IALA GUIDELINES

ON

REMOTE MONITORING

AND CONTROL

OF

AIDS TO NAVIGATION

IALA ENGINEERING COMMITTEE

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EXECUTIVE SUMMARY

These Guidelines on Remote Monitoring and Control have been prepared to assist members when they are considering providing a system for the first time, replacing an existing system or up-dating a system. The guidelines will enable members to establish the basic operational decision criteria and performance standards for these systems and provide a knowledgeable basis for equipment selection and purchase.

These Guidelines are not intended to establish a new mandate to expand the use of electronic monitor systems. Rather, they are to provide advice on how to develop an effective, modern system when a management decision has been made to employ electronic monitoring

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CONTENTS Page No.

1. INTRODUCTION

1.1 During the 1994 IALA Conference in Hawaii delegates noted the developments in Monitoring and Control Equipment. In particular, they noted the advances being made in micro-electronics used in these systems, thus enabling the size, cost and power supply requirements to be reduced and reliability improved. These advances, together with developments in manufacturing techniques, would enable Remote Monitoring and Control systems to be introduced where before it was not considered feasible or possible, on the grounds of cost, size and complexity of equipment.

1.2 Delegates also noted the absence of any Guidelines on the basic requirements for Remote Monitoring and Control Systems and IALA, through its committee structure, was requested to produce suitable Guidelines for the membership.

1.3 These Guidelines have been prepared by the IALA Engineering Committee, with assistance from the IALA Radionavigation Committee on information provided at Annex 2. They have been prepared as a basic guide to members who may wish to install a system for the first time or to replace or update an existing system. The Guidelines will enable members to establish the basic operational requirement and performance standards for their individual system and provide an informed basis for equipment selection and purchase.

1.4 Two surveys of IALA members were carried out in 1996 to establish their policies and practices regarding Remote Monitoring and Control. The results of these surveys are detailed in Annex 1.

1.5 Technical advances in manufacturing techniques will continue as will advances in the development of new communications techniques. Therefore it will be necessary to update these Guidelines periodically.

2. METHODS OF MONITORING

2.1 There are a number of ways to monitor an Aid to Navigation (AtoN)

2.1.1 *User Monitoring*

The provider of the AtoN relies on information received from the user of the aid. Reliability of the system and the integrity of information are low. Prior information on the cause of failure and advance warning of an impending failure is not available. Control facilities are not available.

2.1.2 *Visual/Audible Monitoring*

These systems can be used when the AtoN or associated indicator lights can be directly observed or heard. Both the reliability and integrity of the system depend directly on the reliability of the observer whose attendance may be part-time. It is unlikely that information on the cause of failure and advance warning of an impending failure will be available. Because the Attendant / Monitoring Operator is not employed full-time, some time can elapse between that occurrence and identification of a failure. Control facilities are not available.

2.1.3 ***Attendants/Keepers***

This method keeps the AtoN under either regular or continual observation. The reliability and integrity of the system depends directly on the reliability of the observer. This system has the advantage that, subject to his technical competence, a Keeper or Attendant can intervene to effect repairs in the case of a failure without waiting for a maintenance crew. As the Keepers are on site, full control facilities are available.

2.1.4 ***Remote Monitoring***

Generally taken to mean that the location of the person doing the monitoring is sufficiently remote from the location of the AtoN that some electronic communication medium must be employed, eg. Radio or Satellite. This will normally mean that no local assistance, Keeper or Attendant, is available. Control facilities vary depending on the type of Remote Monitoring and Control System used. A detailed description of various types of Remote Monitoring and Control Systems is included in Section 6.

2.1.5. ***Mobile Interrogation Monitoring***

The AtoN, such as a buoy, may be interrogated occasionally by a passing buoy tender or shore Attendant to verify the operation and condition of the AtoN. Limited control capability is available.

2.2 The level of monitoring and the parameters to be monitored are discussed elsewhere in this document but they can be categorised as the AtoN state and the Engineering state.

- AtoN state. Generally the status (eg On or Off) of the AtoN is monitored.

- Engineering state. Additional parameters are monitored to indicate the health of the AtoN including redundant standby equipment and its supporting systems (e.g. fuel level in the case of a diesel generator set).

2.3 To improve the availability of information the remote monitoring system will generally be capable of obtaining information from the remote location in a variety of ways. Chiefly by:

- continuous on-line communications between the base station and the remote site.

- regular polling from the base station and on demand.

- periodic programmed reporting by the remote site. (eg 2 hours after sunrise and sunset or to suit the monitoring centre operators shift patterns).

- exception reporting. When a nominated event occurs or preset parameter is exceeded, this report is generated by the remote site and transmitted to the monitoring station.

- a combination of two or more of the above. A typical combination is reporting of normal events, such as light on, by polling with exception reporting for alarms.

3. OBJECTIVES OF REMOTE MONITORING AND CONTROL

3.1 When considering a remote monitoring and control system it is necessary to identify the purpose and use of the system. Questions which arise include, why monitor, what aids and systems should be monitored, what communications should be used, what records should be kept**,** etc.

3.2 The typical operational goal of an Aid to Navigation (AtoN) is to provide a requisite availability of service and reduce as much as possible any down time. Availability is inversely proportional to the Mean Time Between Failures (MTBF) and the Mean Time to Repair (MTTR). Both MTBF and MTTR should be reduced as far as possible. When planning his passage the mariner anticipates that the AtoN on his route will be functioning in accordance with the published characteristics laid down in nautical documentation and on charts. In the interests of safety the mariner should be notified as soon as possible of any failures of AtoN. A minimum Time to Detect is therefore necessary. The availability of the AtoN can be maintained by identifying faults which reduce redundancy. AtoN availability can be affected by both the AtoN system redundancy and by support systems such as power systems, which must therefore be considered. Similarly, security, intruder and flood alarm systems must be considered because of the threat such events may pose to the AtoN. The cost effectiveness of the AtoN service should be maximised with the provision of remote monitoring and control.

3.3 The objectives of a remote monitoring and control system may vary depending on the policies of the administration, the type and importance of the AtoN being monitored, and the local conditions. The designer of a remote monitoring and control system may not need to include all of the following objectives and will only select those which best suit the application.

- Provide information to the operator consistent with his level of competence.
- Provide controls to the operator consistent with his level of competence.
- Monitoring and control system reliability and availability must be comparable with the systems being monitored.

3.3.1 ***Identification of Failures (affecting AtoN system provider liability):***

- Identify failure of AtoN to operate within published specification.

- Notify failure of AtoN within a time period consistent with the phase of the voyage in which the aid is used and the criticality of the aid for safe navigation.

- Compile and maintain a record of operation of AtoN.

3.3.2 ***AtoN Availability***

- Confirm operation of AtoN within specification.

- Identify faults which reduce redundancy and which therefore threaten the AtoN.

- Notify faults within a time period necessary to carry out repairs before failure of the redundant stand-by system.

- Reduce downtime and improve availability through use of remote control resets.

- Verify status of redundant systems through remote control testing.

3.3.3 ***AtoN Maintenance (affecting MTBF and MTTR):***

- Reduce downtime through use of remote control resets.

- Testing of redundant systems using remote control testing.

- Reduce incidence of faults through identification of recurring faults using post mission analysis.

- Assist investigation of cause of faults and failures using additional monitored parameters.

- Assist investigation of cause of faults and failures using historical data.

3.3.4 ***AtoN Cost Reduction (affecting cost of providing AtoN service):***

- Reduce maintenance visits through use of remote control resets.

- Reduce maintenance visits by testing of redundant systems using remote control testing.

- Reduce costs through identification of recurring faults using post mission analysis.

- Monitoring and control system costs should be in proportion to the cost and importance of the systems being monitored.

4. AIDS TO NAVIGATION TO BE REMOTELY MONITORED

In general, the providers of AtoN monitor the operation by one of the methods described in Section 2.

A decision must be made as to which aids merit the extra security offered by remote monitoring and control described in section 3. Typically the decision is strongly determined by the relative importance of the aid in the waterway aid system.

The AtoN facilities for which monitoring should be considered fall into the categories detailed below.

4.1 Fixed Aids

4.1.1 ***Major lighthouses and Stations*** are frequently remotely monitored. When doing so, all AtoN signals should be monitored. These will include the main light, standby light, emergency light, sector light and fog signals where fitted. Radio aids to navigation which include radiobeacons, with or without DGPS, and racons should also be monitored. In addition, the ancillary equipment such as power supplies, intruder alarms, fire fighting and detection equipment should be monitored.

4.1.2 ***Minor lights*** are rarely remotely monitored, but the Operating Authority sometimes elects to do so for a critically important aid.

4.1.3 ***Sector lights.*** Depending on the complexity of the aid and its importance in the waterway, consideration should be given to monitoring sector lights.

4.1.4 ***Leading lights.*** Depending on the complexity of the aid and its importance in the waterway, consideration should be given to monitoring leading lights.

4.2 Floating Aids

4.2.1 ***Lightvessels.*** All AtoN signals should be monitored. These will be similar to those fitted to major lighthouses with the exception of radiobeacons and sector lights. Additional ancillary equipment may be fitted such as collision monitors and position tracking systems. The output of the latter may be used to operate off station and riding lights. Alternatively, a remote control may be provided for this function.

4.2.2. ***Lanbys and Lightfloats*** may contain AtoN similar to those fitted to lightvessels and should be monitored.

4.2.3 ***Major buoys*** fitted with a light, racon and a position tracking system should be considered for remote monitoring

4.2.4 ***Other navigational buoys*** are rarely remotely monitored, but the Operating Authority sometimes elects to do so for a critically important aid.

4.3 Offshore Structures

4.3.1 ***Offshore structures*** comprising oil and gas rigs have their AtoN approved by the Authority, but are generally monitored by the operator of the structure.

5. PARAMETERS TO BE MONITORED

5.1 Introduction

This section addresses the parameters required to monitor the status and condition of the Aids to Navigation (AtoN), to assist in with the analysis of the reason for failure and to enable the remote control of the AtoN, should automatic systems fail to function. It sets out to prioritise the parameters to be monitored indicating those most appropriate for a given system together with the control necessary to achieve maximum availability of the service.

5.2 Priorities

The parameters to be monitored may be prioritised into three levels. Controls proposed are those which are regarded essential to maintain the service, therefore no priority is attached to these parameters..

5.2.1 ***Level 1 - Status:*** The primary aim of any monitoring and control system (MCS) is to indicate the operational status of the AtoN. These are called events, that is, occurrences that take place during the normal operation of the AtoN.

5.2.2 ***Level 2 - Condition:*** A further aim of the MCS is to report failures of any equipment and provide additional information that will enable the Operations and Maintenance Staff to identify and determine the reasons for any abnormal conditions that may exist. These are called alarms.

5.2.3 ***Level 3 - Analogues:*** This level of monitoring is applicable to a more sophisticated MCS enabling the analogue value of parameters such as voltage and current to be reported. By analysing this data to produce trends, Maintenance and Engineering Staff can review the events leading to a failure and may also be able to detect the onset of failures and enable corrective action to be taken to prevent complete breakdown and hence maximise availability.

5.2.4 ***Controls:*** In order to test certain types of equipment and to reset fault conditions without visiting a station, control facilities may be incorporated in a MCS. This can be used to increase AtoN availability and improve cost effectiveness by reducing maintenance costs. The design of the interface between the MCS and the AtoN must be such as to not interfere with the operation of the AtoN in the event of failure of the MCS.

5.3 Aids To Navigation (AtoN)

Todays mariner has an extensive array of AtoN to assist his safe passage ranging from buoys (lit or unlit), lanbys, light vessels, beacons (lit or unlit) and lighthouses. Each may have a variety of AtoNs and hence monitoring and control requirements. Individual AtoNs are discussed and parameters to be monitored and controlled together with their level of importance, as defined above, are indicated.

The following paragraphs concentrate on individual systems and list the parameters that are considered most useful in monitoring and controlling the AtoN and associated systems. It cannot be exhaustive but it indicates the principle behind the selection of parameters.

5.3.1 *Navigation Light*

A typical navigation light system consists of a main light, a standby light and an emergency light. The main and standby lights are on a lampchanger while the emergency light is a smaller, separately powered light.

PARAMETER	OPTIONS	LEVEL
Main Light Status	*On / Off*	*1*
Standby Light Status	*On /Off*	*1*
Main Light Condition	*Normal / Fail*	*2*
Standby Light Condition	*Normal / Fail*	*2*
Nav Light Status	*On / Off*	*1*
Nav Light Condition	*Normal / Fail*	*2*
Emergency Light Status	*On / Off*	*1*
Emergency Light Condition	*Normal / Fail*	*2*
Penultimate Lamp Selected	*Yes / No*	*2*
Optic Drive A Status	*On / Off*	*1*
Optic Drive B Status	*On / Off*	*1*
Optic Drive A Condition	*Normal / Fail*	*2*
Optic Drive B Condition	*Normal / Fail*	*2*
Nav Light Control	*On / Off*	*C*
Emergency Light Control	*On / Off*	*C*
Nav Light Reset to Normal	*Reset*	*C*

It is not only necessary to know that the light is 'ON' or 'OFF', but also that it is exhibiting the correct character/code and that the range of the light is achieved. If any of these conditions are not met a main light fail signal should be transmitted which may be derived from monitoring the lamp current, the light output from a photocell and in the case of a lamp-changer an ‘out of position’ indication. Failure of the optic rotation drives and hence light character should automatically cause the main light to extinguish and illuminate the emergency light. This in turn will cause a “nav light fail” to be transmitted.

5.3.2 ***Fog Signal***

PARAMETER	OPTIONS	LEVEL
Visibility Status	*High / Low*	*1*
Fog Detector Condition	*Normal / Fail*	*2*
Fog Signal Status	*On / Off*	*1*
Fog Signal Condition	*Normal / Fail*	*1*
Emitter Current Condition	*Normal / Fail*	*2*
Character / Code Condition	*Normal / Fail*	*2*
Visibility	*Visibility in Nautical Miles*	
Fog Signal Control	*On / Off*	*C*
Fog Signal Reset to Normal	*Reset*	*C*

Using multi emitter fog signals it is necessary to decide when a fog emitter failure constitutes a casualty. Normally a fog signal is designed to provide the published range, consequently a failure of a single emitter will necessitate a notice to mariners, and therefore all emitters should be monitored and their status relayed to the base station.

The control facility should be arranged so that the operation of the fog signal system is not affected in the event of failure of the MCS.

5.3.3 *Radiobeacon*

PARAMETER	OPTIONS	LEVEL
Main Transmitter Status	*On / Off*	*1*
Standby Transmitter Status	*On / Off*	*1*
Main Transmitter Condition	*Normal / Fail*	*2*
Standby Transmitter Condition	*Normal / Fail*	*2*
Antenna Current	*Current in Amps*	*3*
Main Transmitter Control	*On / Off*	*C*
Standby Transmitter Control	*On / Off*	*C*
Transmitter Reset to Normal	*Reset*	*C*

The transmitter fail signal is a combination of a number of parameters failure of any one resulting in a failure of the radio direction finder (RDF) service provided by that transmitter including the RDF character/code.

The control facility should be arranged so that the operation of the radiobeacon system is not affected in the event of failure of the MCS.

5.3.4 *Differential Global Positioning System (DGPS)*

When DGPS is transmitted the above list should be augmented by alarms derived from the reference station and integrity monitor as follows:

PARAMETER	OPTIONS	LEVEL
Correction Age	*On / Off*	*2 & 3*
Message Error Ratio	*On / Off*	*2 & 3*
Beacon S.N.R.	*On / Off*	*2 & 3*
Beacon S.S.	*On / Off*	*2 & 3*
Numbers of SV's	*On / Off*	*2 & 3*
Horizontal DOP	*On / Off*	*2 & 3*
Position Error	*On / Off*	*2 & 3*
PR Residual	*On / Off*	*2 & 3*
PR Residual	*On / Off*	*2 & 3*
Low UDRE	*On / Off*	*2 & 3*

Notes:	SNR	:	signal to noise ratio
	SS	:	signal strength
	SV	:	space vehicle
	DOP	:	dilution of position
	PR	:	Pseudo range

5.3.5 ***Racon***

PARAMETER	OPTIONS	LEVEL
Racon Status	*On / Off*	*1*
Racon Condition	*Normal / Fail*	*2*
Racon Reset to Normal	*Reset*	*C*
Racon Position	*On Station / Off Station*	*2*
Racon Change Code	*Normal / Morse D*	*C*

Where racons are mounted on floating aids, the position of the racon should be monitored. If the racon goes off-station, it should be either switched off or the identification code changed to Morse D.

5.4 Power Supplies

The power used to drive the AtoN may come from many different sources dependent on the station location, energy requirements and the availability of services. A mainland base station will normally have an AC mains supply available but will usually back this up with a battery and possibly a diesel alternator. An off shore station however is unlikely to have a mains AC supply and may derive its supply from a diesel alternator set or a renewable energy source such as photovoltaic solar, wind or wave power using batteries for energy storage.

Various combinations of power sources are used and three examples of these systems are described below:

- Mains with mains failure diesel alternator set
- Mains float charged battery system
- Photovoltaic solar powered battery system

5.4.1 ***Mains with Mains Failure Diesel Alternator***

PARAMETER	OPTIONS	LEVEL
Mains Supply Condition	*On / Fail*	*2*
Generator Status	*Available / On*	*1*
Generator Condition	*Normal / Fail*	*2*
Fuel Level Condition	*Normal / Low*	*2*
Engine Foil to Start	*Normal / Foil*	*2*
Alternator Voltage	*Normal / Low or High*	*2*
Engine Temperature	*Normal / High*	*2*
Engine Oil Pressure	*Normal / Low*	*2*
Engine Speed	*Normal / High*	*2*
Starter Battery Charger	*Normal / Fail*	*2*
Alternator Current	*Current in Amps*	*3*
Generator Reset to Normal	*Reset*	*C*
Generator Control	*Start / Stop*	*C*

A mains failure diesel alternator set would normally include a control cubicle monitoring its performance and providing trips and alarms to maintain the plant in a safe condition. To minimise the data transmitted by the monitoring system these trips and alarms are often combined to give a general alarm indication.

5.4.2 *Mains Float Charged Battery System*

PARAMETER	OPTIONS	LEVEL
Mains Supply Condition	*On / Fail*	*2*
Battery Charger Condition	*Normal / Fail*	*2*
Battery voltage	*Normal / High*	*2*
Battery Voltage	*Normal / Low*	*2*
Battery Voltage	*Volts*	*3*

Where a charger alarm is not available, an alternative is to monitor when the battery voltage drops below the float voltage by preset temperature compensated amount. A high battery voltage alarm should be set below the voltage at which the AtoN may be damaged.

5.4.3 *Solar Powered Battery System*

PARAMETER	OPTIONS	LEVEL
Regulator Condition	*Normal / Fail*	*2*
Battery Voltage	*Normal / High*	*2*
Battery Voltage	*Normal / Low*	*2*
Battery Voltage	*Volts*	*3*
Battery Status	*Standby / Selected*	*1*

In a hybrid system, separate batteries charged from different power sources are often used with automatic changeover. For such systems, a battery status indication can be used.

6. OUTSTATION EQUIPMENT

6.1 Introduction

This section discusses the various types of monitoring and control equipment available and identifies some of the design problems that need to be considered during their selection and implementation.

The equipment employed on station to provide the required remote monitoring and control facilities will be directly dependent on the methods used, as discussed in Section 3. These range from direct monitoring by the user to a fully automated AtoN where the systems are monitored and controlled remotely by a centralised base station.

The choice of method will largely be dictated by the operational requirements, by economics and available expertise. What is appropriate in one part of the world where labour costs are low and technology is comparatively expensive, may be inappropriate where labour costs are high and technology is relatively inexpensive.

It should also be clearly understood that a primary objective of a lighthouse authority is to assure the availability of the Aids to Navigation (AtoN). Whilst a well designed and implemented outstation equipment can assist in achieving this goal, a poorly designed system may be detrimental and threaten their performance.

As described in Section 5, the information to be monitored by the outstation is dependent upon whether purely status information on the AtoN is required, or whether additional information to aid maintenance and to enable the prediction of future performance of the systems is necessary.

RCM equipment should meet approved international and national standards, such as ITU and local PTT standards in as much as they are relevant to the monitoring system.

6.2 Design Considerations

With the wide range of options available for outstation equipment, there are many considerations to be taken into account before a valued judgement can be made upon what type of system is best suited for a particular application and circumstance.

6.2.1 *Design Philosophy*

Simplicity is often the best policy particularly where technical expertise is limited. Well designed electronic systems are significantly more reliable than their electro-mechanical alternatives.

However, the effort required to develop a proven system, particularly software should not be underestimated. Care should be taken during software development to ensure a structured approach thus minimising the design and commissioning effort of subsequent modifications.

6.2.2 *Input / Output (I/O) Segregation*

It is good practice to segregate monitoring and control functions such that failures that may occur in the control outputs do not affect the monitoring, leading to misleading indications. This can be achieved by ensuring that separate (I/O) cards are used for the two functions. Isolation is invariably provided between cards, but is less common between adjacent inputs on the same card. It is also important to monitor the AtoN to confirm that a remote control action has caused the desired change in the equipment.

6.2.3 *Energy Consumption*

A further consideration is the energy consumption of the outstation. This is particularly important where energy is limited, such as photovoltaic solar powered stations in the more polar latitudes and with any system supported by battery back-up. The power consumption of micro-electronics has reduced as it has developed and consequently the requirements of the communications system have become a major proportion of the overall energy consumption calculation. Transmissions can be limited by sending only data resulting from a change of state of an RCM input at the station. Where Maintenance and Operations Staff are required to record data at regular intervals, for example, for trending fuel consumption or battery voltage, this can be achieved by local data storage at the outstation. The data need only be transmitted to the base station when an alarm occurs which requires action by Operations Staff.

6.2.4 *Computerised Systems*

Computer monitoring and control systems present new problems from those experienced with hardwired systems. They operate at high clock rates with significant harmonics. As a consequence they radiate RF energy and are susceptible to electro-magnetic interference, which can not only affect other computerised systems but also interfere with radio communications.

Whichever system is employed, it is likely that failures will occur. It is therefore important that the effects of these failures are minimised by implementing the ‘fail safe’ concept. As an example, signal relays (switching low currents), interconnections and power supplies, are more likely to fail open circuit. Therefore, a system should be designed such that in the event of failure, the AtoN remains operational and the monitoring system indicates an alarm. However, compromises will have to be made since maintaining a relay in its energised condition may have a significant affect on the energy requirement of the power systems employed.

6.3 Local Monitoring

6.3.1 *Status Indications*

Status information may be displayed in its simplest form by indicators on the control equipment, indicating whether the AtoN is ON, OFF or FAILED. Where multiple systems are employed this information may be relayed to a local control point and displayed on an annunciator panel.

This type of display is ideal for local monitoring, since it facilitates the management of events and alarms, whereby:

- a change-of-state of the system has to be accepted in order to silence the audible alarm, and;

- a visual indication is displayed until it is reset at the source and then cleared from the display.

6.3.2 *Maintenance*

Further information can be made available to assist the maintenance of equipment by indications on equipment modules or electronic circuit boards. These may consist of small light emitting diodes (led) at strategic points within the circuit indicating the operational status of the board; whether it is functioning or not. Staff can then carry out front line maintenance by board replacement minimising the downtime of the equipment and maximising availability.

6.4 Remote Monitoring and Control

Over the years remote monitoring has developed from dedicated hardware solutions often utilising relays and simple indicator lamps or electro-mechanical devices, through to flexible systems employing distributed intelligent units such as Programmable Logic Controllers (PLC) software configured to give total control and monitoring. This latter system requiring a computer workstations for processing and display of information. There are many intermediate stages between these two extremes, some of which are discussed in this Section. As an aid to discussion, the remote monitoring and control outstation may be classified into a number of groups:

- dedicated hard wired relay systems
- dedicated hardwired electronic logic systems
- dial alarm systems
- PLC/PC acquisition and control system

- PLC/PC integrated Supervisory Control and Data Acquisition (SCADA) system
- mobile interrogation systems

6.4.1 ***Dedicated Hardwired Relay Systems***

This type of system is the simplest for the user to understand and implement. Also failure modes are predictable, particularly in low current applications, consequently fail safe circuits can be readily designed. However, the systems are inflexible, making it difficult to expand and change its functionality once installed. Information from the system may be relayed to simple indicator lamps or annunciator panel as described in para 6.2 above, or transmitted via a public switched telephone network (PSTN) or private wire.

6.4.2 ***Dedicated Hardwired Electronic Logic System***

This type of system developed from relay circuit design, the relays and their functions being replaced by dedicated discrete transistors. Since the circuits are designed in modular form the system provides increased flexibility and enables more complex designs to be implemented. They are also more reliable, although their increased complexity results in their failure modes being less predictable. As with relay systems, the functionality is easy to understand and maintain.

6.4.3 ***Dial Alarm Systems***

Systems consisting of an autodial modem with software voice messages can be used for Remote Monitoring and Control. The modem can be triggered by a number of inputs to automatically dial a sequence of preset PSTN phone numbers. A specific voice message is associated with each input, which permits the reporting of the condition of each modem input independently. A control channel is often included.

6.4.4 ***PLC/PC Acquisition and Control Outstations***

Further developments in technology saw the advent of the micro-processor from which was borne the programmable logic controller (PLC) and personal computer (PC). Initially the PLC was designed as a relay replacement system, whereby the logic/relay functions were implemented in software. PLC's are easy to install and are highly flexible in allowing changes to be implemented in software. Although software represented a new technology, its initial implementation was in the form of "ladder logic", which enabled personnel familiar with relay logic to be readily retrained. The cost of simple PLC systems has reduced (in real terms) significantly over the years, and as a consequence has largely replaced even the simplest relay logic system.

The PLC/PC installed in outstations is commonly known as a remote terminal unit (RTU). The inputs and outputs from equipment being monitored and controlled are connected to the RTU.

Consequently, the PLC has developed by the use of standard hardware modules comprising digital inputs, digital outputs, analogue inputs and analogue outputs. Their functionality is defined by the software implementation. The system lends itself readily to expansion by the addition of Input/Output (I/O) modules, and these can be integrated into the system by software modifications.

Whilst interfacing with the AtoN hardware has become easier using the wide variety of I/O modules available, it is essential that great care is taken over the development of the software ensuring that it is thoroughly tested. It is necessary to check not only that an output is produced as a result of a defined combination of inputs, but that it is not produced under any other condition.

6.4.5 ***SCADA Systems***

The PLC is now a sophisticated programmable device with which it is possible to implement all the functions of specific AtoN equipment. Using the concept of “distributed intelligence”, each piece of equipment can utilise a dedicated PLC with its own dedicated software. Each being connected by a Local Area Network (LAN) to form an integrated control and monitoring system.

As discussed in Section 7, there are many forms of communications available to enable connection to a centralised base station where monitoring and control of the systems can be effected. Sophisticated computer graphics packages are available which enable information to be displayed to suit individual user requirements. By simplifying the displayed information using colour to indicate the status of systems, monitoring can be undertaken by non-technical staff, whilst retaining all the information within the system for access by technically proficient Engineering and Maintenance Staff.

With the data available on a computer at the base station it becomes possible to integrate other activities into the system enabling planned maintenance and report generation. By connection to a suitable network further integration is possible with for example, the hydrographic service and vessel transit systems.

6.4.6 ***Mobile Interrogation Systems***

A mobile interrogation system can be used by a passing buoy tender or local Attendant to check the status and condition of small AtoN and buoys. A low energy consumption transceiver, installed on the AtoN, can be interrogated by a hand-held, mobile interrogator to report parameters such as lampchanger position and battery voltage. A control channel can be used for test purposes. These systems may also log data, such as AtoN energy consumption or PV solar energy generated, to assist Maintenance Staff.

7. COMMUNICATION LINKS

7.1 This section summarises the various communications media that may be used singly or in combinations to connect from a remote site to a control centre. The final selection of services will be dependent upon investment and running costs that are area specific, and the requirements for availability and data rate that require further detailed engineering studies. A more detailed description of each system is given in Annex 2.

7.2 When planning a communications system, a link analysis should be prepared to ensure that the type of link selected is sufficiently capable in terms of reliability, information quality, capacity and integrity, for the system it will serve. Attention must also be paid to the capacity of the power supply to ensure that sufficient power is available to operate the system in both the low demand of routine operation, as well as the heavy demand of repeated failure transmissions and control centre interrogations. The final choice of communications system is often an economic one.

7.3 Estimation of energy consumption is usually based on assumptions of daily transmit time and is calculated in watt-hours/day (wh/day). The outstation is usually designed to cease attempts to communicate after a number of failed tries.

7.4 There are essentially four main types of communications links:

- Public and Private Networks
- Radio Links
- Hybrid System
- Visual

7.4.1 ***Public and Private Networks***

Public and Private Networks include PSTN, Leased Private Circuits, Owned or Non-leased Private Circuits and ISDN.

7.4.1.1 <u>Public Switched Telephone Networks (PSTN)</u>

Public Switched Telephone Networks can provide facilities ranging from basic on/off switching to complete site control and monitoring. Normally, a PSTN connection comprises a 3kHz-voice channel but higher capacity circuits may be available. Although normally used in a discontinuous communications mode, real time communications is possible.

7.4.1.2 Leased and Private Circuits

Leased Private Circuits can provide facilities ranging from basic on/off switching to complete site control and monitoring. They offer additional reliability, security, capacity and speed and they are usually used where continuous communications is an operational requirement.

7.4.1.3 Owned or Non Leased Private Circuits

Owned or Non Leased Private Circuits can provide facilities ranging from basic on/off switching to complete site control and monitoring. They offer additional security, capacity and speed but their reliability is related directly to the maintenance, which can be provided. They are usually used where continuous communications is an operational requirement.

7.4.1.4 Integrated Services Digital Network (ISDN)

Although essentially designed as a high quality, digital data highway, ISDN can provide all the facilities of the PSTN and Private Circuits. It is therefore capable of providing facilities for total site control and monitoring, in real time.

7.4.2 *Radio Links*

Radio links are generally available utilising Medium Frequency (MF), High Frequency (HF) Very High Frequency (VHF), Ultra High Frequency (UHF) and Microwave Frequencies. Direct Satellites Links are an application of microwave links.

7.4.2.1 Medium Frequency Radio Links

MF radio links can provide facilities ranging from basic on/off switching to complete site control and monitoring. Antenna sizing requirements may be significant.

7.4.2.2 High Frequency Radio Links

HF radio links can provide facilities ranging from basic on/off switching to complete site control and monitoring. Antenna sizing requirements may be significant.

7.4.2.3 Very High Frequency Radio Links (VHF)

VHF links can be used to provide facilities ranging from basic on/off switching to complete site control and monitoring. The performance of VHF radio links are more predictable than MF and HF links as they are generally less susceptible to atmospheric and meteorological conditions. Also careful choice of modulation types can allow the links to operate reliably in high noise conditions. Low power, low data rate links can be suitable for small solar systems and buoys where energy is limited.

7.4.2.4 Ultra High Frequency Radio Links (UHF)

UHF links can be used to provide the whole range of facilities from basic on/off switching to complete site control and monitoring. Smaller antennas are required but some protection may be required against precipitation static electrical discharge. Very low power UHF links can be used over short ranges without the need for licences in many countries.

7.4.2.5 Microwave Links

Microwave links can be used to provide the entire range of facilities from basic on/off switching to complete site control and monitoring. The short operating range of individual links may be significant.

7.4.2.6 Direct Satellite Links

Direct satellite links can be applied across the entire range of requirements in regard to remote control and monitoring.

7.4.3 *Hybrid Systems*

7.4.3.1 Cellular telephone

Cellular telephone systems can be used to provide facilities ranging from basic on/off switching to complete site control and monitoring. The availability for and speed of, data transmissions, on cellular networks may vary from system to system. Coverage, especially to seaward, may not be complete.

7.4.3.2 Radio Paging

Radio paging can be used as a one way remote control system. There is no return path and monitoring of the communications system is therefore not available.

7.4.3.3 Satellite Combined with Telephone or Data Line (Inmarsat C)

The Inmarsat C and Inmarsat M systems can be used to provide all the requirements of a remote control and monitoring system. Coverage is global apart from the polar region and uses start and forward techniques.

7.4.3.4 Packet Radio

Packet radio networks are highly suitable for telemetry applications, allowing two-way data traffic with high reliability and low power requirement. Coverage is usually restricted to populated areas or those of commercial interest, but may extend 20 nautical miles offshore. Running costs are generally very low, of the same order or even lower than PSTN, depending on the amounts of data transmitted.

7.4.3.5 Meteor Burst

Meteor burst communications can be used for remote control and monitoring purposes provided the forwarding delays, which can range from seconds to hours can be tolerated. The system can be used in a line of sight mode at distances up to 100 miles and ranges of up to 1,250 miles can be achieved in the meteor burst mode.

7.4.4 *Visual Communications*

Visual communications can be used in monitoring where a person is on duty near enough to see the AtoN or indicator lights.

8. DISPLAY, STORAGE & CONTROL

8.1 Introduction

Display and storage will be dependent upon the sophistication of the type of monitoring and control used. This may range from manual collection of data recorded on paper logs to fully automatic electronic monitoring systems where data will be retained and archived on electronic media.

Sections 5 and 6 give details of the parameters to be monitored and the equipment to be used. No matter which system is employed, such as log sheets, visual indicators or electronic media, data should be displayed clearly and unambiguously. It is normal practice to store data to assist in maintenance and event analysis. It should be stored to facilitate its quick and easy retrieval whilst ensuring its preservation. The method and length of storage are dependent on the requirements of the Authority.

8.2 Display

There are various types of display which fall into the following categories:

- Visual indicators
- Annunciator panels
- Visual Display Unit (VDU)

8.2.1 *Visual Indicator*

Visual indicators should be coloured to conform to normally accepted practice as follows:

'Red'	indicating	'Alarm'
'Yellow'	"	'Warnings'
'Green'	"	'Normal'

8.2.2 *Annunciator Panels*

Annunciator panels provide visual indications and audible warnings and their operation is described in Section 6.3.

8.2.3 *Visual Display Unit*

With the increasing tendency towards electronic monitoring, the VDU is the most common method of display.

The specification and size of the VDU will be dependent upon the amount of information to be displayed and the frequency of use.

Care should be taken to ensure that the design of the display and the colours used are acceptable for long term viewing. However, alarms and warnings should be clearly indicated in contrasting colours.

8.3 Storage

The type of data storage facilities required will depend upon the type and quantity of data to be recorded, the required storage period and method by which the data was gathered. The storage media available are:

- Paper
- Electronic

8.3.1 *Paper*

Manual monitoring systems normally use paper as a storage medium, for example, watchkeepers log book. Log books are bulky and consequently require large storage areas.

8.3.2 *Electronic*

Electronic storage is more generally used and requires the minimum space for large quantities of data. The electronic media may be in the form of magnetic tape or discs and optical discs (CD), the latter being more suitable for long term storage. Because of the risk of corruption of data, electronic storage systems should include back-up facilities.

8.4 Control

When required, controls can be provided at the base station to operate outstation equipment, for example, navigation lights, diesel generators. When designing the facility, care must be taken to ensure that inadvertent operation of a control function is not possible. For example, this may be achieved by restricting access with the use of a password requiring confirmation of the control requested.

8.5 Security of Computer Based Systems

Access should be restricted to only those parts of the system that the staff require in order to carry out their duties.

The System Manager will require the highest level of access to the system enabling him to carry out system reconfiguration including software upgrades.

Engineers, whilst not having the above level of access will need a sufficiently high level of access to configure the database to introduce modifications brought about by changes to outstation equipment.

Operators require a lower level of access sufficient only to allow them to perform their monitoring and control functions.

Access can be restricted by the use of passwords.

9. INTEGRATION WITH OTHER SYSTEMS

Remote Monitoring and Control Systems present the opportunity for other Authorities or systems to have access to AtoN status information. Currently the transfer is largely carried out manually.

The increased use of computerised database systems provides the opportunity to perform this integration automatically.

Some Authorities have already begun this integration with systems under their direct control, for example:

- repair and maintenance

Further integration of systems not under the direct control of the Authority may also be possible, for example:

- Navigation warnings
- Vessel Traffic Services (VTS)
- Route Planning System

9.1 Maintenance Systems

The RM&C system can provide information to the Maintenance Department to enable speedy and efficient planning of equipment repair and a facility to control equipment for routine operation and fault finding. Data can also be made available to plot trends in equipment performance in order to predict possible future failures.

It is desirable therefore when planning a system that the requirements of both operations and maintenance are considered together.

9.2 Navigation Warnings and VTS

Outputs from the RMC database can be used to generate messages containing AtoN state and transfer these messages to one or more programmed addresses for broadcast to the Mariners as navigation warnings. At the present time the usual method of promulgating navigation warnings is via the Hydrographic Offices of that country. Such messages could also be passed to a VTS control centre for direct broadcast to ships in the area.

9.3 Route Planning

It will be possible in the future to automatically send AtoN data from the RM&C database to a shore based provider, for example, a web site on the Internet, enabling a navigator on a vessel to obtain this information in electronic format for route planning.

10. MAINTENANCE AND TESTING

10.1 General

Modern Control and Monitoring equipment use solid state technology which over the years has proven to be reliable if used in the correct environment and within the voltage/current limits laid down by the component manufactures of the equipment concerned.

The continuing development of integrated circuitry has led to much smaller equipment size, but much more densely populated printed circuit boards. Visual indicators are usually mounted on printed circuit boards to provide basic information on the state of the equipment. However, it is not recommended that repair work be carried out at outstations when faults occur. If the necessary test and repair facilities is not be available on site, the normal practice is to exchange the monitoring or control units and return the faulty item to a suitably equipped workshop for attention.

Whether the system is working continuously or at predetermined time intervals, the control station will be alerted if a system fault/failure occurs eg. radio/line failure. The system does not usually carry out a detailed self check of each individual component or sub-unit and therefore a planned maintenance programme is recommended for the outstation and base station equipment. Where self-testing procedures are provided, the monitoring system only verifies that the main modules of a system are working correctly.

10.2 Outstation Equipment

10.2.1 The system at the outstation can comprise the following equipment:

- Central processor containing circuitry that assembles parallel input data from the on-site plant eg. lights, radiobeacons, racons, power supplies etc. into a serial digital signal format.
- Equipment sensors and controllers to and from the on site plant.
- Modem to convert the output from the processor to a frequency shifted audio signal.
- A PTT line connection or a Transmitter/Receiver Unit which will normally operate into the VHF or UHF bands.
- Transmitter/receiver aerial.
- Power supply.

10.2.2 The equipment mentioned above at section 10.1 can be designed to operate with an annual (twelve month) maintenance visit, which should be carried out by suitably trained staff provided with adequate test equipment and documentation. An annual maintenance visit would typically include the following items:

- Visual inspection of all equipment and connectors.
- Measure all system power supply outputs.

- Check all control and monitoring functions.
- Check levels and frequency shifts of incoming and outgoing audio signals.
- Check transmitter output power, VSWR and receiver sensitivity.
- Other items specified by the manufacturer.

10.3 Base Station Equipment

10.3.1 The equipment at the base station can compromise the following equipment:

- All equipment mentioned in Section 10.2.1
- Display and keyboard units.
- Data storage units.
- Recording equipment.
- Alarm units.
- Power supplies.

10.3.2 As with the outstation the base station equipment can be designed to operate with an annual maintenance period and would include the items listed at Section 10.2.2.

10.4 Maintenance Procedures

Maintenance procedures should be prepared to cover routine and breakdown / event maintenance.

Detailed maintenance procedures should be prepared prior to the commissioning of the equipment and include the following details:

- Equipment handbooks and diagrams
- Equipment performance criteria and working limits
- Equipment test procedures
- Equipment test results
- Equipment test equipment schedule
- Equipment repair documentation and repair procedures

10.5 Maintenance Personnel

Routine maintenance and repair can be carried out by each of the following methods:

- In house maintenance personnel
- Third parties

- Equipment suppliers

In all cases, maintenance personnel should be suitably qualified and trained in all aspects of the equipment concerned.

10.6 Maintenance Philosophy

Careful consideration should be given by the Authority operating the equipment to agree the philosophy to be adopted when carrying out maintenance on control and monitor equipment, for example:

- duplication of equipment to provide redundancy
- modular replacement
- who repairs module and turn around time
- in-house / third parties / suppliers maintenance and repair
- maintenance agreement
- software changes and upgrades
- remote diagnostics

Once the philosophy is agreed the information should be promulgated to all maintenance personnel as a firm instruction.

11. DOCUMENTATION AND TRAINING

11.1 Documentation

It is recommended that all documentation, including drawings, should be provided before the equipment is commissioned and accepted for the operational purposes. Sufficient copies will be required for the base, outstations and maintenance personnel.

The documentation should include the following:-

- Functional description.
- Technical specifications.
- Lay out diagrams.
- Circuit drawings.
- Assembly drawings.
- Wiring diagrams.
- Installation drawings.
- Configuration software.
- Operating and functional procedures.
- Repair procedures.
- Test procedures.
- Test sheets.
- Acceptance procedures.
- Acceptance test sheet.

11.2 Training

Training should be provided to match the sophistication of the system and the skills of the staff involved in the operation and maintenance of the system. Such training should be scheduled to match the implementation programme and should be defined in the light of what the trainee shall be able to do at the end of the period of training. Simple systems will require less training, for example, electro-mechanical systems. Larger computer based systems will require a wider range of training modules as detailed below:

- Operational knowledge of the monitoring and control equipment.
- Principal of the operation and control of outstation equipment.
- Maintenance and repairs of outstation hardware.
- Configuration of outstation software.
- Configuration of base station database and displays.
- Configuration of base station system software.
- System architecture.

Training modules should be selected to suit the operational and maintenance philosophy of the authority and the needs of the staff.

12. FUTURE DEVELOPMENT

12.1 General

Techniques and devices used for Remote Monitoring and Control Systems are constantly under review and development by the manufacturing industry which can lead to reduced equipment costs and improvements in reliability. These advances in technology however do not mean that systems need to be replaced on a regular basis, but only when a clear advantage can be predicted or demonstrated. There are numerous cases where equipment installed 10 to 15 years ago is still working satisfactorily. When a new remote monitoring and control system is acquired, the Purchaser and Supplier will usually define a “working life” for the system, at time of purchase.

12.2 Developments

It is anticipated that development will take place in the field of Remote Monitoring and Control and Communications. The following suggestions are put forward for consideration:

12.2.1 *Energy Consumption*

The introduction of more efficient semiconductors and processors, that reduce power supply requirements and enable the use of Monitoring and/or Monitoring and Control Systems where previously power supply restrictions prevented their use, eg. photovoltaic solar powered stations, buoys.

12.2.2 *Signal Formats*

The introduction of combined navigation equipment and monitoring and control equipment will require Authorities to agree to common signal format standards.

12.2.3 *Communications*

New techniques for communication channels providing greater functionality and reliability using systems such as cellular GSM, direct satellite links, Internet, global mobile personal communications by satellite (GMPCS) and low energy consumption radio links.

12.2.4 *Radio Navigation*

Introduction of a new World Wide Radionavigation System to provide improved accuracy data and integrity facilitating monitoring the position of floating aids to navigation.

The growing dependence of mariners on radio navigation systems, such as DGPS necessitate high integrity RMC systems. This may imply an availability requirement for RMC exceeding that of the AtoN.

12.2.5 *Automatic Identification Systems*

The introduction of Automatic Identification Systems (AIS), sometimes referred to as transponders, facilitates the automatic reporting to ships of the status of an AtoN and, in the case of floating AtoNs, a communication channel to shore which could also be used for a transmission of monitoring data.

12.2.6 *Costs*

Developments in remote monitoring and control equipment are likely to offer lower system costs, reduced energy consumption and greater reliability.

ANNEX I – RESULTS OF 1996 SURVEYS

The IALA Engineering Committee received a mandate during the XIIIth Conference in Hawaii that included that 'The Engineering Committee shall study matters relating to the remote control and monitoring of aids to navigation and recommend those developments which should be brought to the attention of members of IALA'. Two different Questionnaires were developed which were dispatched during February and March 1996 to all IALA members. This Annex contains the result from the Questionnaires.

RESULT OF FIRST SURVEY FEBRUARY 1996

The objectives of the first survey :-

To gather information on IALA members policy on monitoring arrangements and prepare guidelines on various types of aid which should be monitored, taking into account operational and environmental factors, provide advice on the parameters to be monitored and appropriate time intervals for data collection.

The questionnaire consisted of eight parts :

Question A	Contains the basic question as to whether Administrations use Remote Monitoring and / or Control for operation of NavAids or not.
Question B	Covers the reasons for not using Remote Monitoring and Control.
Question C & D	Concerns the present usage of Remote Monitoring and Control and reasons for using it.
Question E and F	Times to establish various technical solutions in use today for different types of NavAids.
Question G	Times to establish the technical solutions in use today for different types of NavAids.
Question H	Finally covers quality assurance aspects of navigation services.

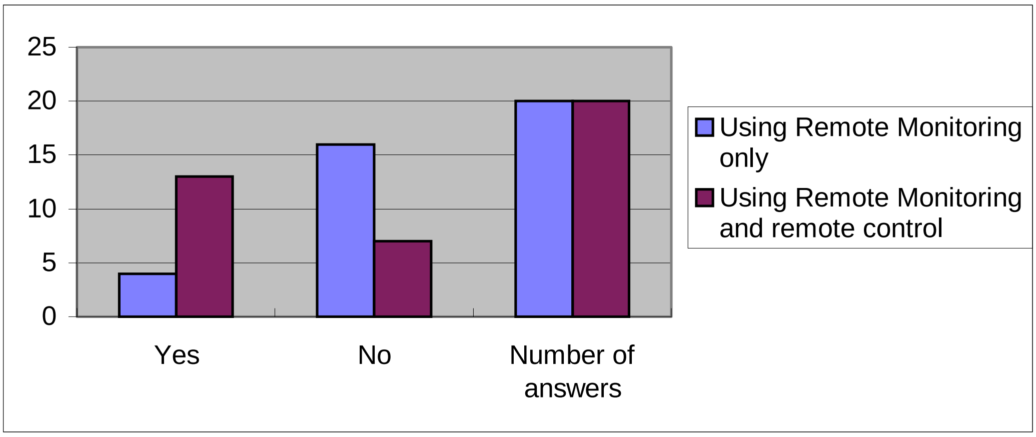
A1.1 Question A

Questions :

Is your administration currently using Remote Monitoring systems only to remotely monitor the operation of aids to navigation?

Is your administration currently using both Remote Monitoring and remote control systems to monitor the statues of the aids to navigation in question where you also have the possibility to remotely changeover to e.g. a standby system, do some testing of the remote system and other tasks?

This questions was a basic one where it was important to create knowledge about how many had Remote Control and Monitoring system or not.



Graph A1.1-1 Distribution of answers for question A.

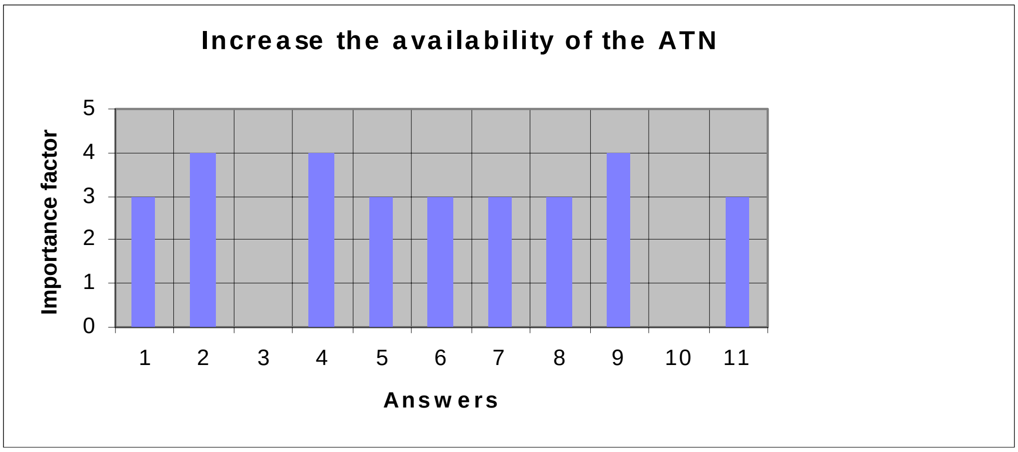
Of 20 replies 4 implemented purely monitoring systems and 13 implemented both Remote Monitoring and Control Systems. It is clear that the control function is of major importance in the Remote Control and Monitoring System.

A1.2 Question B1

Question :

> *Do you consider it better to increase the reliability of the navaid equipment itself rather than to introduce Remote Monitoring even for the most important aid or for the most complex installation (DGPS station). The availability of a aid to navigation can be increased by adding more redundancy e.g. use of lampchangers with enough lamps for the service period.*

Under question B IALA tried to find out the reason why some administrations doesn't want to introduce Remote Control and Monitoring systems. The result from the questionnaire is:



Graph A1.2-1 Distribution of answers for question B1, increase the availability of the AtoN

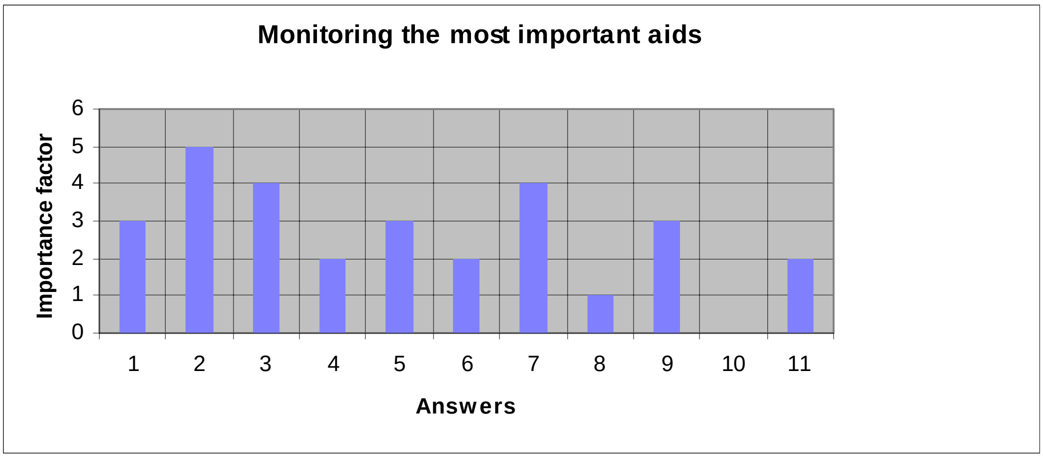
The replies indicated that the preference was to increase availability by redundancy rather than introduce a Remote Monitoring System.

The next statement was:

Do you consider monitoring the most important aid to navigation to increase the reliability of the aids in question regardless of their technical complexity.

The result from the questionnaire was:

Graph A1.2-2 Distribution of answers for question B1, monitoring the most



important Aids to Navigation

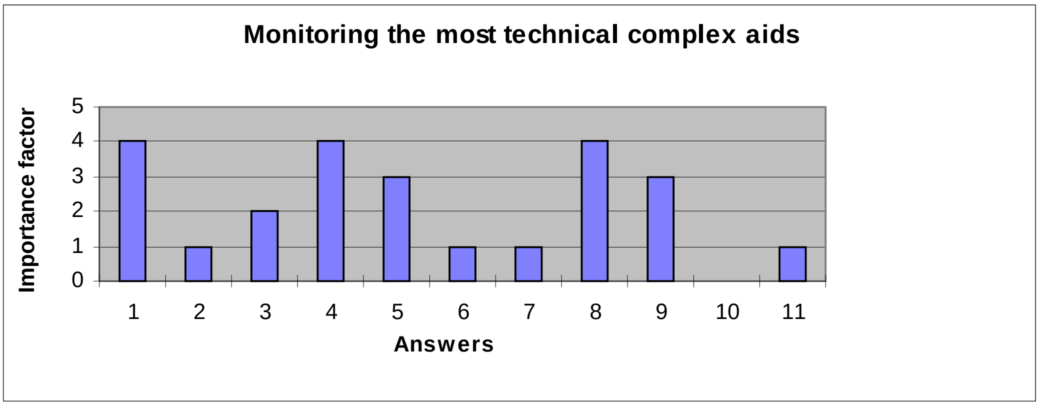
The replies were equally divided on this question. Three considered it important to monitor the main Aid, while four considered other systems should be included.

The last statement in this group was:

Do you consider Monitoring but not Controlling the most technically complex aids to navigation to increase the reliability of the aids in question regardless of navigational importance.

The following answers were given:

Graph A1.2-3 Distribution of answers for question B1, monitoring the most



technical complex AtoN.

The general opinion was that it is more important to monitor the important Aids to Navigation rather than those Aids that are technically more complex.

The main conclusion for this part of the question must be that introduction of a Remote Control and Monitoring system count on several factors not only a single one.

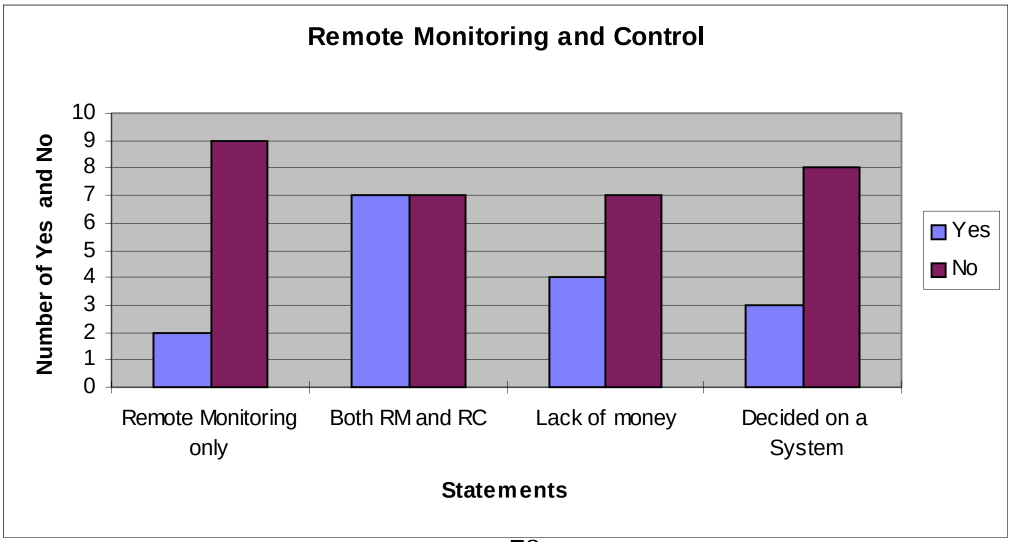
A1.3 Question B2

Question :

Are you currently contemplating remote monitoring and/or control as a valuable tool in the provision of a reliable aid to navigation, in accordance with the answers to the following questions:

This part of the question tried to find out whether IALA members are considering remote monitoring or remote control and monitoring. The aim is also to find the reason why they not yet have introduced such a system.

The result from the questionnaire was:



Graph A1.3-1 Distribution of answers for question B2, Remote Monitoring and Control.

From the graph it is possible to at least draw one conclusion. It is clearly stated that very few will introduce Remote monitoring only. If an organisation implements such system(s) it will also be capable to do Remote Control.

A1.4 Question B3

There were no reasons given for not using Remote Monitoring and/or Control.

A1.5 Question C Aids to Navigation which are monitored.

Remote Monitoring and/or Control can be applied to different kinds of Aids to Navigation. This part of the questionnaire concerns the present use of Remote Monitoring or Control in connection with different kinds of Aids to Navigation.

The following nine categories were considered:

Major Lights with standby power generation……… …… (MAJ)

Minor Lights, battery-, solar- or wind powered………….. (MINE)

Buoys, Lighted………………………………………. (BUOY)

LANBY's………………………………………………… (LANB)

Automated Lightfloat……………………………………. (ALF)

Racons…………………………………………………… (RAC)

Radio Beacons…………………………………………… (RC)

DECCA, LORAN C, DGPS and other radionav. Systems. (RAD)

Other not covered by the above: Laser-lines etc.…………. (SPEC)

In the following we will see how Remote Monitoring and Control is used in different countries.

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
2	52	55	130	1	9	23	12	0	0
4	450	11800	1	0	0	102	50	76	0
5	42	3	164	0	0	5	22	0	0
8	131	3463	1421	0	0	29	18	64	0
10	111	3800	65	0	0	55	0	12	0

11	279	7	398	0	0	42	12	4	0
12	460	223	960	1	4	14	7	4	0
23	60	900	300	0	0	80	8	25	0
34	17	0	0	0	0	0	0	0	0
35	80	3	119	2	2	17	8	2	0
40	0	0	0	0	0	3	0	0	0
41	0	0	0	0	0	0	0	6	0
43	4	11	0	0	0	0	0	0	0
46	0	0	0	0	0	1	0	1	0
47	5	0	2	0	0	0	0	0	0

Table A1.5-1 Based on categories this table shows the total number of installations of Aids to Navigation in those countries that answered.

Administrations are identified only by number. The total number of installations may not be correct as some misinterpretation of the question occurred.

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
2	0	0	0	0	0	8	0	0	0
5	2	0	0	0	0	0	1	0	0
8	33	367	284	0	0	19	12	24	0
11	39	2	0	0	0	0	12	4	0
21	6	5	0	0	0	0	0	0	0
34	17	0	0	0	0	0	0	0	0
35	7	0	0	0	0	8	0	0	0
46	0	0	0	0	0	1	0	1	0

Table A1.5-2 This table shows how many use Remote Monitoring only of those that answered the Questionnaire.

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
2	47	45	0	1	9	0	12	0	0
4	125	0	0	1	0	0	0	76	0
5	22	1	0	0	0	1	14	0	0
8	0	0	0	0	0	2	2	9	0
10	27	0	0	0	0	3	0	8	0
11	28	2	0	0	0	0	0	4	0
12	459	140	0	1	4	0	7	4	0
21	8	4	0	0	0	0	0	0	1
23	29	39	0	0	0	0	8	25	0
35	34	0	0	2	2	4	7	2	0
40	0	0	0	0	0	3	0	0	0
41	0	0	0	0	0	0	0	6	0
43	4	8	0	0	0	0	0	0	0
47	5	0	2	0	0	0	0	0	0

Table A1.5-3 This table shows the number of installations of each category that has both Remote Monitoring and Remote Control.

Answers indicate a majority of respondents that have invested in Remote Monitored have added the additional functionality of Remote Control.

A1.6 Question D   Reasons for using Remote Monitoring and Control.

The following statements describe the reasons for using or introducing Remote Control.

D1 Statement

We use Remote Monitoring primarily to monitor the navigational function of the aid to be able to warn mariners of failure before we get the information from the mariner.

We use both Remote Monitoring and Remote Control primarily to supervise the navigational function of the aid to be able to send warning to the mariners of failure before we get information from the mariner, and to make remote testing possible.

D2 Statement

Remote monitoring only allows us to receive early notice that standby equipment has come into operation and that repair may be required to maintain redundancy.

We use Remote Monitoring and Remote Control to increase the availability of an aid to navigation, and to receive early notice that standby equipment has come into operation and that repair may be required to maintain redundancy.

D3 Statement

We use Remote Monitoring and Remote Control for the above reasons and also because it can enable corrective action to be taken without having to send service personnel to the site. E.g. reset functions, overriding local automatic operations and for testing purpose.

The result from these statements was.

Admin	Remote Monitoring Only to warn Mariners D1	RM&C to Supervise the Navigational Function D1	RM only to receive early notice for stand by equipment D2	RM&C to increase the availability D2	RM&C for enabling corrective action D3
4	0	5	0	5	5
5	1	5	3	5	5
8	3	3	5	3	3
10	3	3	5	5	4
11	5	4	4	4	5
12	5	5	5	5	5
21	1	3	4	4	5
23	5	5	4	5	5
34	4	0	5	5	0
35	5	4	5	4	4
37	4	4	2	4	3
39	5	5	4	4	4
41	2	2	2	5	5
42	4	4	4	4	4
43	0	5	0	5	5

Table A1.6-1 (1 means not important, 5 means very important.)

A1.7 Question E Types of Remote Monitoring and Control.

Question :

The tables below (E1- E3) cover different types of Remote Control equipment ranging from historically simpler designs to more complex systems. Please enter the number of aids to navigation you operate using different types of remote control equipment.

Example : if you monitor 15 major lights by means of a pulse transmission system and 2 by means of a Programmable Logic Controller (PLC), enter 15 in Table E2 column MAJ and enter 2 in Table E3 column MAJ.

A1.7.1 E1, Simple equipment

Frequency multiplex system, usually one audio frequency is used for each function supervised (fairly old type of Remote Control equipment but may still be sufficient reliable in operation).

The answer to the question is as follows:

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC

5	2	0	0	0	0	0	1	0	0
12	13	2	0	0	0	0	1	1	0
21	0	0	0	0	0	0	0	0	1
34	17	0	0	0	0	0	0	0	0
35	5	0	0	0	0	1	0	0	0

Table A1.7-1 Answers regarding use of Simple Equipment for communication

A1.7.2 E2, Intermediate designs

Pulse transmission systems with simple synchronisation. The status of a supervised function is represented by a level or a length of a specific pulse in the transmission. Limited expansion possibilities.

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
2	3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	4	0
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
21	6	5	0	0	0	0	0	0	0
23	1	4	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0
35	2	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0

Table A1.7-2 Answers regarding use of Intermediate designs for communication

A1.7.3 E3, Modern type

Microcomputer based systems or PLC’s, one or several units for a site. Using address/data interrogation schemes to obtain information and to perform remote control.

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
2	44	45	0	1	9	8	12	0	0

4	125	0	0	1	0	0	0	76	0
5	22	1	0	0	0	1	14	0	0
8	0	0	0	0	0	0	0	5	0
10	27	0	0	0	0	3	0	4	0
11	39	2	0	0	0	0	0	4	0
12	446	138	0	1	4	6	6	3	0
21	8	4	0	0	0	0	0	0	0
23	28	35	0	0	0	8	8	22	0
34	0	0	0	0	0	0	0	0	0
35	37	0	0	2	2	11	7	2	0
37	0	11	8	0	0	1	1	0	0
41	0	0	0	0	0	0	0	6	0
43	4	8	0	0	0	0	0	0	0

Table A1.7-3 Answers regarding use of Modern type for communication

A1.8 Question F Communication Methods

The following question was asked :

Different communication methods have been used to convey information between the manned site and the remote lighthouse or installation. Please state communication method you currently use for different kinds of remote controlled navaids. The tables are similar to those in question E.

Here the different Authorities have given their answers for which kinds of communication methods they have in use.

A1.8.1 F1, Dedicated line

Question :

A dedicated line in combination with radiolink or not.

This question asked for whom are using dedicated line together with radio link or not, to which type of installations and how many installations that are covered.

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
2	9	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	1	0
12	424	135	0	0	0	2	5	4	0
34	11	0	0	0	0	0	0	0	0
35	4	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	21	0

Table A1.8-1 Answers regarding question F1, dedicated lines with radio links or not.

A1.8.2 F2, Dialled up connections

Question :

A dialled up connection in combination with radiolink or not.

This question asked for who are using dialled up connections together with radio links or not. The table bellow shows the result.

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
6	2	4	2	0	0	1	1	0	1
10	27	0	0	0	0	3	0	4	0
11	39	2	0	0	0	0	1	4	0
12	35	5	0	0	0	0	2	0	0
21	8	4	0	0	0	0	0	0	0
23	13	15	0	0	0	0	8	25	0
34	5	0	0	0	0	0	0	0	0
35	39	0	0	2	2	11	7	2	0
37	0	0	0	0	0	0	1	0	0
41	0	0	0	0	0	0	0	6	0
43	4	8	0	0	0	0	0	0	0
48	57	1	0	0	0	21	9	0	0

Table A1.8-2 Answers regarding question F2, dialled up connections in combination with radio links or not.

A1.8.3 F3, Dedicated Radio Links

Question :

A dedicated radiolink.

This question asked for who are using dedicated radio links that also include private point to point and scanning radio links.

The table bellow shows the result.

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
2	1	0	0	1	1	0	0	0	0
5	24	1	0	0	0	1	15	0	0
8	0	0	0	0	0	2	0	2	0
12	0	0	0	1	4	4	0	0	0
21	6	5	0	0	0	0	0	0	0
34	1	0	0	0	0	0	0	0	0
35	26	0	0	2	2	11	3	0	0
37	0	11	8	0	0	1	0	0	0

Table A1.8-3 Answers regarding question F3, use of dedicated radio links.

As seen from the answers dedicated radio links are widely used to all types of installations.

A1.8.4 F4, Dialled up Radio Links

Question :

A dialled up radiolink.

This question asked for who are using dialled radio links, which also include cellphone.

The table bellow shows the result.

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
2	37	45	0	0	8	8	12	0	0
23	16	24	0	0	0	21	0	0	0
35	0	0	0	2	1	0	0	0	0

Table A1.8-4 Answers regarding question F4, use of dialled up radio links (Cellphone).

A1.8.5 F5, Satellite

Question :

Satellite communication.

This question asked for who are using satellite communication for Remote Monitoring and Control.The table below shows the result:

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC

Table A1.8-5 Answers regarding question F5, use of Satellite Communication.

Up till now no one is using Satellite communication to serve the Remote Monitoring and Control Function, at least of those that answered the Questionnaire.

A1.8.6 F6, Use of Subcenter

Question :

A control center or a subcenter in connection with a manned site regularly interrogates a number of navaids within its coverage area. An aid to navigation responds when addressed and reports its status. An aid to navigation can also report spontaneously.

This question asked for whether an Authority used a Subcenter or not to gather signals from several remote sites and concentrate the hole into one data channel to the main central station. The table below shows the result:

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
2	44	45	0	1	9	8	12	0	0
5	24	1	0	0	0	1	15	0	0
6	2	4	2	0	0	1	1	0	1
8	0	0	0	0	0	2	0	5	0
10	27	0	0	0	0	3	0	4	0
11	1	0	0	0	0	0	0	1	0
23	29	39	0	0	0	21	8	25	0
35	37	0	0	2	1	10	6	2	0
37	0	11	8	0	0	1	0	0	0
48	57	1	0	0	0	21	9	21	0

Table A1.8-6 Answers regarding question F6, use of Subcenter to concentrate signals from several remote places into one data link.

Use of Subcenters to concentrate signals from several remote places are widely used technique when a Remote Monitoring and Control System is used to monitor and control a Aids to Navigatio*n*

A1.8.7 F7, Continuously reporting

Question :

The remote site reports continuously to a manned site.

This question asked whom that used a continuously reporting or reporting in fixed intervals system

The table below shows the result:

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
2	3	0	0	0	0	0	0	0	0
21	6	5	0	0	0	0	0	0	0
35	3	0	0	0	1	1	1	0	0
48	0	0	0	0	0	0	0	21	0

Table A1.8-7 Answers regarding question F7, use of continuously reporting system.

Use of continuously reporting system is rather limited among those that have introduced a Remote Monitoring and Control System.

A1.8.8 F8, Spontaneous Reporting System

Question :

When a fault condition is detected at the remote site the Remote Monitor or the Remote Controller dials up the master. The master can also call the remote site at any time.

This question asked whom that is using a communication system that permits spontaneous reporting when an abnormal situation occurs. The system also permits polling from a central station to download information.

The table below shows the result:

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
2	1	0	0	0	0	0	0	0	0
6	2	4	2	0	0	1	1	0	1
10	27	0	0	0	0	3	0	4	0
11	38	2	0	0	0	0	0	3	0
21	8	4	0	0	0	0	0	0	0

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
23	29	39	0	0	0	21	8	25	0
34	16	0	0	0	0	0	0	0	0
35	5	0	0	0	1	2	1	0	0
37	0	0	0	0	0	0	1	0	0
48	57	1	0	0	0	21	9	21	0

Table A1.8-8 Answers regarding question F8, use of spontaneous reporting system. The other mode is polling.

As we see from the answers of the Questionnaire, use of a system that is based on spontaneous reporting when an abnormal situation occur on the remote site is widely used. The combination of polling and spontaneous connection makes this communication system attractive for Remote Monitoring and Control System aimed for Aids to Navigation installations.

A1.8.9 F9, Operated by the User (Navigator)

Question :

An aid to navigation can be operated by a user (navigator) who requires the service. The service can be switched on and off by the user.

In many circumstances it can be attractive to the provider of the Aids to Navigation to save cost if the user can operate the Aid by himself when it is needed. This mode of operation will result in much lower power consumption and therefor a smaller installation. The investment will also be lower.

The table below shows the result:

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
2	0	0	0	0	0	23	0	0	0
21	8	4	0	0	0	0	0	0	0

Table A1.8-9 Answers regarding question F9, the user operate the Aid to Navigation by himself.

The result from the Questionnaire tells us that the use of user operated Aids to Navigation is very limited, but seen from benefit/cost analysis it is worth while to take such a system into consideration in area with very low traffic density.

A1.9 Question G Preferred choice of Remote Monitoring and Control System

Question :

If given the opportunity to replace your existing remote control system, which technical solution would you prefer for your different kinds of aids to navigation? Use references to E1 through F3 for your choice.

This question was created to trace the most common opinion among Authorities regarding which type of system would be the best choice if they could have the opportunity to start all over again.

A1.9.1 G1, Equipment types

The table below shows the answers that have been given:

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
2	E3	E3	E3	E3	E3	E3	E3	E3	E3
4	E3			E3				E3	
5	E3	E3	E3			E3	E3	E3	E3
8	E3	E3	E3	E3	E3	E3	E3	E3	E3
10	E3	E3				E3	E3	E3	
11	E3	E3				E3		E3	
12	E3	E3		E3	E3	E3	E3	E3	
21	E3	E3							
34	E3								
35	E3	E3	E3	E3	E3	E3	E3	E3	
37		E3	E3			E3			
41								E3	
43	E3	E3	E3						

Table A1.9.1 Answers regarding question G1, which type of system is the most preferable.

The most preferable system is computer (microcomputer) based. Even for a simpler system as we find in a buoy or in a minor light. The greatest benefit from such a system is standard hardware that make the components cheap and the flexibility is high.

A1.9.2 G2, Communication Links and methods

To make it more convenient to read the table a short list for different communication types follows here.

F1, Dedicated line

F2, Dialled up connections

F3, Dedicated Radio Links

F4, Dialled up Radio Links

F5, Satellite

F6, Use of Subcenter

F7, Continuously reporting

F8, Spontaneous Reporting System

F9, Operated by the User (Navigator)

The table below shows the result from the question G2. The question asked for the most preferable communication method for the time being.

ADMIN	MAJ	MINE	BUOY	LANB	ALF	RAC	RC	RAD	SPEC
2	F4,F5	F4,F5	F4,F5	F4,F5	F4,F5	F4,F5	F4,F5	F4,F5	F4,F5
4	F2,F4,F5			F2				F1	
5	F3,F6	F3,F6	F3,F6			F3,F6	F3,F6		
8	F3	F3	F3	F3	F3	F3	F3	F3	F3
10	F2,F8	F3,F8				F2,F8	F2,F3	F2,F3	
11	F2,F8	F2,F8				F8		F1,F8	
12	F2	F2		F2	F2	F2	F2	F2	
21	F1	F1							
34	F1								
35	F2,F4	F2,F4	F3	F4	F4	F4	F4	F4	
37		F3,F8	F3,F8			F3,F8	F1,F8	F1,F8	
41								F8	
43	F2	F2	F2						

Table A1.9.2. Answers regarding question G2, which type of communication system that is the most preferable.

Different Authorities select a communication system that is the most suitable for that specific installation area. Communications based on satellite seem to have little interest, because of cost. There is a low interest for direct line communication (F1), but a dialled up connection (F2) is of great interest to all. F2 together with F8 seems to be of high interest among several Authorities, while at present use of cellphone seems to be limited due to the low cellphone coverage world wide.

A1.10 Question H Quality of a Navigation Service

The availability of a single aid to navigation is an important factor in the quality of the navigation service of which it is a part. The availability of an aid to navigation is defined as the percentage of a one month period during which the aid has been working according to specification. Other aspects of quality could be accuracy but such qualities are not considered here. In this sense the quality of a gaslight is consequently comparable with the quality of a DGPS system.

Below you will find statements H1, H2 and H3 which concern the quality of a navigation service. Please give your opinion of the statements on a scale of 1-5 where:

1 means:

> *We consider the use of Remote Monitoring and/or Remote Control in this way is unnecessary and extravagant and we can not for the time being see the benefit of such efforts either in short or long term.*

3 means:

> *We see the point of acquiring this extra knowledge and consider it as a useful way of improving the quality of a service.*

5 means:

> *We agree and have already implemented and evaluated such functions.*

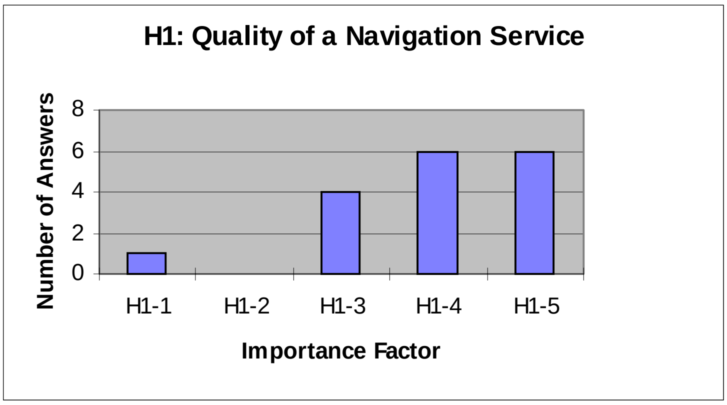
Question H was created to find out which position a quality control system had in the different Authorities and how it was looked upon connected to the navigational service each one is delivering.

A1.10.1 H1, RM&C can be used to increase the availability

Question:

> *Remote Monitoring and/or Control can be used to increase the availability of a aid to navigation and hence the quality of the navigation service, since it can give early warning in case of equipment malfunction. Faults can then be rectified before a navigational error occurs.*

To this statement the following answers were received:



Graph A.10.1. Answers to Question H-1

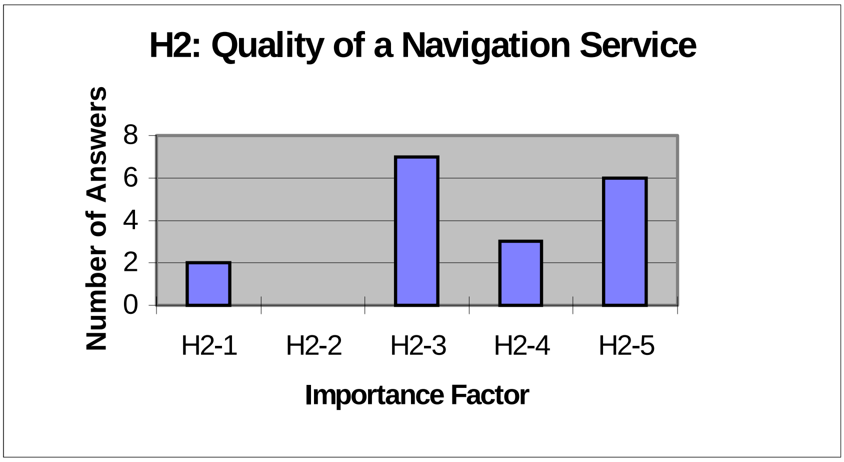
That a Remote Monitoring and/or Control System will increase the availability of an AtoN. Early warning to the Mariner is to be of major importance.

A1.10.2 H2, RM&C can be used to monitor the quality of the navigation ser***vice***

Question:

Remote Monitoring and/or Control can also be used to monitor the quality of the navigation service. This capability would require use of more competent Remote Control-equipment (E3) and more elaborate communication scheme (F1 to F5). Integrity monitors for Differential GPS can be regarded as systems of this kind.

To this statement the following answers were received:



Graph A.10.2. Answers to Question H-2

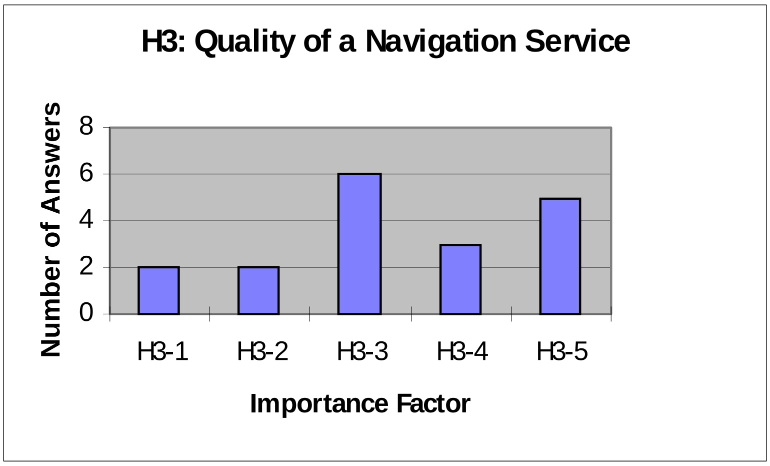
That a Remote Monitoring and / or Control System can be used to monitor the quality of the navigation service. Thus, if an Authority plan to provide a quality management system, they will also have to include a Remote Monitoring and/or Control System.

A1.10.3 H3, RM&C can be used to improve a navigation service

Question:

Remote Monitoring and/or Control can be used to improve a navigation service by enabling the provider of the service to differentiate between equipment faults and faults caused by external factors like adverse weather condition, which can affect the availability of the service to the user.

To this statement the following answers were received:



Graph A.10.3. Answers to Question H-3

Remote Monitoring and/or Control System can improve the navigation service by distinguishing between technical faults and that the service is not available to the user. As a side effect this function will also save resources of the Authority since they know the real situation of the aid in question and they can avoid an unnecessary service action.

A1.11. SECOND SURVEY

The aim of the Questionnaire was to build up an overview of how widespread the use of Remote Monitoring and Remote Control was amongst IALA members. There was also an attempt to get an idea of how much modern equipment was in use.

A total of 43 answers were received from an IALA membership of 85. The Engineering Committee thank all those who spent valuable time on filling out the Questionnaires.

Underneath you will find the simple Questionnaire dispatched from IALA during February and March 1996.

IALA Questionnaire on use of Remote Control and Monitoring

Overview

IALA has requested that: "The Engineering Committee shall study matters relating to Remote Control and Monitoring of aids to navigation and recommend those developments which should be brought to the attention of members of IALA."

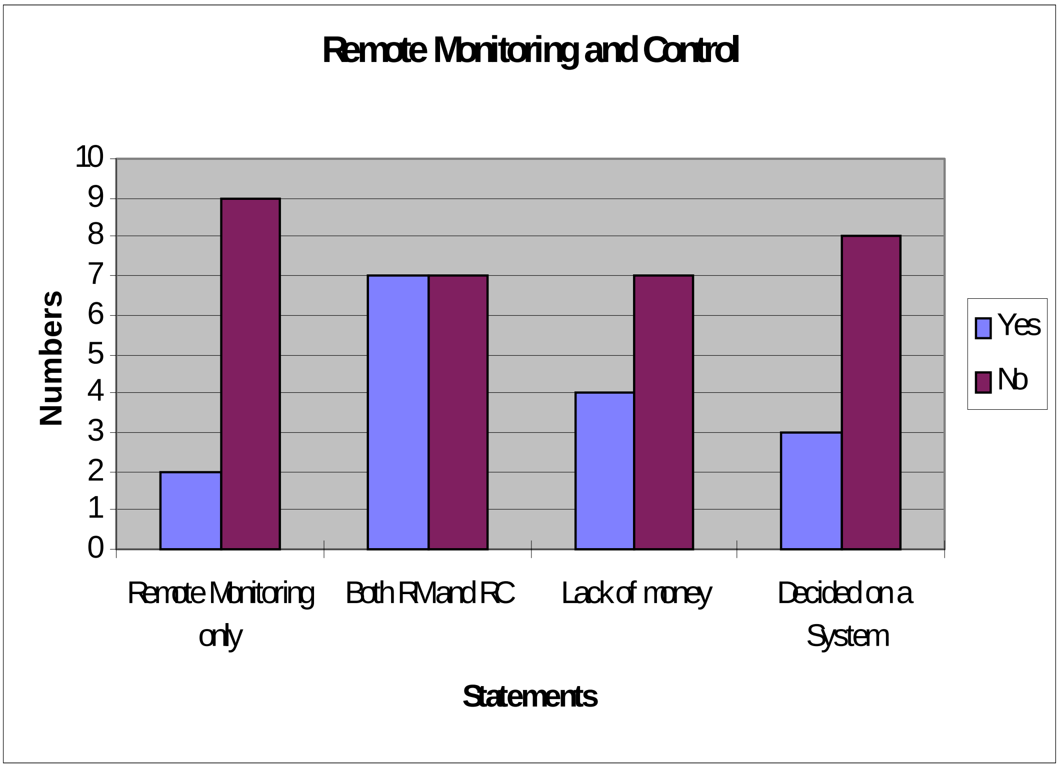
In accordance with the Engineering Committee's work program the Committee has the task of gathering information on IALA members' policy on monitoring arrangement and preparing guidelines on the various types of aid which should be monitored. Taking into account operational and environmental factors, to provide advice on the parameters to be monitored and appropriate time intervals for data collection.

The Engineering Committee will use this opportunity to thank all those IALA members that so kindly respond on the previous questionnaire.

Will all members please complete this new questionnaire to help provide a complete picture of worldwide use of remote monitoring systems?

Do you have Remote Monitoring System Installed?		Do you have Remote Monitoring and Control System?		Are all or some of the Remote Control and Monitoring system computer?		Will you share your experience with other IALA members?	
Yes	No	Yes	No	Yes	No	Yes	No

ANNEX II - COMMUNICATION LINKS



This annex provides generalised descriptions of various communications media that may be used singly or in combinations to connect from a remote site to a control centre. The final selection of services will be dependent upon investment and running costs that are area specific, and the requirements for availability and data rate that require detailed engineering studies beyond the scope of this paper.

When planning a communications system, a link analysis should be prepared to ensure that the type of link selected is sufficiently capable in terms of reliability, information quality, capacity and integrity, for the system it will serve. Attention must also be paid to the capacity of the power supply to ensure that sufficient power is available to operate the system in both the low energy demand of routine operation, as well as the heavy demand of repeated failure transmissions and control centre interrogations. The final choice of communications system is often an economic one.

Estimation of energy consumption is usually based on assumptions of daily transmit time and is calculated in watt-hours/day (wh/day). The outstation is usually designed to cease attempts to communicate after a number of failed attempts.

There are essentially three main types of communications links:

- Public and Private Networks

- Radio Links
- Hybrid System
- Visual

Each system is considered under the headings of System Description, Application, Power Consumption, Availability and Integrity.

A2.1 Public and Private Networks

Public and Private Networks include PSTN, Leased Private Circuits, Owned or Non-leased Private Circuits and ISDN.

A2.1.1 *Public Switched Telephone Networks (PSTN)*

A2.1.1.1 Description of the System

Public Switched Telephone Networks exist in most countries of the world and are interconnected. They provide communications services ranging from simple voice communications to data transmission at various baud rates. The link may be via a variety of transmission media some of which may require specific design considerations. Some form of dial-up capability is normally required.

A2.1.1.2 Application

Public Switched Telephone Networks can provide facilities ranging from basic on/off switching to complete site control and monitoring. Normally, a PSTN connection comprises a 3kHz-voice channel but higher capacity circuits may be available. Although normally used in a discontinuous communications mode, real time communications is possible.

A2.1.1.3 Criteria

a) *Availability*

The availability of the core components of the Public Service Telephone Network (PSTN) is generally very high since there are usually alternative routes, which can be used. If one exchange becomes faulty or a cable is damaged, it should not significantly affect the system as a whole.

The exception to this however is that the remoteness of many lighthouse sites means that they are often at the end of a single communication link. The exposure of a site, for example on a headland, can make overhead wires vulnerable to storm damage. This last segment of the link has the greatest bearing on the availability of the system. PSTN lines are also vulnerable to electrical interference and lightning damage and precautions need to be taken against these effects.

b) *Integrity*

The integrity of the service is the responsibility of the PSTN service provider and is usually high. Data integrity is the responsibility of the user.

A2.1.2 ***Leased and Private Circuits***

A2.1.2.1 Description of the System

The services provided by the PSTN are available on a dedicated basis utilizing the same networks, subject to the same regulatory procedures but not requiring dial-up action. The significant differences are that leased circuits are dedicated to a specific user's requirements, usually at higher cost. Leased circuits installed on behalf of governments may be entitled to priority restoration. Less redundancy than in the PSTN is normally provided.

A2.1.2.2 Application

Leased Private Circuits can provide facilities ranging from basic on/off switching to complete site control and monitoring. They offer additional reliability, security, capacity and speed and they are usually used where continuous communications is an operational requirement.

A2.1.2.3 Criteria

a) *Availability*

The availability of Leased Private Circuits does not differ significantly from that of the PSTN given in paragraph ***A2.1.1.3*** above.

b) *Integrity*

Service integrity is the responsibility of the Private Circuit provider, is usually high and is generally automatically checked. Data integrity is the responsibility of the user.

A2.1.3 ***Owned or Non Leased Private Circuits***

A2.1.3.1 Description of the System

Owned or Non-Leased Private Circuits differs from Leased Private Circuits only in regard to their ownership. This type of circuit is mostly used by utilities or large organisation with existing communications infrastructure.

A2.1.3.2 Application

Owned or Non Leased Private Circuits can provide facilities ranging from basic on/off switching to complete site control and monitoring. They offer additional security, capacity and speed but their reliability is related directly to the maintenance which can be provided. They are usually used where continuous communications is an operational requirement.

A2.1.3.3 Criteria

a) *Availability*

The availability of Owned or Non-Leased Private Circuits should not differ significantly from that of Leased Private Circuits provided that adequate maintenance is carried out.

b) *Integrity*

In this case, the integrity of both the service and the data is the responsibility of the user. It can be automatically checked.

A2.1.4 ***Integrated Services Digital Network (ISDN)***

A2.1.4.1 Description of the System

Digital transmission and digital switching equipment are gradually replacing analogue systems. These new systems are effectively high capacity digital data and voice transmission systems known as ISDN. ISDN enables enhanced facilities such as video conferencing, teleworking, fast file transfer, video surveillance, multi-media transmissions, facsimile and leased line.

A2.1.4.2 Application

Although essentially designed as a high quality digital data highway, ISDN can provide all the facilities of the PSTN and Private Circuits. It is therefore capable of providing facilities for total site control and monitoring, in real time.

A2.1.4.3 Criteria

a) *Availability*

Where ISDN exists, the availability of the system is high. It should be noted however, that there might be difficulties in extending the ISDN service into remote areas.

b) *Integrity*

ISDN by definition has high integrity and is automatically checked.

A2.2 Radio Links

Radio links are generally available utilizing Medium Frequency (MF), High Frequency (HF), Very High Frequency (VHF), Ultra High Frequency (UHF) and Microwave Frequencies. Direct Satellites Links are an application of microwave links.

A2.2.1 ***Medium Frequency Radio Links***

A2.2.1.1 Description of the System

A Medium Frequency radio link operates in the frequency band 300kHz to 3000kHz. MF links can be used for communications ranging from simple voice to data transmissions at relatively low data rates. The reliable range of a MF link is generally considered to be around 100 miles depending upon radiated power.

A2.2.1.2 Application

MF radio links can provide facilities ranging from basic on/off switching to complete site control and monitoring. The primary application of MF is for long distance or mountainous terrain communications. Antenna sizing requirements may be significant.

A2.2.1.3 Criteria

a) *Power Consumption*

The power consumption of a MF radio link is dependent upon the duty cycle; the system efficiency and the operating range. To provide a reliable MF radio link over a distance of 100 miles would require an input power to the transmitter of approximately 300 watts.

b) *Availability*

The availability of a MF radio link is subject to atmospheric and meteorological conditions. This would tend to suggest that the availability may be suspect but it can be enhanced by careful system design.

c) *Integrity*

The integrity of MF radio links and the method of checking are entirely dependent upon the system design can be either automatic or manual.

A2.2.2 ***High Frequency Radio Links***

A2.2.2.1 Description of the System

A High Frequency radio link operates in the frequency band 3MHz to 30 MHz. HF links can be used for communications ranging from simple voice to data transmissions at relatively low data rates. The reliable range of HF links is generally considered to be around 1000 miles.

A2.2.2.2 Application

HF radio links can provide facilities ranging from basic on/off switching to complete site control and monitoring. The primary application of HF is for long distance or mountainous terrain communications. Antenna sizing requirements may be significant.

A2.2.2.3 Power Consumption

The power consumption of a HF radio link is dependent upon the duty cycle; the system efficiency and the operating range. To provide a reliable HF radio link over a distance of 1000 miles would require an input power to the transmitter of approximately 100 watts.

a) *Availability*

The availability of a HF link will be subject to atmospheric and meteorological conditions. Careful system design can minimise these effects.

b) *Integrity*

The integrity of HF radio links and the method of checking are entirely dependent upon the system design and may be either automatic or manual.

A2.2.3 ***Very High Frequency Radio Links (VHF)***

A2.2.3.1 Description of the System

VHF radio links operate in the band 30MHz to 300 MHz. They can be used for communications ranging from simple voice to moderately high data rates - 300 bits/sec to 9.6 kilobits/sec depending on the channel bandwidth. The range is essentially dependent upon line of sight and is therefore determined to a large extent by the heights of the antennas at each end of the link. A typical single hop range would be in the region of 20 miles but greater ranges can be achieved using directional antennae. By using very low data rates ranges of 25 miles are possible with low transmitter power.

A2.2.3.2 Application

VHF links can be used to provide facilities ranging from basic on/off switching to complete site control and monitoring. The performance of VHF radio links are more predictable as they are generally less susceptible to atmospheric and meteorological conditions. Also careful choice of modulation types can allow the links to operate reliably in high noise conditions. Lower power, low data rate links can be suitable for limited power solar systems and buoys.

A2.2.3.3 Criteria

a) *Power Consumption*

The power consumption of VHF links is closely allied to the range required. It is also highly dependent on the requirements for the standby mode. Typical values would be up to 75 watts input power for 25 RF watts out but very low power links in the milliwatt range are available for short-range applications with low data rates. The duty cycle significantly effects the input requirement.

b) *Availability*

The availability of VHF links is generally high, as they are less susceptible atmosphere and meteorological conditions.

c) *Integrity*

The integrity of VHF links is largely dependent upon the system design and the amount of redundancy built in. Performance is normally checked automatically using built-in monitor circuits.

A2.2.4 *Ultra High Frequency Radio Links (UHF)*

A2.2.4.1 Description of the System

UHF radio links operate in the band of 300MHz to 3000MHz. They can be used for communications ranging from simple voice to high data rates. Typically arranged in channels of 12.5kHz, but alternatively due to the relatively wide bandwidth available at UHF and above, spread spectrum techniques can be employed. These essentially are modulation methods, which spread the data transmission over the wide bandwidth to achieve low average power in any narrow band and also to produce high resistance to noise. At UHF, range is again dependent upon line of sight and a single hop would be typically around 15 miles, and, as with VHF, use of directional antennae will increase this range.

A2.2.4.2 Application

UHF links can be used to provide the whole range of facilities from basic on/off switching to complete site control and monitoring. Smaller antennas are required but some protection may be required against precipitation static electrical discharge. Very low power UHF links can be used over short ranges without the need for radio transmitting licences in many countries.

A2.2.4.3 Criteria

a) *Power Consumption*

The power consumption for UHF links is somewhat less than that required for VHF and is dependent upon the range required and the duty cycle.

b) *Availability*

The availability of UHF links is generally high but they can be affected by meteorological conditions.

c) *Integrity*

The integrity of UHF links is high and integrity checking is carried out automatically.

A2.2.5 ***Microwave Links***

A2.2.5.1 Description of the System

Microwave links operate at designated frequencies above 3GHz. They are range limited to line of sight on a single "hop" but can be cascaded over many miles. Microwave links can provide wide bandwidths allowing data rates from 10 to 40 kilobits/sec. They can be cheaper than cable connections.

A2.2.5.2 Application

Microwave links can be used to provide the entire range of facilities from basic on/off switching to complete site control and monitoring. The available band width facilitates high speed transmission of large volumes of data. The short operating range of individual links may be significant.

A2.2.5.3 Criteria

a) *Power Consumption*

The normal power consumption of a microwave link would be of the order of 30 to 40 watts during the transmit period.

b) *Availability*

The availability of microwave systems is generally very high as back up equipment is usually provided.

c) *Integrity*

Microwave links have very high integrity and this is checked automatically.

A2.2.6 ***Direct Satellite Links***

A2.2.6.1 Description of the System

A direct satellite link is one in which the user owns the ground terminals and leases or rents satellite channel access. In this system, the satellites can be geostationary or earth orbiting if sufficient satellites are available to provide continuous coverage. Use of a space segment removes the customary microwave distance limitation and provides long range and wide area coverage. Primary use is for mobile communications or long range communications in difficult or remote terrain where alternative infrastructure is not available.

A2.2.6.2 Application

Direct satellite links can be applied across the entire range of requirements in regard to remote control and monitoring. Data rates of around 600 bits/sec are available. Cost of transmission may be a significant factor. Satellite communications is particularly useful for communications in mountainous or difficult terrain and for mobile applications.

A2.2.6.3 Criteria

a) *Power Consumption*

The ground terminals will require in the region of 10 to 15 watts per receiver and 40 to 60 watts during transmission. Lower power versions with sleep modes may be available.

b) *Availability*

The availability of these links is generally considered to be high.

c) *Integrity*

The integrity of Direct Satellite links is high with automatic checking.

A2.3 Hybrid Systems

A2.3.1 ***Cellular Telephone***

A2.3.1.1 Description of the System

Cellular telephone systems are designed primarily to provide mobile personal voice and data communications. The systems are based on area coverage by means of a number of base stations each covering a portion of the area known as a cell. The cells are connected to the PSTN through Mobile Service Switching Centres and provide national and international coverage. The services provided range from voice communication to ISDN. Cellular telephone systems were originally analogue in nature but digital systems are increasing in number. Line of sight to a base station is generally required with cellular systems.

A2.3.1.2 Application

Cellular telephone systems can be used to provide facilities ranging from basic on/off switching to complete site control and monitoring. The availability for and speed of, data transmissions, on cellular networks may vary from system to system. Coverage, especially to seaward, may not be complete. Although normally used in a discontinuous communications mode, real time communications is possible.

A2.3.1.3 Criteria

a) *Power Consumption*

Early analogue cellular telephone systems have a power requirement in the region of 10-15 watts. This figure has been reduced in later versions. Digital equipment has power requirements of 1 watt or less and is suitable for applications where solar power is involved.

b) *Availability*

The availability of cellular telephone systems is generally very high within the designated coverage areas. Operation near the limit of coverage can be variable and may reduce the availability.

Service providers do not generally warn users of downtime for maintenance, etc.

c) *Integrity*

The integrity of cellular telephone circuits is generally high, as digital services are less susceptible to noise interference and are therefore preferred where available.

A2.3.2 ***Radio Paging***

A2.3.2.1 Description of the System

Radio paging is a one way messaging system. It can be used to transmit a range of signals from a simple "beep" to a data stream. System coverage is variable and not complete.

A2.3.2.2 Application

Radio paging can be used as a one way remote control system. There is no return path and monitoring of the communications system is therefore not available.

A2.3.2.3 Criteria

a) *Power Consumption*

Power consumption is very low as no transmission other than a modem is involved.

b) *Availability*

Availability of the radio paging system is generally high although queuing may occur during busy periods.

c) *Integrity*

This system has no inherent integrity.

A2.3.3 *Satellite Combined with Telephone or Data Line (Inmarsat C)*

A2.3.3.1 Description of the System

Inmarsat C is a two-way store and forward system providing messages and data services of 600 bits/sec using geostationary satellites. Because of the store and forward message format time for message transfer from sender interface to receiving system is typically 10 mins. The system can satisfy all the requirements for remote control and monitoring provided that the absence of real time operation is acceptable. A data reporting service enables small amounts of data to be sent on a signaling channel whilst the polling service enables control or command signals to be sent. The system enjoys worldwide coverage without the need for tracking antennas.

A2.3.3.2 Application

The Inmarsat C and Inmarsat M systems can be used to provide all the requirements of a remote control and monitoring system. Coverage is global apart from the polar region. Care should be taken in designing the telemetry system for the data reporting protocol as call costs can be high.

a) *Power Consumption*

The power consumption of an Inmarsat C terminal in receiving mode is 10-15 watts and this rises to 40-80 watts on transmission. Sleep modes, if available, will reduce the overall power requirement.

b) *Availability*

The availability of Inmarsat C is very high. In general, breaks in the service are scheduled and notified in advance. The service is not very susceptible to noise or interference.

c) *Integrity*

The Integrity of the system is high and checked automatically.

A2.3.4 ***Packet Radio***

A2.3.4.1 Description of the System

Packet radio systems are data only services, which send the data in short bursts, with address information attached, so that the recipient can reassemble the complete messages. Error checking is also incorporated and any packet, which is corrupted or lost, is automatically retransmitted. Services fall into two categories; commercial networks and those based on the radio amateur AX.25 protocol. AX.25 networks have been shown to work on an experimental basis, the equipment is inexpensive and readily available. The protocol allows message forwarding, so that a network can be made to cover large areas, even though transmission in the VHF bands used is restricted to line of sight. A network also allows for alternative routing, increasing the availability.

The commercial networks generally use proprietary protocols and equipment and may operate in VHF or UHF bands. Many telemetry units will interface directly to the radio modem, often referred to as a PAD (Packet Assembler/Disassembler); others may require a protocol converter.

A2.3.4.2 Application

Packet radio networks are highly suitable for telemetry applications, allowing two-way data traffic with high reliability and low power requirement. Coverage is usually restricted to populated areas or those of commercial interest, but may extend 20 nautical miles offshore. Running costs are generally very low, of the same order or even lower than PSTN, depending on the amounts of data transmitted. AX.25 networks would have to be set up by the user, but once the capital costs had been recovered, running costs would be negligible.

A2.3.4.3 Criteria

a) *Power Consumption*

A typical outstation requirement is approximately 2 watts and is therefore suitable for solar powered installations.

b) *Availability*

The availability of commercial packet radio networks is very high with built in detection and retransmission of lost data packets.

c) *Integrity*

The integrity of these systems is generally very high with automatic checking.

A2.3.5 ***Meteor Burst***

A2.3.5.1 Description of the System

Meteor burst communications operate in the 40-50MHz bands and rely on long distance propagation of radio waves by means of refraction and/or reflection from ionised trails in the upper atmosphere. Meteors entering the earth’s atmosphere, at a height of about 96 km (60 miles), ionize the air particles leaving an ionized trail behind them. These trails last from a few milliseconds to several seconds and many are of sufficient density to refract or reflect radio signals. The number of meteors entering the earth’s atmosphere varies diurnally and with the seasons but the number which leave an ionized trail of sufficient density and duration is large enough to provide a reliable data communications link with a range of up to 1200 miles. The signal path varies considerably according to the time of day and season of the year. Data is transmitted in packets each of which requires a 30 millisecond burst. Messages are then reassembled at the receiving end.

A2.3.5.2 Application

Meteor burst communications can be used for remote control and monitoring purposes provided the forwarding delays, which can range from seconds to hours can be tolerated. The system is therefore unsuitable for real time applications. The system can be used in a line of sight mode at distances up to 100 miles and ranges of up to 1,250 miles can be achieved in the meteor burst mode. Networking is available.

A2.3.5.3 Criteria

a) *Power Consumption*

The power requirement is around 280 Watts input to the transmitter for 100 Watts RF delivered to the antenna.

b) *Availability*

Availability is generally high although seasonal variation in noise levels may cause longer delays at certain times of the year. The antenna position can be critical and local electrical noise can also be significant.

c) *Integrity*

The integrity of the system is high and it is unlikely that data will be lost. Integrity is checked automatically.

A2.4 Visual Communications

A2.4.1 Description of System

Visual communications systems are used where a direct view of an AtoN is available. Indicator lights mounted on a structure can be used to signal faults such as standby light on, mains supply failure, racon failed, etc. Periodic visual checking of such indicators constitutes monitoring.

A2.4.2 Application

Visual communications can be used in Direct Monitoring where a person is assigned duty near enough to see the AtoN or indicator lights.

A2.4.3 Criteria

a) *Availability*

The availability of a visual monitoring system depends on the manning level used and can vary from continuous as provided by a Lighthouse Keeper to infrequent as provided by a part-time Attendant.

b) *Integrity*

The conscientiousness of the Keeper/Attendant can be variable.

ANNEX III - BIBLIOGRAPHY

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