IALA GUIDELINE

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REMOTE CONTROL AND MONITORING OF MARINE AIDS TO NAVIGATION

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DOCUMENT REVISION

Revisions to this document are to be noted in the table prior to the issue of a revised document.

Date	Details	Approval
June 2005	Entire document reformatted to reflect IALA document hierarchy.	Council 36
May 2009	Complete review and update. Advances in area of monitoring since original production of document.	Council 45
July 2022	Edition 2.1 Editorial corrections.	

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1. INTRODUCTION

This Guideline on Remote Control and Monitoring has been prepared to assist members when they are considering providing a system for the first time, replacing an existing system or updating a system. The Guideline will enable readers to establish the basic operational decision criteria and performance standards for these systems and provide a knowledgeable basis for equipment selection.

This Guideline is 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.

The first version of this document was developed in 1998 based on a work item from the 1994 IALA Conference and a subsequent 1996 Survey of IALA members on their current and anticipated use of Remote Control and Monitoring Systems (RCMS).

This document has been reviewed in light of the rapid pace of technological changes. Included in this is the widespread use of the Internet and wireless technologies. This has had a significant impact on RCMS systems, reducing costs considerably.

2. MONITORING – GENERAL ISSUES

2.1. MONITORING METHODS

There are a number of ways to monitor a Marine 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. The AtoN failure could contribute to an accident before users can be made aware of the failure.

2.1.2. VISUAL/AUDIBLE MONITORING

2.1.2.1. Observers

These systems can be used where 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 the identification of a failure. Control facilities are not available.

2.1.2.2. Keepers/Attendants

This method keeps the AtoN under either regular or continual observation. The reliability and integrity of the system depend directly on the reliability of the keeper/attendant. This system has the advantage that subject to their technical competence, a keeper or attendant can, in some instances, 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.

2.1.3. REMOTE MONITORING

A remote monitoring system may be used to monitor many different locations or systems from a central location. A variety of different remote monitoring systems exist which can communicate over a combination of diverse communications networks, such as cellular, terrestrial and satellite radio, microwave links, landline telephone, and

Internet. A detailed description of various types of Remote Control and Monitoring Systems is included in section 6.

2.1.4. MOBILE INTERROGATION MONITORING

The AtoN, such as a buoy, may be interrogated occasionally by a passing buoy tender or shore attendant to verify its operation and condition. Limited control capability may be available, for example, changing operational parameters like lux levels of ON/OFF switching.

2.2. CATEGORIES OF PARAMETERS MONITORED

The level of monitoring and the parameters monitored are discussed in section 5 of this document but they can broadly be categorized as:

- AtoN state - Generally the status (e.g., ON or OFF, alarm status, etc.) of the AtoN is monitored. For floating AtoN, the position may also be monitored; and
- Engineering state - Additional parameters are monitored to indicate the health of the AtoN including redundant standby equipment and its supporting systems (e.g., battery voltage in the case of solar systems).

2.3. COMMUNICATION CONSIDERATIONS

2.3.1. INTERFACES AND PROTOCOLS

Many different interfaces and protocols are currently utilized by equipment and systems supplied by different manufacturers. It is beneficial to select equipment and systems utilizing open interfaces and protocols to enable interoperability and interchangeability for remote monitoring and control purposes.

2.3.2. INTEGRITY OF COMMUNICATIONS LINKS

Depending on criticality of the monitored AtoN, it is advisable to perform risk analysis for the communications links used, considering effect of downtime, general development in technology, and level of control (private versus public networks), the necessity of using duplicated (redundant) communication links should be estimated.

A monitoring system should be able to obtain integrity statistics for availability verification of communications links in use. This would assist in management of communications links.

2.3.3. COST EFFECTIVENESS

Cost effectiveness should be analysed, in particular, the lifetime running costs should be modelled for the complete system against predicted availability.

2.3.4. TRANSFER DELAYS

It is advisable to consider typical and worst-case message transfer delays (latency) exhibited by the selected communication link against the operational requirements.

3. OBJECTIVES OF RCMS

3.1. PURPOSE

When considering a remote control and monitoring system it is necessary to identify the purpose and use of the system. Questions that arise include:

- Why monitor?
- What aids and systems should be monitored and at which detail level (system components, number of parameters)?
- What are the monitoring frequency and tolerable transfer delay?
- Are control functions required?
- Which communications system to use?
- How should it be used – user interface requirements?
- Which records should be kept and for how long?

3.2. OPERATIONAL GOALS

The typical operational goal of an AtoN is to provide a requisite availability of service and reduce as much as possible any down time. Availability is proportional to the Mean Time Between Failures (MTBF) and inversely proportional to the Mean Time to Repair (MTTR). The MTBF should be increased and MTTR should be reduced as far as possible.

When planning a passage, the mariner anticipates that the AtoN on their 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 maximum time delay before a navigational failure of an AtoN is detected needs to be defined.

The availability of an AtoN can be maintained by identifying faults which reduce redundancy or in due course, that would directly result in an AtoN failure (if no remedial action is taken). AtoN availability can be affected by both the AtoN system redundancy and by its ancillary equipment, e.g., power supplies. 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 maximized with the provision of RCMS.

3.3. SYSTEM OBJECTIVES

The objectives of RCMS vary depending on the policies of the administration, the type and importance of the AtoN being monitored, and the local conditions. The designer of remote control and monitoring 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 the operator's level of competence.
- Provide controls to the operator consistent with the operator's level of competence.
- Control and monitoring system reliability, availability and cost should be optimized with the systems being monitored.

3.3.1. IDENTIFICATION OF FAILURES (AFFECTING ATON SYSTEM PROVIDER LIABILITY)

- Identify the failure of an AtoN to operate within specifications published for the mariners.
- Notify failure of an 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 an AtoN.
- Confirm third party reports of failures to avoid unnecessary mobilizations.

3.3.2. ATON AVAILABILITY

- Verify operation of an AtoN within specifications.

- Identify faults that are likely to lead to an AtoN failure if no repair action is undertaken.
- Identify faults which reduce redundancy, and which therefore threaten the AtoN.
- Identify 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 the 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.
- As part of conditioned based maintenance, allow remote review of site equipment condition thus assisting in scheduling maintenance visits to maximize MTBF.

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.
- Control and monitoring system costs should be in proportion to the cost and importance of the systems being monitored.
- Reduced maintenance visits through use of remote review of site equipment condition and utilising condition based maintenance techniques to reduce maintenance visits.

4. SELECTION OF AtoN TO BE MONITORED

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 AtoN in the navigation safety infrastructure.

Deciding which AtoN to use an RCMS system on can be simplified by sub dividing the AtoN into different categories. These are generally:

- fixed aids:
- floating aids;
- AtoN on offshore structures;
- AtoN AIS; and
- AtoN on aquaculture sites.

4.1. FIXED AIDS

4.1.1. MAJOR LIGHTHOUSES AND STATIONS

These 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 includes radio beacons, with or without DGPS, and racons should also be monitored. In addition, ancillary equipment such as power supplies, intruder alarms, firefighting and detection equipment should be monitored.

4.1.2. MINOR LIGHTS

These are now relatively easy to remotely monitor. However, the operating authority may elect to monitor all or only the more navigationally important of these AtoN.

4.1.3. SECTOR LIGHTS

Depending on the complexity of the AtoN 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 AtoN 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 radio beacons 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

These may contain AtoN similar to those fitted to lightvessels and should be monitored.

4.2.3. MAJOR BUOYS

Typically fitted with a light, racon and a position tracking system, these AtoN should be considered for remote monitoring.

4.2.4. OTHER NAVIGATIONAL BUOYS

These are now relatively easy to monitor, the operating authority may elect to monitor all or only the more navigationally important of these AtoN.

4.3. ATON ON OFFSHORE STRUCTURES

Offshore structures comprising oil and gas rigs have their AtoN approved by the authority, but are generally monitored by the operator of the structure where the structure is manned. Where the structure is not manned all AtoN signals should be monitored. Wind farms and wave generators also belong to offshore structures.

4.4. AtoN AIS

Where AtoN AIS is installed its basic function can, in part, be checked by a normal RCMS system via equipment self-test facilities. However, it is preferable to monitor the actual signal in space by the use of an AIS Base Station Network and appropriate analysis software. Where such Base Station Network monitoring is in place, AIS can be used to monitor other AtoN equipment and support systems at the location without the need for an independent RCMS system.

4.5. AtoN ON AQUACULTURE SITES

While there is presently not much information available on AtoN at aquaculture sites being remotely monitored, such sites are expected to be monitored by the operator.

5. RCMS SIGNALS AND COMMANDS

5.1. INTRODUCTION

An RCMS system can connect from one up to several hundred RTUs (Remote Terminal Units) to a central monitoring site. An RTU provides a means of transmitting and receiving data between the central monitoring site and AtoN equipment and ancillary equipment.

An RTU should be capable of retransmitting any signal received from connected equipment to a central monitoring site for display. The central monitoring site should be capable of sending commands to the RTU or any equipment connected to the RTU.

5.2. PRIORITIES

An RCMS system can send and receive many different types of signals and commands. When dealing with large quantities of RCMS data, it is important to prioritize incoming data, so that important events are flagged for attention. RCMS data can be divided into the following five main categories:

1 Status signals

A status signal is used to indicate an event at an AtoN that is part of the normal operation of the AtoN. A status signal generally takes the form of a “ON” or “OFF” indication.

2 Condition signals

A condition signal is used to indicate the failure or impending failure of a piece of equipment at an AtoN. A condition signal normally takes the form of a “NORMAL” or “FAIL” indication. A condition signal should remain active or alarming on the central monitoring system until it is cleared at the remote side. There may also be a number of different RCMS alarm levels provided for, ranging from “Normal Alarm” to “Critical Alarm”.

3 Analogue signals

An analogue signal gives a value for a parameter at an AtoN, this can be a voltage, current or temperature for example. The Analogue signals can be measured and digitized by the RTU or ancillary equipment and transmitted to the monitoring centre for processing.

Limits can be placed on the analogue value so that an alarm is generated if a certain threshold is exceeded. This can be used, for example, if a power supply voltage level goes outside its defined boundaries.

4 Digital data

Digital data may be captured from site equipment for local processing, or for direct transmission to the monitoring centre. Alarms can be generated if a certain threshold is exceeded. For example, if a floating aids position received from a GPS receiver indicates drifting outside AtoN defined area.

5 Control signals

Control signals are used to control equipment at an AtoN. The control signal can originate from an operator at the central monitoring site or can be programmed into the RTU. The control signal traditionally takes the form of a closing pair of volt free contacts. An "ON" command is sent when the contacts close and an "OFF" when they open. Digital control signals (commands) transmitted over local area network interfaces can be utilized by modern equipment.

5.3. MARINE AIDS TO NAVIGATION (AtoN)

Today's mariner has an extensive array of AtoN to assist his safe passage, ranging from buoys (lit or unlit), LANBY, lightvessels, beacons (lit or unlit) and lighthouses. Each may have a variety of AtoN and hence control and monitoring requirements.

Because of the wide variety of signals available at an AtoN, it is best to select only the most significant signals for connection to the RTU. By selecting the most significant signals, an attempt is made to ensure the monitoring officer is not flooded with unnecessary indications.

For each piece of equipment at an AtoN there is usually a standard set of standard signals available, these are now listed below.

5.3.1. NAVIGATION LIGHT

A typical navigation light system consists of a main light, a standby light and an emergency light. There may also be an optic drive for rotating the optic lens.

Table 1 Navigation light signals & commands

PARAMETER	OPTIONS	SIGNAL
Main Light	On / Off	Status
Standby Light	On /Off	Status
Main Light	Normal / Fail	Condition
Standby Light	Normal / Fail	Condition
Nav Light	On / Off	Status
Nav Light	Normal / Fail	Condition
Emergency Light	On / Off	Status
Emergency Light	Normal / Fail	Condition
Penultimate Lamp	Yes / No	Condition
Optic Drive A	On / Off	Status
Optic Drive B	On / Off	Status
Optic Drive A (speed/character)	Normal / Fail	Condition
Optic Drive B (speed/character)	Normal / Fail	Condition
Light Sensor Based Switching Level	On / Off	Status
Navigation Light Control	On / Off	Control
Emergency Light	On / Off	Control
Navigation Light Reset	Reset	Control

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 the emergency light to illuminate. This in turn should cause a "nav light fail" signal to be transmitted.

To enhance the capability for interoperability within RCMS from different suppliers, the following two-bit minimum logic level interface specification inspired by IALA Recommendation *R0126* is proposed for smart lanterns.

Table 2 Smart lantern signals

Nr	Name	Signal Level	Meaning of the Signal	Comment
1	Lantern ON	1	The lantern is producing a light signal (ON)	Typical night time status
		0	The lantern is not producing a light signal (OFF)	Typical day time status
2	No Failure	1	The lantern is operating in accordance with manufacturer's specification	Normal mode condition
		0	The lantern is in failure condition; in case that the Lantern ON signal is high, the output is either degraded or exhibiting a wrong flashing character	Failure mode condition

The above interface is actually provided by a lantern's flasher; therefore, it would be advisable to furnish flasher units with the interfaces above.

5.3.2. RACON

Table 3 RACON signals & commands

PARAMETER	OPTIONS	SIGNAL
Racon	On / Off	Status
Racon	Normal / Fail	Condition
Racon Reset to Normal	Reset	Control
Racon Position	On / Off Station	Condition
Racon Change Code	Normal / Morse D	Control

5.3.3. ATON AIS

Table 4 AtoN AIS signals

PARAMETER	OPTIONS	SIGNAL
AtoN AIS	On / Off	Status
AtoN AIS Self-test	Normal / Fail	Condition
AtoN AIS Message Data Stream	Normal / Fail	Condition

It is preferable to monitor the actual signal broadcasted by an AtoN AIS by the use of an AIS Base Station Network and appropriate analysis software. Nevertheless, it is possible to monitor AtoN AIS by RCMS provided that a local RTU connected to the AtoN AIS unit directly via digital (discrete and serial) interfaces is installed at the AtoN site.

5.3.4. DIFFERENTIAL GLOBAL POSITIONING SYSTEM (DGPS)

Some stations may have a DGPS system installed for the transmission of DGPS correction messages.

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

Table 5 DGPS signals

PARAMETER	OPTIONS	SIGNAL
Correction Age	On / Off	Condition & Analog
Message Error Ratio	On / Off	Condition & Analog
Beacon SNR.	On / Off	Condition & Analog
Beacon SS	On / Off	Condition & Analog
Numbers of SV's	On / Off	Condition & Analog
Horizontal DOP	On / Off	Condition & Analog
Position Error	On / Off	Condition & Analog
PR Residual	On / Off	Condition & Analog
PR Residual	On / Off	Condition & Analog
Low UDRE	On / Off	Condition & Analog

Notes:

SNR: Signal to Noise Ratio

SS: Signal Strength

SV: Space Vehicle

DOP: Dilution of Position

PR: Pseudo Range

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 system and possibly a diesel generator.

A remotely located or offshore station however is unlikely to have an AC mains supply and may derive its power from a diesel generator or a renewable energy source such as solar, wind or wave, or a combination of the above sources working in a hybrid system. The energy from these devices can be stored using batteries.

Various combinations of power sources are used, and three examples of typical system configurations are described below:

- Mains with a mains failure diesel generator set
- Mains with a battery backup system
- Renewable (solar, wind) battery charging system

5.4.1. MAINS WITH A MAINS FAILURE DIESEL GENERATOR SET

Table 6 Mains, with a mains failure diesel generator set, signals & commands

PARAMETER	OPTIONS	SIGNAL
Mains Supply	On / Fail	Condition
Generator	On & Off	Status
Generator	Normal / Fail	Condition
Fuel Level	Normal / Low	Condition
Engine Fail to Start	Normal / Fail	Condition
Alternator Voltage	Normal/ Low or High	Condition
Engine Temperature	Normal / High	Condition
Engine Oil Pressure	Normal / Low	Condition
Engine Speed	Normal / High	Condition
Starter Battery Charger	Normal / Fail	Condition
Alternator Current	Current in Amps	Analogue
Generator Reset to Normal	Reset	Control
Generator Control	Start / Stop	Control

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

5.4.2. MAINS WITH A BATTERY BACKUP SYSTEM

Table 7 Mains with a battery backup system signals

PARAMETER	OPTIONS	SIGNAL
Mains Supply	On / Fail	Condition
Battery Charger	Normal / Fail	Condition
Battery voltage	Normal / High	Condition
Battery Voltage	Normal / Low	Condition
Battery Voltage (no load)	Volts	Analogue
Battery Voltage (under load)	Volts	Analogue
Battery Compartment Temperature	Degrees	Analogue

Where a charger alarm is not available, an alternative is to monitor when the battery voltage drops below the float voltage. A high battery voltage alarm should be set below the voltage at which the AtoN may be damaged. Conditions permitting, it is advisable to perform battery voltage measurements both under load conditions (in flash) and during no load conditions (during eclipse) to obtain information on battery health.

5.4.3. Renewable (solar, wind) battery charging system

Table 8 Renewable (solar powered) battery charging system signals

PARAMETER	OPTIONS	SIGNAL
Regulator Condition	Normal / Fail	Condition
Battery Voltage	Normal / High	Condition
Battery Charging Current	Amps	Analogue
Battery Voltage (under load)	Volts	Analogue
Battery Compartment Temperature	Degrees	Analogue

5.5. ANCILLARY SYSTEMS AND SENSORS

Table 9 Ancillary systems and sensors signals & commands

PARAMETER	OPTIONS	SIGNAL
Discrete Parameters	ON / OFF	Condition
Analogue Parameters	Amps	Analogue
Digital Input	Byte Stream	Byte Stream
Activation Commands	Discrete, Analogue, or Byte Stream	Control

Ancillary site equipment, sensors and systems may be interfaced to RTUs using analogue or digital inputs and outputs as required. For example, fire alarm and security systems, measurement apparatus, tidal height gauges, motion sensors, etc.

6. OUTSTATION EQUIPMENT

6.1. INTRODUCTION

This section discusses the various types of control and monitoring 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 control and monitoring facilities will be directly dependent on the methods used, as discussed in section 2.1. These range from direct monitoring by the user to a fully automated AtoN where the systems are monitored and controlled remotely by a centralized base station.

The choice of method will largely be dictated by the operational requirements, 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 AtoN. Whilst 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.

RCMS 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 as to which type of system is best suited for a particular application and circumstance. For electronic systems open architecture formats should be selected to ensure that there is the maximum level of component interchangeability over the system lifecycle.

6.2.1. DESIGN PHILOSOPHY

Simplicity is often the best policy, particularly where technical expertise is limited. Properly 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 minimizing the design and commissioning effort of subsequent modifications.

6.2.2. INPUT / OUTPUT (I/O) SEGREGATION

It is good practice to segregate control and monitoring 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 advisable to regularly test I/O at an AtoN to confirm that an RCMS command has had the desired result.

6.2.3. ENERGY CONSUMPTION

A further consideration is the energy consumption of the outstation. The RTU power requirements should be considered when there is a limited supply of power e.g., solar powered AtoN.

The power consumption of microelectronics 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 RCMS 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 central monitoring site when an alarm occurs, requiring intervention by monitoring staff. In case of mission critical sites, it may be advisable to send status messages at regular intervals to confirm operational availability of the remote site.

It is advisable to pay attention to RCMS behaviour during power failures and in critical backup power conditions (restarts due to battery depletion, etc.).

6.2.4. MICROPROCESSOR SYSTEMS

Most modern control and monitoring systems contain some form of a Microcontroller. This can range from a small 8 bit controller to a large 64 bit processor.

Over the years, due to advances in technology, the distinction between PLC's (Programmable Logic Controller) and RTU's (Remote Terminal Unit) has blurred; PLC's are now capable of the control and transmission of data from remote site.

Whichever system is employed, it is likely that failures will occur. It is therefore important that the effects of these failures are minimized 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 energized condition may have a significant effect on the energy requirement of the power systems employed.

6.2.5. COMMUNICATIONS

Control and Status information may be delivered across an RCMS network in a variety of ways. The communications medium chosen will depend on the data speeds and volumes of the RCMS system and its distance from a main communications network. Some of the methods of communication between an RTU and a central monitoring site include:

- Continuous communications;

  Where there is a constant connection between an RTU and the central monitoring site.

  Either the RTU or the central monitoring site can initiate data transfer e.g., Ethernet, Leased line, Microwave links.

- Polling discontinuous communications;

  The central monitoring site initiates communications to an RTU on a predefined schedule or as required by an operator.

- Systematic (clock and calendar based) discontinuous communications;

  The RTU initiates communications to the base station on a predefined schedule.

- Exception reporting discontinuous communications;

  An exception can be generated by an RTU in response to a change in state of connected equipment. A periodic exception can also be programmed into an RTU (e.g., 2 hours after sunrise and sunset).

- A combination of two or more of the above

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 annunciation 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 CONTROL AND MONITORING

Over the years, remote monitoring has developed from dedicated hardware solutions utilising relays and simple indicator lamps, through to re-programmable microcontroller based equipment.

As all modern systems are invariably microcontroller based, the earlier systems are not discussed further in this Guideline. The key systems discussed are:

- Supervisory Control and Data Acquisition system (SCADA)
- Automatic identification System (AIS)
- Mobile interrogation systems

6.4.1. SCADA SYSTEMS

Modern (SCADA) systems allow the integration of multiple data streams from PLCs, RTU's and other devices. The information from these devices can be stored or displayed locally or at a remote central monitoring site.

Sophisticated computer graphics packages are available which enable information to be displayed to suit individual user requirements. By simplifying the displayed information using appropriate screen design for the user interface 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.

Most modern SCADA applications can now interpret Object Linking and Embedding for Process Control (OPC) data. This means that an OPC enabled application can now connect multiple OPC compatible systems. This can be used where an AIS system can send and receive data from a SCADA system and vice versa, reducing the number of user interfaces required.

Over the years SCADA communication protocols have evolved. Starting at the basic Modbus and proprietary protocols up to the modern IP based protocols such *DNP-3* and *IEC60870-5*. This has meant a move away from vendor specific protocols to more open source protocols, meaning a greater compatibility between SCADA software and hardware.

6.4.1.1. PLC acquisition and control system

Programmable Logic Controllers, PLCs usually comprise several programmable modules in a rack-mounted enclosure. The modules are connected to a Central Processing Unit (CPU) module. The CPU coordinates the data transfer to and from the various modules.

The CPU module is software programmable, so various control algorithms can be developed. All the programmable information is usually stored in non-volatile memory on the CPU module.

Most modern PLCs also contain a communications module for connection to a SCADA system. The communication module transmits and receives data from the central monitoring site or another PLC.

6.4.1.2. RTU data acquisition and control system

Over the years the distinction between RTUs and PLCs has blurred. Most modern RTU also allow for the development of control algorithms, just as most modern PLCs can accommodate a communications module.

An RTU generally comprises a CPU and a number of I/O cards. The CPU transmits and receives information between its I/O cards and the central monitoring site. An RTU can have a smaller form and a lower power requirement when compared to a PLC.

An RTU can have a permanent connection to a central monitoring site or have a discontinuous link, such as PSTN or GSM. An RTU should enter a low powered sleep mode while waiting for a change in state of an I/O signal.

6.4.2. AUTOMATIC IDENTIFICATION SYSTEM (AIS)

When used on an AtoN, AIS can provide basic information on the functionality of the AtoN to the mariner. The AIS system installed on an AtoN can transmit a variety of different AIS message types, no control messages are provided.

- Message type 21 is the primary AtoN information message;

  This message provides details of the identity, position and status of the AtoN and will warn the mariner if any of the AtoN functions are not performing correctly. A set of 8 bits is available for transmitting light status and condition information.

- Message type 6 can be used to transmit additional status information from the AtoN;

  This can include battery voltage, racon status and position status.

- Message 8 can be used to transmit meteorological and hydrological data.

  Sensors on the AtoN, or in the immediate area, provide this data to the AIS AtoN Station, or a local Base Station, to be broadcast in the internationally agreed Message 8 format.

A network of AIS remote base stations can provide a means of monitoring the integrity of transmitted AIS messages. The remote base stations can forward their information to a central monitoring site for storage and display. Refer to IALA Recommendation *R0126* for details of AtoN AIS operation.

6.4.3. 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 transceiver, installed on an AtoN, can be interrogated by a hand-held interrogator to report parameters such as lamp changer 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. GENERAL

This section summarizes 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.

7.2. PLANNING

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. ENERGY CONSUMPTION

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

7.4. TYPES OF COMMUNICATIONS LINKS

There are essentially five main types of communications link:

- Public and private networks
- Radio links
- Cellular telephone systems
- Satellite communication systems
- Visual

7.4.1. PUBLIC AND PRIVATE NETWORKS

Public and private Networks include PSTN, Ethernet, Internet, owned or non-leased private circuits and ISDN.

7.4.2. RADIO LINKS

Radio links are generally available utilising Medium Frequency (MF), High Frequency (HF), Very High Frequency (VHF) (e.g., AIS), Ultra High Frequency (UHF) and microwave frequencies. Direct satellite links are an application of microwave links.

7.4.3. CELLULAR TELEPHONE SYSTEMS

Cellular communications can be broken down into the following generations or standards: 2G (GSM, GPRS, EDGE), 3G (CDMA, HSDPA), 4G (WiMax).

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.

7.4.4. SATELLITE COMMUNICATIONS SYSTEMS

A number of operators offer services for data transmission via satellites that can be used to provide all the requirements of a remote control and monitoring system. The cost of data transfer has come down significantly in recent years, making it a more feasible communications option.

7.4.5. 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 control and monitoring 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, whether it be 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); and
- online webpages.

8.2.1. VISUAL INDICATOR

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

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

8.2.2. ANNUNCIATOR PANELS

Annunciator panels provide visual and / or audible indications; 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. A typical VDU is a computer display connected to a RCMS base station computer.

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.

Most authorities use VDUs for controlling and monitoring their AtoN network. For such larger systems as they evolve and are extended there may be a number of monitoring methods and equipment being used. In such instances it is important to ensure that the user interface merges the various inputs in a coherent manner to allow the system as a whole to operate efficiently.

8.2.4. ONLINE WEBPAGES

Online webpages can be considered as a subcategory of VDUs for provision of convenient thin client (web browser) based multiuser remote access over standard computer networks (Internet) to an RCMS base station server (processor). Web technologies of various degrees of complexity can be utilized depending on application requirements. Limitations and disadvantages of such technologies should be considered prior to system acquisition.

8.3. DATA STORAGE

The type of data storage facilities required depends 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; and
- 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 flash drives, hard drive (magnetic), optical discs (CD, DVD) and magnetic tapes, 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.

Where electronic storage is adopted there are significant benefits to be gained from recording key systems data over time to allow review of trends in assisting in identifying operational problems that may in time lead to an AtoN failure. The trending of battery system voltage is especially beneficial for solar stations.

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 to computer equipment 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 the manager 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 control and monitoring functions.

Access can be restricted by the use of passwords.

9. INTEGRATION WITH OTHER SYSTEMS

Remote control and monitoring systems present the opportunity for integration with other systems and business processes to have access to AtoN status information.

Some examples where authorities have already begun this integration with systems include:

- repair and maintenance;
- navigation warnings;
- Vessel Traffic Services (VTS);
- route planning system; and
- AIS Base Station Networks.

9.1. MAINTENANCE SYSTEMS

The RCMS 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. It is likely that different users will require visibility of different types of information, and control access right requirements will not be uniform for all users.

Remote access to the RCMS equipment for maintenance staff provides significant benefits in the review of data immediately before attending site for a failure or planned maintenance. Keeping serial number based inventory and configuration change records for outstation equipment is a useful feature of computerized RCMS.

9.2. NAVIGATION WARNINGS AND VTS

Outputs from the RCMS 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. With the exception of synthetic AtoN AIS applications, it is not best practice for such broadcasts to be fully automated and there should be a human review of all the relevant circumstances before taking notification action. 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 RCMS 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.

9.4. AIS BASE STATION NETWORKS

Such networks with appropriate coverage and data processing software can monitor the status of AIS fitted AtoN. The AIS information can be merged with the authorities RCMS information using, for example, an OPC data link.

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. Due to the nature of its manufacture field repair is not usually practicable and repair by replacement policies are normally adopted.

10.2. OUTSTATION EQUIPMENT

The system at the outstation can comprise the following equipment:

- central processor containing circuitry that assembles parallel input data from the on-site plant, e.g., lights, radio beacons, racons, power supplies etc. into a serial digital signal format;

- equipment sensors and controllers to and from the onsite plant;
- signal processing unit for connection to the communications means;
- a communication means (VHF, GSM, CDMA, satellite, etc.);
- transmitter/receiver aerial; and
- power supply.

The equipment mentioned above can be designed to operate with extended maintenance intervals (12 months or more). Maintenance visits should be carried out by suitably trained staff provided with adequate test equipment and documentation. A 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 communications link(s); and
- other items specified by the manufacturer.

10.3. BASE STATION EQUIPMENT

The equipment at the base station can comprise the following equipment:

- all equipment mentioned in section 0;
- display and keyboard units;
- data storage units;
- recording equipment;
- alarm units; and
- power supplies with uninterruptible power supply (UPS) backup.

As with the outstation the base station equipment can be designed to operate with an annual or greater period between planned maintenance and would include the items listed above.

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; and
- 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; and
- 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 monitoring equipment, for example:

- Duplication of equipment to provide redundancy
- Modular replacement
- Who repairs module and turnaround time
- In-house / third party / supplier maintenance and repair
- Maintenance agreement
- Software changes and upgrades, configuration management
- Remote diagnostics

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 operational purposes. Sufficient copies will be required for the base, outstations and maintenance personnel.

The documentation should include the following:

- functional description;
- technical specifications;
- layout diagrams;
- circuit drawing;
- assembly drawings;
- wiring diagrams;
- installation drawings;
- configuration software and corresponding user manuals;
- operating and functional procedures;

* repair procedures;
* test procedures;
* test sheets;
* acceptance procedures; and
* 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 control and monitoring 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; and
* 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 control and monitoring 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 control and monitoring system is acquired, the purchaser and supplier will usually define a "working life" for the system, at time of purchase.

As more AtoN are fitted with AtoN AIS it is likely that many authorities will monitor these via AIS if they have access to a base station network with appropriate coverage and data processing.

12.2. DEVELOPMENTS

It is anticipated that development will take place in the field of remote control and monitoring, 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 control and monitoring systems where previously power supply restrictions prevented their use, e.g., photovoltaic solar powered stations, buoys.

12.2.2. Interface and protocol standardization

The introduction of combined navigation equipment and control and monitoring equipment will require authorities to agree to common interface and protocol standards on three levels:

- lantern / RTU hardware/software interface;
- RTU / RCMS communications protocol; and
- RCMS to RCMS data exchange protocol.

As first step, a simple logic level lantern / RTU interface is proposed in section 5.3.1 while a serial information exchange protocol remains to be selected and agreed upon.

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 and updated worldwide radio navigation 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 necessitates high integrity RCMS systems. This may imply an availability requirement for RCMS exceeding that of the AtoN.

12.2.5. Costs

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

13. DEFINITIONS

The definitions of terms used in this Guideline can be found in the *International Dictionary of Marine Aids to Navigation* (IALA Dictionary) and were checked as correct at the time of going to print. Where conflict arises, the IALA Dictionary should be considered as the authoritative source of definitions used in IALA documents.

14. ABBREVIATIONS

AC	Alternating Current
AIS	Automatic Identification System
AtoN	Marine Aid(s) to Navigation
CD	Compact Disc
CDMA	Code division multiple access
CPU	Central Processing Unit
DGPS	Differential Global Positioning System
DNP	Distributed Network Protocol

DOP	Dilution of Position
DVD	Digital Versatile Disc / Digital Video Disc
EDGE	Enhanced Data for GSM Evolution
GMPCS	Global Mobile Personal Communications by Satellite
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications (originally Groupe Spécial Mobile)
HF	High frequency (3 – 30 MHz)
hr	hour(s)
HSDPA	High Speed Downlink Packet Access
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities - AISM
IEC	International Electrotechnical Commission
IP	Internet Protocol
ITU	International Telecommunication Union
I/O	Input / Output
LANBY	Large Automatic Navigation BuoY
MF	Medium Frequency (300 kHz to 3 MHz)
MTBF	Mean Time Between Failures
MTTR	Mean Time to Repair
OPC	Object Linking and Embedding for Process Control
PLC	Programmable Logic Controller
PR	Pseudorange
PSTN	Public Switched Telephone Network
PTT	Postal Telephone and Telegraph
RACON	RADar beaCON (Radar transponder beacon)
RCMS	Remote Control and Monitoring System(s)
RTU	Remote Terminal Units
SCADA	Supervisory Control and Data Acquisition
SNR	Signal to Noise Ratio
SS	Signal Strength
SV	Space Vehicle
UHF	Ultra High Frequency (300 MHz and 3 GHz)
UPS	Uninterruptible Power Supply
VDU	Visual Display Unit
VHF	Very High Frequency (30 MHz to 300 MHz)
VTS	Vessel Traffic Services
W	watt
WiMax	Worldwide Interoperability for Microwave Access
2G	2nd Generation (of mobile telecommunications technology)
3G	3rd Generation (of mobile telecommunications technology)
4G	4th Generation (of mobile telecommunications technology)