Safe and Efficient Use of an Uncrewed Surface Vessel (USV)

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1 Foreword

This guidance has been produced by IMCA (the International Marine Contractors Association) to provide a pertinent reference document for the safe and efficient offshore operation of Uncrewed Surface Vessels (USVs) and the relevant support systems. This document represents the initial guidance for this new, and rapidly developing, technology.

Designed for use by both contractors and clients, the guidance purposely avoids subjects of minority interest. It contains guidelines and recommendations that, when combined with manufacturers' instructions and companies' operational procedures/processes, allow for the maintenance of a high level of safety and efficiency across the sector. However, it does not attempt to replace the need for contractors to maintain comprehensive operations manuals, maintenance manuals, policies, and procedures.

This guidance is intended to apply internationally, but it is recognised that some countries will have regulations that require different standards or practices to be followed. Where local or national regulations are more stringent than those contained herein, they will always take precedence over this guidance.

IMCA anticipates that adoption of this document and adherence to the guidance contained within it will contribute to a safe and efficient industry that operates to common standards.

This guidance is a dynamic document and the advice given in it will change with the development of the industry. It is intended that this document be reviewed on a regular basis and any necessary improvements made. Any person with suggested improvements is invited to forward these to IMCA (e-mail imca@imca-int.com) for consideration by the appropriate technical committee.

This document is intended to be specifically applicable to Uncrewed Surface Vessels (USVs) and is not intended for wider Marine Autonomous Surface Ship (MASS) systems.

MASS is a classification of vessels which can range from crewed, but with high levels of automated systems through to uncrewed, fully autonomous vessels which have onboard independent decision-making equipment.

USVs are sub classification of MASS, identified by IMO as Degree 3, which have no crew onboard but are controlled, and monitored remotely from another location.

2 Introduction

The use of Uncrewed Surface Vessels (USV), to perform surveys or inspections have been steadily maturing over the past few years. With limited regulation for USVs, the IMCA USV committee have formed a working group to create a guidance document to establish best practice for the safe and efficient use of USVs in energy fields.

2.1 MASS/USV Vessel Classification

The IMO Maritime Safety Committee (MSC) during MSC 100 in December 2018 defined 4 degrees of MASS vessel autonomy:

- **Degree one**: Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.
- **Degree two**: Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.
- **Degree three**: Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.
- **Degree four**: Fully autonomous ship: The operating system of the ship can make decisions and determine actions by itself.

This document is concerned primarily with Degree 3 vessels. However, Degree 4 vessels may be included within future revisions as the industry grows.

3 Glossary of Terms

3.1 Abbreviations and Acronyms

ASOG	Activity Specific Operating Guideline
AUV	Autonomous Underwater Vehicle
COLREG	International Regulations for Preventing Collisions at Sea
CRS	Coordinate Reference System
CSO	Company Security Officer
FLIR	Forward Looking Infrared (camera)
FMEA	Failure Modes and Effects Analysis
IMCA	International Marine Contractors Association
IMDG Code	International Maritime Dangerous Goods Code
IMO	International Maritime Organization
IOGP	International Association of Oil & Gas Producers
IT	Information Technology
JNCC	Joint Nature Conservation Committee
LARS	Launch and Recovery System
LNG	Liquid Natural Gas
LoS	Line of Sight
LPG	Liquid Petroleum Gas
MASRWG	Maritime Autonomous Systems Regulatory Working Group
MASS	Maritime Autonomous Surface Ships
MBES	Multi Beam Echosounder
MMS	Maintenance Management System
MSR	Malton Salt Reactor (Nuclear)
OT	Operational Technology
OtH	Over the Horizon
RCC	Remote Control Centre
RCSV	Remote Controlled Surface Vessel
ROs	Recognised Organisations
ROV	Remotely Operated Vehicle
S&ORA	Safety and Operational Risk Assurance
SBP	Sub Bottom Profiler (Echosounder)
SIMOPs	Simultaneous Operations
SOLAS	Safety of Life at Sea
SSS	Side Scan Sonar
STCW	Standards of Training, Certification and Watchkeeping for Seafarers
UAV	Unmanned Aerial Vehicle (Drone)
UNCLOS	United Nations Convention on the Law of the Sea
USV	Uncrewed Surface Vessels
USVOPEP	USV Oil Pollution Emergency Plan

4 USV

4.1 Tasks

USV systems have the potential to provide a full scope of services as currently provided by crewed vessels. The ability to undertake tasks as outlined below may require specific sensor configurations, integration of towed systems, or the use of secondary systems (UAVs, AUVs ROVs).

4.1.1 Hydrographic Operations

Hydrographic operations or geophysical surveys combine navigational, geodetic, (sea)water properties and underwater measurement data to define the nature and topography of the seabed and below the seabed relative to per determined datums, both horizontal and vertical. Application may include, but are not limited to: maritime navigation, marine construction, dredging, hydrocarbon exploration/ drilling, the offshore renewables industry.

The use of acoustic hydrographic sensors such as MBES, SSS and SBP may require oversight from a Marine Mammals perspective. Such sensors have no 'soft start' capability and as such are either 'on' or 'off'.

4.1.2 Bathymetric Operation

Currently the most commonly used USV task, i.e. the measurement of the water depth at a given area with a predetermined accuracy and precision and the associated production of bathymetric (or hydrographic) charts.

4.1.3 ROV/AUV Support Operations

A USV may be equipped with an AUV or ROV system, or a hybrid version employing smart umbilical technology (underwater connect / disconnect providing towage, power, and communications).

AUV Operations

AUV operations may focus primarily on hydrographic operations employing a suite of sensors such as Multibeam Echosounder (MBES), Side Scan Sonar (SSS) and Sub Bottom Profilers (SBP).

ROV Operations

ROV operations will involve inspection, observation, and light intervention roles.

4.1.4 Unmanned Aerial Vehicles Support Operations

Unmanned Aerial Vehicles (UAV) may be used to provide a rapid inspection of surface assets, parts of which may otherwise be difficult to access, to determine whether further, more robust inspection or maintenance, is required.

UAVs may also be used to transfer smaller stores items and medication, between vessels and platforms.

Potentially aerial vehicles may be used to increase local communication ranges to over the horizon.

4.1.5 Seabed Drilling Operations

USVs may be used to deploy self-powered mobile seabed drilling units for seabed sampling. Cone tip resistance and friction measurements may be obtained to determine type and strength of seabed and lower layers.

4.1.6 Environmental Monitoring

USVs offer an opportunity to gather environmental data constantly whilst operating. Parameters such as salinity, temperature, depth, contaminants, noise, oxygen, and nitrogen levels can be gathered. Marine mammal information could also be monitored.

4.1.7 Inspection and Intervention Operations

Similar to the bathymetry operations but now with additional sensors to detect the object that requires inspection. This could include the deployment of sub-bottom profiler or towed equipment like a side scan sonar or magnetometer.

4.2 USV Tools

In order for USVs to be effectively used for various operations, attention must be paid to the various tools, equipment and systems on board that facilitate safe and proper use.

All USVs are equipped with systems and tools, each of which fits into one of the following three areas:

1) navigation equipment for basic operation as a vessel (see section on USV Operations)
2) communications equipment (see section on Communications/RCC)
3) survey equipment:
    a) vessel-mounted
    b) passive deployed
    c) active deployed.

As industry use of USVs now encompass a wide range of vessels, ships, and craft, each of them may exhibit varying degrees of the above; from the most basic having only simple navigation hardware to the most complex being equipped with a large number of different systems and tools.

4.2.1 Survey Equipment

Vessel-mounted

The most common type of sensor equipment mobilised on USVs are vessel-mounted sensors. These can include inertial navigation systems, doppler velocity logs, acoustic current doppler profilers, ultra-short baseline positioning transponders, single-beam and multibeam echosounders, fixed-head sub-bottom profilers and fixed side scan sonar transducers. These are traditionally mounted on the hull of the vessel, or in a

subsea gondola, but can also be attached to fixed or articulated pole-mounting systems.

By definition, these are fixed sensors that do not usually require additional consideration for deployment, operation, or recovery – they are most commonly permanently mobilised and can be instructed to acquire data with no physical intervention or deployment required on the USV.

As such, except for their effect on the available communications bandwidth and robustness, it is anticipated that these sensors do not require additional focus for use on USVs above what would be considered when operating the sensors from conventional vessels.

Passive deployed

Larger and more capable USVs can often be mobilised with towed sensors for temporary deployment into the water. These are designed either to operate on the surface with positive buoyancy, at depth within the water column at a range of altitudes above the seabed, exhibiting negative buoyancy and requiring forward motion to remain active, or in a more neutral environment exhibiting neutral buoyancy.

Equipment such as side scan sonar towfish, magnetometer towfish and UXO survey equipment, towed surface or deep-tow sub-bottom profiling systems, seismic sources and seismic streamers can be deployed using remote control deployment mechanism such as bespoke LARS, A-frames, moonpools and winches.

These sensors are towed behind or underneath the vessel, and the position, altitude and speed is controlled by the vessel, LARS and winch setup used, and therefore require additional focus when being operated from a USV. Consideration should be given to the positioning of these towed systems, both on the surface and in the water column, and ensuring that adequate positional information is fed back in near-real time to the vessel operators or supervisors. This is especially important when working near fixed structures, or in shallow waters.

In addition, near-real time ability to control the winch, LARS or deployment mechanism is critical in providing a safe survey setup from a USV, and the communications setup on board should be robust enough to provide this. Those USVs with higher levels of autonomy, and those without 1-to-1 supervision by both mariners and survey crew, will need to exhibit automated behaviour and control over any towed equipment in the event of a critical situation.

Active deployed

The most advanced USVs have the ability to deploy and support vehicles for subsea survey. Deployment of AUVs, HAUVs, ROVs, ROTVs and UAVs can be deployed to support a range of survey, inspection, and intervention tasks. These vehicles can operate both whilst tethered to the USV and while operating as a standalone vehicle.

These vehicles generally operate under their own power and control, with a tethered link to the USV providing data communication in some cases.

For vehicles with a permanent tether providing data and control links to the USV, near-real time communication will likely be maintained, in order to provide

supervision, command and/or control updates, and to monitor progress of subsea operations. The on-board communications setup should be robust enough to handle high bandwidth demands, as well as providing redundancy in the event of failure to ensure vehicles can be recovered if necessary.

Tethered vehicle operations are most likely to be carried out whilst using vessel dynamic positioning, and therefore it is crucial to link all systems on board to ensure automated or remote-control systems are suitable for uncrewed operation of both a vessel and vehicle simultaneously.

In those cases where vehicles are untethered, operating autonomously or with limited communication, the USV can be equipped to track and monitor progress via visual or acoustic means. Attention should be paid to LARS procedure, ensuring that both operational capability and communications setups allow for recovery of untethered vehicles in the event of partial failures.

4.3 Environmental Considerations

4.3.1 Weather

Weather tolerance for uncrewed vessels will vary depending on the USV itself, but also the task being carried out.

Different USVs have dramatically different weather monitoring and observational setups on board, and therefore each operator should have robust procedures for monitoring environmental conditions and conducting safe mission planning.

In addition, monitoring of weather conditions in near-real time whilst offshore is important to ensure safe operations, transits and if required, equipment deployment or recovery.

Sea State and Swell

As with all offshore operations, sea state and swell heights affect different vessels in different ways. It should be left to the vessel owner and operator to provide operational limits for different tasks. Generally, when conducting data acquisition, data quality degrades before there is any risk or danger to vessel seaworthiness.

However, additional consideration should be given to operations with deployed vehicles or equipment. In particular, the length of time taken to safely recover and stow deployed sensors in the event of degrading weather conditions. With no offshore personnel, emergency response procedures should be in place to ensure safety in the event of rapidly deteriorating weather conditions.

Currents

As above, vessel owner and operator to provide operational limits for different tasks, ensuring that surface currents are taken into account when conducting mission planning, especially near fixed structures.

With deployed equipment or vehicles, subsurface currents should be considered during mission planning, and effective monitoring of the position of towed sensors, vehicles and tethers deployed in the water should be always maintained to ensure safe and effective operation.

Additional guidance and regulation imposed by asset owners should also be taken into account regarding drift-off requirements for work near fixed structures.

4.3.2 Marine Life

Joint Nature Conservation Committee

The JNCC are currently unaware of any issues regarding USV operations and interference with marine mammals. The use of sub-bottom profilers and seismic airguns may require similar mitigations to those for conventional vessels. It is not clear at this point how this may be achieved and may depend on the location and deployment of the vessels. Discussion will continue with JNCC as the technology develops and is monitored but the use of AI, imaging systems and audio systems are expected to be utilised.

4.4 Systems

USV systems managing power and onboard auxiliary support systems requirements must demonstrate safety and require management systems that communicate to shore to monitor the potential for uncontained release of energy damaging the environment or USV.

4.4.1 Operating Criteria

Safe State

A safe state is required to be defined for the particular vessel; this is the state that the machinery will default to, should a failure occur. Anticipated and potential failures need to be considered when in the design stage of the vessel systems.

4.4.2 Redundancy

To achieve a system which meets the necessary fault tolerance (e.g. a single point failure criterion), equipment and machinery which is necessary for the USV to function will be redundant in both number and capacity.

System Reliability

Equipment failures and a loss of redundancy may result in a vessel being unable to complete its mission until the redundancy of the USV has been restored. Planned maintenance, condition monitoring and testing contribute to reliability in service. However, the most effective way to ensure good reliability is through design, for example by specifying high reliability components and reducing the number of fault paths that lead to a loss of redundancy.

One of the most important elements to ensure system reliability is to provide software assurance for software used in USV systems and any systems (such as vessel management systems, power management systems and engine control units) which are necessary for the USV to operate. Such software should be the subject of a software conformity assessment. Software conformity and controls should be maintained throughout the life of the USV, including updates and configuration changes. No changes should be permitted to be made to software without first being reviewed in a management of change (MoC) procedure which considers how the system software assurance could be affected.

Redundancy of Systems

Redundancy and fault tolerance for support of key systems will be defined by the Classification Society Rules being applied at the vessel design stage, temporary loss of certain vessel functions may not be acceptable, where this is the case then redundancy and/or fault tolerance will need to be incorporated within the design.

Redundancy should apply to the following, but not limited to:

- ship to shore comms link
- steering gear
- power management systems
- position reference systems
- HVAC systems, where applied to sensitive equipment
- navigation lights.

Restoration of systems should in general be possible remotely without the requirement for personnel to attend the vessel at the location.

Performance Protection Detection

General

Three key elements of a fault tolerant design which are:

1) performance
2) protection
3) detection.

The objective is to ensure that the three key elements of fault tolerant design can be proved:

- **Performance** – For a vessel system to be fault tolerant each redundant equipment group and all of the related machinery and systems within it must be capable of their defined performance – Performance means more than steady state capacity, it also includes dynamic performance, response time and accuracy.
- **Protection** – Even the best separated systems inevitably have some common points **between** redundant equipment groups, and these represent potential fault propagation paths. There must be effective protective functions or features to prevent faults in one system adversely affecting the operation of others.
- **Detection** – It is important to know when full fault tolerance has been lost. Potential **hidden** failures can be detected by suitable alarms and testing.

4.4.3 Power Units

The nature of a USV means that very large savings in fuel consumption can be made, simply by not having to maintain an environment for humans, this fuel saving is a benefit to the environmental footprint of the vessel.

Internal Combustion Engine (ICE)

ICE powered systems are the more conventional propulsion systems, however there will be the necessity for electrical power which will require a generator, this can be integrated into the main propulsion engine or as a stand-alone unit.

An engine can be directly coupled to the propulsion with a power take off unit for electrical generation, however this would create many complexities with power take off for electrical consumers and speed control for the propulsion that may well involve the use of clutches and/or controllable pitch propellors all of which will add subsystems using space and increase of weight.

The control systems that will require control from the RCC will also have to be more complex.

ICE / Electric

Diesel electric would at this time be the simplest option, where you have the ICE as a generator that then supplies electrical power to all consumers such as propulsion, navigation, and industrial mission equipment.

This type of power unit allows for a lot more flexibility than pure ICE for propulsion as generators can be placed anywhere and propulsion motors can be relatively small, batteries would be able to provide clean power to a centralised switchboard. Submarines have adopted this method of providing power for over 100 years.

The use of batteries will determine how the ICE is leveraged, will it be continuous running or stop start?

Solar panels can also be integrated into this system to provide top up.

It could be that the 'diesel' generator can be fuelled with an alternative fuel, such as LPG, LNG, or hydrogen. Where space is of issue marine gas oil (diesel) give more energy per volume than all the alternatives currently

Electric

This would only be used where charging can be undertaken of for short mission durations, energy density and weights will dictate how pure electric USVs will be deployed.

4.4.4 Alternative Fuels

The tables overleaf give an overview of the current climate with the alternative fuels on the market.

Table 1 – Carbon fuels

Fuel Type	Converter	Storage	Source
LNG-Methane	• ICE	• 3x > MGO	• Hydrocarbon
LPG	• ICE • Gas turbine	• 3x > MGO	• Hydrocarbon
Methanol	• ICE hi press specialised engines, or • FC	• 3x > MGO	• Hydrocarbon • Renewable

Table 2 – Carbon neutral fuels

Fuel Type	Converter	Storage	Source
Bio B30	• ICE	• = MGO	• Hydrocarbon • Renewable
Bio B100		• = MGO	• Renewable
Synthetic Methane	• ICE	• 3x > MGO	• Hydrogen & Bio

Table 3 – Carbon zero fuels

Fuel Type	Converter	Storage	Source
Hydrogen	• ICE • FC	• 4x > MGO	• Hydrocarbon • Renewable
Ammonia	• ICE • FC	• 1.9x > MGO	• Hydrocarbon • Renewable
MSR	• Turbine	• Non required	• N/A

5 Operations

5.1 Operational Activity

5.1.1 Risk Assessment

The basis of safe offshore USV operations is an adequate assessment of the risk and this should be carried out before commencing any such operations.

5.1.2 Operating Procedures

All operations undertaken by USVs in the offshore energy sector should be subject to activity-based operational planning and risk assessment in line with operators safety management systems. This is as relevant to USVs as it is to other vessels, regardless of the industrial mission of the unit.

Operational Activity Planning

Operational activity planning should:

- define the USVs systems and equipment configuration appropriate to the location and the activity the USV is undertaking
- define the variable limits in equipment and operational parameters for the location and specific activity (ASOG), including the triggers and criteria that would cause a change in the traffic light system used in the ASOG
- define the actions to be taken by the RCC personnel in response to faults deteriorating conditions and a change in status of the traffic light in the ASOG
- present the guidance to key vessel personnel in a user friendly, easy to understand decision support tool.

Activity Specific Operating Guidelines (ASOG)

Provide guidelines on the operational, environmental and equipment performance limits for the location and specific activity.

The performance limits are established based on the level of risk. Because they are activity specific a USVs may have several different ASOG, each applying to different locations and activities and different levels of risk.

The terms field specific operating guidelines (FSOG) and location-specific operating guidelines (LSOG) denote equivalent concepts as applied by specific offshore sectors.

ASOG are to be based on:

- a thorough knowledge of the USV systems
- the USV FMEA
- the industrial mission
- USV location
- risk assessment.

When developing the ASOG, it is necessary to refer to information of the location and the activity and, if available, from project plans, procedures, and drawings.

The final ASOG should be available at the RCC. It should be a brief document providing a cross-reference for the USV Operators in a range of responses or actions to be taken in the event of degraded condition. Appropriate initial and periodic checklists can be used to set up a USV for operations.

The use of digital/electronic ASOG should be considered, that can be integrated within the software.

5.1.3 Manuals and Documentation

USV FMEA

An FMEA is a design tool that has been around for many years and is recognised as an essential tool in design from concept through to the development of every conceivable type of equipment. It is commonly defined as 'a systematic process for identifying potential design and process failures before they occur, with the intent to eliminate them or minimise the risk associated with them'. An FMEA can also be used to improve an existing system performance depending on many factors, such as change of equipment mission, lessons learned from the similar processes or from the wider industry, technological enhancements, and so on. FMEA procedures are based on standards in the reliability engineering industry, both military and commercial.

The FMEA should be viewed, first and foremost, as a means of proving the redundancy concept of the vessel to ensure safe and reliable operations. It can only be used as such if it has been continuously reviewed and updated to include all changes and modifications to the vessel's systems throughout its life cycle.

USV Operations Manual

The USV operations manual ideally only contains information necessary for operating the USV under RSS system control. The Ops manual is required to address the following but not limited to:

- organisation and responsibility
- vessel data
- systems descriptions
- navigation/positioning philosophy
- USV capability (capability plots?)
- system checklists
- failure modes and effects analysis (FMEA)
- event reporting policy
- activity-specific operating guidelines (ASOG)
- logs
- operational files
- emergency procedures
- lost contact procedures

5.1.4 Communications

There are two communication and control modes currently available:

1) Over the Horizon (OtH)
2) Line of Sight (LoS).

Line of Sight (LoS)

The straight path between a transmitting antenna (as for radio or television signals) and a receiving antenna when unobstructed by the horizon. Your line of sight is an imaginary line that stretches between your eye and the object that you are looking at.

LoS is a type of propagation that can transmit and receive data only where transmit and receive stations are in view of each other without any sort of an obstacle between them. FM radio, microwave and satellite transmission are examples of line-of-sight communication.

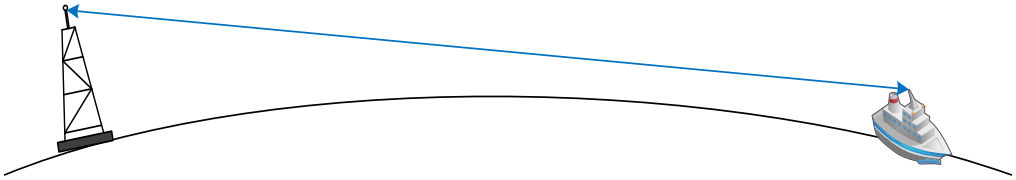


Figure 1 – LoS example

Over the Horizon (OtH)

An over the horizon communications system includes a transmitter for generating a signal to be communicated, an acoustic source located on the earth in a direction from the transmitter that the communication is to take place which can provide periodic variations in the density of the atmosphere and means for directing the transmitter at the variations to cause the signal to be redirected over the horizon to a point of reception. The point of reception may be a radar target and the signal may be returned, or the point of reception could be a communication receiver.

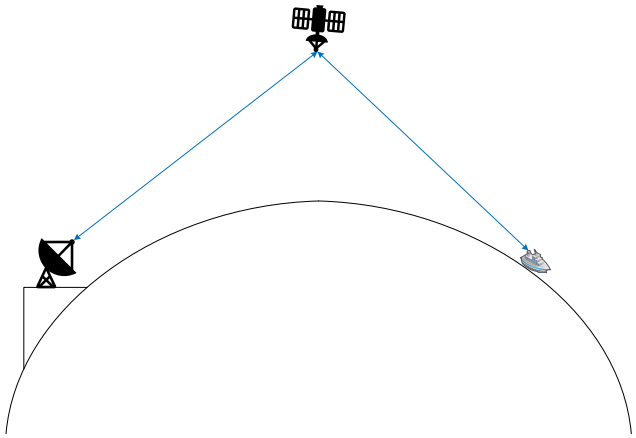


Figure 2 – OtH example

5.1.5 Cyber Hazards

Hacking and infiltration methods have grown to extraordinary levels. Using available technology like artificial intelligence, cyber antagonists can commit stealth cybercrimes. As such, operators should always expect attempted intrusions at any time. For this reason, every organisation should implement and continuously update a plan for responding to cyber incidences. The programme should also consist of measures for recovering from an attack.

Therefore, to actively monitor, detect, and respond to security threats, operators should consider implementing solutions such as security information management systems. Such systems allow security teams to keep track of all activities at the system or network level. In addition to that, organisations should assign responsibilities to security teams. Every individual needs to be aware of their role in responding to cybersecurity incidents.

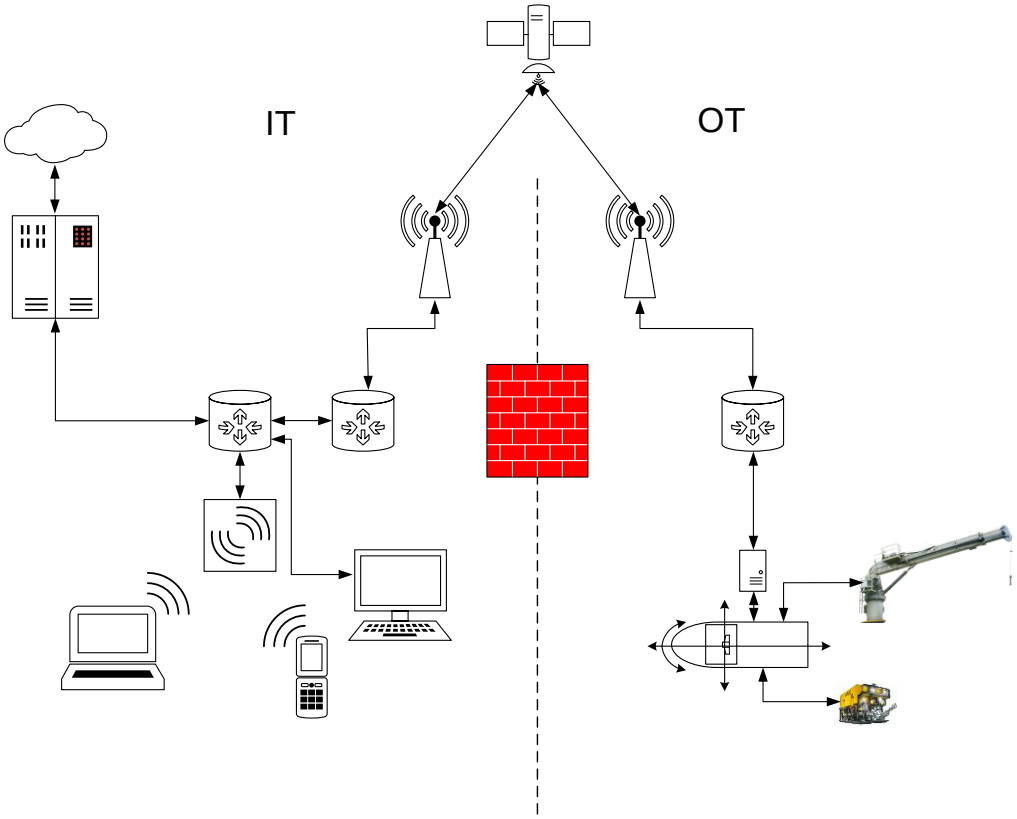


Figure 3 – IT/OT system topology example

Operational Technology (OT) and IT Risks

Connecting industrial systems to an IT network allows a more detailed view of individual equipment and creates a comprehensive view of the entire industrial ecosystem, simplifying management and operation. This enables constant monitoring of the performance and condition of equipment and systems, which improves uptime. These benefits are compelling and explain the explosion of interest in IT/OT integration.

Traditional OT systems bring with them a long list of cybersecurity concerns, including equipment with decades-long life cycles, an inability to patch systems due to stability concerns, and a lack of basic cybersecurity features such as user authentication or encryption. In the idealised past, where such systems were "air-gapped" to ensure perfect isolation from the rest of the world, these concerns were assumed to carry acceptable risk. Complete isolation has become all but impossible today, however, and to mitigate new risks to OT, operators will need to deploy a combination of traditional IT cybersecurity products and services with tailored, OT-specific cybersecurity solutions.

Knowing the most likely attack scenarios for a given organisational infrastructure provides a solid starting point for building a security reference architecture that can hopefully protect against such attacks.

Modern, distributed, interconnected remote systems demand a more comprehensive and robust OT-based cyber security system which can be defined as:

"Technologies, processes, and practices designed to prevent the intended or unintended use of a cyber technology system to do damage to the cyber technology (networks, computers, programs, data), and vessel or harm to people, and environment."

To achieve this level of protection we need to be able to verify the satisfactory performance of the OT cyber security system by:

- ensuring correct, safe, efficient, and reliable operation through software quality engineering
- preventing malicious and non-malicious threats through the cybersecurity system.

Functional testing will help assess a system against "known" errors or threats but makes no allowance for, as yet, unknown events. Using a maturity model provides ongoing monitoring, assessment and improvement to a cyber security system and will help defend against these unknown events

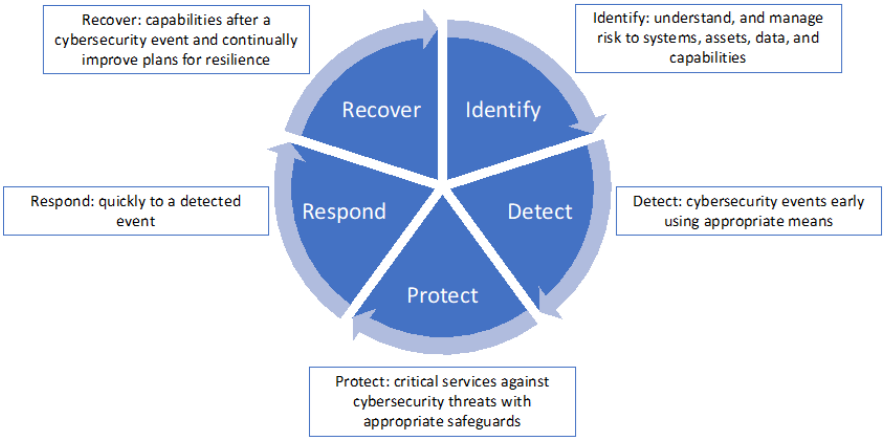


Figure 4 – Flow diagram

To be comprehensive an evaluation of any system must include the processes used by the technology system owners, designers, users, and suppliers, and should consist of active audit and testing of known threats, access points and protection from potential threats such as spoofing and phishing using penetration and scanning tests.

One final consideration is the stage, in the life cycle, where these security measures are applied. Ideally the security measures should be integrated as part of the initial designs. Robust security systems are much harder to ensure when viewed as an afterthought and their safety is harder, maybe impossible, to ensure. Each component of a system, where threat access could occur, should have adequate threat protection designed and built it by the equipment manufacturers.

5.1.6 Physical Hazards

Obstacle Avoidance/Anti Collision

The International Maritime Organization (IMO) has defined the international rules for collision avoidance – COLREGs. Their application is dependent on several variables, including the type of encounter. Although COLREGS coach the navigator on the correct strategy for collision avoidance, it does not fully avoid subjectivity by navigators since its application is based on the "evaluation of the situation-decision to apply a respective rule-taking action". The navigator is required to have perfect knowledge of each rule and to be able to decide the application in the light of the respective rule. Even when COLREGs are fully defined, human interpretation is still required since ship navigation manoeuvres are performed in real time, and sometimes under demanding external factors inputs.

The design of autonomous ships for a safe operation must consider the human element, the tasks operators need to accomplish, the tools needed for the successful accomplishment and their possible failure in completing the tasks. The risk assessment of autonomous ships operation and collision avoidance models need to consider the human-system interaction and human failure.

5.2 Remote Control Centre

5.2.1 Risk Assessment

The basis of safe offshore USV operations controlled from an RCC is an adequate assessment of the risk and this should be carried out before commencing any such operations.

5.2.2 Operating Procedures

All operations undertaken from the RCC in the offshore energy sector should be subject to activity-based operational planning and risk assessment in line with operators safety management systems. This is as relevant to USVs as it is to other vessels, regardless of the industrial mission of the unit.

Operational Activity Planning

As defined above in Section 5.1.2.

Activity Specific Operating Guidelines (ASOG)

As defined above in Section 5.1.2.

5.2.3 Manuals and Documentation

See Section 5.1.3 above. All documentation will be located and readily available within the RCC, the RCC operators will be required to be conversant with all relevant manuals and documentation in the same way that a vessel crew would be.

6 Personnel

6.1 Aim

The aim of these guidelines is to improve the safety and efficiency of USV operations, by defining minimum industry guidelines for:

- training, qualification, and competence levels of key USV personnel
- developing and sustaining competence through continuous professional development (CPD) for key USV personnel.

6.2 Objectives

The completion of the following objectives supports the achievement of the aim:

- to develop internationally accepted guidance for the training and competence levels of key RCC personnel
- to recommend onboard training, familiarisation programmes and maximise potential of simulators and other advanced training technologies
- to describe a recommended verification process for assessing the level of competence of key RCC personnel, enabling owners/operators to manage change effectively and efficiently
- to encourage open event reporting including 'near misses'
- to promote the principle of the sustainment of competence for key RCC personnel as being integral to a USV safety management system
- to recommend definitions of terminology for use in describing the status of key RCC personnel.

6.3 Key RCC Personnel Identified

6.3.1 RCC Commander

The RCC Commander has overall responsibility and authority for the safety of all the vessels under the RCC control, for the protection of the vessel, assets, and marine environment

6.3.2 USV Controller

The person fulfilling the role of USV Controller is the lead watchkeeper with responsibility for the navigational safety and the positioning control required to achieve the effective and efficient progression of the industrial mission of the vessel during the time period on duty.

6.3.3 USV Operator

The person fulfilling the role of USV Operator is the second person on the watch and is not in charge of the watch. The USV Operator is responsible for fulfilling their duty as a USV control system operator during their time on watch to the extent enabled by their level of training, vessel system knowledge and experience.

6.3.4 RCC Engineer

The RCC engineer is the head of the technical department within the RCC and is responsible for ensuring all the mechanical and electrical systems of the vessel are operated and maintained in a safe and efficient manner in order to support the safe navigation and operation of the vessel. They should also ensure that effective communication channels to the RCC Commander are available.

6.4 Training

Training of key RCC personnel is essential and can take several forms:

- training courses including use of simulator systems
- RCC training as operations permit and under the supervision of a qualified instructor or an experienced operator with a vessel owner/operator issued endorsement to train other RCC personnel – for example, senior Commander or senior RCC Engineer
- RCC simulator instruction and exercises – scenario-based specific to the operations expected; one of the methods of doing this is using 'touch drills', where switches and controls are not actuated only touched to indicate operation and simulation
- RCC instruction and continuation training to mitigate for skill fade
- supervised operation of the control systems
- manufacturers' training
- seminars with open discussions on USV operation
- vessel owner/operator training schemes relevant to the specific USV operations
- refresher courses, both theory and simulator
- computer (including web) based training.

All training should be given by suitably qualified and experienced personnel. Vessel owners are advised to provide training for their senior RCC personnel to enable them to deliver effective training and mentoring.

6.5 Qualification and Knowledge Requirements of RCC Personnel

All RCC personnel qualifications and knowledge requirements will be updated once further IMO and flag state guidance is developed and issued.

7 Further Reading

MASRWG, Maritime Autonomous Surface Ships – UK Code of Practice