AISM Association of Internationale de Signalisation Maritime IALA

International Association of Marine Aids to Navigation and Lighthouse Authorities

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On

Data Collection for Aids to Navigation Performance Calculation

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Table of Contents

1. Introduction 3
2. Scope 3
3. The need for data collection 3
4. Sources and means of data collection 4
4.1 Sources of data 4
4.2 Means of collecting data 5
4.2.1 Operation reporting 5
4.2.2 Failure reporting 5
4.2.3 Maintenance reporting 5
4.3 Data storage, updating and checking procedures 6
5. Performance measures 6
5.1 Availability performance 6
5.2 Reliability performance 6
5.3 Maintainability performance 6
6. Data required 6
6.1 Data for performance indicators 6
6.2 Data for reliability improvement 7
7. Data analysis 7
7.1 DGPS 8
7.2 Performance data presentation 9
7.3 AtoN performance improvement 10

1. Introduction

A typical mission statement of a lighthouse authority is to deliver a reliable and cost effective network of aids to navigation for the benefit and safety of mariners and the protection of the marine environment. In order to achieve this it is necessary to collect data on AtoN equipment performance.

These guidelines provide details of methods that can be used to collect information on the availability and reliability of AtoN equipment. It covers general aspects with an overview of sources, measures and information that may be involved when collecting information.

It should be noted that meaningful data must include the data on successes (operation without failures) as well as data on failures and faults. In other words, these Guidelines are not intended to be a failure reporting guideline only.

2. Scope

These Guidelines provide information to the AtoN service provider on how data collection and reporting methods can be applied within its organisation to monitor all equipments. Reference should be made to the *'IALA Guide to Availability and Reliability Theory and Examples'* for the calculation of availability and reliability figures as well as definitions.

It is considered that, if these guidelines are followed, accurate and complete of reporting will be enforced and the data collected can be used to help improve the quality of the monitored equipment on a medium to long-term basis. Moreover, such an effort will facilitate the interchange of information between user and suppliers.

These Guidelines do not recommend how maintenance support should be organised. However, it will be self evident that some items will be repaired on site whilst others may only be replaced on site and repaired at a central facility or returned to the supplier for repair. Field data may be obtained at each of stage in the process.

In order to obtain maximum efficiency from the collection of data, it is suggested that the programmes of reporting, analysis and dissemination of results be closely co-ordinated. This may require close liaison between departments who contribute to the collection and analysis of the data.

3. The need for data collection

Performance indicators are management tools that can be used to measure, analyse and monitor the performance of a network of aids to navigation or specific systems and equipment. It is essential that the data collected is useful. The performance indicators in the IALA Navguide are:

- Availability,
- Reliability,
- Continuity,
- Redundancy,
- Integrity,
- Mean time between failures (MTBF), and
- Mean time to repair (MTTR).

This Guideline describes the collection and presentation of data on failures and reliability of AtoN equipment.

It is considered that an AtoN system comprises the AtoN signal equipment plus ancillary components such as power supplies. Availability is a useful indicator of the level of service provided by individual or defined groups of aids to navigation because it is representative of all the considerations within the control of the authority that have gone into providing and maintaining the facility. These include:

- Quality assurance procedures;
- Design and systems engineering;
- Procurement;
- Installation;
- Maintenance procedures;
- Failure response;
- Logistic arrangements.

While availability is the essential measure of the service provided to mariners, it is necessary to measure the other performance indicators in order to ensure that a lighthouse authority is operating an efficient and cost effective service.

The specific objectives of field data collection and presentation are to:

- Provide information of the actual performance level of the equipments monitored
  - to enable management reporting of availability of AtoNs, and
  - as information for operations and planning, maintenance support, training of personnel, etc.;
- Indicate a possible need for the improvement of:
  - AtoNs already installed and in operation,
  - further equipments to be delivered,
  - future designs;
- Compare the specified or predicted characteristics of the equipment(s) with the actual field performance;
- Improve related processes, such as training;
- Improve predictions (data bases and procedures);
- Inform the supplier about the performance of items on a regular or on a single occasion basis; and
- Provide a common reporting basis for IALA members.

4. Sources and means of data collection

In this section, the various information sources are described and the methods for systematically collecting information are outlined.

4.1 Sources of data

The following sources of data on reliability and failures of AtoN equipments are generally available:

- Mariner report;
- Keeper report;
- Remote monitoring;
- Maintenance activities;
- Repair activities on site, in workshop or at suppliers;
- Scheduled inspections.

4.2 Means of collecting data

It is not intended to recommend any particular format for the recording medium (e.g. paper based which may include notebooks, forms and photographs or computer database which may include digital photographs). However, it should be recognised that early consideration of the format is necessary in setting up an effective data collection scheme and also help subsequent successful processing.

Frequently the recording of data will be by manual means, however automated and interactive data collection systems may be also considered. The advantages to be gained from holding data in a database suitable for processing by an electronic data processing system includes easy and accurate access and updating of information as well as the possibility of performing new extended analyses.

Performance of AtoNs includes the time during which the AtoNs are performing correctly, as well as down time. One or several reporting means may be used to collect data.

4.2.1 Operation reporting

Operation reporting means information provided from the day to day management and monitoring of AtoNs and includes up time as well as down time. Data reporting should be supported by information on the use of the items such as the number of Aids and Aids up time. Cognisance should be taken of the IALA categories of AtoNs described in 'IALA Recommendation on Availability Objectives of Aids to Navigation Services'.

4.2.2 Failure reporting

A **failure** is defined as the unintentional termination of the ability of a system or part of a system to perform its required function. This means failure to display its correct characteristics or to be on its assigned position for proper use by mariners.

A **fault** is the failure of part of a system that does not affect the ability of the AtoN to perform its required function.

Data collected on failures is used to calculate the Availability of the AtoN and ensure compliance with IALA availability recommendations. Data collected on faults is used to provide information on reliability and cost effectiveness of systems and can be used to improve the performance of existing systems or improve future designs.

The information available from failure reporting is dependent on the available test resources and capability. Cases such as "fault not found" or "right when tested" should be clearly mentioned.

Failure reporting should cover all failures that have been observed. The reports should also contain sufficient information to identify failures as listed in 6.2. Failures considered to be attributable to any maintenance action should be so noted. It should be noted that failure of ancillary equipment or individual components within an AtoN system might not cause complete failure of the AtoN.

The failure reporting should be sufficiently comprehensive to cover the requirements of detailed investigation of an individual failure and the resulting fault. Where economic reasons or lack of resources make it impractical to collect all of the failure data indicated, the data required to calculate availability should be considered as the essential minimum.

4.2.3 Maintenance reporting

The maintenance report should contain all information relevant to the action taken to restore the condition of the system.

Maintenance activities can be divided into breakdown (AtoN performance is compromised - repair of failures), corrective (component failure – AtoN performance not compromised – repair of faults), preventative (scheduled to prevent failures) and inspection. When there is need to distinguish between corrective maintenance if no replacements or repairs are made, and preventive maintenance reporting, the action can be classified as a preventive maintenance report. If a preventive maintenance action results in

unscheduled replacement or repair, the report may be treated as a corrective maintenance report even though the item has in fact not failed in operation.

4.3 Data storage, updating and checking procedures

Independent of the structure chosen for the data storage, data should be checked at the time of input to ensure validity.

5. Performance measures

The performance indicators identified in Section 3 that are considered are listed as follows.

5.1 Availability performance

This measures the performance of the service provided to the mariner.

AtoN availability per Aid and category of Aid

Calculated from: AtoN cumulative down time per Aid and category of Aid
AtoN total time per Aid and category of Aid

5.2 Reliability performance

This measures the reliability performance of equipment and systems.

Mean operating time between failures (MTBF)

Calculated from: AtoN cumulative up time
Number of failures

5.3 Maintainability performance

This is a measure of the performance of the maintenance team.

Mean time to repair (MTTR)

Calculated from: Cumulative down time
Number of failures

6. Data required

The selection of the data to be collected is very dependent on the kind of performance measures to be evaluated/estimated.

Field data reporting may have to be limited by economic necessity to the minimum necessary to meet the requirement, whilst recognising that collection systems should be capable of future expansion.

It is likely that certain data may be needed for more than one purpose, and careful consideration can therefore result in the most cost-effective data collection scheme.

Consideration of the foregoing performance indicators defines the need for a system that provides for the collection of documented data covering:

- the identity of items or population of items under observation;
- operational conditions (remote or mainland site);
- performance monitoring.

For each individual item, sufficient information has to be recorded to clearly identify the item itself.

6.1 Data for performance indicators

For each failure the following information should be collected.

- Date and time of failure
- Date and time restored
- Aid type and category
- Station

6.2 Data for reliability improvement

In order to improve the reliability of systems it is necessary to collect data additional to the data required for performance indicators.

For each failure the following additional information should be collected.

- Type of item failed (e.g. battery, generator, lantern etc.)
- Item identification (e.g. model number, serial Number, etc.)
- Root cause of failure
    - Misuse
    - Maintenance induced
    - Lightning
    - Corrosion
    - Fatigue
    - Lubrication
    - No fault found
    - Right when tested
    - Collision
    - Component failure (specify component)
    - Infant mortality etc.
- Action taken: Replacement, repair, adjustment, modification, lubrication, etc.
- Time to travel to station.

7. Data analysis

The performance indicators in Section 5 can be calculated in accordance with the IALA Guide to the Availability and Reliability Theory and Examples, the IALA Recommendation on the Availability Objectives of Aids to Navigation Service, and the IALA Navguide.

The data can be analysed to show the reliability of individual subsystems and components and to identify the principal causes of unreliability. This will facilitate a planned approach to maintenance with predictable maintenance free operation periods for stations. In addition, reliability information can influence future purchasing decisions and improve system design. The following is a typical method of recording data on aids to navigation failures and calculation of aids to navigational availability, meantime between failures (MTBF) and meantime to repair (MTTR).

Failures are reported to a central point, such as the Monitoring Operations Centre, from a variety of sources including the remote monitoring and control system (RCMS), reports from mariners, reports from local Attendants and Lighthouse keepers, etc.

A weekly record of all failures is compiled at the Monitoring Operations Centre. This record, see typical example in Figure 1, includes AtoN, station, date and time of the failure, date and time of restoration of the AtoN service, and cause of the failure.

AtoN performance should be reviewed periodically, typically annually. The above weekly records of AtoN failures can be used to calculate the cumulative down time and number of failures for each category of aid.

In accordance with IALA recommendations, AtoN performance is calculated over a three year rolling average period. Thus the availability, MTBF and MTTR are calculated from failure data over the three-year period. The following tables and graphs show typical methods of presenting the AtoN performance data.

Station	Station Type	System	Station Category	Date of Failure	Time of Failure	Date Restored	Time Restored	Down Time [hrs]	Root Cause	Cause Item
Station A	Buoy	Optic	3	02-09-03	21.30	03-09-03	19.00	21.7	No fault found	No fault found
Station B	Lanby	Optic	2	02-09-03	23.31	03-09-03	17.20	17.89	Component failure	Relay fault
Station C	Lighthouse	Optic	1	04-09-03	10.00	04-09-03	16.00	6	Maintenance induced	Planned maintenance
Station D	Lighthouse	Optic	2	17-09-03	9.50	17-09-03	13.00	3.5	Lightning	Fuse blown
Station E	Lighthouse	Fog Signal	3	22-09-03	3.51	22-09-03	20.30	16.79	Component failure	Coder board
Station F	Lighthouse	DGPS	1	29-09-03	0.22	29-09-03	3.18	2.96	Component failure	PRC correction error
Station G	Lighthouse	Racon	1	16-10-03	6.41	19-10-03	3.07	8.04	Component failure	Flies in antenna chamber

Fig 1: Table showing a typical database method of recording information. AtoN are subdivided into categories based on the IALA availability categories.

7.1 DGPS

Because of the unique characteristics of the IALA deferential GPS (DGPS) system using radio beacon transmitters, the method of collecting data and calculating this AtoN performance is different from traditional aids.

A typical mission statement for a DGPS system is

> *"to provide an unencrypted DGPS correction integrity warning service, covering at least the coastal zone, with an accuracy of better than 10m(95%) and a signal availability of 99.8%".*

Failures of the DGPS service are, therefore:

- Transmitter power output outside the limit of plus or minus 3dB with respect to nominal performance.
- Accuracy of the DGPS fix less than the advertised limit.

A local monitoring receiver monitors each DGPS transmitter station. This measures signal strength, accuracy of the DGPS corrected fix, signal to noise ratio, bit error rate (BER), the number of satellites in view, HDOP, PDOP, VDOP. The monitoring receiver has built in limits and generates an alarm on any occasion when the transmitted signal goes outside the preset limits. Each monitor receiver reports the failures automatically to the Central Monitoring System.

- The Central Monitoring Log is examined monthly and data on failures arising from accuracy, and signal strength are extracted.
- This failure data for each month is used to calculate the availability, MTBF and MTTR for each station.

A common method of ensuring the high availability required from DGPS is to establish transmitter stations such that there is overlapping coverage from at least two stations in all areas within the nominal DGPS service area. In this way, failure of one transmitter does not effect the service to the mariner since the mariner can receive DGPS signals from the overlapping station.

DGPS Service performance is defined as the performance of the service as seen by the mariner. DGPS Broadcast performance is the performance of individual transmitter stations. In the case of overlapping coverage, a failure of one transmitter will affect the Broadcast availability of that station but will not affect the

Service availability, as the overlapping stations continue to provide uninterrupted DGPS service to the mariner throughout the advertised DGPS coverage area.

In order to calculate the performance of the DGPS service it is, therefore, necessary to check **all** DGPS transmitter failures to establish if the failure occurs at the same time as failures from the overlapping stations. A second calculation of availability, MTBF and MTTR is then carried out to establish the performance of the DGPS Service.

The IALA Navguide recommends calculation of DGPS Service availability from measurements taken over a two-year period. IALA also recommends that DGPS signal availability is calculated over a 30-day period. The above review, therefore, should be carried out on a monthly basis.

7.2 Performance data presentation

Fig 2 and Fig 3 show a typical method of presenting AtoN performance data using the methods described in the IALA Guide to Availability and Reliability Theory and Examples. The example shown is for availability. A similar format can be used for MTBF and MTTR.

CATEGORY	AtoN Description	IALA	1999/2000		2000/01		2001/02		2002/03		2003/04	
		MINIMUM	ACTUAL	DIFF	ACTUAL	DIFF	ACTUAL	DIFF	ACTUAL	DIFF	ACTUAL	DIFF
1	LIGHTS	99.8%	99.80	0.00	99.82	0.02	99.79	-0.01	99.83	0.03	99.83	0.03
	RACONS		99.85	0.05	99.92	0.12	99.94	0.14	99.94	0.14	99.89	0.09
	DGPS *		99.98	0.18	99.99	0.19	99.95	0.15	99.92	0.12	99.89	0.09
2	LIGHTS	99.0%	99.76	0.76	99.73	0.73	99.72	0.72	99.75	0.75	99.74	0.74
3	FOG SIGNALS	97.0%	99.47	2.47	99.61	2.61	99.62	2.62	99.72	2.72	99.78	2.78
	BUOYS	97.0%	99.53	2.53	99.48	2.48	99.51	2.51	99.64	2.64	99.67	2.67

Fig 2. Typical Table of AtoN Availability, three year rolling average.

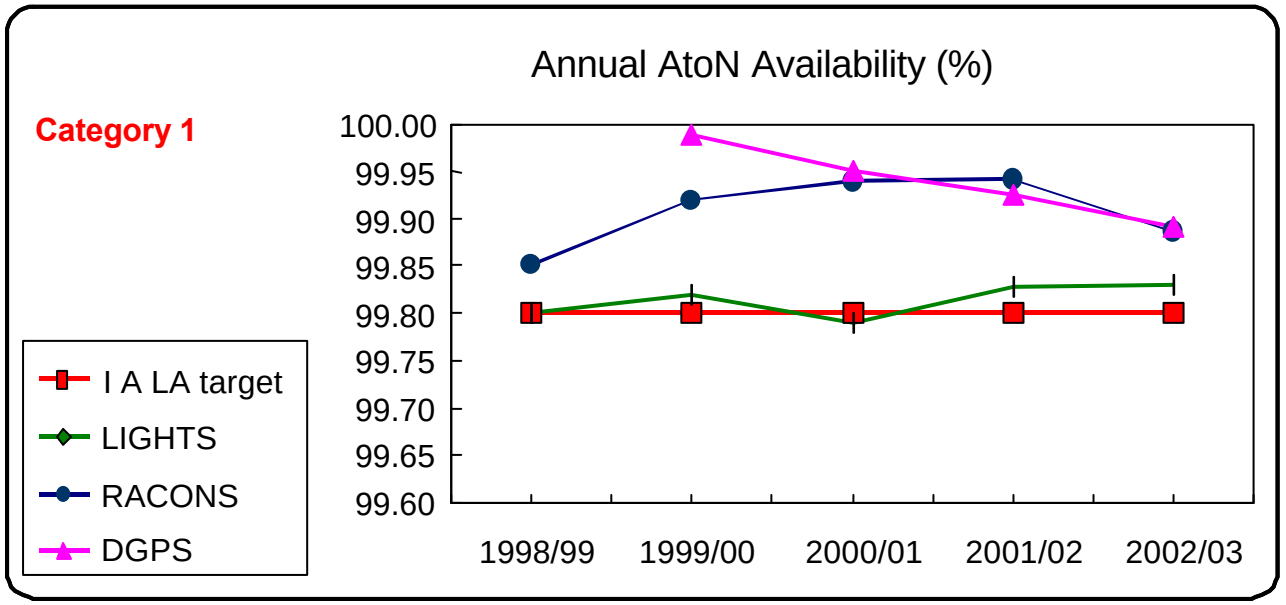

Fig 3: Typical Chart displaying annual Availability of AtoN

7.3 AtoN performance improvement

In addition to ensuring that the AtoN performance meets the IALA minimum requirements, the above analysis can be used to improve the performance of AtoN's.

Availability and MTBF can be calculated for individual stations, station types, systems or station categories from the data in Figure 1. Figures 2 and 3 are typical of published data detailing the Availability of different categories or types of AtoN. Availability of individual aids should be at least 95% in accordance with the IALA Recommendation on Availability.

If the faults are categorised, the fault data can be examined to identify any recurring causes of faults. This facilitates correction of the underlying cause of frequent faults with a consequent improvement in performance and reduction of costs associated with fault repairs. The Figure 4 shows a typical categorisation of fault causes. Categorisation of faults by station can also provide useful data on fault trends.

The information available from analysis is dependent on the initial information input to the database. The above example includes data on AtoN failures only. If information is required about the performance of redundant systems, a system to collect information on all faults for input to the database must be put in place.

Figure 4: Categorisation of fault causes

Station Category	Type of Navigation Aid	Number of Failures	Root cause		Item cause	
1	Lights	35	Component	28	1	Battery charger fault
					1	DC/DC converter fault
					1	Earth fault
					6	Electrical connection fault
					3	Fuse failure
					2	Generator set control system fault
					1	Generator set fuel control solenoid
					1	Lamp failed
					1	Lamp changer fault
					1	Lamp holder wiring
					5	Optic control system fault
					1	Optic drive bearing failure
					2	Relay fault
					1	Time switch fault
					1	Wind generator brushes fault
			Corrosion	2	1	Solar array fault
					1	Water ingress
			Lubrication	2	2	Generator set lubrication system fault
			Maintenance induced	3	3	Battery charger set up
	Differential GPS	8	Component	3	2	Antenna shackle failure
					1	ATU fault
			Contamination	5	5	Salt contamination of transmit aerial insulators
	Racons	2	Component	2	1	Racon fault
					1	Monitor circuit
2	Lights	6	Component	2	1	Generator set coupling failure
					1	Generator set starter motor fault
			Corrosion	4	3	Cable damage
					1	Electrical connection fault
			Storm	1	1	Aid washed away
3	Fog Signals	5	Component	3	1	Monitor circuit
					1	Emitters tripped due to generator set power fluctuations
					1	Generator Set coupling failure
			Lubrication	1	1	Generator set lubrication system fault
			Maintenance induced	1	1	Isolators off
	Lights	1	Component	1	1	Gas leak
	Buoys	18	Collision	1	1	Lantern damage

Station Category	Type of Navigation Aid	Number of Failures	Root cause		Item cause	
			Component	12	1	Lamp failed
					3	Lantern flasher fault
					1	Photocell fault
					7	Solar array fault
			Corrosion	1	1	Water ingress
			Leak	1	1	Battery box flooded
			Mooring	3	2	Buoy out of charted position
					1	Mooring shackles failed

Figure 4: Categorisation of fault causes

Figure 5 below shows an overview of the flow of information from source to performance indicator.

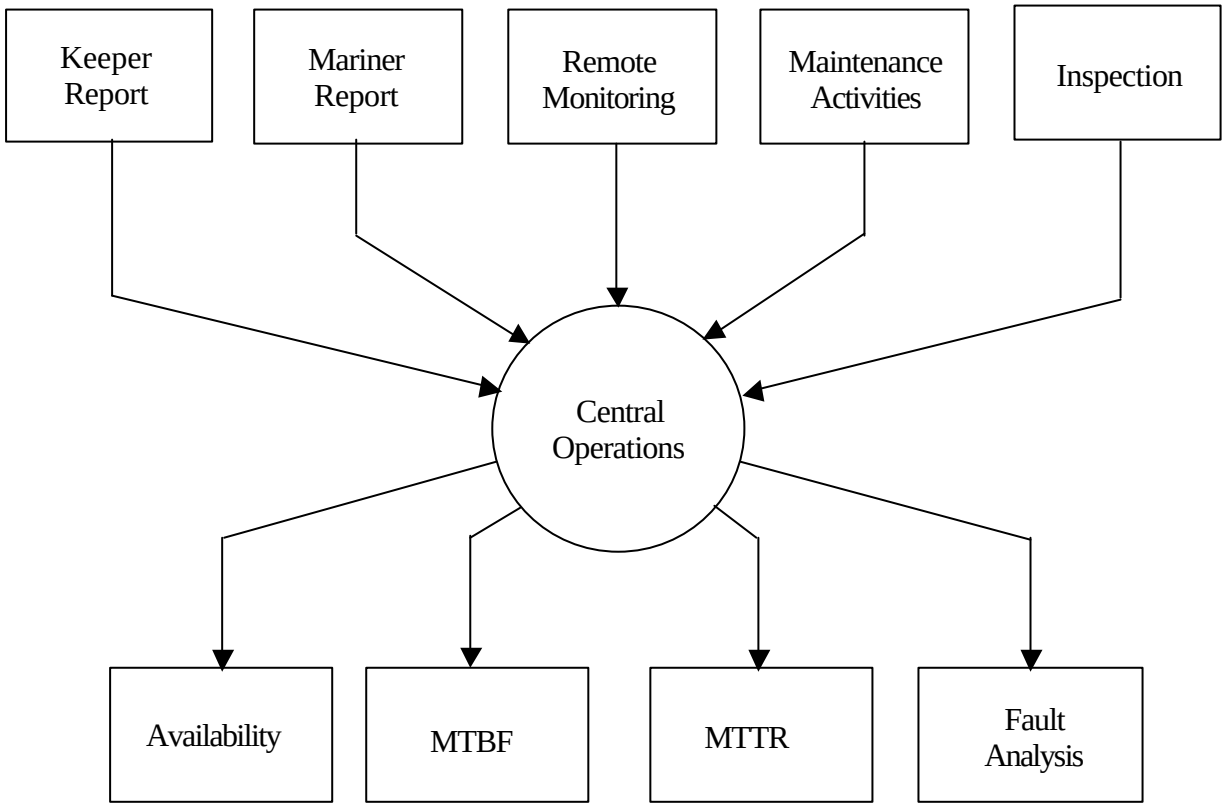

Figure 5: Reliability and failures information flow