, Approach Control and Aerodrome Control. Each type of control is provided to aircraft flying in a particular area at a particular altitude.

The airspace within the Tanzanian FIR is divided into a lower and an upper airspace at flight level FL245 or at an altitude of 24,500 ft.
Area Control in Tanzania is applied for the upper airspace in the entire FIR by means of VHF and HF radio communication. Control is done from the Area Control Centre (ACC) at DIA. Area Control by means of VHF radio is done by the ATC section and Area Control by means of HF radio is done by the Communication section.
Approach Control is applied to aircraft flying in the lower airspace inside Terminal Areas (TMAs), surrounding either DIA or KIA.
Aerodrome Control is applied to aircraft flying in the lower airspace within Control zones (CTZ), surrounding all DCA-manned airports.
The remaining lower airspace between the manned airports and the TMAs is uncontrolled, so pilots have to be alert of any other aircraft in their vicinity by means of constant radio monitoring.

11.1.1 Area Control: ATC section

Area Control by the ATC section is applied by means of VHF radio communication. VHF radio for Area Control is specially used within the FIR for en-route air traffic in the upper space. Area Control is co-located with Approach Control to simplify the hand-over of control of aircraft between Area Control Officers and Approach Control Officers.

The Tanzanian FIR is divided into two Area Control areas: a Western area and an Eastern area. A frequency is assigned to both areas, which is 119.3 MHz. for the Western FIR Area

Control and 123.3 MHz. for the Eastern FIR Area Control. To cover all Tanzania, the Dar es Salaam station is accompanied by six VHF relay stations, placed across Tanzania.

VHF relay stations are located at the following sites with the corresponding frequency:

Bondwa	119.3 MHz
(Dar es Salaam	119.3 MHz)
Lolkisale	119.3 MHz
Mtwara	119.3 MHz
Mbeya	123.3 MHz
Mwanza	123.3 MHz
Tabora	123.3 MHz

Appendix E shows the positions and the coverages of the relay stations. The figure shows, that the coverages are enough to cover the entire FIR.
It has to be noted that the actual coverages are not perfect circles. The contour of the terrain, like mountain ranges, determines the actual shape of a coverage. For this reason, the relay stations have been placed on top of high hills or mountains. They are, therefore, difficult to reach by the maintenance vehicle despite the Four Wheel Drive of the car, specially during the rainy season.

Besides the back-up power, TTCL is also responsible for the tie-lines between the stations and the ACC in Dar es Salaam and the connections between the links and the equipment at the stations.

Due to problems with transport and lack of time, the VHF relay stations have not been visited and comments are based on statements made by DCA maintenance engineers and on maintenance records.

The Bondwa VHF relay station was unserviceable from May 1996 until August 1996. The direct cause and causes for prolongation of the unserviceability are described with the summary of the problems and consequences. The unserviceability of the particular station does not have much effect on the overall Area Control, because the coverages of surrounding stations is enough to provide the service in the entire FIR (see appendix E). However, possible unserviceability of other stations, like Mbeya, would have been more problematic, since they are not covered by other stations.

The controllers are located inside the **Area Control Room (ACR)** within the ACC. They use *consoles* where they can plug in their head-sets for the air-ground communication and where they can place the flight strips[27] in front of them. The console also contains the switches of all VHF relay stations, which a controller can use to choose the best signal reception.
There are four consoles for Approach and Area Control of which one console is not serviceable and one console is stripped to obtain spare-parts for the other functioning consoles. One console is assigned to Area Control and one to Approach Control. This increases the number of tasks of the remaining Area Control Officer.
A supervisor can see all consoles from a *supervisor desk* and co-ordinates all tasks performed by the ATC controllers at each console. At the time of the research, the Area Control Officer also had to do the tasks of the supervisor due to a lack of staff. The work load and the effects on the morale of the personnel is dealt with in section 15.2.
The supervisor desk also contains the *ATS/DS exchange* with eight channels with which a controller can talk directly with a controller working at another ATC centre in Tanzania or in a neighbouring country.
The ATS/DS network is described more profoundly in section 11.2.2.

The ACR is described in appendix F.1. The VHF transmitters and receivers for Area Control are located in the Equipment Room inside the airport's tower. The *Equipment Room Tower*

[27] The flight strips contain characteristics and flight information of each aircraft, flying in the airspace along their routed (see also Nolan, Micheal S., Fundamentals of Air traffic Control (Belmont California USA: 1994, pages 236 and 237)).

is described in appendix F.2. The transmitters and receivers are described in respectively appendix G.4 and G.5.
VHF monitoring equipment is used to monitor all the VHF relay stations and the connections between the stations and the ACC in Dar es Salaam. The equipment is located inside the Equipment Room of the ACC. The *Equipment Room ACC* is described in appendix F.3.
The sites of the *VHF relay stations* are described in appendix F.4.

Problems Area Control ATC section

6.1.1 Continuity of service

reliability:
- only one out of two consoles serviceable, because other console was stripped
- console is obsolete

Consequences of problems:

- one controller for Area Control instead of two
- rise in work pressure (see also section 15.2)

6.1.1 Continuity of service

external aspects:
- Bondwa station unserviceable, due to broken cable between station and ACC DIA

8.5.3 Maintenance organisation

facilities:
- only one maintenance vehicle for trips to remote sites
- broken down vehicle took three months to be repaired until it could be used again

maintenance management:
- management did not hire replacement maintenance vehicle

accessibility:
- station Bondwa difficult to reach, because road washed away

7.6.4 Cabling

state:
- cable between Bondwa and ACC DIA broken, because of rodents

7.6.5 Security

state:
- TTCL cabinet with connection unit entered by rodents

10.5.2 National services

national telecommunications company:
- dependency on TTCL for maintenance connection VHF relay station and tie-line

Consequences of problems:

- when stations unserviceable, irresponsible prolongation of unserviceability because of transport problems
- Area Control ATC section hampered, when stations are unserviceable
- possible decrease level AMS
- possible decrease level ATS

11.1.2 Area Control: Communication section

For radio communication at the border or even across the border of the FIR, HF radio communication is used. Since HF radio can have a range of 2,000 NM and the FIR does not stretch further than 680 NM, it is sufficient to have equipment at one location inside an FIR the size of Tanzania. Therefore, this part of the AMS provision is done from the Communication Room inside the ACC at DIA by the Communication section.

For this purpose, there are two booths in the **Communication Room** inside the ACC from which two Communication Officers provide their part of the AMS. The booths are connected with an HF Transmitter station and an HF Receiver station via underground cables. The stations have been put apart from each other, so that interference between transmitted and received HF signals is avoided.

Besides the head-sets for the controllers, the booths also contain DATA SELCAL code transmitters. With these transmitters, identification codes are send to corresponding aircraft in case vocal contact is hard to make. The pilot has to respond immediately to the code by contacting the controller. This provision is made, due to the poor transmission quality which HF radio is known for.

At the moment, the HF transmitters cannot be used, because the cables to the Transmitter station were vandalised. This also means that the DATA SELCAL code transmitters cannot be used as well.

The Communication section uses an HF transceiver to be able to practice Area Control. With the transceiver, four HF frequencies are used. The HF transceiver is described in appendix G.3.
Only one transceiver can be used, because another transceiver would cause to much interference. Therefore, this part of Area Control is provided by only one Communication Officer instead of two.

Table 5 shows the HF frequencies used for Area Control.

HF radio equipment	Freq. (KHz)	Remarks
Barrett SB250 HF transceiver	8,879	Used to be AFTN RTT frequency
	11,300	
	13,306	Used to be AFTN RTT back-up frequency
	5,658	Night frequency; is planned to be replaced by 5,517 KHz.
Vigilant SR722 RC	8,879	Monitoring only
	11,308.20	Monitoring only

Table 5: HF Area Control frequencies

The Communication Room is described in appendix F.5. The Transmitter Station and Receiver Station are described in respectively appendix F.6 and appendix F.7. The HF transmitters and receivers are described in respectively appendix G.1 and G.2.

Problems Area Control Communication section

6.1.1 Continuity of service

external aspects:
- communication cable Transmitter station and ACC DIA broken due to vandalism in beginning 1996
- cables difficult to retrieve and repair, due to disorderly manner of installation
- cables difficult to replace in time, due to procurement new cables

7.6.4 Cabling

state:
- cables laid badly in ground

7.6.5 Security

measures:
- cables vandalised

10.5.1 National government

purchase control:
- Tender Board delays procurement of new cables

Consequences of problems:
- repair of connection between Transmitter station and ACC delayed
- no use of Transmitter station and Receiver station for Area Control
- use of HF transceiver
- only one controller
- HF receivers only used for monitoring purposes
- limited Area Control Communication section

11.1.3 Approach Control

Approach Control is applied in Terminal Areas (TMAs), which usually lie around major airports. In Tanzania, there are two TMAs which lie around respectively Dar es Salaam International Airport (DIA) and Kilimanjaro International Airport (KIA). Appendix C shows the way the two TMAs are shaped. Each TMA is modified to accommodate local terrain and traffic patterns.28 With traffic patterns is meant the approach routes to the airport. The widest radius of the KIA TMA is 150 NM and the widest radius of the DIA TMA is 125 NM.

The airport of Dodoma has a separate frequency for Approach Control in the lower airspace, but it does not have a TMA. Therefore, Dodoma is discussed with Aerodrome Control.

Approach Control in Tanzania is done by the ATC section and it uses VHF radio equipment at both airports.

Approach Control at DIA is located inside the ACR together with Area Control. Like Area Control, Approach Control is provided only by one controller instead of two because of unserviceable consoles.

The VHF transmitters and receivers for Approach Control are located in the Equipment Room inside the airport's tower. The *Equipment Room Tower* is described in appendix F.2. The transmitters and receivers are described in respectively appendix G.4 and G.5.

Problems Approach Control DIA

6.1.1 Continuity of service	Consequences of problems:
reliability: - console is obsolete - only one out of two consoles serviceable, because other console stripped for maintenance other console	- only one Approach Control Officer instead of two - limited Approach Control

Approach Control at KIA has been moved from a separate room into the Visual Control Room (VCR) of the Tower together with Aerodrome Control, due to lack of serviceable consoles for Approach Control.

The VHF transmitters and receivers for Approach Control are located in the Equipment Room of the ATC building. The *Equipment Room* is described in appendix F.18. The transmitters and receivers are described in respectively appendix G.4 and G.5.

Problems Approach Control KIA

6.1.1 Continuity of service	Consequences of problems:
reliability: - Approach Control consoles are not present - console is obsolete	- Approach Control combined with Aerodrome Control - only one controller for both types of Control

11.1.4 Approach Radar Control

The first Radar system in Tanzania was introduced in 1971 at the airport of Kilimanjaro. The Radar system at DIA was installed in 1983 during the French rehabilitation project.

[28] Nolan, Michael S., *Fundamentals of Air Traffic Control* (Belmont California, USA: 1994, page 154).

At both DIA and KIA, Approach Radar Control used to be applied, but has ceased to be since the Radar at KIA has been withdrawn and the Radar system at DIA is out of service for several years.

The Radar system consisted of the following equipment in the corresponding rooms and sites:

Primary Surveillance Radar (PSR) antenna	Radar site
Secondary Surveillance Radar (SSR) antenna	Radar site
Radar consoles	ACR
Radar programming equipment	Equipment Room ACC
Radar monitoring equipment	Equipment Room ACC
Radar modem	Equipment Room ACC

The Radar programming equipment was used to load the features of the aerodrome onto the radar screen.
Both the ACR and the equipment Room ACC are described in section 11.1.1.

The **Radar site** in Dar es Salaam is located along the main runway, a few hundred meters before the end of the runway. The Radar site consists of one building, which contains the transformers of the VHF signals into Radar signals. On top of the building are the PSR and SSR located. The Radar site is described in appendix F.14.

Radar antennas have been kept operative occasionally to avoid the antennas to become rusty, according to the responsible Maintenance Engineer. However, it is very unlikely that the Radar will be used again in the near future.

Problems Approach Radar Control

6.1.1 Continuity of service *reliability* - Radar system broke down - Radar system has become obsolete	Consequence of problems: - equipment cannot be repaired - no Approach Radar Control at DIA
9.5.4 Motivation *promotion:* - ATC Officers cannot obtain Radar Control licenses and Maintenance Engineers cannot obtain maintenance licenses, due to lack of practice in Tanzania 10.5.1 National government *governmental interference:* - Scheme of Service for ATC Officers and Maintenance Engineers allows promotion to higher grade only after obtaining relevant licenses - Scheme of Service connects wage level with grade	Consequence of problems: - ATC Officers and Maintenance Engineers cannot be promoted beyond certain grade - ATC Officers and Maintenance Engineers earn up to certain wage level

The promotion possibilities of the ATC Officers and Maintenance Engineers is described more elaborately in section 15.1.

11.1.5 Aerodrome Control

Aerodrome Control is applied inside the Control Zone (CTZ) of an airport. The CTZ has a radius of 15 NM and goes up to 15,000 ft above the CTZ.
Aerodrome Control or Tower Control is applied by the ATC section at all DCA-manned airports, shown in table 6.

Domestic	International
Arusha	Dar es Salaam International Airport (DIA)
Dodoma	Kilimanjaro International Airport (KIA)
Iringa	Zanzibar International Airport
Kigoma	
Mbeya	
Mtwara	
Pemba	
Songea	
Tabora	
Tanga	

Table 6: major airports Tanzania

Since DIA and KIA also apply Approach Control, the use of Aerodrome Control sometimes differs from Aerodrome Control at the other manned airports. An Approach Control Officer guides an aircraft until the pilot of the aircraft has the runway in sight, specially during bad weather. This can mean, that the hand-over to the Aerodrome Control Officer is not done until the aircraft has already landed. At the other manned airports, the Aerodrome Control Officer guides the aircraft from first radio contact to the ground.

Basically, Aerodrome Control is performed from the tower's Visual Control Room (VCR) of an airport by an Aerodrome Control Officer which is a grade within the ATC section. The controller uses VHF radio equipment to communicate with the pilots of aircraft.

The VCR of DIA is described in appendix F.8, the VCR of KIA is described in appendix F.17 and the VCR of Arusha is described in appendix F.24.

Problems Aerodrome Control Tanzania

As far as the Aerodrome Control is concerned, there are no problems with the provision by means of the VHF equipment. The VHF equipment is described in appendices G.4 to G.6.

11.2 Aeronautical Fixed Service (AFS) in Tanzania

The AFS is provided by means of the Aeronautical Fixed Telecommunication Network (AFTN) and the Air Traffic Service/Direct Speech (ATS/DS) network.

11.2.1 Aeronautical Fixed Telecommunication Network (AFTN)

At all DCA-manned aerodromes, Aeronautical Information Service (AIS) units are located, which send information concerning a certain aerodrome by means of Notice-To-Airmen (NOTAM) through the Aeronautical Fixed Telecommunication Network (AFTN) to the International NOTAM Office (NOF) based inside the ACC at DIA.

In Tanzania, the AFTN-network is implemented by using teletypewriters and hired telephone lines, owned by the national telephone company TTCL. Some of the connections are duplex and some are simplex connections.
A map of all the AFTN connections and links in Tanzania and in adjacent countries is shown in appendix H.1.

The appendix shows that Dar es Salaam is the centre of the AFTN in Tanzania. Apart from the Nairobi-connection of KIA, it has the only connections between Tanzania and foreign AFTN centres. Dar es Salaam is the tributary centre of Nairobi within the African AFTN network.[29]

[29] International Civil Aviation Organisation, *Doc. 7474/26: Air Navigation Plan Africa-Indian Ocean Region, Part III Communications* (Montreal, Canada: May 1993, chart COM 1A).

Other domestic AFTN centres are Dodoma, which is connected with Kigoma, Mbeya and Mwanza, and Kilimanjaro which is connected with Nairobi and Arusha. It is planned to re-route the Tabora connection from Dar es Salaam to Dodoma.

11.2.1.1 AFTN communication centre DIA

Figure 4 shows the present situation of the AFTN centre in Dar es Salaam. It shows all serviceable links, presented by a solid line, and the non-existing links, presented by an interrupted line. The latter links do not exist anymore, due to problems at the centre.

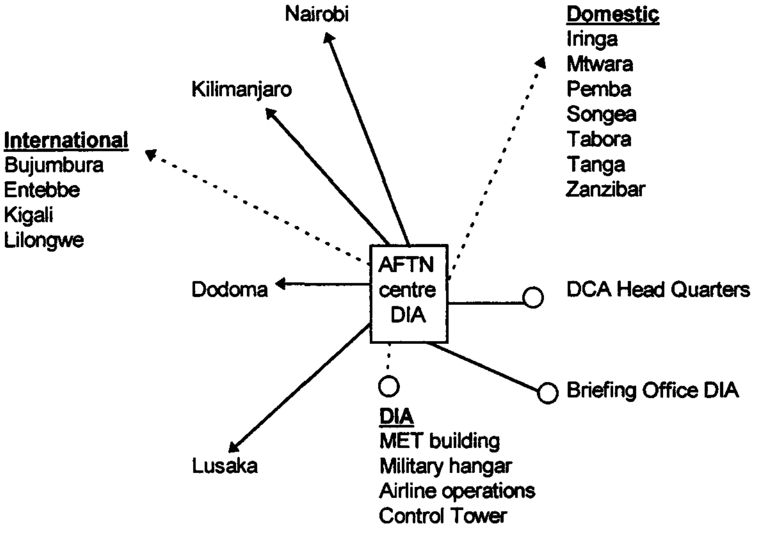

Figure 4: AFTN links from Dar es Salaam

All existing connections are handled by **teletypewriters**, which have to be controlled manually. All transmitters, receivers and transceivers are teletypewriters. The room itself has further one terminal which handles rejected messages and a desk for a supervisor.

Table 7 shows the actual manning of the equipment in the centre along with the required manning per shift, according to the Senior Communication Officer. The total number of operators per day is shown between parenthesises.

AFTN position	$Operator_{required}$	$Operator_{actual}$
AFTN processing terminal	4 (20)	2 (10)
Rejected messages terminal	1 (5)	1 (5)
Supervisor	1 (5)	0 (0)
Total	6 (30)	3 (15)

Table 7: Manning AFTN Communication Centre DIA

The operators at the processing terminals include one operator at the Briefing Office and one operator at Head Quarters. The centre itself is manned by only one man per shift, who is also responsible for the tasks of the supervisor and the processing of the rejected messages.

The Communication section has also an **Automatic Message Switching (AMS) computer** which routes all incoming AFTN telex messages to their destinations automatically. The computer has a routing capacity of 256 connections.
The computer broke down in December 1995 after a power failure for several days and is still down.

The AFTN in Tanzania has also been implemented by **HF radio communication**.

In 1978, the Dutch Philips company set up HF Radio TeleType (RTT) AFTN connections with Bujumbura in Burundi and Kigali in Rwanda.
In 1985, a project was set up between ATC centres in the Indian Ocean area. The network consisted of HF RTT connections between the ATC centres of Dar es Salaam in Tanzania, Nairobi in Kenya, Mogadishu in Somalia, the Seychelles, Moroni on the Commores, Antananarivo on Madagascar and Beira in Mozambique.
For both networks, DIA used HF transmitters and receivers to establish two simplex links with each connection. After the break-down of the transmitters, the Communication section used an HF transceiver to maintain connections with Rwanda and Burundi.
Both HF networks do not exist anymore, since all counterparts have broken down equipment. Of the equipment in Dar es Salaam, only the receivers are still functioning.
HF RTT will not be used in the future, since it is no longer an ICAO standard and new investments in RTT are not recommended.

A list of all AFTN specific equipment is shown in appendix G.7 and the HF equipment is shown in appendix G.1, G.2 and G.3. The AFTN communication centre is described in appendix F.8. The sites of the transmitters and the receivers are described in respectively appendix F.6 and Y.7.

11.2.1.2 Availability AFTN links

ICAO has recommended, that the daily reliability of the AFTN links should be 97% in order to provide a proper AFS by means of the AFTN.[30] As described in section 6.1.1, the availability of the links is a good measure for the reliability of the links. Therefore,
appendix H.2 shows the availability of all incoming and outgoing AFTN links to both international and domestic destinations in 1995 and the first four months of 1996. All figures are summarised by the Communication section on a monthly basis and recorded in monthly reports.
In contrast with the serviceability percentages of aeronautical telecommunication equipment in Tanzania in the monthly reports (see section 14.6.1), the AFTN percentages are more reliable, because they are monitored during the whole day. In 1995, the recording of the availability of links was done by the computer on a continuous basis per day. In 1996 after the break-down of the computer, the recording was done by employees of the statistical department of the Communication section per half hour. The monthly records of the availability figures are made by these employees. The records of the missing months could not be found during the research, due to unknown reasons.
The appendix also shows the average percentages over the available months in a year to indicate to what extent a certain link stayed near the 97% during a long period. In 1995, the period is seven months and the period in 1996 is three months.

When one considers the average availability of the links over the available months in 1995, one can see that only the connections with KIA and Dodoma met the ICAO recommendation. Problems with connections in 1995 can be subscribed to problems of the tie-lines and equipment at the other side. After the break-down of the computer, the problems with the old and obsolete teletypewriters contributed even more to the low availability of the links.
Also clear to see is the complete drop to zero percent of some connections. Due to a restricted number of teletypewriter machines, the old number of connections could not be serviced.
The break-down of the AMS computer is also shown by the decreased number of handled messages as shown in appendices H.3 and H.4. Appendix H.4 also shows the increase of the number of messages between 1992 and 1995. Statistical data on this subject are not available, but a Communication Officer stated, that this was because of the increased traffic above Tanzania. Specially the number of international flights from Europe and Northern Africa to Southern Africa and vice-versa had increased.

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[30] International Civil Aviation Organisation, *Doc. 7474/26: Air Navigation Plan Africa-Indian Ocean Region, Part III Communications* (Montreal, Canada: 26th edition, 1989, page E 3-0-1).

Problems AFTN communication centre DIA

Problems	Consequence of problems
6.1.1 Continuity of service *external aspects:* - Philips teletypewriters obsolete, so spare part procurement not possible - spare part procurement problem SAGEM teletypewriters **8.5.1 Preventive and corrective maintenance** *preventive maintenance & corrective maintenance:* - present teletypewriters cannibalised for maintenance of functioning equipment - no more spare teletypewriters	- when a teletypewriter breaks down, connection cannot be served anymore - only most important connections remain - possible decrease of level AFS - possible decrease of level ATS
6.1.1 Continuity of service *reliability:* - AMS computer broke down - considerable decrease in number available connections **8.5.3 Maintenance organisation** *maintenance personnel:* - insufficient knowledge for maintenance broken AMS computer - insufficient knowledge for programming AMS computer **10.5.3 Manufacturer aeronautical infrastructure** *dependency:* - no response at ordering spare parts SAGEM - no response for programming address-line changes and CIDIN[31] procedures	- maintenance including proper trouble-shooting AMS computer is not possible - necessary programming AMS computer could not be done - Communication section had to switch to manually controlled teletypeprinters - not sufficient equipment to service all original connections - of seventeen connections, only six remained - decrease of level AFS - decrease of level ATS
10.5.4 International counterparts *availability counterparts:* - counterparts Indian Ocean network no longer exist **6.1.1 Continuity of service** *reliability:* - HF RTT transmitters broke down *external aspects:* - cable between ACC and Transmitter Station broken	- HF RTT is not possible - functioning HF RTT receivers not used - decrease of level AFS - decrease of level ATS
6.1.1 Continuity of service *reliability:* - availability AFTN links poor	- decrease level AFS - decrease level ATS
6.1.3 Transit-time low speed AFTN *relay time:* - messages have to be handled manually - lack of staff AFTN Communication Centre - relay time more than 5 minutes average	- messages cannot be handled within required processing and relaying times - decrease level AFS - decrease level ATS

In the mean time, the DCA management has decided, that a new computer will be purchased. CIDIN procedures are now ICAO requirements, so the computer has to meet these requirements.

[31] CIDIN = Common ICAO Data Interchange Network

11.2.1.3 Other AFTN centres in Tanzania

Of the AFTN centres in Tanzania beside the AFTN centre at DIA, only the centres of KIA and Arusha Airfield have been visited, due to a lack of time.

The *AFTN Communication Room* of KIA is located in the ATC building of the airport. The AFTN Communication Room is described in appendix F.19. The AFTN equipment is described in appendix G.7.
The *AFTN Room* of Arusha Airfield is located inside the ATC building of the airfield. The AFTN Room is described in appendix F.25. The AFTN equipment is described in appendix G.7.

All other AFTN centres also handle the messages manually, but the volume of traffic is much lower, compared to Dar es Salaam. Even centres like Kilimanjaro or Dodoma are manned sufficiently with operators to handle the AFTN traffic at their centres.

Besides the problems with the availability of the links and the equipment, the other communication centres do not experience any other problems.

11.2.2 Air Traffic Service/Direct Speech (ATS/DS)

Due to lack of time, the ATS/DS network has not been examined elaborately. Only the functioning of the equipment and available serviceability records have been examined.

The Air Traffic Service/Direct Speech lines (ATS/DS) are meant to convey urgent ATS information to ATC centres in either adjacent countries or in Tanzania in order to provide the AFS. Since the network conveys urgent information, all exchanges or telephones are located inside ATC rooms. As described in section 11.1.1, the ATS/DS centre in Tanzania is located inside the ACR within the ACC at DIA. The ACR is also described in appendix F.1. The ATS/DS exchange at KIA and the ATS/DS telephone at Arusha Airfield are located inside the VCRs of the relevant airports. Both VCRs are described in respectively appendix F.17 and F.24.

In appendix I.1, a map is shown of all the ATS/DS connections inside the Tanzanian FIR and of connections to adjacent ATC centres. Of these lines, the links with Iringa and Entebbe are not serviceable.
All ATS/DS connections are copper-wire telephone lines rented from the national telephone company TTCL.

The map shows, that links with international ATC centres, like Lusaka and Lilongwe, and with domestic centres in the south-west of Tanzania do not exist. According to ICAO recommendations for the Africa-Indian Ocean Region (AFI), *States should accord special priority to the implementation of ATS/DS circuits with first priority circuits between Air Traffic Service units providing service in contiguous airspace where ATC service is provided or is required.*[32] It is clear, that this is not the case. Specially in emergency cases, direct telephone lines with the ATC control in Dar es Salaam can be of convenience to the orderly flow of air traffic and the safe flight of aircraft in the Tanzanian airspace.

To give a general overview of the availability of the ATS/DS lines, appendices I.2 and I.3 show the availability figures of the ATS/DS links from the airports of respectively DIA and KIA. Due to problems with the available records as described in section 14.6, appendix I.2 only shows the figures of January, February and May of 1996 for DIA. They are merely used to give an indication of the problems. Also, ICAO has not given recommendations with respect to the daily reliability of the ATS/DS lines. Therefore, the 97% is used here as a guideline for the particular figures of appendix I.2.

[32] International Civil Aviation Organisation, *Doc. 7474/26: Air Navigation Plan Africa-Indian Ocean Region, Part III Communications* (Montreal, Canada: 26th edition, 1989, page E 2-0-5).

The figures of KIA show that the lines are either available or not available at all. The figures of DIA show that some lines are reasonably available with averages just below 97% per month, but some are far below the 97%.

Problems ATS/DS Tanzania	
6.1.1 Continuity of service *reliability:* - availability some ATS/DS lines from DIA varies enormously - availability link KIA - Arusha sometimes null	Consequence of problems: - some ATC centres cannot always be reached - decrease level AFS - decrease level ATS
6.1.1 Continuity of service *reliability:* - availability Iringa and Entebbe null - availability link KIA - Arusha sometimes null - ATC centres in south-west Tanzania and adjacent countries not present	Consequence of problems: - ATC centres Iringa and Entebbe cannot be reached anymore - lower level AFS - lower level ATS

It is hard to say more about the quality of the AFS provision by ATS/DS. More data about the availability and the quality of the network should be gathered in order to indicate the exact problems of the ATS/DS network.

12. AERONAUTICAL TELECOMMUNICATION EQUIPMENT IN TANZANIA

To be able to give a good overview of all aeronautical telecommunication equipment in Tanzania, the equipment is viewed from two different angles.
This section deals with a general overview of all equipment in Tanzania. The section gives also a general overview of the problems encountered by the ANS department.
Chapter 17 deals with the visited airports and sites at these airports and their specific problems, according to the factors of chapter 7 which deals with auxiliary infrastructure.

The aeronautical telecommunication equipment in Tanzania consists only of the communication equipment and the navigation aids. The surveillance equipment, consisting of Primary Surveillance Radar (PSR) and Secondary Surveillance Radar (SSR) systems, are no longer in use. The Radar at DIA is described and discussed in section 11.1.4.

12.1 Communication equipment

Communication equipment in Tanzania consists basically of VHF and HF radio equipment, AFTN equipment and telephones. Appendix G shows the inventory of all communication equipment in Tanzania.
The AFTN and the ATS/DS networks in Tanzania are described and discussed elaborately in section 11.2.1 and 11.2.2.

12.1.1 HF radio communication equipment

Use of HF radio communication is used for Area Control purposes (described in section 11.1.2), for AFTN RTT purposes (described in section 11.2.1.1) and for internal communication within DCA. Internal communication is done with the aid of HF transceivers, which enables maintenance engineers to communicate easily with other engineers stationed at various airports. Appendix G.3 shows the equipment and the relevant stations.

Beside the atmospheric problems which HF radio communication is known for, there are no problems with the HF transceivers.

12.1.2 VHF radio communication equipment

The VHF radio equipment is the work horse of the Tanzanian ATC section. Every airport is equipped with at least a transceiver.

Over the years, old VHF transmitters and receivers at small airports have been replaced by the Walter Dittel FSG-70 VHF transceiver. The major advantages are the single equipment instead of two pieces of equipment and the built-in, chargeable batteries. The batteries can last for 24 hours. Because of its small size, it is easy to place and easy to move.

With the VHF equipment, there are no known problems.

12.1.3 Public telephone network

Because of the availability problems with the ATS/DS lines, the ATC section sometimes uses the public telephone network of the national telephone company TTCL to pass any Air Traffic Service information to the relevant ATC centre.

The public telephone network has not been examined, due to lack of time.

12.2 Navigation aids

This section gives an inventory of all navigation aids (NAVAIDs) in Tanzania. Relevant paragraphs of chapter 17 go deeper into the problems of the NAVAIDs located at their respective sites at the airports of DIA, KIA and Arusha. Since ILS in Tanzania is only used at DIA, it is discussed in section 17.1.1.

Appendix J1 to J4 shows the inventory of all NAVAIDs in Tanzania and their status.

Problems NAVAIDs except NDBs

6.1.2 Integrity of service	<u>Consequence of problems:</u>
accuracy: - calibration after ground checks not always done - flight calibration not done for more than five years	- integrity NAVAIDs except NDB not ensured - level ARNS decreased - level ATS decreased

12.2.1 NDB

The NDB is the work horse of DCA with respect to the ARNS provision. All DCA-manned airports have at least an NDB. Appendix J.4 shows the status of all NDBs in Tanzania.

Appendix J.5 shows the coverage of all NDBs in Tanzania. The map shows that Tanzania is covered sufficiently by the beacons.

Problems NDBs

6.1.1 Continuity of service	<u>Consequence of problems:</u>
powering of equipment: - NDBs of Arusha, Mtwara, and Songea only powered by Tanesco	- NDBs Mtwara and Songea unserviceable during Tanesco rationing - decrease level ARNS - decrease level ATS
10.5.2 National services industries	
national power supply: - Tanesco rationed power in Mtwara and Songea	

12.2.2 VOR

The VOR is normally used for en-route navigation to mark the beginning and the end of an airway and for marking an airport.

Appendix J.2 shows the status of all VORs in Tanzania.

In Tanzania, the VOR is only used at the airports of DIA, KIA and Mwanza. Appendix J.6 shows the actual and first coverages of the working VORs and the coverages of the unserviceable VORs in Tanzania.
The map shows, that only the airways between the three mentioned airports are marked with VORs. Other airways within the Tanzania FIR are not.

Problems VORs

6.1.1 Continuity of service	Consequence of problems:
reliability: - VORs Mbeya and Tabora unserviceable - age VORs DIA and Mwanza 6 years past their economical life - VOR DIA operates intermittently (see section 17.1.1)	- VORs DIA and Mwanza may break down - airways in Tanzanian FIR not longer marked with VORs - possible lower level ARNS - possible lower level ATS

12.2.3 DME

The DME is usually used in conjunction with the VOR. In Tanzania, the DME is only used at the airports of DIA and KIA. Appendix J.6 also shows the actual and first coverages of the working DMEs and the coverages of the unserviceable DMEs in Tanzania.
The map shows, that only with respect to DIA and KIA, a position can be determined.

Appendix J.3 shows the status of all DMEs in Tanzania.

Problems DMEs

6.1.1 Continuity of service	Consequence of problems:
reliability: - DMEs Mbeya and Tabora unserviceable - age DMEs DIA 6 years past its economical life - DME DIA operates intermittently (see section 17.1.1)	- DME DIA may break down - possible lower level ARNS - possible lower level ATS

13. POWER SUPPLY AIRPORTS TANZANIA

The maintenance and installation of the power supply is done by the Electrical section of the Directorate of Aerodromes.

To give an idea of the structure of power supply and power systems at DCA-manned airports, the description of the Dodoma Airport is given. All airports have approximately the same facilities which are powered via the same structure as in Dodoma.
The power systems of DIA, KIA and Arusha Airfield are discussed more elaborately in respectively section 17.1.2, section 17.2.2 and section 17.3.2.

13.1 Example: power system Dodoma Airport

Dodoma Airport is powered primarily by the national power supply company Tanesco. The 33 KV cable enters the airport at a sub-station which also contains two secondary back-up diesel generators. The number of generators depends on the number of sites to be powered, so some airfields only have one generator.

The 33 KV is stepped down to 11 KV at the sub-station and subsequently distributed to transformer stations near the facilities. At the transformer stations, the voltage is stepped down to 400 Volts. Because diesel generators have a limited capacity, they only power the most critical facilities during Tanesco power failure.

Table 8 shows the facilities, powered by the two generators.

Generator 1 (40 KVA)	Generator 2 (50 KVA)
Control Tower	Terminal Building
Offices	Airfield lighting
Communication Centre	

Table 8: Powering facilities Dodoma Airport

Facilities at Dodoma, which will not be powered during Tanesco power failure, are the Fire Station, the MET building, a DCA store, two hangars and some small buildings on the airport ground. Also the NDB of Dodoma will not be powered. The reason for the latter is not known.

Problems power supply Dodoma

7.6.1 Power system	Consequence of problems:
reliability: - both generators are more than 30 years old - both generators unserviceable	- entire airport is only powered by Tanesco - decrease of level ATS during Tanesco power failure

The problem of the back-up power supply at Dodoma Airport also applies to most of the airports in Tanzania besides DIA and KIA. Most of the back-up power supply at most of the airports consists of diesel generators.

Problems power supply airports Tanzania

7.6.1 Power system	Consequence of problems:
reliability: - back-up diesel generators are more than 30 years old - most back-up diesel generators unserviceable	- most airports only powered by Tanesco - decrease of level ATS during Tanesco power failure at most of airports
10.5.2 National service industries	**Consequence of problems:**
national power supply: - rationing of Tanesco in some areas in Tanzania (e.g. Songea, Mtwara)	- no main power during rationing Tanesco - only back-up power supply

14. MAINTENANCE OF AERONAUTICAL TELECOMMUNICATION EQUIPMENT

14.1 Organisation of maintenance organisation

The organisation of maintenance of all aeronautical telecommunication equipment in Tanzania is a hybrid form between a decentralised and a centralised organisation.
Decentralised is the preventive and possible corrective maintenance, done by Telecommunication Engineers and/or Technicians stationed at six airports.
Centralised is the corrective maintenance on all equipment in Tanzania which could not be repaired within six hours after break down or which is located at a remote site[33]. The maintenance is done by engineers of the Central Workshop, located at DIA. Also the main storage of spare parts is for a large part centralised and is located in the Technical Store in Dar es Salaam.

[33] A remote site contains aeronautical facilities, which is not manned by engineers or technicians

14.2 Procedure preventive maintenance

The Telecommunication section performs preventive maintenance with the aid of Acceptance Test Data Sheets (ATDSs). The ATDS is a document, that accompanies new equipment and is drawn up by the manufacturer of the equipment. The document describes the equipment and the maintenance procedures. The maintenance procedures are described for each parameter of the equipment along with the required frequency of checking.

The objective of the Telecommunication section is to check some of the parameters of all NAVAIDs daily with the help of the ATDSs. Other parameters are checked every week, quarterly or every year, according to the ATDS. The communication equipment is checked daily for its functioning by the ATC section and the Communication section. Appendix K shows the type of parameters along with the required frequency.

For recording of the daily parameters is done with maintenance forms. The forms are typed and contain the parameters which are stated in the ATDSs.
The range of the NAVAIDs and the radio communication equipment is checked once a week by asking pilots at what point they cannot longer receive a signal. This method of range measuring is rather rough and is merely done to check the functioning of each item of equipment.
The quarterly checks are referred to as ground checks. With ground checks, an alarm is given to see how the system reacts. After each ground check, the equipment needs to be calibrated again in order to maintain the integrity.

A Dutch expert of the Luchtverkeersbeveiliging (LVB)[34] has said that daily checks by engineers are not necessary, because a monitor system already does that. Only when there is no monitor system, daily checks have to be done by the Engineers and Technicians and only to check each system for worn out parts or components.
But since daily checks are the objective of DCA, problems influencing this objective are described below, along with the other problems.

Problems preventive maintenance

8.5.1 Preventive and corrective maintenance

preventive maintenance:
- calibration after ground checks not always done
- DCA aircraft flight calibration is broken down

10.5.4 International ATS counterparts

availability
- foreign flight calibration services (Kenya or South Africa) not available for more than five years

Consequences of problems:

- integrity NAVAIDs except NDB is not ensured
- level ARNS decreased

8.5.3 Maintenance organisation

facilities
- maintenance vehicle DIA broke down
- vehicle DIA took more than six months to be repaired
- shared CW vehicle not always available at DIA
- shared electrical section vehicle at KIA not always available, except with emergencies
- maintenance vehicle remote sites broke down
- vehicle remote sites took more than six months to be repaired
- both DIA and remote site vehicles used for other purposes than maintenance during work hours

maintenance management
- management choose not to hire a temporary vehicle for DIA, during break down original vehicle
- management choose not to hire a temporary vehicle for remote sites, during break down original vehicle

Consequences of problems:

- objective daily checks DIA not met
- objective daily checks KIA not met
- objective quarterly checks remote sites not met

[34] The LVB is the Dutch Air Traffic Control.

14.3 Procedure corrective maintenance

Basically, the procedure for corrective maintenance of equipment in Tanzania is as follows. Locally stationed engineers try to repair faulty equipment within six hours. If they do not succeed, engineers of the Central Workshop come to the site with the necessary test-gears and spare parts to repair the equipment.

√ Appendix L.1 shows the entire procedure including the administrative steps to be followed by the CW engineer, in case the engineer has to go to the site.
The procedure shows first of all that the number of steps an engineer has to take before he is at the particular site is significant and several people have to give their approval. This part of the procedure can take one to two weeks, although it also sometimes includes a request from the Chief of Telecommunications or the Director General to call the remote station for more details to avoid unnecessary trips and with that unnecessary costs.

More time expires when the CW engineer cannot repair the equipment at the site. The engineer has to choose then whether extra spare parts or more appropriate test-gears have to be brought to the site or the equipment has to be brought back to the CW in Dar es Salaam.
When the spare parts have to be brought to the site or when the equipment has to be brought to the CW or vice versa, the expired time is determined by the means of transport, the particular location of the site and the availability of the spare parts. Means of transport can be scheduled flights, a DCA car or public long-distance bus. The particular site is decisive for the means of transport and how long it takes for the parts to arrive. When spares are not available in Tanzania, they have to be bought abroad by the Technical Store. It can take then between one to six months for the spares to arrive at the site, depending on the type of spare part. This includes the problems with the Tender Boards (see section 16.1.2).
The transport has to be arranged by Head Quarters and can take one to two weeks before the equipment is actually brought to the Central Workshop.

Problems corrective maintenance	
8.5.1 Preventive and corrective maintenance	<u>Consequences of problems</u>:
corrective maintenance - bureaucracy corrective maintenance procedure	- unserviceability equipment is prolonged considerably, when corrective maintenance cannot be done within six hours

To underline the problem of the corrective maintenance procedure, appendix L.2 shows the example of the NDB-ZZ. The diagram of the serviceability of the NDB at Zanzibar Airport in 1995 shows, that the serviceability in February decreased from 100% to 83% and then dropped to zero percent during the following three months. Maintenance records showed that during this period the NDB broke down, the beacon was visited and checked by engineers of the CW, the beacon was brought to the CW and repaired and it was re-installed at Zanzibar.

14.4 Maintenance plan

According to the Head of Maintenance Engineers Communication, there is not a maintenance plan or program for all equipment in Tanzania as it is described and advised by *Lawrence Mann, Jr.*[35] The items mentioned in section 8.3 are discussed below to show what is known to all maintenance employees.

Although the task proportion of ANS maintenance organisation itself is not documented explicitly, the policy of DCA is to perform all maintenance of all equipment in Tanzania.

[35] Mann, Lawrence, Jr., *Maintenance Management* (Lexington, Massachusetts Toronto, revised edition, 1976, 1983, page 135).

This is expressed in the job description of all engineers and technicians in the Scheme of Service for Civil Servants.[36] In there, the description is given of all tasks an engineer or technician has to do within a certain grade. All task descriptions of all grades together indicate the total task proportion of the entire organisation. The equipment's Acceptance Test Data Sheets (ATDSs) are used to indicate which parameters of each piece of equipment have to be checked.
The task distribution among the maintenance personnel is based on the grades and executed by Senior Engineer or Senior Technician at each station. In practice, the distribution may vary due to circumstances like number of staff and number of tasks to perform.
The frequency of each task is stated in the ATDSs and is followed exactly by the Telecommunication section.
The procedures of maintenance are not documented, but shown to aspirant engineers or technicians on the job by experienced engineers.
The way maintenance data such as parameter checks and availability figures should be recorded is not documented, but also shown on the job by experienced engineers. The way maintenance data should be analysed is also not documented.
The distribution of resources and facilities is also not documented. There is only an overview of all the engineers and technicians, their grades and their station. There is not an overview of the status of all facilities in Tanzania concerned with the maintenance, like maintenance vehicles, test-gears, etc.

Problems with maintenance program

8.5.2 Maintenance program	<u>Consequences of problems</u>:
presence:	- procedures of maintenance and way of recording maintenance data has to be explained to every new employee
- overall maintenance plan for whole Tanzania is not present	- no analysis of maintenance data

14.5 Task proportion ANS organisation

The task proportion of the maintenance organisation in the case of DCA involves both types of maintenance completely.
The only time that other parties are involved with the maintenance is when the equipment has not yet been commissioned[37] or in the case that DCA engineers are not capable of performing maintenance. Other parties are usually foreign engineers of the relevant manufacturers.

14.6 Maintenance management

The management of the Telecommunications section consists of the Director of ANS, the Chief of Telecommunications and the Heads of Maintenance Engineers of respectively NAVAIDs and communication equipment. Both Heads of Maintenance Engineers are responsible for the operational management in their fields, but decisions have to be approved by the Chief of Telecommunications and the Director of ANS.

[36] Ministry of Communication & Transport, *Scheme of Service for Civil Servants* (Dar es Salaam, Tanzania: 1995). Ministry of Works, *Scheme of Service for Civil Servants* (Dar es Salaam, Tanzania: 1995).

[37] Commissioning is the cross-checking and testing of the newly installed equipment to prove that the values of the parameters are correct for the Tanzanian situation. The values are drawn up by foreign engineers in the presence of local engineers and noted in the ATDS. After the commissioning, DCA and the manufacturer sign the documents and the responsibility for the equipment and its maintenance is handed over to DCA.

Problems maintenance management

8.5.3 Maintenance organisation	Consequences of problems:
Maintenance management - management decided to hire governmental grader - when grader did not became available, management did not hire grader from private company	- Outer Marker and NDB-DS DIA unavailable for three years - incomplete ILS for three years - decreased level ARNS provided by ILS at DIA for three years
8.5.3 Maintenance organisation	Consequences of problems:
Maintenance management - management did not hire replacement maintenance vehicle for trip Bondwa	- unavailability Bondwa VHF relay station prolonged for three months - limited Area Control

14.6.1 Maintenance records for management

Two types of maintenance records can be distinguished, which are the monthly report and the quarterly report. The reports are collected in one map, spanning one or more years.
The monthly reports are summarised overviews of the status of equipment. This includes the serviceability percentage of equipment in a month, comments on encountered problems by responsible engineers and requests of these engineers, concerning repair or replacement of equipment which is about to break down. The reports are the only available copy.
Quarterly reports are summarised overviews of the Heads of Maintenance Engineers on the status of equipment in Tanzania. On basis of these reports long-standing problems are viewed and decided on by the management.
All reports of an airport are collected in one map together with all other memos and copies of AFTN messages concerning the maintenance at a particular airport of one or more years. When a map has reached a certain thickness, the map is closed and stored. Since decisions on maintenance issues have to be assessed and approved by at least three people within the management, the map with the monthly reports circulates between the relevant offices.

Problems maintenance records

8.5.3 Maintenance organisation	Consequence of problems:
maintenance records: - maps of important airports like DIA with its large number of problems circulate frequently	- statistical information in maps cannot be used for analysis

14.6.2 Problems serviceability percentages

The serviceability percentages of aeronautical telecommunication equipment inside the **monthly reports** are not reliable. The ATC section also records the percentages and it does that on a daily basis. However, the maintenance figures are recorded with larger and irregular intervals. Records of the same equipment in the same month show considerable differences between the two recordings which sometimes is more than thirty percent.
The **serviceability percentages** of aeronautical telecommunication equipment are not recorded by every airport in Tanzania. The airports which do record do not send their reports to the Head Quarters on time every month. This means that information concerning certain months is not available and that the situation cannot be viewed. For example, appendix L.2 shows the serviceability percentages of all equipment at Zanzibar Airport in 1995. The information of all months during one year was collected in May 1996 and it shows that Head Quarters was missing information of six months. It is hard for management to base conclusions about the status of equipment on such few data.
Besides the fact that monthly information is missing, the serviceability percentages are not summarised for a whole year or longer. Or in other words, management does not use statistical information to assess the status of equipment in Tanzania over a period of one year or more. The information is merely recorded to give a rough assessment per month.

14.7 Maintenance personnel

The Telecommunication section, involved with the actual maintenance, consists of Executive and Operational Engineers and Technicians. The number of employees includes both Heads of Maintenance Engineers, since they sometimes perform maintenance in their particular field. Table 9 shows the distribution of the Telecommunication section employees over the particular stations.

Station	Engineers	Technicians
Head Quarters	2	-
Dar es Salaam International Airport (DIA)	13	7
Central Workshop	8	1
Technical Store	1	1
CATC	4	-
Kilimanjaro International Airport (KIA)	6	2
Dodoma	-	1
Mwanza	1	-
Tabora	1	-
Zanzibar	1	-
Total	37	12

Table 9: Distribution Telecommunication section

This number used to be higher, but some engineers left DCA to work in the private sector, usually to earn a higher income. Although several new engineers are trained at the moment. It has not been examined what the consequences are for the actual maintenance of equipment and the contribution of the Telecommunication section to the ATS. The effects on morale as well as the level of knowledge and skills of the present employees is described in chapter 15.

14.8 Facilities

14.8.1 Repairshop

In Tanzania, the airports which have repairshops and are manned with Engineers or Technicians are DIA with the Central Workshop (CW) and the AFTN repairshop inside the ACC, Dodoma, KIA, Mwanza, Tabora and Zanzibar.
The airports besides DIA have small repair-shops with small quantities of spare parts to perform the minimum preventive and corrective maintenance. KIA has a repairshop which is better equipped than the small repair-shops at the other airfields, but it also has small quantities of spare parts. Basically, the repairshops have to order spares with the TS every time corrective maintenance has to be performed.

14.8.1.1 Central Workshop (CW) DIA

The function of the engineers of this facility is to install and commission new equipment, perform preventive maintenance to equipment at remote sites and perform corrective maintenance to all NAVAIDs and communication equipment in Tanzania which cannot be repaired within six hours. When foreign experts train local engineers, at least some engineers and/or technicians of the Central Workshop take part in this training.
There are at the moment eight engineers and one technician working for the Central Workshop. Together with the four engineers of the Radio Maintenance section, three

instructors and the Chief of Instruction, and the Heads of Maintenance Engineers, there are fifteen employees who do all the maintenance for whole Tanzania.

The CW is equipped with multi-meters, signal generators, oscilloscopes, a Vector Volt meter and other auxiliary equipment like soldering iron. Out of twenty oscilloscopes, the CW has only one good working oscilloscope and one half working oscilloscope. The Vector Volt meter, which is the only one in Tanzania, has a broken coupling part and cannot be used. Although the CATC has some oscilloscopes, they are not keen on lending the equipment to the Central Workshop, because they are afraid that it will be damaged.

Problems Central Workshop

8.5.3 Maintenance organisation	Consequences of problems:
facilities - insufficient number of test-gears for testing analogue, digital and micro-processor controlled systems *maintenance personnel* - CW engineers have not knowledge to repair broken micro-processor controlled test-gears - CATC only teaches to use test-gears but not to repair them	- maintenance unserviceable equipment delayed - prolongation unserviceability equipment

14.8.1.2 KIA repairshop

The engineers and/or technicians of the KIA repairshop perform preventive and corrective maintenance to equipment located in the KIA Terminal Area (TMA). Corrective maintenance is done to the abilities of the engineers with respect to the present facilities and spare parts.

The repairshop is located inside the ATC building of the airport. The repairshop is equipped with signal generators, a voltage-meter, an oscilloscope, an oscillator, a frequency counter, a multi-meter, a DC-power generator and a VOR test signal generator.
The VOR test signal generator can only be used for the old, conventional VOR system and not for the new D-VOR.

For the testing and/or repair of the new D-VOR and DME system, both systems have so-called Built-In-Test-Equipment (BITE) and they can be tested by the computer with which the equipment is also controlled. Repair of the new equipment is restricted to replacement of units. The Telecommunication section is not able to repair broken units. They have to be send back to the manufacturer.

Present spare parts and D-VOR/DME units are stored on shelves in the repairshop.

Problems repairshop KIA

8.5.1 Preventive and corrective maintenance	Consequences of problems:
corrective maintenance - problems with spare parts acquisition from Technical Store in Dar es Salaam 8.5.3 Maintenance organisation *facilities* - insufficient number of spare parts	- maintenance unserviceable equipment delayed - prolongation unserviceability equipment

Problems of the KIA repair shop also apply to the repair shops at the airports other than DIA.

14.8.1.3 Technical Store (TS)

The Technical Store (TS) is located approximately two kilometres from DIA and was set up in 1973 by Philips NV. It is not clear to what extent the location influences the procurement of spare parts for unserviceable aeronautical telecommunication equipment and with that the quick repair of the equipment. Procurement would probably be speeded up when the TS is located at DIA, near the Central Workshop and the possible transport by air.

The TS supplies all the repairshops in Tanzania with spare parts. In case the TS does not have the particular spare part, it is ordered from abroad by its engineers who also order auxiliary equipment, like air-conditioning.
The time-period of obtaining new spares is usually one month for small parts. But the ordering and delivering of a complete system can take six months. This includes also the problems with the Tender Boards as described in section 16.1.2.

The Technical Store is also described in appendix F.16.

Problems Technical Store

8.5.3 Maintenance organisation	Consequences of problems:
facilities: - maintenance on building not done for several years - holes in roof Technical Store - rain water damages shelves on which spare parts are stored	- state spare parts may deteriorate due to bad state shelves
10.5.1 National Government	Consequences of problems:
purchase control: - dependency on Tender Boards	- delayed procurement of spare parts or new equipment

14.8.2 Maintenance vehicles

Only the maintenance vehicles of DIA and KIA and the encountered problems have been examined, due to lack of time.

14.8.2.1 Dar es Salaam International Airport (DIA)

Telecommunication section DIA
The Telecommunication section at DIA has one vehicle to perform the preventive and corrective maintenance of all aeronautical telecommunication equipment at the airport. It is specially used for equipment located at sites away from the ACC, like the Localizer site and the Transmitter Station.

To give a slight indication of the problems with the transport at DIA, engineering log books which are at all times at the remote sites of the NAVAIDs were examined to see how many days the sites were visited during the whole year of 1995 and the year of 1996 up to 22nd of August. It is an indication, because the engineers do not always fill in the books when they make a visit to the site.
In table 10, the percentages of daily visits in each year are shown.

Cabin	1995	1996
Localizer	52 %	46 %
Glide Path	43 %	24 %
VOR/DME	53 %	20 %

Table 10: Percentages of visits of NAVAIDs sites

When comparing 1996 with 1995, one can see that the situation has worsened for all sites. An engineer estimated that 20 % of the visits are not noted by the engineers or technicians.

Even when this figure is lifted to 30 %, the percentages of visits is still under DCA's objective.
The percentages of visits are not of direct influence for the serviceability of the NAVAIDs themselves. But observations and the engineering log books have shown that specially the DME and also the VOR are problematic, due to their age. Despite the severity of the problems, the cabin with the VOR and DME was the least visited site.

Central Workshop (CW) DIA

The Central Workshop (CW) has two vehicles for maintenance purposes. One vehicle is used to get spare parts with the Technical Store. The other vehicle is a Four Wheel Drive and is used for trips to remote sites or airports other than DIA. It is used for both preventive maintenance and corrective maintenance of remote stations and equipment which cannot be repaired by local engineers.

14.8.2.2 Kilimanjaro International Airport (KIA)

The Telecommunication section of KIA uses a vehicle for preventive maintenance purposes to go to sites, located at considerable distance from the ATC building. It has to share the vehicle with the Electrical section.

Problems maintenance vehicles

The problems with the maintenance vehicles are described with the discussion of preventive maintenance in section 14.2. Therefore, only the consequences are shown.

Consequences of problems:

- objective daily checks DIA not met
- objective daily checks KIA not met
- objective quarterly checks remote sites not met

14.9 Accessibility sites

VHF relay stations are located on top of hills or mountains. To be able to perform maintenance of any kind, a Four-Wheel-Drive is necessary.

Problems accessibility

8.5.3 Maintenance organisation	Consequences of problems:
accessibility: - part of the road to the top of Bondwa VHF relay station washed away during rain storm	- top Bondwa can only be reached by carrying all necessary equipment and spares on foot - unserviceability station prolonged, due to problems with accessibility

15. HUMAN RESOURCES ANS ORGANISATION

The human resources of the Tanzanian ANS organisation consist of the ATC Officers, the Communication Officers and Assistants and the Telecommunication Engineers and Technicians.

15.1 Questionnaire human resources

Some of the information concerning the human resources of the ANS organisation, has been gathered by means of a questionnaire.

The questionnaire has been used to gather information on:

- general information like age and time with DCA
- basic training plus refreshments
- specific training plus refreshments
- opportunities for extra training with varying conditions
- job description plus tasks deployment
- satisfaction level of:
    - wage level
    - promotion possibilities
    - amount of staff

The total population of interest consists of three sub-groups which are the ATC Officers, Communication Officers, and the Telecommunication Engineers and Technicians. The latter have been taken together, since they are within the same section. Questionnaires have only been handed out to those employees who are directly involved with the ATS provision. Therefore, employees at Head Quarters have not been approached beside the two Heads of Maintenance Engineers, because they perform maintenance of remote sites. Furthermore, employees who did not play a part with the ATS provision at the time of the research are also not a part of the population. This refers to employees on leave or on training. The final population has 160 employees. Of the population, 38% returned a questionnaire.
However, random sampling was not possible. This was, because the population was distributed over whole Tanzania and because of a lack of time and financial resources to visit airports. Also, the response within all sections with respect to the total number of handed out questionnaires is not representative for the sections. For example, the response of the ATC section was only 16%, whereas the ATC section contains 42% of the total population. Therefore, conclusions on the total population cannot be derived from statistics and are only there to support observations or findings. Where used, the statistics are not contradictory to the observations made.
As it is concerned with the basic and specific training, the questionnaire is merely used to make a general overview of received training.

15.2 General information human resources

In this section, some aspects of all human resources are discussed together to be able to compare the different departments with one-another. This way the differences and similarities between the departments become apparent.

Appendix M shows the **basic and specific training** received by all ANS organisation employees. The basic training is shown with all major subjects given per course. With some basic training courses, it is not clear which subjects are given with which course and are, therefore, shown once. An example are the subjects for the Aerodrome and Approach Control courses.

15.2.1 Received refreshment courses

Table 11 shows the percentages of refreshments of both basic and specific training, received by the questioned employees.

Section	$Refreshment_{basic}$	$Refreshment_{specific}$
ATC	0 %	0 %
Communication	38 %	0 %
Telecommunication	43 %	20 %

Table 11: Received refreshment basic and specific training

With almost all received refreshment training courses, extra subjects were added.

It has to be noted, that the ATC section is not directly exposed to changing technologies. Most training has the emphasis on procedures, rather than on technologies. This is different with the other sections, specially the Telecommunication section. Changes like the implementation of micro-processor controlled systems (e.g. the AFTN Automatic Message Switching computer) place a higher need of refreshments. Although, refreshment in all cases is a good instrument for the maintaining of the level of knowledge and skills.

15.2.2 Wage levels

Table 12 shows the wage levels per month of all sections. The amounts contain allowances for transport and housing.

Profession	Wage level$_{starting}$ (Tsh.)	Wage level$_{highest}$ (Tsh.)
Air Traffic Control Officer	44,279 (US $75)	127,605 (US $214)
Communication Officer	44,279 (US $75)	127,605 (US $214)
Operational Engineer	44,279 (US $75)	127,605 (US $214)
Executive Engineer	40,212 (US $68)	68,839 (US $117)
Technician	32,988 (US $57)	57,455 (US $98)

Table 12: Wage levels[38,39]

The low wage levels are apparent within all sections. Depending on the grade, a civil servant has 1,100 to 4,300 Shilling per day to spend for food and clothes.
In table 13, the retail prices of selected commodities are shown to give an idea about the purchasing power of DCA employees.

Commodity	Price (Tsh)
Bread (half loaf)	200
Sugar (1 kg)	450
Eggs (dozen)	960
Milk (1 litre)	800
Potatoes (1 kg)	250
Tea (1 kg)	1,500
Beer (half litre) Safari	500
Rice (1 kg)	350

Table 13: Retail prices selected commodities[40]

It is estimated, that 75% to 80% of the income is spend on food. It is apparent that the purchasing power of all civil servants is very poor. This has been confirmed by the results of the questionnaire. Of all people questioned, 98% said that they are not *paid according to the number of tasks* they are carrying out. Besides that, 87% of the interviewees is not content with the present *secondary conditions of employment.*

Also because of the low wage levels, employees seek other sources of income. Examples are the farming of beans or maize on a piece of land, the keeping of chicken for eggs, the renting of houses or having a Telecommunication company.
The government allows Civil Servants to have these other sources of income beside their civil servant salary.

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38 Ministry of Communication & Transport, *Scheme of Service for Civil Servants* (Dar es Salaam, Tanzania: 1995). Ministry of Works, *Scheme of Service for Civil Servants* (Dar es Salaam, Tanzania: 1995).

39 In 1996, Tsh. 10,000 is about US$17.

40 Business Times (Dar es Salaam, Tanzania: 21 September 1996).

Problems wage level	
9.5.3 Motivation	Consequence of problems:
wage level: - Civil Servant salary too low to subsist, according to DCA employees	- DCA employees have other sources of income - DCA employees sometimes make shifts of 24 hours straight, so the next two days they work for the other source of income - this can result in fatigue on the job, leading to hazardous working situations

Example
Engineers at KIA sometimes swap shift hours with colleagues to work a whole day at the airport. The next day or two days, they are able to work for the other source of income.

15.2.3 Attitude towards opportunities for extra training

DCA employees were asked how they feel about taking extra courses to upgrade their level of knowledge as such, when courses won't have to be paid, when it would yield a promotion and when it would yield a qualification.

The survey showed that 93% of all employees was willing to take extra courses as such. The survey also showed that the wage level influences the choice of taking extra courses. When the courses won't have to be paid, 75% would take the opportunity and when it would yield a qualification, 79% would take the opportunity. But when it would only yield a promotion, only 34% would take the opportunity, whereas 56% would not take the opportunity. According to the Head of Maintenance Engineers, the latter opportunity deviates from the other ones, because it is regarded that a promotion would only yield a small increase of the already low wage level. However, a qualification can be of use in the future, when employment is sought elsewhere. A qualification could then make a difference in the received income.

15.2.4 Extra tasks

Of the questioned employees in all sections, 74% said that they had to perform more tasks besides the tasks they were originally assigned to. The extra tasks were usually in the field of management and were usually done because of a lack of staff.
With respect to the received training, 83% indicated that it was not sufficient to carry out all the tasks to their abilities. It is therefore not surprising that 72% of the employees was not satisfied with the extent of the received training.

15.2.5 Promotion opportunities

In order to obtain promotions to higher grades, DCA employees have to perform their duties satisfactory and pass exams of courses, as indicated in the Scheme of Service for the relevant employees.[41] With certain courses, licenses can be obtained for the control or maintenance of certain aeronautical telecommunication equipment.
With every promotion to a higher grade, the wage level is increased.

41 Ministry of Communication & Transport, *Scheme of Service for Civil Servants* (Dar es Salaam, Tanzania: 1995).

Problems promotion opportunities

6.1.1	Continuity of service

reliability:
- Radar and AMS computer unserviceable

9.5.3	Motivation

promotion:
- promotion not possible, due to unserviceable aeronautical telecommunication equipment

Consequence of problems:

- DCA employees stay on a certain wage level
- DCA employees can become demoralised

The results of the questionnaire indicate, that 71% of all questioned is not content with the *promotion opportunities* within DCA.

Example
ATC controllers who want to be promoted to Senior ATC Officer Grade II, have to have four ATC ratings according to the Scheme of Service, which includes a Radar Control rating. In order to achieve a Radar Control rating, a controller must follow a Radar Control course and have experience with Radar Control techniques. But since the Radar in Tanzania is completely unserviceable, this experience cannot be gained and maintained. In practice this means that a controller cannot be promoted any further after ten years of duty, despite the number of years he will be employed after that. This also means that a controller will stay on a certain salary level.
This situation also applies to the other sections.

15.2.6 Brain drain

Table 14 shows the brain-drain in the Telecommunication section in the field of specific equipment, which were installed in 1984 during the French rehabilitation project.

Specific equipment	$\text{Engineers}_{\text{trained}}$	$\text{Engineers}_{\text{remaining}}$
Instrument Landing System	6	2
Radar system	6	1
VHF Area cover equipment	6	1
Automatic Message Switching computer	6	0
Total	24	4

Table 14: Brain drain Telecommunication section

With some of the above mentioned equipment like the Radar system, the training was divided over different parts of the system for different engineers. So, each engineer knew only a specific part of the equipment.

The brain drain of DCA is not restricted to the Telecommunication section, but also applies to the other two sections. Although exact figures are not known, since records in this matter are not kept.

Problems general human resources

10.5.1.	National government

difference public and private sector
- GoT liberalised markets

Consequence of problems:

- wage level difference public and private sector in some cases six times
- employees DCA leaving DCA
- brain drain DCA

9.5.3 Motivation	Consequence of problems:
lack of staff: - decrease in or lack of staff with Telecommunication section - present engineer(s) only knows a part of system and not whole system	- very difficult to train engineers for achieving licenses and accompanying promotions - employees stay on certain wage level without chance of improvement - motivation DCA employees possibly effected negatively - broken down equipment cannot be repaired due to insufficient number of professional engineers
8.5.1 Preventive and corrective maintenance *preventive and corrective maintenance:* - maintenance some aeronautical telecommunication equipment not possible, due to lack of professional engineers	

15.3 Air Traffic Controllers

Air Traffic Control Officers have to perform the duties depending on their grade as is noted in the Scheme of Service for Civil Servants.
The job description of the ATC Officers meets the general description of section 9.1.

An ATC controller is promoted based on his merits and his achieved ratings. The ratings can be achieved by taking training for each rating which are endorsed to the license achieved during basic training. All ATC courses have to be followed at Civil Aviation Training institutions. The courses for basic and specific training are shown in appendix M.

Table 15 shows the distribution of the controllers at various stations.

Station	Nr.
Head Quarters	7
Dar es Salaam International Airport	28
Kilimanjaro International Airport	10
Other airports	25
CATC	4
Working abroad	8
Total	82

Table 15: Distribution ATC Officers

Also five Aeronautical Information Assistants provide ATS at some remote stations in Tanzania.

Dar es Salaam International Airport (DIA) contains the largest number of ATC controllers, because it provides Aerodrome Control, Approach Control and Area Control for the entire FIR of Tanzania on a 24-hours basis. To provide a 24-hours service, five shifts with each eight controllers and one supervisor are required, according to the Chief of Air Traffic Service at DIA.
Because Kilimanjaro International Airport (KIA) also provides Approach Control within the KIA TMA besides Aerodrome Control on a 24-hours basis, this airport has also a substantial number of controllers. To provide the 24-hours service, 20 controllers per day are needed, according to the Chief of Air Traffic Service at KIA.

Problems ATC section DIA

9.5.3 Motivation	Consequence of problems:
number of staff: - DIA has 28 controllers, where 41 are required - controllers not equally divided among types of control - Area Control has only 7 controllers to man 5 shifts - ATC control supervisor is not present at DIA - Area Control Officer performs tasks supervisor	- general lack of staff ATC section DIA - Area Control Officer performs tasks of two controllers - Area Control Officer too many different tasks - work over load Area Control Officer - possible negative effect on morale Area Control Officers - possible dangerous work situation Area Control

Problems ATC section KIA

9.5.3 Motivation	Consequence of problems:
number of staff: - KIA has 10 controllers, where 20 are required	- general lack of staff ATC section KIA - strain on controllers - controllers can become demoralised

15.4 Communication Officers and Assistants

The job description of the Communication Officers meets the general description of section 9.2.
All Communications Officers can start their career either as a Communications Assistant or start as a Communications Officer Grade III. For the service entry, advanced certificates of education in English, physics and mathematics are required.
The basic and specific training received by the Communication Officers is shown in appendix M.2.

Table 16 shows the distribution of the Communication Officers and Assistants over the various stations.

Station	Nr.
Head Quarters	3
Dar es Salaam International Airport	29
Kilimanjaro International Airport	11
Other airports	27
CATC	3
Working abroad	-
Total	73

Table 16: Distribution Communication Officers and Assistants

Every manned airport has at least one Communication Officer or Assistant to provide a Communication Service.
The large number of personnel at DIA and KIA is because they are international airports, which requires 24-hours service. Besides that, DIA has the control of all international traffic over-flying the Tanzanian FIR which occurs also for 24 hours per day. Because of this, ATS messages have to be exchanged for 24 hours per day.

The AFTN and the problems, encountered by the Communication section, are described and discussed in section 11.2.1.

15.5 Maintenance employees

Maintenance of all NAVAIDs and communication equipment is done at different levels by either engineers or technicians. The differences between engineers and technicians are

expressed in the required qualifications and the responsibilities on the job, according to the Scheme of Service for civil servants.
Although the Scheme of Service distinguishes Executive Engineers, Operational Engineers and Technicians, in practice, there are no differences between the duties of Executive and Operational Engineers and these engineers sometimes do tasks which are supposed to be done by Technicians. Therefore for the sake of convenience, these three categories have been put together under the category of Maintenance Engineers.

15.5.1 Task proportion Telecommunication section

As described in section 14.5, the Telecommunication section has to perform preventive as well as corrective maintenance in whole Tanzania. Besides these tasks, the Telecommunication section also has to perform the extra tasks, according to the description in section 9.3.

Only the installation of new NAVAIDs and communication equipment is done by foreign engineers. Engineers of the relevant airport and the Central Workshop (CW) are trained by the same foreign engineers to be able to install the same equipment whenever this is required.

15.5.2 Distinction Operational and Executive Engineers

The distinction between Operational and Executive Engineers is based on qualifications.
Operational Engineers are specially mentioned in the Scheme of Service for Civil Servants, because their training is confined to aviation engineering at Civil Aviation Training Centres (CATCs). The relevant Scheme of Service is the responsibility of the Ministry of Communication & Transport. Executive Engineers receive high level training at engineering institutions other than the CATCs. This category also includes engineers in other fields than aviation, like civil, mechanical or electrical engineering and their Scheme of Service is the responsibility of the Ministry of Works.
The different Ministries are also the reason for the difference in wage levels (see table 11 of section 15.1). However, this aspect has not been examined thoroughly, so remarks cannot be made. It is however recommendable to examine this situation carefully, because both groups of engineers perform the same tasks within DCA. The wage difference can create discontent and demoralisation with the Executive Engineers.

15.5.3 Training

Appendix M.3 shows, that the basic training for engineers and technicians is done at similar institutions, although depth and duration differ.
The specific training applies to both Engineers and Technicians, since both groups sometimes attended the same courses. For specific training, every effort is made by DCA to train the engineers and technicians for specific equipment and also for new techniques and technologies. Of the 16 institutions, only 3 are Tanzanian and the rest is received abroad.
Most of the specific training courses took 3 months with variations between two weeks and 8 months. Questions can be raised by courses of only two weeks, but generally the duration is sufficient.

The general level of knowledge of the Telecommunication section is sufficient to do their tasks. However, it is hard to tell, whether the level of knowledge in the field of new technologies like micro-processor controlled systems is sufficient.
A foreign expert stated in a letter, sent to the Airport Commander of KIA, that the general knowledge of the local engineers in this field was not adequate enough to understand the exact operation of the control and monitor systems of the new Doppler-VOR and DME at that airport. Although these systems have Build-In-Test-Equipment (BITE), the inadequate level of knowledge can become a problem in the case the systems break down. In that

case, foreign experts have to come to assist. The training given by this expert, who adjusted the courses somehow to the level of knowledge of the engineers, lasted only four weeks, while a computer course given at the Dar es Salaam University takes three months minimum.

15.5.4 Skills

Skills for the maintenance of equipment covered during basic training is limited by the level of practice given at the mentioned training institutions. Because of limited time and problems with reachability, only the Radio Maintenance section at the CATC was visited.

Problems skills

9.5.4 Quality Civil Aviation training institute	Consequence of problems:
training facilities: - CATC Tanzania is lacking sufficient and qualitative training equipment, like ILS or Radar system - CATC Tanzania lacks proper test gears and spare components to practice with	- skills cannot be gained at CATC Tanzania - skills can only be achieved with on-the-job training experience

Number of staff

The staff shortage in the Telecommunication section of DIA has already been described in section 15.1, but also the Telecommunication section of KIA faces a lack of staff.

Because KIA is an international airport with a 24-hours service, DCA has also set the objective of daily routine checks by maintenance engineers. At KIA, there are six engineers for the maintenance. With these six engineers, three shifts have been formed of two engineers per shift.

Problems number of staff KIA

9.5.3 Motivation	Consequence of problems:
number of staff: - During sickness or leaves shifts cannot be manned sufficiently	- objectives daily checks KIA cannot be met

15.6 Civil Aviation Training Centre (CATC) Tanzania

After the break-up of the EAC, DCA had to arrange training of its own for its personnel.
In 1985, the Civil Aviation Training Centre (CATC) was founded inside the old terminal building of DIA. It provides DCA with the training of Air Traffic Controllers, Communication Officers, Maintenance engineers, Fire and Rescue Officers and Aerodrome Operators. From 1996, the CATC also trains AIS Officers. Each group of profession has its own section within the CATC. Of the sections, the Radio Maintenance, the Air Traffic Control and the Communications Operation sections are described, because they are relevant to the research. The number of instructors at the CATC for these sections is eleven.

The CATC instructors base their courses on ICAO reference material, like the Annexes, and on their received training in their particular field and in the field of basic instructional techniques. With respect to the basic instruction techniques courses, they are generally felt as insufficient in time and depth of the courses.
Besides the CATC instructors, part-time instructors give some courses in case of specific courses like Radar Techniques. They are usually DCA employees working with the ACC.

Appendix M shows all courses received by all relevant DCA employees, including the courses given at the CATC with their nature and duration.

Problems CATC generally

9.5.4 Quality Civil Aviation training institute	Consequence of problems:
instructors: - shortage of staff in all sections - instructors also instruct students other sections	- limited capacity for training students - postponing of courses - delay training students

9.5.4 Quality Civil Aviation training institute	Consequence of problems:
instructors: - no refreshment training of subjects for CATC instructors - most training more than five years ago - training newest technologies felt too short for sufficient comprehension	- lack of knowledge or update of newest technologies - updates cannot be taught

9.5.4 Quality Civil Aviation training institute	Consequence of problems:
training facilities: - CATC is lacking sufficient and qualitative training equipment, like ILS, AMS computer or Radar system - CATC lacks proper test gears and spare components to practice with	- skills cannot be gained at CATC Tanzania - skills can only be achieved with on-the-job experience

15.6.1 Aeronautical Radio Maintenance Section

The general goal of the Radio Maintenance section is to teach the students how to maintain the navigation and communication equipment used in Tanzania. For maintenance of specific equipment like VOR or DME, a student has to take extra courses after he has completed the three-year study for general maintenance of equipment. For this training of engineers, licenses are achieved. Based on these licenses, promotions and with that wage levels are determined.

Besides training students, engineers working in the Radio Maintenance section also perform sometimes maintenance tasks along with the engineers of the Central Workshop.

Problems Radio Maintenance Section

9.5.4 Quality Civil Aviation training institute	Consequence of problems:
training facilities: - lack of real-situation equipment, like AMS computer, Radar systems, ILS equipment with CATC	- proper training for skills in specific equipment cannot be given - lack of skills hamper achievement licenses - without licenses, promotion is not possible - engineers stay in certain wage level - engineers may become demoralised

9.5.4 Quality Civil Aviation training institute	Consequence of problems:
nature of received training: - advanced technologies like micro-processor controlled techniques are not taught at the CATC, because instructors have only little knowledge, according to Head of Instructors *number of refreshment training:* - no refreshment training of subjects given at CATC for CATC instructors	- knowledge in field micro-processor controlled and computer systems not enough to train engineers at CATC properly

15.6.2 Air Traffic Control (ATC) section

This section deals with the training of ATC Officers. For this purpose, the CATC is equipped with three simulators with which Aerodrome, Approach and Area Control can be simulated. The simulators were bought from the Canadian company Skykeesh in 1985.

For each course, working experience has to be gained in real situations under supervision of a licensed ATC controller in order to obtain a license and a rating.

Problems ATC section

9.5.4 Quality Civil Aviation training institute	Consequence of problems:
training facilities: - simulators are obsolete, since manufacturer is out of business - Aerodrome Control simulator has broken down - simulator for Approach and Area Control stripped to obtain spare parts remaining simulator - no simulators for training in Radar Control techniques	- skills for Aerodrome Control cannot be obtained with CATC - limited number of students for Approach and Area Control, due to limited simulators - skills for Radar techniques cannot be obtained at CATC in Tanzania - ATC Officers cannot achieve Radar Control license with training at CATC

15.6.3 Communication Operation section

The Communication Operation section conducts two main courses which are the Aeronautical Fixed Service (AFS) course and the Aeronautical Mobile Service (AMS).
When a Communication Officer has completed both courses, a third course can be followed which is the Aeronautical Communication Supervisory course. This course is the stepping stone for seniority in the Communication section.
The main document on which the courses are based is the Annex 10 of ICAO. Besides that operational manuals of equipment like teletypewriters or the message switching computer, specific documents for the planning of AFTN or the ATN and books from libraries in Dar es Salaam are used.

Problems Communication Operation section

9.5.4 Quality Civil Aviation training institute	Consequence of problems:
facilities: - computer practice courses at university or technical college Dar es Salaam too short, according to Head section - shortage of funds for longer courses	- limits the capacity of students which can be trained. - computer practice too short for full comprehension

16. EXTERNAL ASPECTS

With the term external aspects is meant, those aspects which influence the functioning of the ANS organisation or on which the ANS organisation relies with the ATS provision and cannot be controlled or controlled with difficulty by the ANS organisation.

16.1 National government

Since DCA is a governmental institution, the Government also influences the organisation. Specially in the past when the responsibility for all policies lay with the relevant Ministry.

16.1.1 Governmental interference

As is described in section 10.1, the degree of ownership by the Government of the ANS organisation determines the degree of ATS provision. Specially, the degree of financial and operational control determines the degree of freedom to take actions with respect to problems, which are directly connected to the proper functioning of aeronautical telecommunication equipment and/or the relevant sections.

The degree of ownership by the government was and is still for the full hundred percent. The final responsibility lies with the relevant Minister. In 1996, the responsibility lay with the Minister of Communication and Transport for both the Directorate of Civil Aviation (DCA) and the Directorate of Aerodromes. In future, the intention is for DCA to become a governmental agency.

As described in section 1.5, financial control of DCA was already gained in the financial year of 1994/1995. With respect to the financial year of 1993/1994, the revenues doubled. The revenues consist of several sources, but the large part comes from the landing and parking charges, paid by the airlines. Important here is that the foreign airlines have to pay in US Dollars, which means a direct influx of foreign exchange.

From June 1996, the Directorate of Aerodromes was founded and was made responsible for the operations at the airports of Dar es Salaam and Kilimanjaro. The responsibility of DCA became the operations at the other airports in Tanzania and the ATS provision. Also from that date, the responsibility of the operational control has been moved from the Minister of Communications and Transport to the Director Generals of DCA and the Directorate of Aerodromes. The Minister only holds the overall responsibility. So, as far as governmental interference with respect to ownership is concerned, there are no problems.
The remaining governmental interference with the operational policy is the influence of the Tender Boards on the acquisition of spare parts and new equipment. The problems with the Tender Boards are described in section 16.1.2.

16.1.2 Purchase control

All expenditures on spare parts or new equipment, made by DCA and the Directorate of Aerodromes, have to be approved by the government. For this matter two tender boards have been formed, which are the Regional Tender Board (RTB) and the Central Tender Board (CTB). The boards are governmental institutions which regulate the expenditures of governmental money to prevent excessive expenditure.

Table 17 shows the criteria for involvement of the tender boards.

	Expenditure per item[1]
No tender board	< 0.5
Regional Tender Board	0.5 - 10
Central Tender Board	> 10

Table 17: Criteria involvement tender board

[1] All figures times Tsh. 1,000,000

The Regional Tender Board takes only one to two weeks to decide, but the Central Tender Board takes over six months and sometimes even longer than that. The Head of Electrical section at DIA thinks that it is because the RTB has visited DIA which the CTB has not. The RTB knows now what type of equipment is bought, the reason for the purchase and the costs involved, while the CTB does not.
An extreme example is the ordering of batteries by the Electrical section in 1991, which the CTB has not yet approved. The Electrical section still awaits the batteries.

Problems Tender Boards

10.5.1 National government

purchase control:
- Central Tender Board takes six months or more to decide on purchase of equipment or spares

Consequence of problems:
- acquisition of equipment or spares worth more than Tsh. 10,000,000 is delayed
- possible unserviceability equipment delayed

16.1.3 Difference public and private sector

Beside the direct interference or influence of the Government on the operations with DCA and the Directorate of Aerodromes, the Government also places an indirect influence on the functioning of the ANS organisation by measures concerned with the policy on general matters within the Tanzanian economy.

After the retreat of Julius Nyerere from the political platform in Tanzania, the next governments gradually tried to liberalise the economy in order to achieve help from the IMF or Worldbank. This meant that the private sector was allowed to become commercial and import and export taxes were lowered or tax waves could be achieved.
The result of this was that the private sector began to grow and within certain sectors a reasonable income could be earned. For example, the telecommunication market grew with the starting of Mobile Cellular services in Dar es Salaam by MOBITEL and TRITEL. Within a year, they established reasonable market shares. With that the salaries earned with these companies became much higher than comparable jobs in the public sector.

Table 18 shows the wage level difference between a starting Engineer of DCA and a starting Engineer of MOBITEL. A DCA Engineer has had basic training on the Technical College or Polytechnic School for three to four years and the MOBITEL Engineer has had basic training on the University of Dar es Salaam for three years and has achieved a grade lower than a Masters of Science title. So, roughly they have had a comparable level of education.

Function employee	Monthly salary
Telecommunication Engineer DCA	Tsh. 44,279/-[42]
Telecommunication Engineer MOBITEL	Tsh. 300,000/-[43]

Table 18: Wage level difference public and private sector

The huge wage level difference between the two sectors is apparent. It is not hard to imagine that DCA is confronted with a brain drain.

Problems difference public and private sector

10.5.1 National government	Consequence of problems:
difference public and private sector: - wage level difference engineer DCA and MOBITEL six times	- leaving of DCA engineers to private sector - brain drain DCA - problems with proper maintenance aeronautical telecommunication equipment

16.2 National service industries

The national service industries, which have an influence on the proper ATS provision by the ANS organisation, are the national power supply by Tanesco and the national telecommunications company Tanzanian Telecommunications Ltd. (TTCL).

16.2.1 National power supply

Tanesco is the main supplier of power to the airports and remote sites in Tanzania. Most airports have back-up power, but a lot of these back-up power consists of very old and unreliable diesel generators. So, there is a dependence on the main power supply and it is determined by the reliability of the supplied power.

[42] Source: Scheme of Service for Civil Servants, 1995 corrected for 1996.
[43] Source: MOBITEL, 1996.

The reliability of the power supply is expressed by the number of power failures and fluctuations. A power failure is the absence of any supply of power to a connected station. The Tanesco power supplied to the public net fluctuates due to the way it used by the connected stations. For example, the power, supplied to DIA, is also used by other users connected to the same supply line.

Both the power failures and fluctuations imply the use of the back-up power facilities at DIA. A power failure always triggers the sensors which activate the starters of the generators. A power fluctuation also triggers the sensors, when the fluctuation is out of tolerance for too long. So, a measure for the reliability are the power failure rate and the power fluctuations rate.
Appendix N.1 shows the number of Tanesco power failures and fluctuations at DIA in 1995 and in the first seven months of 1996. Although the number of failures and fluctuations have decreased comparing the first seven months of 1995 with the first seven months of 1996, they still occur. Besides, the average length of failures in a month is relatively the same and varies between 31 and 170 minutes.

Beside the airport, there are also sites around DIA which are only powered by Tanesco and have no back-up power measures or protection against power fluctuations. Power failures imply immediate unavailability of equipment for as long the failure lasts. Power fluctuations can damage the equipment, since it is not protected.

Problems national power supply

10.5.2 National service industries *national power supply:* - rate of power failures Tanesco Dar es Salaam has been high 6.1.1 Continuity of service *external aspects:* - powered by unreliable Tanesco national power supply	<u>Consequence of problems:</u> - wear end tear of switch gears power station DIA - possible break down switch gears - DIA possibly only powered by back-up generators - equipment at sites with no back-up power unavailable during power failure - equipment at sites with no back-up power possibly damaged by power fluctuation - level ATS decreases during power failure - level ATS possibly decreases due to break-down of equipment damaged by power fluctuations
10.5.2 National service industries *national power supply:* - rationing Tanesco in some areas Tanzania	<u>Consequence of problems:</u> - no main power supply at some airports - only back-up power at some airports

16.2.2 National Telecommunications company

There are two major areas in which the national telecommunications company TTCL provides services which DCA depends on to provide the ATS.

The first service is the supply of telephone lines which are hired by DCA for the implementation of the AFS and the AMS.
For the AFS provision, the hired lines or tie-lines are used for the implementation of the AFTN and the ATS/DS links between all existing stations. For the AMS provision, the tie-lines are used to connect the six VHF relay stations with the ACC in Dar es Salaam. The AFTN and the ATS/DS are described and discussed in respectively section 12.1 and section 12.2.
All tie-lines are maintained by TTCL and the responsibility for the reliability of the lines lies therefore with TTCL.

The second service is the back-up power supply of the VHF relay stations. The power is also used as back-up for the tie-lines. Responsibility for the maintenance and thus for the reliability of the back-up power lies with TTCL.

Problems national telecommunications company

10.5.2 National service industries	Consequence of problems:
national telecommunications company: - low success rate of telephone calls due to too low capacity of transmission equipment, faults in the transmission cables and radio equipment and faults in the telephone exchanges[1] - quality connection of long distance telephone calls is very bad due to poor state of communication lines[44] - ability to use tie-lines is hampered severely due to high number of faults and long repair times[45]	- unreliable AFTN service provision[46] - unreliable ATS/DS service provision - decreased level of ATS
6.1.1 Continuity of service	
external aspects: - dependence on TTCL for availability and quality AFTN, ATS/DS and VHF relay station-ACC links	

16.3 Manufacturers aeronautical infrastructure

Manufacturers of aeronautical infrastructure influence the ATS provision of an ANS organisation, when they delay the procurement of spare parts or new equipment or give no response at requests of assisting ANS organisations with the proper ATS provision.

To provide the AFTN service to all connections with Dar es Salaam, the AFTN communication centre used to be equipped with the Automatic Message Switching (AMS) CC-256 computer. In 1995, ICAO changed the standard of AFTN messages by changing the number of lines for the AFTN address. Since this change had to be programmed and engineers or Communication Officers of DCA did not have the knowledge to do that, the manufacturer of the computer SAGEM was requested to send engineers to do the programming.

In December 1995, the AMS CC-256 computer broke down.

Problems manufacturers aeronautical infrastructure

10.5.3 Manufacturers aeronautical infrastructure	Consequence of problems:
dependency: - manufacturer AFTN computer DIA did not respond to requests of DCA concerning assistance and spares	- computer did not operated according to ICAO standards - unserviceability computer prolonged - AFTN from DIA only handled by manually controlled teletypewriters
6.1.1 Continuity of service	
external aspects: - dependency manufacturer AFTN computer	

[44] Puttenstein, J.G., *Quality of the telephone service of the Tanzania Telecommunications Company Limited* (Eindhoven, The Netherlands: October 1996, page 139).

[45] Puttenstein, J.G., *Quality of the telephone service of the Tanzania Telecommunications Company Limited* (Eindhoven, The Netherlands: October 1996, page 138).

[46] The reasons for the low ability to use tie-lines is based on a report about TTCL lines used for the public telephone network. Since the same technologies are used for the tie-lines and problems lay with the organisation of TTCL, the report is used to make a statement about the ability to use the tie-lines. The statement is backed up by statements of DCA engineers and users of the tie-lines, which complained about the availability of the lines. There is, however, no statistical information available to indicate exactly the influence of the state of the lines on the availability of the ATS/DS and VHF relay station-ACC links. Information about the reasons of the unavailability of AFTN links is recorded, but not examined due to lack of time.

16.4 International ATS counterparts

In the case of international counterparts with the ATS provision, DCA depends on the availability of the counterparts. The nature of the dependency is either the dependency on counterparts within an international telecommunication network or the dependency on the services of other ANS organisations, vital for the ATS provision by DCA.

The networks which have international counterparts are the AFTN and the ATS/DS networks.
The international AFTN connections are either implemented by means of land-wires or HF RadioTeleType (RTT) connections. The latter has been used for the set-up of an AFTN network between countries in the Indian Ocean region. The international ATS/DS connections are implemented by land-wires.

Flight calibration of all NAVAIDs in Tanzania except the NDBs can only be done by hiring the services of other ANS organisations outside Tanzania. DCA used to do its own flight calibration, but the aircraft broke down and has not been repaired. For the DCA objective of yearly flight calibration of the relevant NAVAIDs, DCA uses the services of either the Kenyan Civil Aviation Authority (CAA) or the South African CAA.

Problems international ATS counterparts

10.5.4 International ATS counterparts *availability:* - all counterparts HF RTT AFTN Indian Ocean network became unserviceable	Consequence of problems: - no AFTN service Indian Ocean area - decreased level AFS - decreased level ATS
10.5.4 International ATS counterparts *availability:* - flight calibration services foreign CAAs not available for more than five years 6.1.2 Integrity of service *accuracy:* - relevant NAVAIDs not flight checked for more than five years	Consequence of problems: - objective yearly flight calibration not met - integrity relevant NAVAIDs not ensured - decreased level ARNS - decreased level ATS

17. AIRPORTS IN TANZANIA

Since June 1996, the organisational structure of the ANS organisation at airport level has changed. The operations of the airport like passenger and cargo handling are now the responsibility of the Directorate of Aerodromes. Only the ATS provision is now done by the ATC section, the Communication section, the AIS section and the Telecommunication section.

17.1 Visited airports

For the research, Dar es Salaam International Airport (DIA), Kilimanjaro International Airport (KIA) and Arusha Airfield were visited.

DIA and KIA were visited, because they are international airports with relevant facilities. At DIA is also located the Area Control Centre (ACC) from which the Area Control is provided for the entire Tanzanian Flight Information Region (FIR).
Arusha Airfield was visited to get an idea of a small airfield, which still handles a lot of traffic albeit only small aircraft.

To give an indication of the size of the airports of Dar es Salaam, Kilimanjaro and Arusha and the amount of handled traffic, the number of passengers and the number of aircraft movements in 1995 are shown in table 19.

Airport	Aircraft movements	Passenger movements
Dar es Salaam International Airport (DIA)	22,249	451,990
Kilimanjaro International Airport (KIA)	10,020	123,306
Arusha Airfield	8,781	18,848

Table 19: Aircraft and passenger movements

N.B. the number of aircraft and the number of passenger movements at DIA consist of the number of internationally movements in 1995 and the number of domestic movements in 1992.

One can see, that DIA is the most important airport of the three and that Arusha Airfield has to handle relatively a lot of traffic. Specially because it is a small airport, consisting of a small, tarmac runway and few facilities, the strain on this airport is larger than on KIA, which handles a lot more passengers but only a few more aircraft. The big difference in passenger movements is because of the large number of small aircraft, using Arusha Airfield as a basis for safaris to the national parks.

17.2 Dar es Salaam International Airport (DIA)

Dar es Salaam International Airport (DIA) was first constructed by means of a gravel strip in 1954 before independence. The airport was expanded with a tarmac runway during the period of the East African Community (EAC). After the break-up of the community in 1977, the airport was first rehabilitated from 1978 until 1982 with help of the Netherlands government. In 1984, a new terminal and a new Area Control Centre including a new Control Tower were constructed as part of a French rehabilitation project. The old terminal building is now used by small charter companies and the Civil Aviation Training Centre (CATC).

The nature of the traffic at DIA is as follows:

- international flights (KLM, British Airways, Air France Cargo, Gulf Air, etc.)
- national flights (Air Tanzania, Precision Air, etc.)
- small charter companies (Tanzanair, etc.)
- governmental aircraft

17.2.1 Aeronautical telecommunication equipment

At DIA, aeronautical telecommunication equipment is located at the following sites (a little star indicates that the site has been visited):

- Area Control Room (ACR)* (ACC)
- Equipment Room ACC*
- Communication Room* (ACC)
- AFTN Communication Centre* (ACC)
- Equipment Room Tower*
- Transmitter Station*
- Receiver Station*
- LLZ site*
- GP site*
- Middle Marker site
- Outer Marker site
- NDB-DM site
- VOR/DME site*
- Radar site*

Problems of the entire airport are concerned with the powering of all aeronautical and auxiliary equipment at sites which are powered by the power system of the airport.

Problems Dar es Salaam International Airport (DIA)	
6.1.1 Continuity of service	Consequence of problems:
powering of equipment - failures of power system - poor state power system	- unserviceability of or damage to equipment

The powering of DIA and the encountered problems are described and discussed in section 17.1.2.

Area Control Room (ACR) ACC

The ACR is described in section 11.1.1. and appendix F.1. The ATS/DS network is described in section 11.2.2.

Equipment Room ACC

The Equipment Room contains various types of equipment as can be seen in appendix F.3.

The Automatic Terminal Information System (ATIS) transmits pre-recorded weather messages to provide the Aeronautical Broadcast Service (ABS) by means of VHF radio communication. However, the system has never been used, because the low density of the air traffic at DIA made it unnecessary. At the moment, a controller simply calls the MET-office for a weather report and reports this to the pilot by radio communication.
The VHF transmitters are described in appendix G.4.

The internal safety telephone switching unit is located inside the ACC building. The network includes the Tower and the MET building. The ATS/DS network is used by Engineers, ATC controllers and Communication Officers at the ACC in case there is a problem with equipment or a problem of another sort, concerning flight safety. The conversations are recorded so that they can be played back in case the problem is such that it has to be cleared up.

Communication Room ACC

The room is described in section 11.1.1 and appendix F.5.

AFTN Communication Centre ACC

The centre is described in section 11.2.1 which deals with the AFTN in Tanzania and includes the description of all encountered problems. The centre is also described in appendix F.8. The AFTN equipment is described in appendix G.7.

Equipment Room tower

The Equipment Room, located one story below the Visual Control Room (VCR) inside the tower, contains the VHF transmitters and receivers for all types of control from DIA. It also contains a channel selector, which chooses the channel with the best quality.
The Equipment Room Tower is described in appendix F.2. The VHF transmitters and receivers are described in respectively appendix G.4 and G.5.
The Equipment Room Tower has no problems.

Transmitter station

The Transmitter Station site contains the building with HF transmitters, an HF antenna park and a building that contains the NDB-DR. The site is described in appendix F.6.

The HF transmitters are described in appendix G.1. The NDB-DM is described in appendix J.4.

Problems site

6.1.1 Continuity of service

powering of equipment
- unreliable Tanesco main power (see section 16.2.1)
- back-up diesel generator for all equipment unserviceable

external aspects
- poor security: hardly fenced, one guard entire area

Consequence of problems:
- equipment unserviceable during Tanesco power failures
- no power fluctuation protection
- possible damage to equipment due to power fluctuation
- possible decrease level ATS
- area can be accessed easily by trespassers

Problems HF transmitters building

6.1.1 Continuity of service

reliability:
- all transmitters are obsolete, except for two
- lack of spares to repair broken equipment

external aspects:
- commissioning delay, due to programming problems

Consequence of problems:
- obsolete equipment cannot be repaired
- only one serviceable transmitter for Area Control
- limited Area Control
- AFTN Radio TeleType (RTT) transmission not possible

Problems NDB-DR building

6.1.1 Continuity of service

powering of equipment:
- power fluctuation is possible cause of break down transmitter NDB-DM

7.6.2 Building, cabin or hut

state:
- holes in the roof

Consequence of problems:
- only one transmitter NDB-DM dual system working
- water leakage in room during rain
- possible water damage and/or short-circuiting of NDB
- possible break-down NDB
- possible decrease level ARNS
- possible decrease level ATS

Receiver station

The Receiver station site contains the building with the HF receivers and the HF antenna park. The HF antennas consist of three directional antennas and one omni-directional antenna. The directional antennas have been used for AFTN RTT purposes, are 11 years old and in a good state. The omni-directional antenna is used for Area Control, is 20 years old and in a good state.

Problems Receiver Station

6.1.1 Continuity of service

external aspects:
- intermittently working air-conditioning

7.6.3 Air-conditioning

state:
- reasons break-down unknown

Consequence of problems:
- possible heating up of HF receivers
- possible break down HF receivers
- possible decrease level AMS
- possible decrease level ATS

LLZ site

The Localizer (LLZ) at DIA is positioned 100 meters from the end of the runway. The directional antenna consists of 13 dipoles aimed at the runway and is connected with the LLZ equipment.
The site is described in appendix F.9. The Localizer is described in appendix J.1.

Since the ILS is a Category-I system, the use of a far field monitor would be redundant and is not present. The use of a near field monitor is also not required and would not add to the overall integrity standard of the LLZ as a measure of the ATS provision by the Category-I installation. A near field monitor can, however, act as a good aid to measure the integrity from a third angle, beside the internal and the integral monitor systems.[47]

Problems LLZ site

6.1.1. Continuity of service *reliability:* - intermittently serviceable *external aspects:* - intermittently working air-conditioning 7.6.3 Air-conditioning *state:* - problems with the compressor and with gas leaking - air-conditioner breaks down regularly	Consequence of problems: - equipment heats up when air-co breaks down - over-heating shortens life span LLZ - LLZ may break down - possible decrease level ARNS - possible decrease level ATS
6.1.2 Integrity of service *accuracy* - intermittently working air-conditioning 7.6.3 Air-conditioning *state* - problems with the compressor and with gas leaking - air-conditioner breaks down regularly	Consequence of problems: - equipment heats up when air-co breaks down - over-heating causes possible drift LLZ signal - when signal-drift out of tolerance, monitor shuts down LLZ - decrease level ARNS - decrease level ATS
6.1.2 Integrity of service *accuracy* - last flight check more than five years ago - only parameter checks inside shelter - equipment not completely ground checked after break down 10.5.4 International ATS counterparts *dependence:* - foreign flight calibration units not available for more than five years	Consequence of problems: - integrity LLZ not ensured due to insufficient ground and flight checks - decrease level ARNS - decrease level ATS
6.1.2 Integrity of service *monitor systems* - radomes integral monitor system have holes and rain water can come inside	Consequence of problems: - possible break down integral monitor, due to damaged radomes - when integral monitor breaks down, shut down LLZ

The overheating is recorded only occasionally, so it is hard to tell whether overheating causes the equipment to deteriorate and if so to what extent. The exact relation between the overheating and drifting of the signal is also unknown, due to a lack of recording.

GP site

The Glide Path (GP) cabin is located along the side of the main runway, one hundred meters beyond the threshold. The antenna of the GP consists of three poles connected on top of each other on an antenna mast.
The GP has a near field monitor.

The site is described in appendix F.10. The Glide Path is described in appendix J.1.

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[47] The responsibility of the fact, that the average rate of a fatal accident during the landing of an aircraft with the help of an ILS, has been generally accepted to be vested completely in the pilot with a Category-I ILS system (International Civil Aviation Organisation, *Annex 10 - Aeronautical telecommunications: Attachment C to part I* (Montreal Canada: 1985, page 197)).

Problems GP site

6.1.2 Integrity of service	<u>Consequence of problems:</u>
monitor systems - trespassers can walk through signal near field monitor - when signal is blocked, monitor shuts down GP	- possible decrease level ARNS - possible decrease level ATS
7.6.5 Security	
state - insufficient fencing DIA - people trespass airport ground - trespassers can walk through signal near field monitor	

Middle Marker site

Due to problems with transport and lack of time, the site has not been visited and comments are based on statements made by DCA maintenance engineers.

At the moment, the Middle Marker is serviceable and in a good state. The site is described in appendix F.11. The Middle Marker is described in appendix J.1.

Outer Marker site

Due to problems with transport and lack of time, the site has not been visited and comments are based on statements made by DCA maintenance engineers.

The Outer Marker site consists of the Outer Marker beacon of the ILS system and the NDB-DS and is located 20 kilometres from the threshold of the runway. The site is described in appendix F.12.
The Outer Marker is in a good state and can be used properly. The Outer Marker is described in appendix J.1.
The NDB marked Delta Sierra (DS) with a range of 25 NM serves as a locator for DIA. The equipment of the NDB-DS is serviceable. The NDB-DS is described in appendix J.4.

Because a power cable between the power system of DIA and the site has been vandalised, the management of the Telecommunications section decided to install solar panels to power the site.

Problems Outer Marker site

| 6.1.1 Continuity of service |

powering of equipment
- Outer Marker and NDB-DS cannot be used, because they are not powered
- no stand-alone back-up power at site present

external aspects
- no powering, due to broken power cable from power system DIA
- planned solar panels not installed, because ground not levelled
- ground not levelled, due to unavailable grader
- grader not available, due to management decision

| 8.5.3 Maintenance organisation |

Maintenance management
- management decided to hire Governmental grader
- when grader not available, management did not hire grader private company

| 7.6.4 Cabling |

state
- power cable broken, due to vandalism

| 7.6.5 Security |

state
- power cable dug up and vandalised

Consequence of problems:

- site not powered for three years
- Outer Marker and NDB-DS unavailable for three years
- incomplete ILS for three years
- ARNS provided by ILS below required level for three years[48]
- decreased level ARNS
- decreased level ATS

VOR/DME site

The VOR/DME site contains the VOR and the DME which are co-located in the same cabin, 100 meters before the threshold of the main runway.
The site is described in appendix F.13. The VOR is described in appendix J.2 and the DME is described in appendix J.3.

The VOR is ground checked every three months, which is a reasonable replacement of flight checks, according to a Dutch expert. The insufficient flight checks of the VOR are therefore not a significant problem.

Problems VOR/DME site

| 7.6.3 Air-conditioning |

state
- problems with compressor and gas leaking

| 7.6.2 Building, cabin or hut |

state
- holes along air-conditioning
- rain water can enter the cabin

Consequence of problems:

- intermittent working air-conditioning
- pool of water on the floor with the equipment, during rain

[48] Bad weather causes bad visibility and decreases the decision height. The decision height is the height at the point where a pilot just can see the aerodrome. With bad visibility, visual contact with the aerodrome can only be made at such a low altitude that the aircraft has to be guided by ground aids. When one or more parts of the ground aid are not working, the guidance during bad weather cannot be ensured. Through the years, a lot of airlines have complained about the situation with the ILS at DIA. It is one of the reasons for airlines to stop flying at DIA.

Problems VOR

6.1.1 Continuity of service	Consequence of problems:
reliability - equipment is aged - power fluctuations shortened life span - output power decreased by maintenance section, due to deterioration *external aspects* - intermittent working air-conditioning causes cabin and VOR to heat up - VOR stands in pool of water during rain	- range decreased - over-heating can shorten life span VOR - possible short-circuiting of VOR, due to rain water - integrity of VOR is not ensured completely
6.1.2 Integrity of service *accuracy* - last flight check more than five years ago	

Problems DME

6.1.1 Continuity of service	Consequence of problems:
reliability - equipment is aged - power fluctuations can shorten life span DME - long periods of unserviceability *external aspects* - intermittent working air-conditioning causes cabin and DME to heat up	- DME has deteriorated - over-heating can shorten life span DME - possible short-circuiting of DME, due to rain water - integrity of DME is not ensured
6.1.2 Integrity of service *accuracy* - last flight check more than five years ago	

17.2.2 Power supply

The information about the situation of the power supply was gathered by observations at the power house of DIA and through interviews with the Head of the Electrical section at DIA and the Head of Electrical Maintenance Engineers in Tanzania with the Head Quarters of the Directorate of Aerodromes.

Lay-out primary power system

In appendix N.2, the lay-out of the power distribution at DIA is shown. It shows the primary power supply entry coming from the national power supply company Tanesco, the three secondary back-up power generators and the two bus bars from which the power is distributed over the airport to the airport facilities.

The Tanesco power supply does not only power the airport, but also the Transmitter Station and the industry along Julius Nyerere Road (former Pugu Road).

From the entry at the Power Station, the 11 KV is fed to a General Bus bar via control and protection equipment. The protection equipment consists of sensors which monitor power fluctuations. In case of a 4% deviation of the 11 KV, it disconnects the power-lines of Tanesco and starts the generators.

The general bus bar feeds the Technical and the Commercial bus bars. They are connected through so-called circuit breakers. Their function is to prevent damage to parts of the network whenever there is a power glitch involving switching phenomena.

Because the Technical Priority Bus bar feeds the aeronautical telecommunication equipment and the runway lighting, the designers of the power system designed a ring

construction. In that case when ever there is a break in one of the connecting lines, all equipment can still be powered via the other direction.
From the Technical Priority Bus bar, the following Power Centres (PC) are connected with each other:

Power centre	**Equipment or building**
T1	Airfield lighting, Localizer site, half of runway lighting
T2.1	Radar site, half of runway lighting
T2	ACC, MET buildings
T3	Glide Path site, VOR/DME site

Transformers at each PC step down the 11 KV to 400 Volts to power the present equipment. Only in the case of the airfield lighting, the voltage is stepped up again to 5 KV, which is needed for sufficient power. The transformers can take up to 4.5 or 5 % voltage difference.

From the Commercial Priority Bus bar, one direct line is leading to Terminal 2, which is the main passenger terminal. In case of problems with the generators, the Technical Priority Bus bar is always fed first. When necessary, a small generator feeds some of the circuits in Terminal 2.

The power cables are all laid underground and are 13 years old. Problems like punctures occur specially with cables lying in water, but according to the Head of Electrical section at DIA the power cables can last up to 20 years from date of installation, before they have to be replaced.

Back-up power generators

In the Power Station, there are three Alsthom Atlantique diesel generators of which two are used to power the entire airport. The remaining generator serves as a back-up in case another generator won't start and to slow down the wear end tear of the engines. Each generator generate 400 Volts which is stepped up to 11 KV via transformers and then fed to the Reverse Bus bar. The Reverse Bus bar feeds the Priority Bus bars via load break switches.
A Westac Power Pac generator powers the Power Station in case of complete power failure and powers lights and air-conditioning.

The main generators are started by air-pressure. The Power Station has two compressors, of which the biggest compressor can start up all three engines in one to two seconds automatically after power failure. A smaller, manually pressurised compressor serves as a back-up and it can start up only one engine at the time in forty to fifty minutes.
Recently, the automatic compressor has been replaced by a new one for the time being. Before that from October 1995 until May 1996, only the smaller compressor was serviceable which had a major impact on the serviceability of the equipment at the airport during power failure or fluctuation. Because of the manual control, it took forty to fifty minutes to get power for a part of the airport.

Appendix N.3 shows the recording of the Tanesco power supply at the power station and the corresponding power supply at the Equipment Room in the ACC. The high rise of voltage about 12.2 KV at the power station and the 250 Volt power rise at the Equipment Room can be observed clearly.

Problems power system DIA

7.6.1 Power system *reliability main power supply:* - Tanesco power fluctuations beyond 4% sensor tolerance - power fluctuation at transformers and sub-stations beyond 5% voltage difference 10.5.3 Manufacturers aeronautical infrastructure *dependency:* - foreign engineers made wrong estimation of expansion of industrial area Pugu Road	Consequence of problems: - sensors trigger switching main to back-up power too fast - equipment connected with sub-stations can be damaged by power fluctuation - power fluctuations wear out transformers sooner than was calculated - engineers by-pass sensors to avoid frequent switching between Tanesco and generators and to minimise excessive use of switching gears - fluctuations watched by engineers or technicians - possible break-down equipment
7.6.1 Power system *reliability back-up power system:* - mechanical load-breakers are out of alignment due to wear end tear - wear end tear, due to many operations - load breakers are obsolete	Consequence of problems: - Electrical section has to ignore load-breakers during maintenance - replacement or spare part procurement is not possible - break-down load-breakers implies break-down whole power system - no power DIA
7.6.1 Power system *reliability back-up power system:* - circuit-breakers trip frequently due to their age and wear end tear[49] - circuit breakers no longer maintained, because they might break-down	Consequence of problems: - aeronautical equipment like runway lighting, Radar antennas and control desk VCR not powered - decrease level ATS

17.3 Kilimanjaro International Airport (KIA)

The entire airport of Kilimanjaro including the control tower building was constructed in 1969 and became in full service in 1971.
The control tower building of KIA consists of the control tower which is built on top of the offices for the Telecommunication section, the equipment room, the repairshop and the communication centre.

The nature of traffic coming to KIA is as follows:

- international flights (KLM, Corsair, Ethiopian Airlines, Gulf Air, etc.)
- national flights (Air Tanzania and Precision Air)
- small charter planes (Fleet Air, TGT, MAF, etc.)
- government aircraft
- national park aircraft
- crop spraying aircraft

17.3.1 Aeronautical telecommunication equipment

At KIA, there are the following sites (an little star indicates that the site has been visited):

- Visual Control Room (VCR)*
- Equipment Room*
- AFTN Communication Room*
- D-VOR/DME site*
- NDB-KB site
- NDB-KL site

[49] Mrs. Mkwizu, *Unserviceability of utilities* (Dar es Salaam International Airport, June 1996).

- NDB-KO site

Problems of the entire airport are concerned with the powering of all aeronautical and auxiliary equipment at sites which are powered by the power system of the airport.

Problems Kilimanjaro International Airport (KIA)	
6.1.1 Continuity of service	Consequence of problems:
powering of equipment - poor state power system	-possible unserviceability of or damage to equipment

The powering of KIA and the encountered problems are described and discussed in section 17.2.2.

Visual Control Room (VCR)

The VCR is located on top of the ATC building. From the VCR, Approach Control and Aerodrome Control are provided. The VCR contains a VHF transceiver which is used for Area Control monitoring purposes, the ATS/DS exchange and auxiliary equipment for the control at KIA. The latter equipment consists of monitoring systems for the withdrawn ILS and VOR, an approach indicator, a videograph and a cloud indicator. The equipment is either unserviceable or never used.

The VCR is described in appendix F.17. The VHF transceiver is described in appendix G.6. The ATS/DS exchange is described in section 11.2.2.
There are no problems with the VCR.

Equipment Room

The Equipment Room, located one story below the Visual Control Room (VCR) inside the ATC building, contains the VHF transmitters and receivers for both Approach and Aerodrome Control from KIA. It also contains the Remote Control Unit computer of both the new Doppler-VOR and DME with which the beacons are monitored and with which operational data of both beacons can be analysed. At the time of the visit, an air-conditioned separate room was built inside the Equipment Room to host the computer.

The Equipment Room is described in appendix F.18. The VHF transmitters and receivers are described in respectively appendix G.4 and G.5.
There are no problems with the Equipment Room.

AFTN Communication Room

The AFTN Communication Room contains the AFTN communication centre of KIA and is located inside the ATC building. The centre at KIA is connected with Dar es Salaam, Arusha and Nairobi through TTCL tie-lines.

The AFTN Communication Room is described in appendix F.19. The AFTN equipment is described in appendix G.7. Problems with the AFTN service in Tanzania are described and discussed in section 11.2.1.
There are no problems with the AFTN Communication Room.

D-VOR/DME site

The D-VOR/DME site contains one cabin with the Doppler-VOR and DME and is located 200 meters before the runway threshold.

The D-VOR/DME site is described in appendix F.20. The Doppler-VOR is described in appendix J.2 and the DME is described in appendix J.3.

Problems D-VOR/DME site

6.1.1 Continuity of service *reliability* - one of dual system DME unserviceable for unknown reasons *external aspect* - equipment not commissioned during problem 10.5.3 Manufacturers aeronautical infrastructure *dependency* - DCA has to wait for people of manufacturer to repair DME, because equipment not commissioned	Consequence of problems: - unserviceability one system DME is prolonged
6.1.2 Integrity *accuracy* - installed in January 1996 and not flight checked for 9 months, although operational 10.5.4 International ATS counterparts *dependency* - aircraft necessary for flight checking equipment has to be hired from other country - aircraft not immediately available	Consequence of problems: - both D-VOR and DME are operational, but not flight checked - integrity D-VOR and DME not ensured - decrease level ARNS - decrease level ATS

NDB-KB site

Due to problems with transport and lack of time, the site was not visited and comments are based on statements made by DCA maintenance engineers.

The NDB-KB is located five kilometres to the South of Kilimanjaro airport. The site is described in appendix F.21 and the NDB-KB is described in appendix J.4.
There are no problems with the NDB-KB site.

NDB-KL and NDB-KO sites

Due to problems with transport and lack of time, the sites have not been visited and comments are based on statements made by DCA maintenance engineers.
Since both sites are have the same characteristics and since DCA experiences the same problems with both sites, the two sites are discussed together.

The NDB-KL and NDB-KO are located respectively two and four kilometres to the North of Kilimanjaro airport. The sites are described in respectively appendix F.22 and appendix F.23. The NDBs are described in appendix J.4.

Problems NDB-KL site and NDB-KO site

6.1.1 Continuity of service *powering of equipment:* - no main power from KIA - generator only run during scheduled flights to save fuel *external aspects:* - wind blows down poles with power cables - power cables are subsequently stolen by local people 7.6.5 Security *state:* - blown down power cables are stolen by local people	Consequence of problems: - only powered by back-up diesel generator - NDB only run during scheduled flights

17.3.2 Power supply

Information about the powering of KIA was gathered through an interview with an engineer of the Electrical section of KIA.

Lay-out power system

The main power for the airport is supplied by Tanesco by means of 33 KV power cables and enters the airport at the main power station. Two transformers step down the 33 KV to 11 KV. From the power station, a ring network feeds eight power centres (PCs) of which only five are used. All PCs convert the 11 KV to 440 Volt.

The PCs power the following equipment or buildings:

PC1	Terminal building, ATC building, fire services
PC2	fire services
PC3	half of runway lighting, PAPI lighting system, Meteorological Radar, PC6
PC4	VHF Receiver station (not used anymore)
PC5	number has been skipped accidentally by people who designed the network
PC6	D-VOR/DME site
PC7	half of runway lighting, threshold lighting, taxi-way lighting, approach lights, MET observatory station, PC8, PC9
PC8	NDB-KO (not used anymore; see section 17.2.1)
PC9	NDB-KL (not used anymore; see section 17.2.1)

PC4 is not used anymore, because the VHF receiver station is not serviceable.

Problems of the Electrical section at KIA

7.6.1 Power system	Consequence of problems:
reliability: - explosion destroyed power station in 1993 - ring construction punctured - power station KIMAFA only one transformer for own hangar plus airport - transformer deteriorated faster because of overload	- power system airport now powered by powers station of KIA Maintenance Facility (KIMAFA) - safety benefits ring construction no longer present - possible break-down transformer KIMAFA - possible break-down power system KIA - possible lower level ATS
10.5.3 Manufacturer aeronautical infrastructure	**Consequence of problems:**
dependency: - manufacturer power system out of business	- situation still the same for three years

The Swiss company ABB SACE has made a feasibility study a year ago for the rehabilitation of the power network, but the engineers at KIA have not heard from them yet.

17.4 Arusha Airfield

Arusha Airfield as it is today was constructed in 1991 when the present building which includes the communication centre, the offices of the Aerodrome Manager and the Control Tower was erected. The runway at Arusha Airfield is hard and has a length of 1,600 meters. This means that the type of aircraft, which are allowed to land at Arusha, are twin-engine aircraft like the Fokker F-27.
The new Tanzanian airline Precision Air is stationed at Arusha and operates services from Arusha to Kilimanjaro, Mwanza, Bukoba, Seronera, Nairobi, DIA and Zanzibar.

The nature of traffic at Arusha Airfield are the following:
- scheduled flights by Precision Air
- charter flights
- private flights
- flying doctors
- crops spraying

- national park aircraft

17.4.1 Aeronautical telecommunication equipment

At Arusha Airfield, there are the following sites (an little star indicates that the site has been visited):

- Visual Control Room (VCR)*
- AFTN Communication Room*
- NDB-AR Shed*

Problems of the entire airfield are concerned with the powering of all aeronautical and auxiliary equipment at sites which are powered by the power system of the airport.

Problems Arusha Airfield

6.1.1 Continuity of service	Consequence of problems:
powering of equipment - back-up diesel generator is not running, due to high costs	- no back-up power - only relying on Tanesco

The powering of Arusha Airfield and the problems are described and discussed in section 17.3.2.

Visual Control Room (VCR)

The VCR is located on top of the ATC building. The VCR contains two VHF transceivers, used for Aerodrome Control and monitoring of the Approach Control frequency of KIA, and the ATS/DS telephone.

The VCR is described in appendix F.24. The VHF transceivers are described in appendix G.6. The ATS/DS telephone and the problems with the network are described in section 11.2.2.
There are no problems with the VCR.

AFTN Communication Room

The AFTN Communication Room is located inside the ATC building underneath the VCR. The room is described in appendix F.25 and the AFTN equipment is described in appendix G.7.
There are no problems with the AFTN Communication Room.

NDB-AR Shed

The NDB-AR is located in a separate shed within a building. The shed is described in appendix F.26 and the NDB-AR is described in appendix J.4.

The functioning of the beacon is monitored by the Air Traffic Controller in the VCR by tuning a small radio receiver to the LF frequency of the NDB.
There are no problems with the NDB-AR shed.

17.4.2 Power supply

All information regarding the powering of Arusha was gathered from the Senior Air Traffic Controller at Arusha Airfield.

Arusha Airfield is powered by Tanesco through an 11 KV connection. From the entry-point, the offices, the VCR, the NDB-AR and the hangars are powered. For back-up power in case of Tanesco power failure, a diesel generator is present.

Problems power supply	
7.6.1 Power system	Consequence of problems:
reliability: - back-up diesel generator is not running, because of too much costs for fuel	- no back-up power during Tanesco power failure - all equipment unserviceable during Tanesco power failure - decrease level ATS during Tanesco power failure

18. SUMMARY PROBLEMS ANS ORGANISATION TANZANIA

As described in chapter 5, the Aeronautical Telecommunication Service (ATS) consists of the Aeronautical Mobile Service (AMS), the Aeronautical Fixed Service (AFS), the Aeronautical Radio Navigation Service (ARNS) and the Aeronautical Broadcast Service (ABS). Of the ATS, the ABS is not provided in Tanzania.
Since the proper ATS provision is the main objective of the ANS organisation, section 18.1 summarises the problems which have or may have a negative effect on the level of the provided ATS. This includes the negative effects on the AMS, the AFS and the ARNS.
Further any other important problems encountered by the ANS organisation are shown with their main reason or reasons.

18.1 Major consequences of problems

This section shows a summary of the major consequences of problems with their main direct reason or reasons. They are grouped according to main terms.

A. Aeronautical Telecommunication Service (ATS)

Decrease level ATS
1. decrease level AMS
2. decrease level AFS
3. decrease level ARNS

Possible decrease level ATS
1. Arusha and Dodoma Airport possibly not powered (sections 17.3.2 and 13.1)
2. possible decrease level AFS as well as ARNS with Transmitter Station site DIA (section 17.1.1)
3. KIA possibly not powered (section 17.2.2)

B. Aeronautical Mobile Service (AMS)

Decrease level AMS
1. No Approach Radar Control in Tanzania (section 11.1.4)

Possible decrease level AMS
There is no possible decrease of the AMS level, due to existing problems.

C. Aeronautical Fixed Service (AFS)

Decrease level AFS
1. original number of AFTN connections from DIA decreased from 17 to 6 (section 11.2.1.2)
2. AFTN HF RTT connections out of service (section 11.2.1.2)
3. AFTN messages are not handled within required processing and relaying times

(section 11.2.1.2)
4. some ATC centres cannot be reached at all via ATS/DS from DIA (section 11.2.2)
5. some ATC centres cannot be reached at all times via ATS/DS from DIA (section 11.2.2)

Possible decrease level AFS

1. possible decrease of number of AFTN connections (section 11.2.1.2)

D. Aeronautical Radio Navigation Service (ARNS)

Decrease level ARNS

1. integrity NAVAIDs except NDBs not ensured (section 12.2)
2. NDBs Mtwara and Songea unavailable (section 12.2)
3. VORs and DMEs Mbeya and Tabora unserviceable (section 12.2)
4. Range VORs DIA and Mwanza decreased from 200 to 150 NM (section 12.2)
5. ILS DIA incomplete (section 17.1.1)
6. NDB-DS DIA unserviceable (section 17.1.1)

Possible decrease level ARNS

1. airways Tanzania may not longer be marked by VORs (section 12.2)
2. DME DIA may break down (section 12.2)
3. NDB-DR DIA may break down (17.1.1)
4. Localizer (LLZ) ILS DIA may become unserviceable (section 17.1.1)
5. integrity Localizer (LLZ) ILS DIA may not be ensured (section 17.1.1)
6. Glide Path (GP) DIA may become unserviceable (section 17.1.1)

E. Air Traffic Control

Limited Area Control

1. limited Area Control ATC section (section 11.1.1)
2. limited Area Control Communication section (section 11.1.2)

Limited Approach Control

1. Limited Approach Control DIA (section 11.1.3)
2. Limited Approach Control KIA (section 11.1.3)
3. No Approach Radar Control in Tanzania (section 11.1.4)

F. Power supply

Bad state power supply DIA

1. possible break-down load breakers power system DIA (section 17.1.2)
2. possible break-down transformers power system DIA (section 17.1.2)
3. possible break-down circuit breakers powers system DIA (section 17.1.2)

Possible break-down power system KIA

1. possible break-down single transformer power system KIA (section 17.2.2)

G. Maintenance

Objectives preventive maintenance not met

1. Objective daily checks DIA not met (section 14.2)
2. Objective daily checks KIA not met (section 14.2)
3. Objective quarterly checks remote sites not met (section 14.2)
4. Objective yearly checks NAVAIDs except NDBs not met (section 14.2)

Objective corrective maintenance not met

1. bureaucracy procedures corrective maintenance of equipment remote sites or equipment, which cannot be repaired within six hours (section 14.3)
2. procurement spare parts or new equipment of more than Tsh. 10,000,000 delayed (section 16.1.2)

Overall maintenance plan not present (section 14.4)

Statistical data functioning aeronautical telecommunication equipment not used for long-term planning
1. statistical information in maintenance maps cannot be used for analysis (section 14.6.1)

Limited maintenance by repairshops
1. limited maintenance by Central Workshop DIA (section 14.8.1.1)
2. limited maintenance by repairshop KIA (section 14.8.1.2)

H. Knowledge base DCA

Brain drain DCA
1. DCA employees leaving DCA (section 15.1.6)

Low quality CATC Tanzania
1. training CATC students in micro-processor control techniques not possible (section 15.5)
2. skills by practice with specific equipment cannot be achieved (section 15.5)
3. number of students ATC section and Communication Operation section limited (section 15.5)
4. CATC instructors have limited knowledge to pass on students (section 15.5)

I. Morale DCA employees

Demoralisation DCA employees
1. Low wage level (section 15.1.2)
2. Little promotion opportunities (section 15.1.5)

Demoralisation ATC section
1. work overload Area Control DIA (section 15.2)
2. work overload ATC KIA (section 15.2)

J. External aspects

Procurement spare parts or new equipment delayed
1. dependence Central Tender Board (section 16.1.2)
2. dependence manufacturer aeronautical infrastructure (section 16.3)

Dependence national service industries
1. dependence unreliable Tanesco power supply (section 16.2.1)
2. dependence unreliable TTCL lines (section 16.2.2)

19. CONCLUSIONS

The functioning of an Aeronautical Navigation Service (ANS) organisation depends on the scope it has been given to operate in. When the scope in which it can operate changes, the way the organisation operates change as well.

Because the civil aviation was not given high priority within the Tanzanian governments' policy before 1993, a straight forward policy for DCA was not present and revenues, received by DCA, were divided among other transport sector besides the aviation sector. This caused the decline and deterioration of the aviation sector in general and the aviation infrastructure in particular.

Since 1994, DCA was allowed to make its own financial policy and, from July 1996, DCA can determine the policy for the aeronautical infrastructure. DCA has to pay its expenditures with its own incoming revenues, received mostly from airlines landing in or flying over

Tanzania. This implies a more cost-conscious operational policy and a strive for a more qualitative sound ATS in Tanzania.

The following conclusions are based on the findings of the research and should be seen as an identification of possible bottle-necks that stand in the way of achieving a sufficient level of ATS and dealing with the changed scope in which the ANS organisation is allowed to operate.

Conclusion 1: Aeronautical Mobile Service (AMS). HF and VHF radio communication are used to provide the AMS in Tanzania. VHF radio communication is used for all three types of control, which are Area, Approach and Aerodrome Control. **Area Control** within the Tanzanian FIR is done from the Area Control Centre (ACC) in Dar es Salaam by means of sufficient VHF radio area cover and limited HF radio communication. The available number of VHF consoles at the centre is limited, because some of the equipment is used to obtain spare parts for the remaining equipment. Area Control has to be done with an insufficient number of staff. Also the distribution of the three different types of control at DIA is unequally divided, which increases the work load for the Area Control Officers in particular. HF transmitters in the transmitter station cannot be used, due to broken control cables and difficulties with the restoration of these cables. Therefore, only one portable HF-transceiver is used for Area Control. **Approach Control** at DIA is co-located with Area Control and experiences the same problems with the consoles and the number of staff. Approach Control at KIA is also faced with a staff shortage. The only Radar system present in Tanzania is located at DIA, but it is out of service. It cannot be repaired, because it has become obsolete. Therefore, Radar Control cannot be done. This also means that Air Traffic Control Officers cannot gain experience with Radar Control and thus they cannot achieve the relevant rating, necessary for promotion to higher grades. **Aerodrome Control** services is provided sufficiently according to ICAO regulations.

Conclusion 2: Aeronautical Fixed Service (AFS). The AFS in Tanzania is provided via the Aeronautical Fixed Telecommunication Network (AFTN), the Air Traffic Service/Direct Speech (ATS/DS) network and occasionally via the public telephone lines. All connections are land lines which are either rented or public TTCL lines. **AFTN** via HF radio is not done anymore. The AFTN communication centre within the ACC at DIA, which provides the AFS for connections in Tanzania and adjacent countries, has to work with old teletypewriters which have become obsolete. Because of a limited number of equipment, the number of connections has decreased as well. The AFTN messages are handled manually by only one Communication Officer per shift, which means that processing and relaying times are way beyond the required times, specially during peak hours.
The provision of AFS via **ATS/DS** lines is poor. Lines to some of the neighbouring countries are non-existent or out of service for a long time and of the existing international lines, only the connection with Nairobi comes close to the required availability.

Conclusion 3: Aeronautical Radio Navigation Service (ARNS). The **NDB** is the most used type of NAVAID in Tanzania. Most of the NDBs are in a good state and serviceable, which enables pilots to use the beacons for navigation along the airways. **VORs** and **DMEs** are mainly used for terminal approaches on the airports of Dar es Salaam, Mwanza, Mbeya, Tabora and Kilimanjaro, but only the new VOR and DME of Kilimanjaro are in a good state. The other VORs and DMEs are more than fifteen years old, their operational range has decreased and they are either intermittent serviceable (Mwanza and Dar es Salaam) or out of service (Mbeya and Tabora). Only Dar es Salaam has an **ILS** which is more than ten years old, incomplete due to an unserviceable Outer Marker and intermittent serviceable. Because of the absence of yearly flight calibration for more than five years, the integrity of all NAVAIDs in Tanzania, except the NDBs, cannot be ensured which lowers the level of provided ARNS.

Conclusion 4: power supply. The power supplies at most of the airports in Tanzania are faced with frequent Tanesco power failures and fluctuations. Most power systems of the airports in Tanzania consist of old, deteriorated and obsolete equipment, concerning the power system as well as the back-up generators. The power supplies at both DIA and KIA have the possibility of complete break-down, which means the unavailability of all facilities and services at both airports and consequently a big decrease of the level of ATS provision.

Conclusion 5: maintenance. The maintenance **organisation** of aeronautical telecommunication equipment in Tanzania is a hybrid form between centralised and decentralised.
Preventive maintenance at each station or site is done by the relevant stationed engineer or technician and consists of checking of parameters on a daily, weekly, quarterly and yearly basis. However, objectives of preventive maintenance of the aeronautical infrastructure in Tanzania are not met on a daily, quarterly and yearly basis. Preventive maintenance is only based on the directions in the Acceptance Test Data Sheets, delivered by the manufacturer for each piece of equipment. A limited number of maintenance vehicles and problems with their functioning and limited maintenance by repair shops at DIA and KIA obstruct the preventive maintenance. Yearly checks of NAVAIDs should consist of flight calibration, but is not done for more than five years due to problems of acquiring flight calibration services.
Corrective maintenance on equipment in Tanzania is done mostly by engineers of the Central Workshop in Dar es Salaam. The period in which equipment is unserviceable in case resident engineers are not able to repair the equipment is prolonged, because of bureaucratic procedures and the means of transport, moving the equipment to Dar es Salaam and back to the original station. Spare parts are mainly stored in the Technical Store in Dar es Salaam and not at the sites themselves, which implies lengthening of unserviceability due to bureaucratic procedures and means of transport, transporting spares to the site. The repair of unserviceable equipment at remote sites which are hard to reach is hampered by the limited number of maintenance vehicles and the use of the vehicles for other purposes.
A general **maintenance plan** is not present. The job description of the engineers and technicians is documented in the Scheme of Service for Civil Servants. The way how to do their job is told during training and by experienced engineers on the job.
All **statistical information** gathered during the routine checks is not analysed for management purposes.

Conclusion 6: human resources. The **training** received by the Air Traffic Controllers, Communication Officers and Maintenance Engineers and Technicians is experienced to be insufficient to carry out all the assigned tasks, including extra tasks which are added due to lack of staff in every section. Insufficient training and number of refreshments, concerning the practice of real-situation equipment, has been caused by the unserviceability of relevant telecommunication equipment. Although efforts already have been made to increase the present level of knowledge with respect to new technologies and techniques like microprocessor and digital techniques, the present level of training is insufficient for DCA employees to fully comprehend these techniques. Courses are too short and have been followed at many different institutions with different degrees of training.
The level of knowledge within the ANS organisation is further decreased by a **brain-drain** of the DCA organisation. The brain-drain is caused by the leaving of large numbers of employees to the private sector, due to wage level differences.
All sections within the **CATC** are faced with a staff shortage and with instructors who have not received refreshments for the courses they give and therefore have a lack of knowledge of the latest technologies. The CATC lacks sufficient test gears and equipment for real-situation simulation, which means that students cannot be trained adequately and DCA employees cannot obtain licenses and ratings. Because of these problems, students have to be sent to other institutions in Tanzania or abroad to obtain a sufficient level of knowledge in the technologies, presently used in aviation.
The **morale** of all Air Traffic Controllers, Communication Officers and Telecommunication Engineers and Technicians is low. They are not paid sufficiently, according to the number and level of their tasks and experience a big **wage level** difference with the private sector. This has caused employees having other sources of income. All employees experience difficulties with **promotion**, due to the inability of getting proper training for the achievement of licenses and ratings on which promotions are based. This means that they will stay longer in the same wage scale. The difficulties are caused by unserviceable or a lack of aeronautical telecommunication equipment with which experience should be gained.

20. RECOMMENDATIONS

Where conclusions follow the structure of the report, the recommendations are shown in order of importance with respect to implementation. This is done to separate the most immediate fields of attention from problems which do not need immediate attention.
Because my professional background lies in the field of computer communication and telecommunication in general and not aeronautical telecommunication infrastructure, recommendations are given for the short and middle long term future.

Upgrading of present AFTN communication centre DIA. The communication centre has to automate the handling of the AFTN messages. The automated handling of the messages will reduce the tasks of the present staff and will reduce the processing and relaying times of the messages considerably, so that they fall within the times required by ICAO. One Automatic Message Switching computer is necessary to increase the number of connections served by the centre. The present number of staff has to be increased to form sufficiently manned shifts for the execution of all communication tasks and to reduce work overload. This way the level of **AFS** provision is increased to acceptable standards.

Standardisation and upgrading of maintenance organisation. A standardised **maintenance plan** should be made for every type of equipment accompanied with standardised and complete forms to simplify the maintenance and the transfer of knowledge to new engineers. **Repair shops** besides the Central Workshop should be better equipped with proper test gears and more spare parts of relevant equipment to reduce the involvement of the Central Workshop and to avoid the bureaucracy involved with the procurement of spare parts and with that the prolongation of the possible unserviceability of equipment. Also, engineers resident at airports or sites other than Dar es Salaam should have more responsibility in the preventive maintenance in general and the procurement of spares in particular to reduce the bureaucracy in these matters. All efforts should be made to have good contract deals with foreign **flight calibration** services to ensure a flight calibration at least once a year. The number of **maintenance vehicles** should be increased and the use of maintenance vehicles should be restricted to the purpose of maintenance only to ensure the meeting of maintenance requirements at all times. The **Technical Store** should be relocated in a new building which is a more safe and cleaner environment for the storage of spare parts and new systems, preferably on the grounds of the airport near the Central Workshop. **Statistics** of the functioning and state of every piece of equipment in every field within the Aeronautical Navigation Service organisation should be used for the planning and decision making on management level for the short, medium and long term future.

Upgrading and rehabilitation of the power supply at airports in Tanzania. All power networks, but specially those of DIA and KIA, should be investigated and rehabilitated, if necessary, to ensure the continuity of the overall ATS provision in Tanzania. Stand-by generators which are older than their technical life should be replaced with new generators. All aeronautical telecommunication equipment which are located remotely should be powered by solar power systems to decrease the dependence on Tanesco power supply and to lower the possibility of people vandalising systems or cables.

Upgrading of navigation aids in Tanzania. The remaining aged **NDB** should be replaced to ensure an overall NDB coverage of all the airways in Tanzania. All **VOR**s, which are in a bad state or are unserviceable, should be replaced and each of them should be co-located with a **DME** to improve the level of ARNS in Tanzania along the major air routes. Also, airports which have no VOR and DME facilities, but which are located at the knots of air routes should be equipped with these navigation aids to improve the navigation quality in Tanzania. Special attention should, therefore, be given to the airports of Dodoma, Songea and Zanzibar. The **ILS** at Dar es Salaam should be rehabilitated, according to the ICAO requirements of a Category-I ILS. This means the restoration of the serviceability of the Outer Marker and the co-located NDB-DS by installing a solar power system to ensure continuous powering.
This way the level of **ARNS** provision is increased to acceptable standards.

Increase of income for all DCA employees. From the questionnaire, it has appeared that all DCA employees feel that they are underpaid for the number and nature of tasks they have to do. This has a major effect on their motivation and it caused the seeking for other sources of income in the form of other jobs besides DCA. The **wage level** should be improved by using gradually revenues, coming from landing, parking and over-flying charges. This will also result in less DCA employees transferring to the private sector and in a better job appreciation.

Upgrading of the Civil Aviation Training Centre in Dar es Salaam. Because training cannot be given for the latest technologies and techniques, students and DCA employees have to be sent abroad, which implies huge costs for DCA. Also, certain licenses for specific equipment cannot be achieved, due to a lack of real-situation practice equipment. Therefore, the CATC in Dar es Salaam should be upgraded in such a way, that students and DCA employees can be trained locally by local instructors instead at other institutions in Tanzania or abroad. All sections should be equipped with proper up-to-date **teaching materials** for both theory and practice. The CATC should be equipped with **real-situation equipment** which resembles the type of equipment used in aviation in Tanzania to enhance the possibility of DCA employees achieving licenses and ratings. This will enhance their promotion possibilities. All instructors should have **refreshment training** for the courses they are now given to increase their level of knowledge on the newest technologies, which they can pass on to the students and DCA employees. It should be investigated to what extent co-operation with other Civil Aviation Training Institutions is possible, whether supported by ICAO or not, to enhance the present level of training at the institute.

Improvement of present level of knowledge of all ATC Officers, Communication Officers and Telecommunication Engineers and Technicians. Besides the upgrading of the CATC, the present **level of knowledge** of before mentioned DCA employees should be improved by periodical refreshment training to ensure the up-date of newest technologies. Efforts should be made to have as much training at the CATC as possible to make the level of knowledge and received training the same for all DCA employees. Also meetings among employees of their own section and of other sections should improve the understanding of relevant systems and techniques used by DCA and to transfer knowledge within the organisation.

Upgrading of present Air Traffic Service/Direct Speech network. The present number of connections of the ATS/DS network and the present serviceability is insufficient to provide a good AFS. The number of connections should be extended to destinations which receive such an amount of air traffic that a connection is required. Specially, airports which are located along the busy international routes or which are major near-by destinations, like Lusaka in Zambia, require to be connected to the communication centre in Dar es Salaam. This way the level of **AFS** provision is increased to acceptable standards.

Upgrading of Area and Approach Control in Tanzania. The VHF consoles inside the Area Control Room at DIA should be rehabilitated to enhance a safe **Area** and **Approach Control**. The number of staff should be increased to be able to perform tasks for each type of control, including the supervisory tasks, in a safe manner. The distribution of functions per type of control should be equally divided to relieve the work load of all the ATC controllers. The **Approach Control** at KIA should also be upgraded by locating the VHF consoles in a separate room and increasing the number of staff. This way the level of **AMS** provision is increased to acceptable standards.

PART IV TECHNOLOGY AUDIT AFS PROVISION

Part IV describes a case within a case. The case of the Aeronautical Fixed Service (AFS) provision via the low speed Aeronautical Fixed Telecommunication Network (AFTN) is done by the Communication section of DCA in Tanzania, being a part of the ANS organisation. Chapter 21 describes the general elements, necessary to provide an Aeronautical Telecommunication Service (ATS). The technology audit methodology is used to eventually find the causes of the shortcomings of the AFS. Chapter 22 gives a general introduction of the methodology. It includes the description of scheme which shows the step by step approach. The scheme consists of four major steps of which each step is dealt with in a separate chapter. Chapter 23 describes the limiting of the scope to one service and one service implementation. Chapters 24 and 25 describe how to come to the shortcomings of respectively the service and the service provision. The following chapter describes why social-economic aspects with respect to the AFS provision influence its functioning and how it helps to find the causes for the found shortcomings. The final chapter gives final remarks about implementation of the audit, taking into account technological and organisational developments.

PART IV TECHNOLOGY AUDIT AFS PROVISION

As shown in part three of this report, the ANS organisation of the Directorate of Civil Aviation (DCA) of Tanzania encounters many problems in many fields of the Aeronautical Telecommunication Service (ATS) provision. For the ANS organisation, it is important to have a methodology to identify shortcomings in the ATS provision and their causes and to come up with possible solutions.
This part of the thesis describes such a methodology. It focuses on one field within the total of ATS provision, but it can be used for other fields as well, provided they are defined properly.
The particular field is the Aeronautical Fixed Service (AFS) provision via the Aeronautical Fixed Telecommunication Network (AFTN) by the Communication section of DCA of Tanzania.

Since the description of the methodology is applied to one particular field, it is preceded by a description of the elements of the ATS provision to clarify the terminology.

21. AERONAUTICAL TELECOMMUNICATION SERVICE (ATS) PROVISION

ATS provision is the transferring of aeronautical information via aeronautical telecommunication infrastructure to the service recipient in a correct, timely and cost-efficient manner by the responsible service provider. The responsibility of the provider is to make sure that aeronautical information, supplied by an originator, is transferred and served to the recipient.
The ATS is regarded as an international telecommunication service, since it is provided to recipients which are not in the same State as the State in which the service is provided.[50]

As described in chapter 5, the ATS consists of the Aeronautical Fixed Service (AFS), the Aeronautical Mobile Service (AMS), the Aeronautical Radio Navigation Service (ARNS) and the Aeronautical Broadcast Service (ABS). The objective and the nature of aeronautical information determines the actual service to be used and the means with which the service is provided.

21.1 Elements of service provision

The ATS provision consists of the following elements:

A. ATS provider
B. aeronautical telecommunication infrastructure
C. aeronautical information
D. ATS users

A. ATS provider

The provider is the service organisation with operators or controllers and has the responsibility for the proper service provision.

B. Aeronautical telecommunication infrastructure

A telecommunication service is made possible by technical facilities and consist of the following elements:[51]

1. Equipment:

[50] International Civil Aviation Organisation, *Annex 10: Aeronautical Telecommunications - Volume II: Communication Procedures* (Montreal, Canada: July, 1995, page 2).
[51] van Duren, J., Kastelein, P., Schoute, F.C., *Telecommunication Networks and Services* (Cornwall, Great Britain: 1992, page 121).

a. transmission equipment (transmitters and receivers or transceivers[52])
b. switching equipment
c. terminals
2. Telecommunication circuits

Switching equipment is necessary when information has to be relayed from one connection to another.
The terminals are used for the processing of aeronautical information from a usually written form into a transferable form and/or vice versa.

C. Aeronautical information

The objective(s) and the nature of aeronautical information determines the service to be used and the means with which the service is provided.

Aeronautical information can be divided into the following types of communication:
1. voice communication
2. message/data communication

D. ATS users

ATS users are those who produce the aeronautical information and those who receive the aeronautical information. The producers of the information make use of the aeronautical services to transfer the information to the information recipients. In case equipment produces the information, the users are only those who receive the information.

ATS users are all personnel concerned with flight operations. Roughly, they can be divided into airline pilots and operators or controllers of stations, related to aeronautical matters. Although with some services, pilots receive their information from direct service users. For example, AIS units which use the AFTN to gather information.

22. TECHNOLOGY AUDIT METHODOLOGY (TAM)

In order to identify and to analyse the technological shortcomings of the Aeronautical Fixed Service (AFS) as provided via AFTN in Tanzania, a methodology is required which helps to identify the shortcomings of the service as such and also to identify the possible shortcomings with the service provision and the organisation which provides the service. An important feature of the methodology must be, that all the shortcomings are identified by taking a number of actions, of which each action logically comes forth from the previous one.

This kind of methodology is available in the Technology Audit Methodology (TAM), which was developed for small and medium large enterprises in the manufacturing sector.[53] The methodology describes in four major steps the shortcomings of a product, the technological shortcomings of the production process and the causes of the product's shortcomings. Each step consists of subsequent actions to be undertaken in a logical order, resulting in the wanted outcomes.

Figure 5 shows the model as it is used for this research.

52 Transceivers have both transmitting and receiving functions.

53 Lapperre, P.E., van der Ploeg, J., *Technology audit methodology for medium and small scale enterprises* (Eindhoven, The Netherlands: second draft, August 1996).

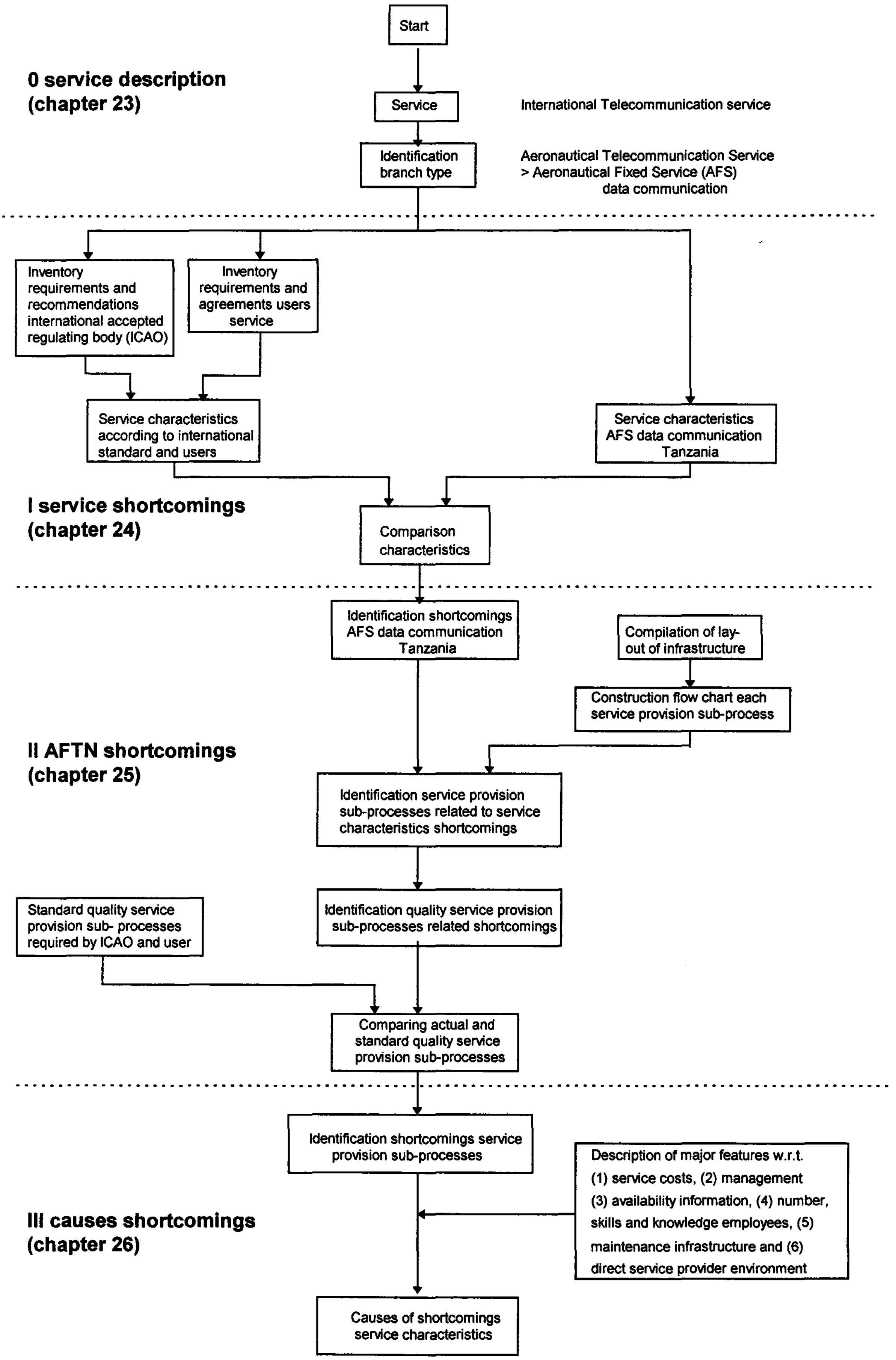

Figure 5: schematic presentation technology audit AFS provision

Figure 5 shows the four steps, clearly distinguished by the horizontal interrupted lines. In practice, each step is actually a comparison between aspects in the actual situation and aspects as they should be according to ICAO requirements and recommendations and to requirements and agreements of users.

The steps are preceded by the identification of the branch type within the service sector at hand. The identification of the service branch type is shown to limit the scope to one particular service within one particular service branch, implemented in one particular way. The identification of the way of implementation is at least necessary within the aeronautical telecommunication service, because aeronautical services are provided via various ways, depending on the nature of the information to be transferred. It determines also the service characteristics and the service provision characteristics.

In the *first step*, a specific service, provided by a specific provider in a specific way, is compared with requirements and recommendations of an internationally accepted regulating body, active within the specific type of service branch, and requirements and agreements of the users of the specific service. The comparison leads to a list with shortcomings of the service. This step is very much technology centred.
In the *second step*, the total process of the service provision by the relevant service provider is described and divided into sub-processes, which are subsequently related with the shortcomings of the particular service. The relevant sub-processes are subsequently compared with the requirements, recommendations and agreements of the regulating body and users, which results in the shortcomings of the service provision. Also, this step is very much technology centred.
In the *third step*, elements like (1) costs of operation, (2) management, (3) availability of relevant information, (4) number, skills and knowledge of employees, (5) maintenance of infrastructure and (6) direct service provider environment are taken into consideration. These elements are considered, because they can show the additional root causes of the shortcomings of both the service provision and the service.

23. STEP 0: SERVICE DESCRIPTION

Before the technology audit is applied, the identified service is described, including:

1. name of service
2. elements of the service provision via way of implementation
3. proposed functioning and usual application mode(s) of the service (viewpoints of service provider and user)

23.1 Name of service

The name of the service is the Aeronautical Fixed Service (AFS), which has the following objectives:

Service is provided for the safety of air navigation and for regular, efficient and economical operation of air services.[54]

Air navigation applies to airline pilots, navigating through FIRs. Air navigation is based on a number of methods of which one is based on the use of ground aids. Aeronautical information like presence and status information of the ground aids are important aspects for a pilot to know, so that the safety of air navigation is enhanced. Also, weather status reports are important information for safe navigation. Therefore, additional information on any change of any navigation related aspects along the route an aircraft will fly, has to be send to the aeronautical station from which the pilot will depart.

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[54] International Civil Aviation Organisation, *Doc. 8259-AN/936: Manual on the planning and engineering of the Aeronautical Fixed Telecommunication Network* (Montreal, Canada: 5th edition 1991, page 1).

An example of aeronautical information sent via the AFTN is the Notice-To-Airmen (NOTAM[55]). A pilot receives a collection of NOTAMs, which are collected by Aeronautical Information Service (AIS) units. The point where the pilot can collect the NOTAM-collection is the Briefing Office or Flight Planning Office at an airport.

23.2 Elements of service provision

The elements of the ATS provision are specified to the AFS provision via the AFTN, provided in the Tanzanian FIR.

A. service provider

The AFS provision via the AFTN within the Tanzanian FIR is done by the Communication section of the Directorate of Civil Aviation (DCA) of Tanzania.

B. service provision infrastructure

The infrastructure used for the AFS provision is the Aeronautical Fixed Telecommunication Network (AFTN). The AFTN is a standardised telex network. Standardisation of communication procedures, equipment and network planning is done by the International Civil Aviation Organisation (ICAO), the internationally accepted regulating body.[56]
The AFTN in Tanzania is a meshed network with three AFTN communication centres of which the AFTN communication centre in Dar es Salaam is the main international centre in Tanzania. The centre is the Tributary centre to Nairobi, according to the ICAO plan for the Africa - Indian Ocean region.[57] This plan also states, that the international communication centres of Kigali and Bujumbura are Tributary centres to Dar es Salaam.[58] All other AFTN stations are connected to the main centres as a star network.
Appendix H.1 shows the AFTN in Tanzania.

The AFTN centres in Tanzania are all equipped with so-called torn-tape teletypewriter equipment. The switching technique at the centres is fully manual control.

Information transfer rate
The transfer rate for telex messages is expressed by Baud rate and ICAO has set proposed Baud rates for international tributary connections from Dar es Salaam at 50 Baud.[59] This includes the connections with Nairobi, Kigali and Bujumbura.

Structure
The AFTN conveys aeronautical information via telex messages. Messages are sent as a block and received as such. The first character sent is the first character received. Transit-times of messages are based on agreements between relevant administrations.

Establishment of communication
Establishment of communication is in this case establishment of connection. All connections are permanent. The teletypewriter equipment is connected via Land TeleType (LTT) lines, rented from the national telecommunications company TTCL.

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[55] **NOTAM.** A notice distributed by means of telecommunication containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operation.

[56] One of ICAO's chief activities is standardisation, the establishment of International Standards, Recommended Practices and Procedures covering the technical fields of aviation. Besides that, they support regional meetings which deal with aviation problems which cannot be dealt with on a world-wide scale and technical co-operation for development, specially in developing countries.

[57] International Civil Aviation Organisation, *Doc. 7474/26 Africa - Indian Ocean Region Air Navigation Plan* (Montreal, Canada: 26th edition, 1989, Chart COM 1A).

[58] International Civil Aviation Organisation, *Report of the 10th Meeting of the AFI Planning and Implementation Regional Group (APIRG)* (Dakar, Senegal: 3-7 June, 1996, appendix 4.3A).

[59] International Civil Aviation Organisation, *Report of the 10th Meeting of the AFI Planning and Implementation Regional Group (APIRG)* (Dakar, Senegal: 3-7 June, 1996, appendix 6-4-E, pages 2 and 3).

Symmetry
The relationship of information between two access points is bi-directional symmetric. The flow characteristics are the same in both directions, whether it is a simplex or duplex connection.

Communication configuration
Although, procedures and communication protocols are provided by ICAO for multi-point transmission of AFTN messages, only the Briefing Office at DIA is connected to both the international communication centre at the ACC and the SITA network. All other connections in Tanzania are point-to-point connections.

Message format
The message format code, which has among others signalling and addressing information, knows two types of formats with respect to the low-speed AFTN. These are the International Telegraph Alphabet No. 2 (ITA-2) and the International Alphabet No. 5 (IA-5). The ITA-2 is the first used format, but is now gradually replaced by IA-5, which is more adaptable to digital message transfer. Although agreements between administrations have to be made, this is only done during the planning stage of the AFTN. It does not state anything about the quality of the service.
Tanzania uses the ITA-2 format.

Since the description of the infrastructure is a part of the technology audit method, this matter is elaborated upon in section 24.1.

C. Aeronautical information

From the objectives of the AFS, the type of aeronautical information is derived.
The aeronautical information has to consist of presence and status information of aeronautical facilities and the weather. The location of the originators of the information determine to which area the information applies.

The categories of messages are with their relevant priority ranking:[60]

1. distress messages (1)
2. urgency messages (2)
3. flight safety messages (2)
4. meteorological messages (3)
5. flight regularity messages (3)
6. Aeronautical Information Services (AIS) messages (3)
7. aeronautical administrative messages (3)
8. service messages (x)*

* Note: service messages are used to request for a re-transmission of previous AFTN messages. Priority ranking of the service message depends on priority of the concerned AFTN message.

The distinction between aeronautical information and AFTN message determines the scope of the service. When any aeronautical information provided to the service provider - which in the case of the AFTN is usually in a written form - is accepted by the service provider, the responsibility for the message and the information is accepted. The responsibility for the message is related to the transit-time of a message. The transit time is defined by ICAO as:

The time taken from the moment that an acceptable message is offered to the AFTN until the moment that it is made available to the addressee.[61]

Thus, the responsibility for the service is limited to the period between the acceptance of a message and the successful reception of the message by the addressee. The responsibility

[60] International Civil Aviation Organisation, *Annex 10: Aeronautical Telecommunications - Volume II: Communication Procedures* (Montreal, Canada: July, 1995, page 11 and 12).
[61] International Civil Aviation Organisation, *Doc. 8259-AN/936: Manual on the planning and engineering of the Aeronautical Fixed Telecommunication Network* (Montreal, Canada: 5th edition, 1991, page 49).

of the service is extended to delivery of the message with the relevant AIS unit, when the unit is located within the airport boundaries.

Since the AFS is an international service, the service provision on one circuit can be shared by two service providers, when the circuit crosses the border of States or established AFTN territories. Therefore, the responsibility for the service must be clear for each provider.

D. Users service

From the objectives of the AFS, the users of the service are derived. From the first objective it seems, that the primary users of the service are pilots of aircraft. They require a final update on the status of aeronautical facilities and/or weather conditions along the air-routes they are about to fly to be able to navigate through the relevant air spaces in a safe way. Although their relevant information is conveyed via the AFTN from the relevant sources, they finally receive the information from the responsible AIS unit at an airport. This is, however, considered a separate service (i.e. the Aeronautical Information Service). Since the responsibility of the AFS ends with the successful arrival of the message with the AFTN addressee, the users of the AFS are considered the AIS units.
Besides, any provider of aeronautical information is a user of the service, because this ensures the regular, efficient and economical operation of air services, the second objective. Besides the AIS units with the Briefing Offices or Flight Planning Office, other AFTN stations are meteorological stations, airline offices, Civil Aviation Agencies (CAA) offices - in this case DCA Head Quarters - , air force offices and SITA[62] offices. The latter are set up by the International Air Transport Association (IATA)[63]. The SITA offices are also connected with each other by the SITA network, which airlines use to verify aeronautical information send via the AFTN.

23.3 Proposed functioning and usual application of AFS

The proposed functioning and usual application of the AFS is the same, since ICAO requirements state that the service cannot be used for any other purposes than the transfer of aeronautical information.

The AFS via the AFTN cannot be used for other purposes, since it transfers only messages and/or digital data, containing specific aeronautical information. ICAO has documented the categories of messages which are allowed to be send over the AFTN and has ranked them according to their priority. The responsibility for the acceptance of messages rests with the relevant administrations.

The messages and/or digital data are standardised and preparation and use of them can only be done after training at relevant Civil Aviation Training Institutes for both operators and airline pilots.

24. STEP I: IDENTIFICATION SHORTCOMINGS SERVICE CHARACTERISTICS

The core of the technology audit is a comparison between the technical characteristics of the AFS, provided by the Communication section in Tanzania, with the technical characteristics of the service, according to the requirements and recommendations of ICAO and the requirements of and agreements between the users of the service.

The actions undertaken in this step are the following:
1. inventory required documents, concerned with requirements, recommendations and agreements regulating body and users
2. identification important service characteristics

[62] SITA = Société Internationale de Télécommunications Aéronautique
[63] IATA is the international representative organisation for all airlines in the world.

3. comparison quantified or qualified service characteristics of documents and actual situation

The last step identifies the differences between the service characteristics of documents and actual situation. Those characteristics which show negative differences are the service shortcomings.

24.1 Inventory requirements, recommendations and agreements

In step one, the first two actions are to make inventories of all requirements and recommendations of ICAO and of all requirements and agreements of the AFS users.

At first, a list of relevant documents is presented, in which the requirements and recommendations are stated and in which recommendations with respect to agreements between users are stated. These documents are listed below. Appendix P provides a summary of the contents of the documents.

According to Doc. 7474/26, the following documents have to be applied by relevant States:[64]

1. Africa - Indian Ocean Region Air Navigation Plan (Doc. 7474/26)
2. Annex 10: Aeronautical Telecommunications, Volume I: Communication systems
3. Annex 10: Aeronautical Telecommunications, Volume II: Communication procedures
4. Regional Supplementary Procedures; part 2: Communications (Doc. 7030)
5. Manual on the Planning and Engineering of the Aeronautical Fixed Telecommunication Network (Doc. 8259-COM/533/4)

Additional documents, containing background information:

1. Report of the 6th Meeting AFI RAN Meeting (Doc. 9298)
2. Report of the LIM AFI RAN Meeting (Doc. 9528)
3. Report of the 10th Meeting of the AFI Planning and Implementation Group (APIRG)

The requirements, recommendations and agreements can actually be divided over three areas. First of all, there are the requirements and recommendations of ICAO, which come down to procedures, planning and engineering requirements. Secondly, there are regional meetings, which in the case of Tanzania are the Africa - Indian Ocean Regional Meetings. These meetings are supported by ICAO and decisions on regional level have to meet at least the requirements of ICAO at world-wide level. Thirdly, bilateral agreements have to be made between DCA and administrations other than DCA and specially those located outside Tanzania. Beside foreign administrations, other organisations are the meteorological organisation and the SITA organisation. Bilateral agreements between States are usually based on requirements or recommendations made at regional meetings. Agreements are specially made to solve inter-connectivity problems and to set-up quality standards with respect to operational characteristics of the network which both counterparts have to meet.

24.2 Service characteristics

Whereas ICAO gives guidance in implementing the services, the service characteristics are best examined when taken from the point of view of the user and independently from the way they are implemented. Then, the most important characteristics are:

1. extent of service
2. speed of service
3. reliability of service

[64] International Civil Aviation Organisation, *Doc. 7474/26: Air Navigation Plan Africa - Indian Ocean Region* (Montreal, Canada: 26th edition, 1989, page E 3-0-1).

4. continuity of service
5. maintainability of service

Since most of the characteristics can only be examined per connection, concentrated in AFTN centres, the examining of the actual service characteristics should first of all take place in AFTN centres. The number of connections and the importance of a centre indicates the order of examining. First, the international centres should be examined and then, subsequently, the centres with less importance. If necessary, AFTN destination stations should be examined to get a complete view of the AFS via the AFTN in a State.

Extent of service

With extent of the service is meant the percentage of the number of possible destinations AFTN users can reach with respect to the original total number of destinations.
The examining of the extent of the service is the first action to be taken, since all other characteristics are examined per connection.
The ICAO policy on the AFTN planning states, among other considerations, that the network topology should be based on the volume and geographical distribution of messages and/or digital data.[65] Since the users determine the destination of the messages and/or digital data, the number of stations connected to the AFTN is determined by the traffic transferred to the stations. Since the messages and/or digital data contain aeronautical information, the stations are related to aeronautical matters.
The number of stations during the technology audit is determined by the original plan and any change of the plan since the implementation of the AFTN.
With respect to international connections, ICAO and regional plans should indicate the present number of international connections. This includes temporary bilateral agreements between administrations, in case plans could not be implemented on the short term.
Since administrations still have freedom with respect to the AFTN on national level, national policy plans should be examined, whether absence of certain stations in the network are justified by a lack of traffic or are implemented sufficiently by other means beside the AFTN.

A shortcoming with respect to the extent of service is identified, when the actual number of connections is less than the required number of connections.

Speed of service

As stated in the definition of the NOTAM, the timely knowledge of aeronautical information to all personnel concerned is essential.[66] Also, when looking at the performance of the AFTN, the factor of most concern for the user is the speed with which messages are transferred.[67] Therefore, the main indicator for the speed of service is the message transit-time, as defined in section 23.2. Because of the variable nature of some of the delays occurring in the network, the time which a message will take to pass from the AFTN station of filing to the addressee station can only be forecast on a statistical basis.

In a report of the 6th Africa - Indian Ocean regional air navigation meeting, transit-time requirements were reviewed and agreed that with teletypewriter circuits operating at 50 Baud the following values could be attributed:[68]

- 5 minutes for messages for centres handling flights with less than 1,000 NM of flying distance to the common FIR boundary
- 10 minutes for centres handling only flights with greater than 1,000 NM of flying distance to the common FIR boundary

Note: these distances should be calculated for flights originating in the FIR concerned, from their point of departure

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[65] International Civil Aviation Organisation, *Doc. 8259-AN/936: Manual on the planning and engineering of the Aeronautical Fixed Telecommunication Network* (Montreal, Canada: 5th edition 1991, page 2).
[66] International Civil Aviation Organisation, *Annex 11: Air Traffic Services* (Montreal, Canada: July, 1995, page 4).
[67] International Civil Aviation Organisation, *Doc. 8259-AN/936: Manual on the Planning and Engineering of the Aeronautical Fixed Telecommunication Network* (Montreal, Canada: 5th edition, 1991, page 49).
[68] International Civil Aviation Organisation, *Doc. 9298-AFI/6: Report of the 6th AFI Regional Air Navigation Meeting* (Arusha, Tanzania: 12 December 1979, pages 12-5 and 12-6).

to the respective FIR boundary, and for over-flying traffic from FIR boundary to FIR boundary concerned.

It should be noted, that these values were attributed in 1979 and that other arrangements may have been made. Besides, ICAO has given the criteria for transit-time performance and States are allowed to make their own arrangements. Therefore, it should be examined first, whether regional agreements or agreements per connection have been made. In case transit-times are agreed upon per connection, it should be clear to which stations or offices the agreed transit-times refer to. In case the same arrangements still apply, the required transit-time is 5 minutes, since the nearest foreign AFTN communication centres are within the range of 1,000 NM with respect to the Dar es Salaam AFTN communication centre.

The general criteria for the establishment of AFTN transit-time performance for the users of the network are stated in ICAO's AFTN planning and engineering manual. The following form is given:

> *In the average peak hour in the peak season of the year, at least 95 per cent of messages of higher priority classifications (SS, DD and FF priority indicators) flowing from ... (the specified AFTN station at which the messages are filed) to ... (the specified AFTN addressee station) should achieve a transit time of less than ... (a specified number of minutes).*[69]

The establishment of transit-times of lower priority messages is of concern of the users and can have either the same transit-times as the higher priority messages or may have longer times based on bilateral agreements between users.
Since users are distinguished between users of separate administrations (e.g. an AIS unit of a CAA and an airline office) and users within the same administration (AIS units of a CAA), the above mentioned agreement form applies certainly for the first type of users. Transit-time agreements for circuits between AIS units within a CAA are the responsibility of the CAA itself, but ICAO recommends to use the same form and recommends administrations to engineer their networks so *that the overall transit-times from their stations to the international centres and vice-versa are kept to a strict minimum.*[70]

When actual transit-time information is not available, it has to be collected by the consultant with the relevant service-provider, which in this case is DCA.
Important are the identification of the peak season and the average peak hour. Since the AFI ANP document states that AFI AFTN communication centres should at least be able to provide statistical data on AFTN traffic as stated in the concerned AFI Meeting report, identification of the necessary data should be based on that. The aspects, which should be recorded, are shown in appendix Q. The report states, that in a year statistical data should be collected on the 23rd day of January, April, July and October for each channel, originating from the communication centre. From these four dates, the peak season can be derived. The advantage of choosing between these four dates for the peak season is that administrations are recommended to record these figures. This means, that there is a good chance that this information is available. Also, the chance that all administrations keep these figures is high, so the method can be used with any administration. The availability of information is elaborated upon in more detail in section 26.3.
After the identification of the peak season, the identification of the peak hour is done per circuit and also here information is supposed to be gathered by the relevant Administration.

The calculation of the transit-times is not entirely clear at the moment. ICAO has formulated formulas for the calculation of the transit-time by dividing them up into components. Appendix R shows the components of the transit-time. Because of the distances between originating and addressee stations, it is hard to calculate the transit-time for one or a number of message(s).
However, the advantage of the method of dividing the transit-time into components is that relay times within centres can be calculated. When the relay time is larger than the required

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[69] International Civil Aviation Organisation, *Doc. 8259-AN/936: Manual on the planning and engineering of the Aeronautical Fixed Telecommunication Network* (Montreal, Canada: 5th edition, 1991, page 50).

[70] International Civil Aviation Organisation, *Doc. 7474/26: Air Navigation Plan Africa - Indian Ocean Region* (Montreal, Canada: 26th edition, 1989, page E 3-0-3).

transit-time, one already has identified a shortcoming on that particular circuit. This does not mean, that when a relay time is below the required transit-time there is not a shortcoming. Another advantage of the method is that one only has to examine all AFTN communication centres, since all other AFTN stations are connected to them.

Any additive deviation from the agreed transit-time on a connection is a shortcoming of the service on that connection. The total quality of the service is based on the total number of connections meeting the transit-time requirement out of the total number of connections.

Reliability of service

The user must be able to rely on the provider, that the quality of the service is maintained whenever it is used. Since the transit-time is the factor of most concern for the user, the reliability of the service is based on the transit-times of all transferred messages between all users of the particular network. The more messages are transferred within the maximum permitted transit-time, the higher the reliability. Therefore, the reliability is the percentage of number of messages, transferred within the maximum permitted transit-time out of the total number of transferred messages.

As stated with the form ICAO has given, 95% of the messages should achieve a transit-time of less than the agreed period. Again, this should be examined per connection, using the above mentioned information. In stead of the average transit-time in the peak hour, the percentage of messages having transit-times of less than the agreed time is examined.

The shortcoming of the reliability of service is identified, when the percentage is below 95%.

Continuity of service

The service must be provided at any time, since aeronautical information is supplied at random during the day. This means, that the service must be continuously available at least during the time stations are manned. Some airports receive only air traffic during a specified period of the day, so AFTN stations need only to be opened during this period.
ICAO has recommended, particularly at centres with relay responsibilities and regardless of the air traffic of the airports they are located, that circuits and communication centres should operate continuously throughout the 24 hours.[71]

Therefore, the main indicator is the availability of the service, which should be 100% in the ideal case. Since the service is examined per connection, the availability of equipment and circuits per connection should be examined. Also, the availability of the operators at AFTN communication centres is important in this case. Since all circuits have a connection with one of the communication centres in a country, the examining can be limited to the communication centres.

Since availability in the future is hard to examine, relevant information should be gathered from the past and the near past in particular. In section 11.2.1.1, the availability of the AFTN is already discussed. There, the ICAO requirement for daily reliability of a circuit of 97% is used to indicate the level of acceptable availability, since 100% availability is difficult to meet, specially in developing countries with unreliable power supply.

A shortcoming of the service characteristic is identified, when during the past year the availability of a circuit has been less than 97%. The total quality of service is based on the number of connections meeting the requirements out of the total number of connections.

Maintainability of service

The supplier of the aeronautical information must depend on the service provider, that the information is conveyed to the recipient without alteration of the contents. For this reason,

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[71] International Civil Aviation Organisation, *Doc. 7474/26: Air Navigation Plan Africa - Indian Ocean Region* (Montreal, Canada: 26th edition, 1989, page E 3-0-2).

two characteristics are defined, which are the ability to correct service and the ability to conserve service.
In case of **correction of service**, ICAO has formulated a time requirement, in case a received message has been mutilated such that re-transmission is required. A message should be re-transmitted within 8 minutes after the request for re-transmission has become available within one hour since the previous transmission.[72] Since the speed of re-transmission depends on the amount of traffic and number of staff at a centre, this characteristic should be examined per centre. It should be examined, whether examining of other AFTN stations is justified by large amounts of traffic, received and transmitted by the stations.
A shortcoming is identified, when the re-transmission time is more than 8 minutes per centre.
For the **conservation of service**, all messages should be stored for at least 30 days in case re-transmission may be necessary within this time period.[73] With each station or centre, the dates should be checked, whether they expand the period of 30 days or not.
In case messages are not stored for at least 30 days, a shortcoming of the maintainability of the service at a station is identified.

24.3 Comparison service characteristics

Now that the service characteristics and their required values have been identified, they are compared with the values of the corresponding characteristics in the actual situation, which in this particular case is the Tanzanian case.
Appendix S shows three major columns for the comparison of the characteristics. The first column shows the list of service characteristics with the relevant indicators. The second column shows the requirements or recommendations which have to be met, according to the requirements, recommendations and agreements of ICAO and the users. It shows the values per item to be checked. The last column shows the components for the actual values of the characteristics in the Tanzanian situation.

24.4 List of service characteristic differences

The comparison of the previous section has yielded either similar values of both the service characteristics in the actual situation and the required situation or has yielded differences between some of the characteristics. Of interest are those characteristics which have yielded negative differences, meaning the inability of meeting requirements or agreements. The table of appendix S is used to mark any negative deviation and from this table the list of shortcomings is derived. The list is subsequently used to identify those sub-processes of the total service provision which are related to the shortcomings, as done in section 25.3.
The list shows all shortcomings found with the comparison. In order to be complete, all service characteristics are shown, including those with which no shortcomings have been identified.
It should be noted, that in the Tanzanian case not enough data has been gathered to be able to compare all service characteristics. For sake of clarity, those characteristics with which shortcomings have been identified are shown.

Extent of service
Out of the 23 required total circuits, 13 connections are not present. The shortcomings of the extent of the service are on the circuits between:

72 International Civil Aviation Organisation, *Doc. 8259-AN/936: Manual on the planning and engineering of the Aeronautical Fixed Telecommunication Network* (Montreal, Canada: 5th edition, 1991, page 9).
73 International Civil Aviation Organisation, *Annex 10: Aeronautical Telecommunications - Volume II: Communication Procedures* (Montreal, Canada: July, 1995, page 2).

1. Dar es Salaam - Kigali (RTT[74])
2. Dar es Salaam - Bujumbura (RTT)
3. Dar es Salaam - Zanzibar
4. Dar es Salaam - Pemba
5. Dar es Salaam - Tanga
6. Dar es Salaam - Tabora
7. Dar es Salaam - Iringa
8. Dar es Salaam - Mtwara
9. Dar es Salaam - Songea
10. Dar es Salaam - Airline office
11. Dar es Salaam - Meteorological Office (MET Office)
12. Dar es Salaam - Air Force
13. Dar es Salaam - Control Tower

Of the international connections, the links with Lusaka, Lilongwe and Entebbe are no longer required to be operative. The rationalised AFTN plan for the Africa - Indian Ocean region indicates, that these centres are served through the main centre of Nairobi.[75]

Speed of service
The shortcomings with respect to the speed of service in the Tanzanian case are not known. This should be examined thoroughly. Since absence of data, not all required values cannot be shown in appendix S. The appendix shows, that either regional arrangements for one international transit-time is made or that agreements are established for separate connections. Since at the time of the research the exact nature of the agreements with respect to connections between stations or centres was not available, the appendix shows the links between international centres. This is done, since it is likely that agreements apply to them. All other links are referred to them, since international links have the most strict requirements. Meeting of transit-time requirements by national and internal links ensures the speed of service.

Reliability of service
The shortcomings with respect to the reliability of service in the Tanzanian case are not known. This should be examined thoroughly. The same construction of the appendix and scope of application as with speed of service apply to reliability of service, since it is related to speed of service.

Continuity of service
The shortcomings with respect to the continuity of service in the Tanzanian case are only known as far as the AFTN communication centre in Dar es Salaam is concerned. Appendix H.2 shows the availability figures from the centre during 1995 and the beginning of 1996. It clearly shows the failures to meet the continuity requirement. Other centres should be further examined thoroughly.

Maintainability of service
The shortcomings with respect to the **ability to correct the service** in the Tanzanian case are not known. This should be examined thoroughly. The shortcomings with respect to the **ability to conserve the service** in the Tanzanian case are not known.[76] This should be examined thoroughly.

25. STEP II: IDENTIFICATION SHORTCOMINGS SERVICE PROVISION

This step focuses on the service provision and the means with which the service provision is realised.
Step two comprises of the following actions:
1. compilation of lay-out infrastructure
2. construction flow chart each service provision sub-process
3. identification relevant service provision sub-processes using identified service characteristics' shortcomings
4. identification required quality relevant service provision sub-processes

[74] RTT = Radio TeleType

[75] International Civil Aviation Organisation, *Report of the 10th Meeting of the AFI Planning and Implementation Regional Group (APIRG)* (Dakar, Senegal: 3-7 June, 1996, table COM 1A).

[76] Observations with the statistical department of the Comunication section dealing with the AFTN in Dar es Salaam showed, that messages are conserved for at least 30 days, although records of message numbers were not present. This can be a problem, when transmissions are interrupted but number counting continues.

5. identification actual quality relevant service provision sub-processes
6. comparison actual and required quality relevant service provision sub-processes

25.1 Compilation lay-out infrastructure

As described in section 21.1, the particular AFS at hand is provided via the Aeronautical Fixed Telecommunication Network (AFTN).

The compilation of the lay-out of the AFTN infrastructure is done at two levels.
First, the total network in an FIR is examined. The FIR in this particular case is the Tanzanian FIR. The network consists of all domestic, internal and international circuits and all the AFTN stations and communication centres. With internal circuits is meant the circuits which connect a communication centre with stations or offices at an airport or within a city. The lay-out of the country is important for the construction of the flow chart of the message transfer process from one station in the network to an other station.
Secondly, the lay-outs of the AFTN stations and communication centres are compiled. They show all equipment inside a station or a centre. They are important, because they serve as the basis for the construction of the flow charts of the service provision sub-processes. The total service provision process of one message consists of a number of sub-processes at the centre. The sub-processes at the level of a centre include the transmission of the message on an outgoing circuit.

25.1.1 Lay-out AFTN Tanzania

Appendix H.1 shows all connections of the AFTN in Tanzania. For sake of clarity, it shows all connections, including those which became unserviceable after the break-down of the AMS computer in 1995, although some of the links are no longer part of the extent of the service.[77] Normally, the map should indicate the actual extent of the service.
Table 20 shows all circuits per communication centre. They are all land-lines, rented from TTCL except where indicated.

Dar es Salaam
International
1. Dar es Salaam - Nairobi
2. Dar es Salaam - Entebbe
3. Dar es Salaam - Kigali (RTT[78])
4. Dar es Salaam - Bujumbura (RTT)
5. Dar es Salaam - Lusaka
6. Dar es Salaam - Lilongwe

Domestic
7. Dar es Salaam - Zanzibar
8. Dar es Salaam - Pemba
9. Dar es Salaam - Tanga
10. Dar es Salaam - Kilimanjaro
11. Dar es Salaam - Tabora
12. Dar es Salaam - Dodoma
13. Dar es Salaam - Iringa
14. Dar es Salaam - Songea
15. Dar es Salaam - Mtwara

Dar es Salaam (internal)
16. Dar es Salaam - Briefing Office
17. Dar es Salaam - Meteorological Office (MET Office)
18. Dar es Salaam - Air Force
19. Dar es Salaam - DCA Head Quarters
20. Dar es Salaam - Control Tower

Briefing Office* (also connected with Dar es Salaam)
21. Briefing Office - SITA

Kilimanjaro (also connected with Dar es Salaam)
22. Kilimanjaro - Arusha
23. Kilimanjaro - Nairobi

Dodoma (also connected with Dar es Salaam)
24. Dodoma - Mwanza
25. Dodoma - Kigoma
26. Dodoma - Mbeya

Table 20: AFTN circuits Tanzania

* Note: the Briefing Office is not a communication centre, but has multi-point connections with the AFTN communication centre inside the ACC and the SITA network.

[77] More information on the AMS computer is found in section 11.2.1.1.
[78] RTT = Radio TeleType

All circuits are connected to transmitter and receiver equipment or transceiver equipment at the stations. All equipment are torn-tape teletypewriters.

25.1.2 Lay-out AFTN communication centre and station

As noted in section 24.2, the examining of the service and the service provision should be concentrated first on the most important communication centres, since they serve the most circuits. Usually, there is one international centre and several domestic centres. By examining all centres, all circuits are examined. Only in case of deviating switching or relaying techniques and/or message handling, AFTN origin and destination stations should be examined as well.[79] Examining all stations falling under the same Administration will take a lot of time and is usually unnecessary, specially in the case the same relay and message handling techniques are used.
Table 20 shows, that there are three communication centres in Tanzania which are the following along with their role in the network:

- Dar es Salaam (ACC) main international centre and tributary to Nairobi main centre
- Kilimanjaro domestic centre with international link to Nairobi
- Dodoma domestic centre

All centres use manually torn-tape relay techniques.

In its simplest form, a torn-tape teletypewriter consist of a keyboard teletypewriter with an attachment which will provide perforated tape on incoming and outgoing messages, together with an automatic transmitter, for each (simplex) circuit terminated at the communication centre. The starting pulse (when required) and the heading are then transmitted by keyboard operation at the beginning of each transmission.
With increasing size of the centre, the most busy circuits should be established as duplex circuits to segregate the incoming and outgoing circuit positions. Unless this is done, the handling of large numbers of tapes becomes a confusing process with an unacceptable risk of error.
A typical major torn-tape communication centre may therefore consist of:[80]

1. a group or a number of separate groups of printing reperforators
2. a similar group of "double-headed" automatic transmitters
3. a group of starting code generators and automatic channel sequence numbering equipment
4. a position where mutilated messages, and messages requiring the addition of a diversion indicator and/or a shortened address, can be dealt with.
5. a position, or a number of positions, at which the tape of a multiple-address message can be multiplied prior to transmission on a number of outgoing circuits. The nature of the centre and the traffic handled at the centre determine, whether this function is necessary, although it is not indicated at exactly what point this is recommendable
6. a group of printing reperforators or page-copy teletypewriters monitoring the traffic on outgoing (and sometimes, incoming) circuits so as to provide a record and to permit previously relayed messages to be repeated when this is requested by another communication centre
7. a number of items of ancillary equipment, such as "washboards" and "tape springs" for holding message tapes queuing for access to an outgoing circuit

Only the lay-out of the AFTN communication centre in Dar es Salaam is compiled, due to lack of time. It serves in this paper as an example for the methodology.

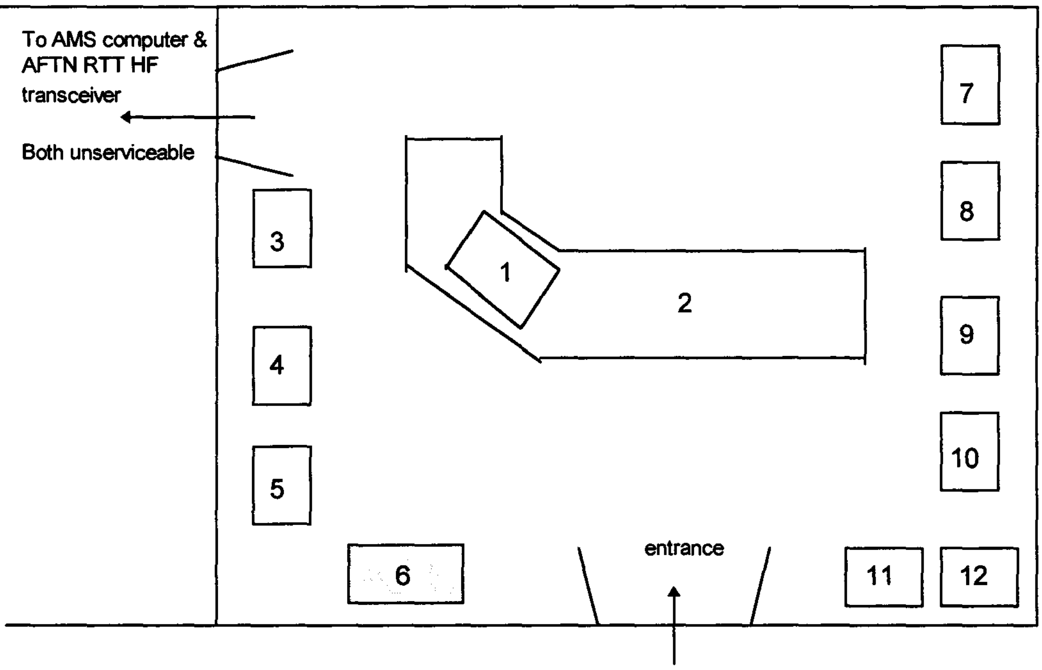
[79] An AFTN origin station is an AFTN station where messages and/or digital data are accepted for transmission over the AFTN and an AFTN destination station is an AFTN station to which messages and/or digital data are accepted for transmission over the AFTN.

[80] International Civil Aviation Organisation, *Doc. 8259-AN/936: Manual on the planning and engineering of the Aeronautical Fixed Telecommunication Network* (Montreal, Canada: 5th edition 1991, pages 100 and 101).

25.1.2.1 Lay-out AFTN communication centre Dar es Salaam

Following the above list of section 25.2.1, the AFTN communication centre in Dar es Salaam Tanzania has equipment which incorporates item numbers 1 to 3 and 6. Item number 4 is present at the centre. Item numbers 5 and 7 are not present.

Figure 6 shows the lay-out of the centre with all relevant equipment and their position. The position of the equipment is important, since moving messages between equipment is an important aspect of the service provision. For example, when a lot of relay traffic is taken place between two connections, the position of the transmitter and receiver equipment of both connections becomes important since it can shorten the relay time.



Nr. type of equipment

1. processing terminal for correction of mutilated message
2. supervisor desk
3. teletypewriter transceiver
4. teletypewriter transceiver
5. teletypewriter transceiver
6. switch board cabinet

Nr. type of equipment

7. teletypewriter transmitter
8. teletypewriter receiver
9. teletypewriter transmitter
10. teletypewriter receiver
11. teletypewriter transceiver
12. teletypewriter transceiver

Figure 6: lay-out AFTN communication centre Dar es Salaam

One can see, that all circuits end inside the centre. In an AFTN destination station, the circuits also end in the station, but the printed messages are taken from the receiver and handed over to the relevant AIS unit. A transmitter connected with the same circuit is used for transmission of messages.

A communication centre usually relays all messages, specially when the AIS unit at the same airport is connected with the centre through a separate circuit. The lay-out of figure 6 shows that relaying of messages is done by taking the printed messages from the receiver of an incoming circuit and move them physically to the relevant transmitters of the outgoing circuits by an operator.

Summarising, there are three types of processes involved with AFTN message handling, namely transmitting, receiving and relaying. These processes are discussed in the following section.

25.2 General AFS provision process

As described in chapter 21, the general Aeronautical Telecommunication Service (ATS) provision consists of the transfer of aeronautical information from an information supplier to an information user.
This also applies to the general AFS provision.

The general AFS provision flow chart is shown in figure 7.

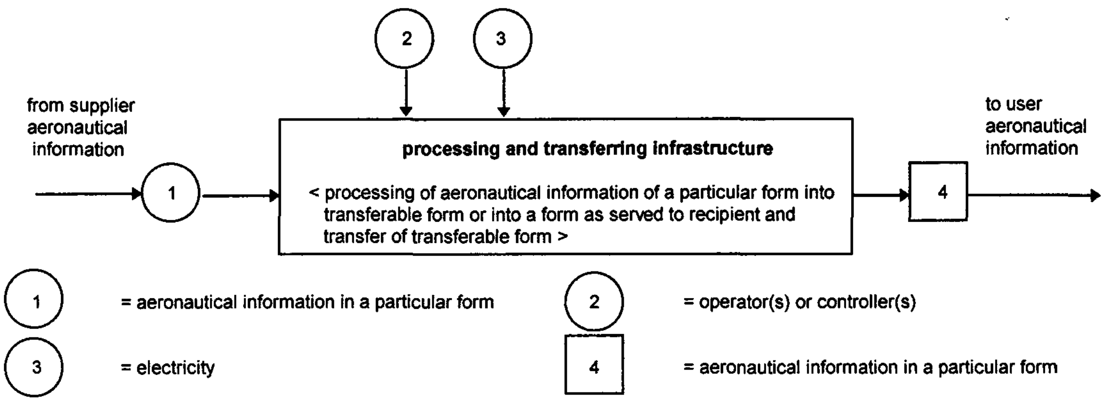


Figure 7: flow chart general AFS provision

The aeronautical information is transferred via the aeronautical infrastructure (e.g. the AFTN or the ATS/DS network) from the information supplier (e.g. a Briefing Office) to an information user (e.g. an AIS unit).

25.2.1 AFS provision sub-processes low-speed AFTN

Since the implementation of the AFTN is done in different ways, different standards apply to them and can, therefore, not be compared. Thus, only one implementation form must be identified. Since the AFTN in Tanzania is implemented by means of low speed circuits and equipment, the flow chart of the service provision process has to be constructed as such.
The general lay-out is subsequently divided into AFS provision sub-processes.
The total AFS provision via the low speed AFTN can be divided into two or three types of series of sub-processes, depending on the type of AFTN station. The three series of sub-processes are:
1. transmitting series
2. receiving series
3. relaying series

Transmitting series
The supplied aeronautical information, usually a written document, is processed into an AFTN message, according to ICAO procedures. The aeronautical information is supplied to the recipient in the form of an internal electronic signal.[81] The recipient has the responsibility of processing the signal into the aeronautical information. The transmitting series apply to an AFTN origin station.

The transmitting series consists of three parts, namely:
1. processing of information into transferable message and printed form
2. transferring of message onto out-going circuit
3. conveying of message on out-going circuit

Appendix T.1 shows the flow-charts of the sub-processes of the transmitting series.

[81] A distinction is made between an internal and an external electronic signal. 'Internal' refers to an electronic signal within the teletypewriter. 'External' refers to an electronic signal outside the teletypewriter on a circuit.

Receiving series
The aeronautical information is received in the form of an external electronic signal and the service provider is responsible of processing it into the form, desired by the eventual user of the information. For example, a message coming from Nairobi and which is destined for the AIS unit at KIA is processed from an external electronic signal into a message, printed on paper in an AFTN message format. The receiving series apply to an AFTN destination station.

The receiving series consists of only one part, namely:
1. transforming of incoming message into printed and torn-tape form

Appendix T.2 shows the flow-charts of the sub-processes of the receiving series.

Relaying series

The type of relaying and type of used transfer form determine whether processing is necessary or not. For example, in case of "torn-tape" teletypewriters, the external electronic signal from an incoming circuit is processed into a torn-tape, which is subsequently moved to the terminal of the outgoing circuit and there processed into an internal electronic signal. In case of an Automatic Message Switching computer, the signal is directly relayed from the incoming circuit to the outgoing circuit.

The relaying series consists of a receiving and a transmitting part. The transmitting part of the relaying series distinguishes itself from the transmitting series in the fact, that the aeronautical information is delivered in the already processed form of a "torn-tape" instead of the written document. The receiving part is the same as with the receiving series, but is shown here for clarity. The relaying series apply to an AFTN communication centre.

The relaying series consists of five parts, namely:
1. transforming of incoming message into printed and "torn-tape" form
2. moving of "torn-tape" from teletypewriter receiver to processing part teletypewriter terminal
3. transforming of "torn-tape" into internal electronic signal and printed form
4. transmitting of internal electronic signal onto out-going circuit
5. conveying of external electronic signal on out-going circuit

Appendix T.3 shows the flow-charts of the sub-processes of the relaying series.

25.3 Identification relevant service provision sub-processes

The identification of relevant sub-processes of the service provision is necessary, since not all service characteristics may have shortcomings. By identifying only the relevant sub-processes, the description of the processing of the service characteristics into sub-processes is shortened and avoids unnecessary research time.

The scope of the service characteristics determine which type of sub-processes are examined and how many times the same sub-processes are examined for different locations. For the scope, there are distinguished centres, connections - consisting of a number of circuits - and separate circuits.

Extent of service
Shortcomings with the extent of service are expressed by the number of stations which are not connected to the AFTN within the responsibility of one Administration. All stations used to be connected with communication centres. Therefore, of interest here are the equipment at these centres, the circuits between the centres and the stations and the equipment at the disconnected stations.
From the above, one can derive the relevant sub-processes. These are the transmitting and receiving series at the centres and stations.

Examples

Of the international circuits, Dar es Salaam is obliged to have connections with Nairobi, Kigali and Bujumbura. For the Dar es Salaam (ACC) - Kigali circuit, both the transmitting and receiving series at both the Dar es Salaam and Kigali centres have to be examined.
Of the national circuits, Dar es Salaam is obliged to be connected with a number of stations of which Zanzibar is one. For the Dar es Salaam (ACC) - Zanzibar circuit, both the transmitting and receiving series at the Dar es Salaam centre and the Zanzibar station have to be examined.

Speed of service
Shortcomings with the speed of service are expressed by the connections which fail to meet the transit-time requirement.

For each connection, the sub-processes should be examined. Depending on the nature of the connection, i.e. the relevant AFTN station(s), communication centre(s) and circuit(s), the type and number of sub-processes are identified.

Example

For the connection between Dodoma and Kilimanjaro, the series which have to be examined are the transmitting series of sub-processes in the Dodoma centre with respect to the outgoing circuit to Dar es Salaam, the relaying series at the Dar es Salaam centre with respect to the incoming circuit from Dodoma and the outgoing circuit to Kilimanjaro and the receiving series at the Kilimanjaro centre with respect to the incoming circuit from Dar es Salaam.

Reliability of service
Shortcomings with the reliability of service are expressed by the connections which fail to meet the requirement of the percentage of messages below agreed transit-time.

The sub-processes involved are the same as with the speed of service.

Continuity of service
Shortcomings with the continuity of service are expressed by the circuits which fail to meet the availability requirement.

Of interest are the sub-processes involved with each circuit. At each centre, each connection originating from the centre should be examined on the outgoing circuit as well as on the incoming one. The relevant sub-processes are the transmitting series as well as the receiving series of sub-processes per circuit per centre.
Since some connections may have alternative routing in case the original circuit or circuits are unserviceable, these connections should also be examined when examining message transfer between certain stations. Therefore, before examining the sub-processes, one must have identified all possible routes between two stations. Alternative routes should also be taken into account, since they enhance he availability of the connection.

Example

The circuit between Nairobi and Dar es Salaam does not meet the availability requirement, thus the transmitting and receiving series of sub-processes at the Dar es Salaam centre with respect to the incoming circuit from Nairobi and the outgoing circuit to Nairobi have to be examined. Comparable series at the Nairobi centre are not of concern, since it falls under the responsibility of the Kenyan Administration. Besides, the transmitting and receiving series of sub-processes at the Dar es Salaam centre with respect to the incoming and outgoing circuits from and to Kilimanjaro plus the transmitting and receiving series of sub-processes at the Kilimanjaro centre with respect to the incoming and outgoing circuits from and to respectively Dar es Salaam and Nairobi should be examined as well.

Maintainability of service
Shortcomings with the maintainability of service are expressed by the centres which fail to meet one or both types of maintainability requirements.

<u>Ability to correct service</u>
Shortcomings with the ability to correct the service are expressed by the centres which fail to meet the requirement with respect to the speed of re-transmission of mutilated messages.

Since problems with re-transmission is to be most expected with the circuit with the busiest traffic, this circuit should be examined. Therefore, of interest are the sub-processes involved with the busiest circuit. The busiest circuit of a centre is determined by comparing the peak hours in the peak season of each circuit with each other. This should be done at each centre.
The relevant sub-processes are the transmitting and receiving series of the same circuit, which is the busiest of the centre, per centre.

Example

The AFTN communication centre at Dodoma does not meet the requirement with respect to speed of re-transmission, thus the transmitting and receiving series of sub-processes with respect to the incoming and outgoing circuits of the busiest connection have to be examined.

<u>Ability to conserve service</u>
Shortcomings with the ability to conserve the service are expressed by the AFTN stations and/or centres which fail to meet the requirement with respect to the required length of time, conserving transmitted messages.

As pointed out in section 24.2, the examining of each AFTN station in a country would be an enormous task and is, therefore, limited to the communication centres.
The relevant sub-processes are for the transmitting series part one and for the relaying series part three which transform an AFTN message from any form into a printed form. It is this form which is conserved. Since all transmitted messages should be conserved, all part one and part three sub-processes of all outgoing circuits should be examined at each centre.

Example

Of the Kilimanjaro centre, all part one sub-processes with respect to messages originating from Kilimanjaro transmitted on the circuits to Arusha, Dar es Salaam and Nairobi plus all part three sub-processes with respect to relayed messages transmitted on the same circuits as with the part one sub-process.

25.4 Identification quality service provision sub-processes

To be able to identify shortcomings with the service provision, the quality indicators of the service sub-processes should be identified.
By examining the quality of the sub-processes, one is able to identify the sub-processes which cause the shortcoming.

Since each sub-process involves one or more components of the AFTN infrastructure, these components are described.

25.4.1 AFTN infrastructure components

Since in the Tanzanian case all circuits begin and end with teletypewriter machines, one can make a distinction between the circuits themselves, consisting of a number of channels, the teletypewriter equipment and the operators. Since the AFTN knows different degrees of automated relaying, it is worthwhile to examine in other cases the degree of automation with the relaying. Therefore, it is also mentioned here.

AFTN circuit

For an AFTN circuit, there are three conditions which have to be satisfied before it can be regarded as such:[82]
1. provisions must exist for the relay of messages and/or digital data between the circuit concerned and other circuits of the network
2. messages and/or digital data must be prepared and handled according to the procedures prescribed in Annex 10
3. the ultimate responsibility for its operation must have been assumed by the State or States concerned

All conditions are met in the Tanzanian case. The features of AFTN circuits are the following:

1. capacity	(volume of traffic, number of channels and Baud rate)
2. transfer speed (Baud rate)	(ICAO: 50 Baud)
3. availability	(ICAO: 100%)
4. reliability	(ICAO: AFTN efficiency daily reliability per circuit 97%)
5. implementation	(simplex, duplex or two times simplex)

Capacity
Telecommunication circuits should have sufficient capacity to be able to handle the volume of traffic plus extra traffic, diverted through the link within the required transfer times. The capacity of a circuit is also determined by the number of channels. The more channels, the more traffic the circuit can handle and the less the congestion delay will be.

Transfer speed
The transfer speed should be sufficient to handle the provided amount of traffic. For the international links with Nairobi, Kigali and Bujumbura, ICAO has set the Baud rates for al links at 50 Baud. The Baud rates for the national circuits are set by DCA and should be examined, whether they are sufficient to handle the amount of traffic on the Tanzanian AFTN.

Availability
General availability figures show the availability between circuits on a monthly basis. It does not show the causes for the unavailability. There are also availability figures, which do not only show the availability of the circuits, but also of the equipment. In the Tanzanian case, records are kept, which indicate the degree of availability of the circuits and the causes of possible unserviceability. This includes unserviceability of the equipment at either the side of the centre or the other side and the unserviceability of the circuit itself. Therefore, more accurate availability figures should be also derived from these figures. It should be noted, that the analysis of these figures will take more time, than the monthly figures, since the records are only made on a daily basis. Monthly records or records of even longer periods do not exist.

AFTN efficiency (reliability)
The more reliable a circuit is, the less network capacity the traffic uses and the more efficient the network is. Since 100% AFTN circuit reliability is practically impossible to achieve, a regional recommendation for all African and Indian Ocean region countries states that *appropriate action should be taken to achieve and maintain the highest possible daily reliability, in any case not less than 97% of the AFTN circuits.*[83]

Implementation
The implementation of a connection depends on the predicted or expected amount of traffic. It determines, therefore, the capacity of the connection. The connection can be implemented by using a simplex circuit (only one-way transfer possible per message), a

[82] International Civil Aviation Organisation, *Doc. 8259-AN/936: Manual on the planning and engineering of the Aeronautical Fixed Telecommunication Network* (Montreal, Canada: 5th edition 1991, page 1).
[83] International Civil Aviation Organisation, *Doc. 7474/26: Air Navigation Plan Africa - Indian Ocean Region* (Montreal, Canada: 26th edition, 1989, page E 3-0-1).

duplex circuit (one circuit with two-way transfer of messages possible) or two simplex circuits (two circuits with two-way transfer of messages possible with more capacity per connection).

Teletypewriter equipment

Three types of teletypewriters can be distinguished, namely transmitters, receivers and transceivers. The latter incorporates both transmitting and receiving functions. Processing functions are done with the transmitter and transceiver equipment in the Tanzanian case.

The features of teletypewriters in a centre are the following:

1. availability	(ICAO: 100%)
2. reliability	(manufacturer indications: MTBF and MTTR)
3. type of equipment	(amount of traffic; transmitters and receivers or transceivers)

Availability
For the availability of the equipment, one can use the same figures as mentioned with the circuits, but in case of short time one should only use the monthly figures.

Reliability
The Mean Time Between Failure (MTBF) and the Mean Time To Repair (MTTR) are figures of system reliability supplied by the manufacturer, because they are used to predict the system availability. These figures indicate the weakest link in a system and can highlight the possible necessity of buying new equipment or additional spare parts.

Type of equipment
The type of teletypewriter equipment is determined by the amount of traffic per circuit. When there is a lot of traffic, transmitters and receivers are used to have more operative room and to ensure a constant message flow. The use of transmitters and receivers is only possible in case of duplex or two simplex circuits. In case of a duplex or a simplex circuit, transceivers are used.

Operators

Operators are mentioned, because they are a part of the service provision process, as shown in section 25.2.1, and are regarded as a channel within an AFTN station causing a congestion delay.[84]

The features of operators in a centre are the following:

1. availability	(number of staff and volume of traffic)
2. speed of operation	(handling time is considered here constant)

Availability
The availability of an operator depends on the amount of traffic the particular centre handles and on the number of staff at the centre. The more colleagues an operator has, the more available an operator is to handle a certain amount of messages. The less messages, the more available an operator is to handle them.

Speed of operation
The speed of operation or handling time of a message is considered to be constant. When examining the speed of operation, one assumes that the skills and knowledge of the operator are sufficient to carry out his tasks without problems. With step three of the methodology, the skills and knowledge are taken into account. They are discussed in section 26.4.

[84] International Civil Aviation Organisation, *Doc. 8259-AN/936: Manual on the planning and engineering of the Aeronautical Fixed Telecommunication Network* (Montreal, Canada: 5th edition 1991, page 50).

Relay equipment

ICAO distinguishes four torn-tape relay techniques with different degrees of automation and are here shown with their most important or time-reducing feature with respect to the previous relay technique:

1. manually torn-tape relay (physical movement by an operator)
2. push-button torn-tape relay (avoidment of cross-office handling time)
3. semi-automatic relay (re-transmission of messages during reception)
4. fully automatic relay (avoidment of routing reading by an operator)

The most important feature of relay equipment is the following:

1. speed of relaying (degree of automation)

Speed of relaying
The speed with which messages are relayed from an incoming circuit to an outgoing circuit depends on the used relaying technique and the degree of automation the particular relaying technique is implemented. The fully manual control depends on the speed of an operator and this is mentioned with the discussion of the operator. To indicate the importance of the degree of automation, ICAO has given some average relay speeds for each degree of automation. These are:[85]

1. manual 10 to 12 minutes
2. push-button 2 minutes
3. semi-automatic 1 minute
4. fully automatic 30 seconds

25.5 Comparison qualities relevant sub-processes

With this action, the indicators described in section 25.4 are checked for every relevant sub-process, identified in section 25.3, in the actual situation and the required situation.

The action leads to a comprehensive list of all shortcomings within all sub-processes in all possible situations. Due to a lack of time, not all shortcomings of the service provision in the Tanzanian case have been examined, but an example is given to clarify the chosen methodology.

Example: connection between Briefing Office Dar es Salaam and Zanzibar

The service provision process for the particular connection consists of the transmitting and receiving series at the Briefing Office, the relaying series of the communication centre inside the ACC and the transmitting and receiving series at the AFTN station of Zanzibar International Airport. Appendix T.4 shows all the series for the message flow from the Briefing Office to Zanzibar and for the message flow from Zanzibar to the Briefing Office.

Circuit
Availability
The availability figures of appendix H.2 show, that from January 1996, the availability of both the incoming and outgoing circuit from and to Zanzibar falls down to zero per cent, which compared with the requirement of 100%, is a dramatic downfall. Figures on the link between the communication centre and the Briefing Office are not available. However, observations and statements of Communication Officers made clear that this link has been and is available at all times. This limits the shortcomings to parts four and five of the relaying series for the outgoing circuit and part one of the relaying series for the incoming circuit at the Dar es Salaam communication centre. At the Zanzibar station, the shortcomings are limited to part one of the receiving series for the incoming circuit and at least parts two and three and possibly part one of the transmitting series for the outgoing circuit.

Teletypewriter equipment
Availability
Observations at the centre showed, that there is no teletypewriter equipment present for the connection with Zanzibar. This means, that the sub-processes part four and part five of the relaying series for the outgoing circuit to Zanzibar cannot be executed, due to unavailable equipment. This applies also to the sub-process part one of the relaying series for the incoming circuit from Zanzibar. *(see next page)*

[85] International Civil Aviation Organisation, *Doc. 8259-AN/936: Manual on the planning and engineering of the Aeronautical Fixed Telecommunication Network* (Montreal, Canada: 5th edition 1991, pages 60 and 61).

Shortcoming
The shortcoming of the service provision between the Dar es Salaam Briefing Office and Zanzibar is at least brought back to the indicated sub-processes. Appendix T.4 also shows which particular sub-processes are involved. The shortcoming of the service provision indicates the cause for the shortcomings with the extent of service and the continuity of service. The extent of service is below required level, since Zanzibar cannot be reached, although it should be. The continuity of service is below the required level, since the availability of the stations equipment is zero per cent where it should be one hundred.

The products of the checking are the shortcomings of the sub-processes and through that the shortcomings of the service provision. The shortcomings of the service provision sub-processes can be the direct causes for the shortcomings of the service, but do not need to be as such. Step three examines other aspects with the AFS provision via the AFTN to identify other root causes of the service shortcomings.

26. STEP III: IDENTIFICATION CAUSES SHORTCOMINGS SERVICE CHARACTERISTICS

Where step one and step two focus on the technological aspects of the service and the service provision, step three focuses on aspects in other fields which also have an influence on the service provision and, therefore, on the provided service. These aspects lay in the field of human resources, the organisation, the management and aspects outside the direct environment of the service provider. These aspects are important to examine, since shortcomings of the service provision may not be restricted to technological shortcomings alone.

As shown in the scheme of the methodology (see figure 5), the shortcomings of the service characteristics are used to identify the shortcomings of the service provision. Or in other words, the shortcomings of the service provision are the causes for the shortcomings of the service characteristics. Since step three produces the causes for the service provision shortcomings, they also are the shortcomings of the service characteristics.

The main features to be examined with this step are:
1. service costs
2. management
3. availability information
4. number, skills and knowledge of employees
5. maintenance AFTN infrastructure
6. direct service provider environment

The importance of these aspects is also recognised by ICAO and is expressed by numerous requirements and/or recommendations at specially regional level.

26.1 Service costs

In many cases and specially in the Africa - Indian Ocean region, the service provision is done on a non-profit basis. This means, that the service costs are balanced by the revenues, received by an Administration. Since ICAO encourages provider agencies *to apply reasonable preferential tariffs to aeronautical and meteorological administrations*[86], achievement of cost-efficient operation, beside proper operation, should also be considered important.

For example, circuits which have more capacity than strictly necessary should be examined to see in what way they can be implemented more efficient and, therefore, also more cost-efficient.

[86] International Civil Aviation Organisation, *Doc. 7474/26: Air Navigation Plan Africa - Indian Ocean Region* (Montreal, Canada: 26th edition, 1989, page E 3-0-2).

So, indicators here are the amount of traffic on a circuit over a period of time and the capacity of a circuit.

Another example is the operation at an AFTN station or an AFTN communication centre. Each station should be examined in what way operational efficiency can lead to cost efficiency.

26.2 Management

Proper management is necessary to ensure proper operation at communication centre and stations. Beside operational management, also planning management should be good to operate the AFTN properly in the long term. The tasks of the management should not only be the examining of improvement of efficiency, but also the planning with respect to future plans in the region or globally.

For operational management, ICAO recommends, that States should ensure strict adherence to the adequate management of communication centres and periodic advanced training and refresher courses for keeping supervisory staff at peak efficiency.[87] Also, according to ICAO recommendations, AFTN communication centres in the Africa - Indian Ocean region should have adequate statistical data processing capabilities and should be able to provide at least the statistical information presented in Appendix B to Agenda Item 7 contained in Doc. 9529 (see appendix Q)[88]. The information derived from the statistical data should be used by the planning management to monitor the quality of the centres and stations and act on any shortcomings.

26.3 Availability information

The execution of the methodology is based for a large part on the statistical data, recorded by the Administration, from which the necessary information is derived. Specially the data containing the aspects of the table of appendix Q are vital for the technology audit, since it contains descriptive indicators for the sub-processes of section 25.2.1.

In case of the Tanzanian AFTN, the aspects of the table of appendix Q were recorded as indicated during the days the Automatic Message Switching computer was working. After the break-down of the computer, it has not been done and this undermines the proper management of the centre.
However, other relevant information, like availability figures and the reasons for possible unavailability, are recorded and can be used in some cases for examining the shortcomings of the service provision.

26.4 Number, skills and knowledge of employees

In section 25.4.1, the time an operator needs to handle a message is considered to be constant, since the skills and knowledge of the operator are considered to be sufficient to carry out the task satisfactory. However, when shortcomings are found with the sub-processes dealing with message processing and relaying, it is important to examine the skills and knowledge of the particular operators, employed with the indicated sub-processes. The outcome may be, that the skills and knowledge are insufficient. Also, the apparent sufficient number of professional staff may turn out to be insufficient, since less operators with sufficient skills and knowledges imply a higher chance of mistakes during message processing and handling.

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[87] International Civil Aviation Organisation, *Doc. 7474/26: Air Navigation Plan Africa - Indian Ocean Region* (Montreal, Canada: 26th edition, 1989, page E 3-0-2).

[88] International Civil Aviation Organisation, *Doc. 7474/26: Air Navigation Plan Africa - Indian Ocean Region* (Montreal, Canada: 26th edition, 1989, page E 3-0-1).

ICAO encourages States to take *all possible steps to attract and train a highly competent AFS operating, maintenance and supervisory staff by adequate initial training and certification followed by periodic refresher training, including a programme of proficiency checks.*[89]
The mentioned aspects like initial training, certification, periodic refresher training and periodic proficiency checks should be examined. Any shortcomings in one of those fields indicates shortcomings with the service provision as it is concerned with the human role.

Beside 24-hour operation of circuits and communication centres, the requirement for continuous 24-hour operation also states, that fully qualified technical staff should be on duty at all times in communication centres to be able to keep the centre operative continuously.[90] Therefore, the aspects should also be examined for the maintenance staff.

26.5 Maintenance AFTN infrastructure

As stated in section 26.4, proper maintenance of the AFTN infrastructure is important to keep the AFTN continuous in operation. The total quality of the maintenance should be examined, whether they are the causes for shortcomings with the sub-processes.

General maintenance aspects of aeronautical telecommunication equipment is described in chapter 8 and maintenance of teletypewriter equipment as part of the total of aeronautical telecommunication equipment in Tanzania is described and discussed in chapter 14.

Aspects concerning the maintenance staff are discussed in section 26.4 and are, therefore, omitted here. The other aspects should be derived from the relevant chapters of this report and examined for the sub-processes which showed shortcomings.

Special attention should be paid to the maintenance of border-crossing circuits. This is a matter of mutual agreements between the relevant administrations of both States and the national telecommunication companies of both States. The agreements determine the degree of responsibility for maintenance of circuits. Most circuits are hired from national telecommunications companies and are not the responsibility of the service provider. This aspect is discussed in section 26.6.

26.6 Direct service provider environment

The direct service provider environment is divided into those aspects which fall under the responsibility of the relevant Administration and those aspects which do not fall under the responsibility. The latter influences the service provision, but cannot be controlled or can be controlled with difficulty by the service provider.

The aspects which fall under the responsibility of the service provider are the maintenance of the AFTN infrastructure and the back-up measures in case the main power supply fails. Since the maintenance is discussed in section 26.5, only the back-up measures is discussed here.

The power supply should be continuous for continuous operation of the AFTN and special back-up measures in case of both main power failure and main back-up power failure should be examined. The better the back-up measures, the smaller the chance the continuous operation is interrupted. The main back-up measures are usually part of the power system at an airport and may fall under the responsibility of other Administrations than the service provider. In Tanzania, the responsibility for the power system and the main back-up measures at the airports lies with the Electrical section of the Directorate of

[89] International Civil Aviation Organisation, *Doc. 7474/26: Air Navigation Plan Africa - Indian Ocean Region* (Montreal, Canada: 26th edition, 1989, page E 3-0-2).

[90] International Civil Aviation Organisation, *Doc. 7474/26: Air Navigation Plan Africa - Indian Ocean Region* (Montreal, Canada: 26th edition, 1989, page E 3-0-2).

Aerodromes, while additive back-up measures, like batteries or generators, are the responsibility of the Communication section of DCA.

The aspects which cannot be controlled or can be controlled with difficulty are the following:
1. power system airports
2. national government
   a. governmental interference
   b. purchase control
   c. difference public and private sector
3. national service industries
   a. national power supply
   b. national telecommunications company
4. manufacturers aeronautical infrastructure
5. international ATS counterparts

The nature and the extent of influence of the first aspect is described and discussed in chapter 13 and in more detail in section 17.1.2 and 17.2.2. The other aspects are described and discussed in chapter 16.

The above mentioned aspects should be examined, whether they influence the service provision in a negative way. This way the root causes of all shortcomings are identified.

For example, shortcomings with the reliability of teletypewriter equipment may be found with the unreliability of both the main power supply and the back-up power system. As shown in section 17.2.2, the power system of DIA is highly unreliable and Communication Officers stated that on some occasions power failure has been the cause of the unserviceability of the entire communication centre, leading to major shortcomings of the service provision and of the service.

26.7 Causes of service shortcomings

After completion of the technology audit, a complete overview is accomplished of all shortcomings of the service and the service provision at a technological level and a level containing other aspects beside the technology. The name "Technology Audit" does, therefore, not cover the entire scope of the audit, although it is based for a large part on the technology.

With the list of all shortcomings, the causes can be derived. Solutions for the shortcomings can be based on the causes, since they have been examined on the root level.
Although the technology audit has not been executed, section 11.2.1 shows, that already some causes have been found. The box below shows the example with respect to the extent of service, as given with section 25.5.

Example: connection between Briefing Office Dar es Salaam and Zanzibar
Appendix S.4 shows the sub-processes, which caused the shortcomings with respect to the extent of service. The relevant sub-processes indicate, that the shortcomings are found with unavailability of the circuit and teletypewriter equipment. Observations, made at the Dar es Salaam AFTN communication centre, made clear, that the equipment was lacking. After the break-down of the Automatic Message Switching (AMS) computer, the number of connections decreased due to a lack of space inside the centre and a lack of teletypewriters. Besides, the present equipment is aged and obsolete, which means that spare parts cannot be obtained and proper maintenance cannot be done. For the repair of the AMS computer, the knowledge of the relevant DCA employees is insufficient and the manufacturer of the computer did not respond to numerous requests by DCA.

Causes
So, direct causes for the shortcoming with the extent of service lie with knowledge of DCA employees, maintenance of aeronautical infrastructure and direct service provider environment (i.e. manufacturer aeronautical infrastructure).

27. PRESENT DEVELOPMENTS AND THEIR FUTURE IMPACTS

When one starts examining possible solutions for the found shortcomings, not only the causes found with the audit, but also technological developments and future plans on a regional and global level should be taken into account. With respect to these matters the following sections go deeper into the latest developments. Specially when one seeks solutions for the long term, these aspects should be taken into account as well.

27.1 Common ICAO Data Interchange Network (CIDIN)

Since the origins of AFTN in the 1950s, enormous progress has been made in the field of data communication. Because of inertia associated with a world-wide network containing thousands of stations and the international agreements necessary, the AFTN has not been able to take advantage of this technological progress and communication procedures were several technology generations less advanced than the technology itself.
To close this technology gap, the Common ICAO Data Interchange Network (CIDIN) has been developed by ICAO. The objective of CIDIN is to accomodate more than one application, unless the AFTN which can only transfer AFTN messages. Other applications with CIDIN are interactive computer applications, conversational mode between terminals, transmission of fascimile data and file transfer applications. CIDIN allows computers to communicate with eachother by using bit-oriented messages.[91]

27.2 Aeronautical Telecommunication Network (ATN)

Based on the new technologies and the need for further international standardisation for global efficient use of airport and airspace resources, ICAO is developing a world-wide standard Air Traffic Management (ATM) system. The ATM, consisting of a ground part and an air part, is needed to ensure the safe and efficient movement of aircraft during all phases of flight. The future ATM applications operate on a Aeronautical Telecommunication Network (ATN). The concept of the ATN as a world-wide data network, enables aircraft to communicate via satellite and VHF and Mode-S SSR air-ground data links with ground ATC and Aeronautical Operational Control (AOC) centres. In addition, high-capacity data exchange is provided between ATM systems, and also between systems operated by airline operating agencie service providers and ATM systems.
ICAO has developed a transition plan for States to upgrade the AFS from its present low- and medium-speed AFTN based network to a fully Open Systems Interconnection (OSI) compliant bit-oriented network. The OSI reference model provides data communication service providers with common interface services and protocols, which is a world-wide standard model formulated by the International Organization for Standardization (ISO).[92]

27.3 Effect developments on technology audit

Both the technological and procedural developments, which must lead to an internationally standardised system, have their impacts on the way the service provision is organised by an Administration. Among many changes, the lay-out of the centres will be changed, the particular tasks performed by the personnel will change in nature as well as in number and management of the centres will change.

Section 25.2.1 already stipulates the effects of different implementations of the AFTN on the way the audit is done. Different implementations of the AFTN mean meeting different

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[91] International Civil Aviation Organisation, *EUR Doc. 005: EUR CIDIN Manual* (Montreal, Canada: 1st edition, June 1990, pages 7 and 8).

[92] International Civil Aviation Organisation, *Circular 261-AN/155: Planning Document for Transition from the Current AFS to the Future System* (Montreal, Canada: January 1996, pages 1 and 4).

requirements on the level of the service characteristics as well as on the level of the service provision sub-processes.
When looking for future options as solutions, requirements and the advantages of different implementations should be weighed against each other. A short term solution may be the best cost-wise, but can be more costly when in the long term a whole new implementation form has become the new standard.

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