Guidance Notes for Inspection using Unmanned Aircraft Systems

March 2016

Lloyd's Register

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These Guidance Notes are intended to be a live document and are subject to change without notice.

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■ *Section 1* Introduction

1.1 Purpose

The purpose of this Guidance Note is to provide guidance on:

- Operational considerations to be taken into account when using Unmanned Aircraft Systems (UAS) to conduct an inspection.
- Data capture and treatment considerations during a UAS inspection.

This Guidance Note does not constitute a regulation nor does it grant permission or agreement to conduct inspections by use of UAS for the purposes of collecting data to be used towards the crediting of an inspection/survey or endorsement of a certificate. Permission or agreement to conduct inspections and collect inspection data by use of UAS should be obtained from the representatives of the asset owner or shipowner, as applicable.

Agreement to use data collected towards the crediting of an inspection/survey or endorsement of a certificate should be obtained from the Inspection Data End-User. Acceptance of the data is at the discretion of Inspection Data End-User.

1.2 Scope

With regards to operational considerations, this Guidance Note provides guidelines relating to regulations, personnel, quality, safety, hardware, software and operations.

With respect to inspection, it is focused on visual inspection carried out by the operation of manually operated rotary UAS.

Autonomous operation of UAS is out of scope of this Guidance Note. This is an active area of research for Lloyd's Register as an Inspection Authority and Classification Organisation.

This Guidance Note will be progressively updated to reflect industry specific inspection applications and data requirements.

1.3 Introduction

The use of UAS for inspection is a rapidly developing phenomenon in a number of industries.

Although the use of UAS to conduct inspections provides a number of possible benefits to asset owners and shipowners - principally improving operational uptime of assets and the speed of inspection data capture - it also introduces new questions and concerns about the regulatory acceptance, quality criteria and safety of this new method.

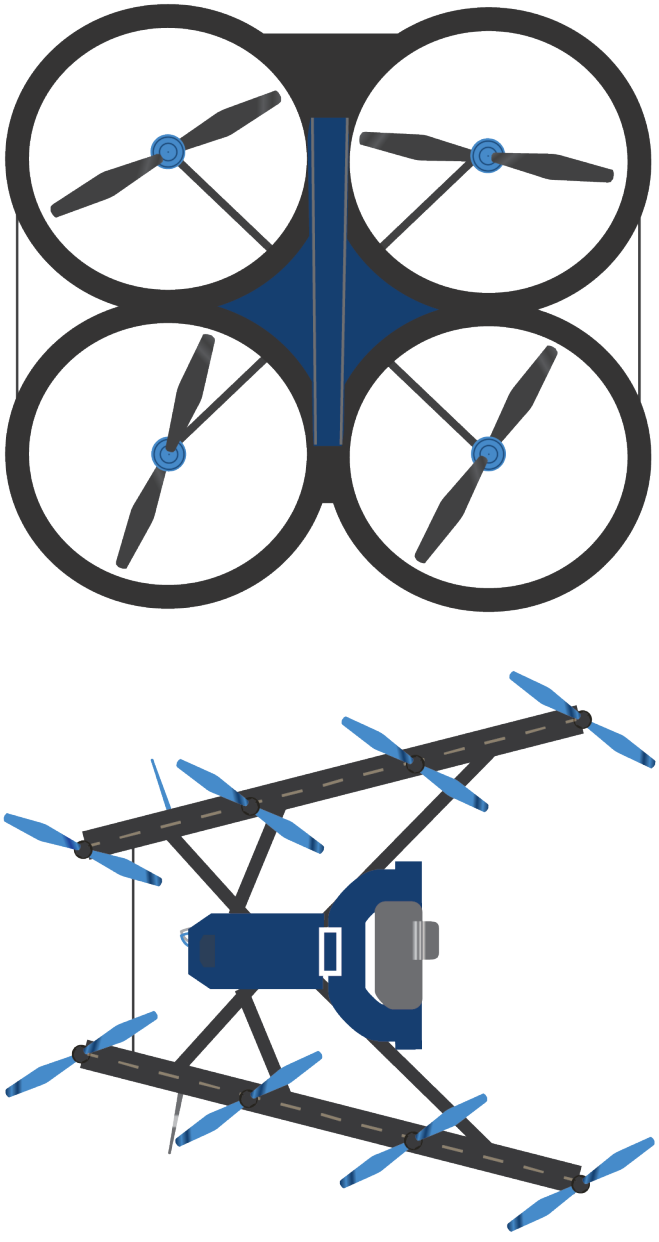

Figure 1 Examples of Rotary UAS

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■ *Section 2*
Abbreviations and Definitions

2.1 Abbreviations

BOSIET	Basic Offshore Safety Induction and Emergency Training
BVLOS	Beyond Visual Line of Sight
EVLOS	Extended Visual Line of Sight
GPS	Global Positioning System
MAV	Micro Aerial Vehicle
OEM	Original Equipment Manufacturer
ROAV	Remotely Operated Aircraft Vehicle
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System
RPV	Remotely Piloted Vehicle
SMS	Safety Management System
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
UAVS	Unmanned Aerial Vehicle System
VLOS	Visual Line of Sight

2.2 Definitions

BVLOS	Flight of a UAS device beyond the pilot's and any remote observer's visual line of sight. The pilot operates the UAS via instrumentation.
Drone	Common and interchangeable terminology for UAS and UAV.
EVLOS	Flight of a UAS device beyond the pilot's line of sight, but within the line of sight of any remote observers. The pilot operates the UAS through constant communication and information from the remote observers.
Inspection Data End-User	The organisation or entity responsible for the capture, use and acceptance of any inspection data results (e.g. Inspection, Verification or Certification Authorities).
Owner or Owner's Representative	Owner or owner's representative of the ship or asset subject to UAS operations. This term does not refer to the owner or operator of the UAS device.
UAS	Unmanned Aerial Vehicle (UAV) and all of the associated support equipment, ground control station, data links, telemetry, communications and navigation equipment necessary to operate the unmanned aircraft.
UAS Device	The UAV involved in aerial flight.
UAS Operations	An individual or several consecutive UAS flight operations.
UAS Operator	The organisation or entity operating the UAS, regardless of commercial or operational arrangements (i.e. internally sourced or third-party supported operations). This term does not refer to members of the flight team (e.g. pilot, payload operator).
UAV	An aircraft with no pilot, that is controlled remotely or by autonomous systems. UAVs are referred to within this Guidance Note as a UAS device.

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■ *Section 3* Considerations for Use of Unmanned Aircraft Systems

Cost	UAS can provide significant cost reductions by minimising or replacing traditional inspection access methods such as rope-access or scaffolding which can be time-consuming and require a ship or asset to undergo down-time.
Inspection Data Requirements	UAS is currently best suited for visual inspections. It is noted that there are active research efforts underway to introduce alternative sensor equipment as payloads for UAS, but the majority of these applications are not yet operationally viable.
Repeatability of Inspection Process	UAS with flight path programming can ensure that inspection coordinates and data capture are repeated throughout the lifetime of a ship or asset, providing greater traceability of defects and degradation over time.
Safety with Working at Heights	UAS can reduce or remove the need for inspection personnel to work at heights through rope-access or scaffolding, subsequently reducing or removing the risk of falls from heights (in these specific circumstances).
Safety with Collisions and Drops	UAS is a potential risk to safety if system failure occurs and the UAS device collides with or falls over personnel or vulnerable equipment (e.g. LNG membrane tanks).
Safety with Hazardous Areas	UAS devices are both a direct and indirect ignition and explosion risk. A UAS Operator must work with the asset owner or shipowner's representatives to ensure the correct precautions, permits and procedures are in place to support operations in hazardous areas.
Ship or Asset Environment Conditions	UAS devices perform best in low-wind, low-wave, dry conditions due to their typical nature of being small and non-rugged.
Skills Required for Flight Team	UAS pilots and camera/payload operators require a level of demonstrable skills and experience to ensure safety and effectiveness during flight.

■ *Section 4* Organisational Recommendations for Unmanned Aircraft System Operations

4.1 Regulations

A UAS Operator must adhere to all applicable national regulatory requirements as specified by relevant governmental bodies and aviation authorities. Where no applicable national or international regulatory requirements apply, it is recommended that a UAS Operator follow and implement best practise adopted by leading aviation authorities (e.g. CAA CAP 722).

4.2 Quality Standards (ISO 9001)

It is recommended that ISO 9001 accreditation is achieved by a UAS Operator. Through this accreditation, a UAS Operator will:

- Demonstrate its ability to consistently provide services that meets customer and applicable statutory and regulatory requirements.
- Aim to enhance customer satisfaction through the effective application of a management system, including processes for continual improvement of the system and the assurance of conformity to customer and applicable statutory and regulatory requirements.

If a UAS Operator has not obtained ISO 9001 accreditation, it is recommended that the UAS Operator follows equivalent quality management system processes and controls.

4.3 Impartiality and independence

It is recommended that a UAS Operator has a written policy of impartiality and independence with regards to all contractual work and obligations. A documented process should be put in place to support any confidentiality issues, data protection or conflict of interest issues between the UAS Operator and Inspection Data End-User.

4.4 Safety Management System (SMS)

It is recommended that a UAS Operator has a Safety Management System (SMS) in place that documents and evidences an organised approach to managing safety, including the necessary organisational structures, accountabilities, policies and procedures.

An organisational risk assessment and management process (including a risk register) should be implemented and maintained for all UAS operations.

4.5 Insurance

It is recommended that a UAS Operator has secured third-party public liability insurance, professional indemnity insurance and employers liability insurance to insure against the risk of any significant hazardous outcomes (i.e. personnel health and safety and property damage) resulting from UAS operations.

4.6 Policies and Procedures

It is recommended that a UAS Operator has written policies and procedures that relate to:

- UAS devices (including procurement and purchasing, governmental registration where applicable, testing and maintenance).
- Operational procedures and an operations manual/handbook (including emergency procedures).
- Inspection data handling (storage, backup, access and transfer) and reporting (including privacy, confidentiality and retention).

4.7 Checklists

Checklists are a simple but effective tool for a UAS Operator to achieve adherence and consistency with routine policies and procedures. A range of checklists should cover:

- Location/on-site inspection.
- UAS device and equipment inspection and test.
- Ground control systems inspection and test.
- Pilot/camera operator readiness.

It is recommended that a UAS Operator regularly reviews and revisits checklists to ensure previous operational experience is incorporated into future operations.

■ *Section 5* Personnel

5.1 General

A UAS Operator should be able to provide evidence that their personnel have the competence to perform and maintain the services for which UAS operations are intended.

5.2 Operations Training

Irregular or inappropriate conduct during UAS operations introduces new operational risks that could affect the health and safety of personnel, and the uptime and quality of an asset or ship. This necessitates a high level of requirements as well as scrutiny on the training regime of a UAS Operator.

A UAS Operator should be responsible for the qualification and training of their personnel to recognised national, international or industry regulations or standards that directly relate or are required where UAS operations are intended. It is also recommended that UAS Operators adhere to the additional qualification and training requirements outlined within these Guidance Notes.

If such regulations or standards do not exist or are proven to not be applicable, a UAS Operator should define, maintain and implement internal mandatory procedures for the training and qualification of their personnel.

All personnel responsible for the control of any aspect of a UAS should demonstrate experience with the operation of any UAS equipment and procedures they intend to use:

- The level of experience to be demonstrated is dependent on the aspect of the UAS and the function of the personnel in question.
- Training should include tiered hazardous scenarios which will provide a level of assurance that the pilot has experience in dealing with sudden loss of functionality or changes in environmental conditions.
- Experience should include supervised or tutored practical training.

Personnel must adhere to any national, international, industry or company-specific requirements for health and safety training (e.g. Basic Offshore Safety Induction and Emergency Training (BOSIET)).

5.2.1 Minimum Training Requirements

It is recommended that a UAS operator consider the following as a minimum criteria for personnel to be considered as competent for UAS operations:

- Evidence of attendance and satisfactory completion of

training at a UAS ground school/flight training school.
- Competency definitions mandated by national, international, industry and company-specific standards that relate to the operation of UAS.
- Flight training using the same UAS equipment (e.g. hardware and software models and configuration) intended for live operations.

5.3 Maintenance Training

It is recommended that the Original Equipment Manufacturer (OEM) of any UAS equipment provides maintenance training and technical bulletins documenting any changes or issues to be aware of and encourages feedback from UAS Operators to facilitate continuous improvement.

All maintenance processes and practices (whether developed or maintained by the OEM or the UAS Operator) should be documented and be actively maintained.

5.4 Records

To demonstrate the competency of any personnel involved in UAS operations, it is recommended that a UAS Operator keep and maintain records of all personnel with direct involvement in the maintenance or live operation of UAS. Each personnel record should include, but is not limited to:
- Medical certification/checks.
- Formal education and certificate records.
- Formal initial and refresher training records.
- Formal safety qualifications and certifications.
- Resume/CV.
- Photo identification.
- Experience/flight logs.

■ *Section 6* Hardware and Software

6.1 Unmanned Aircraft System Selection

It is recommended that a UAS Operator consider the following as minimum criteria for selection of a UAS device:
- The OEM of the UAS device adheres to a type testing regime for new products (e.g. flight testing regime, total flight time and number of test samples) to ensure introduction of reliable and safe devices to the market or UAS operator.
- The UAS device has self-diagnostic capabilities.
- The UAS device should have multiple modes of function that mitigate in-flight failure, including:
  - Maintain and transmit GPS coordinates (for outdoor operations).
  - Ability to switch to manual backup modes.
  - Redundancy for other critical components.
- The UAS device should be able to transmit altitude information to the pilot via a digitally encoded telemetric data feed.
- The UAS device battery compartments should be resistant to impact and degradation to limit release of harmful substances into the environment.

It is forecast that with further developments of collision mitigation software and hardware within UAS devices, collision mitigation capabilities will be considered as minimum criteria in future revisions of this guideline.

6.2 Unmanned Aircraft System Registry

A registry of all operational/intended operational devices should be maintained locally by the UAS Operator and should include, but is not limited to the following information for each device:
- Unique serial number.
- Product specifications.
- Safety data sheet/specifications.
- Known/discovered design and operational limitations.
- Operational and testing malfunctions and anomalies.
- Preventative and reactive maintenance actions.
- Date of next preventative maintenance action.
- Hardware customisation and alteration actions.
- All major software versions, changes and patches.
- Device total running hours.
- Reference to the relevant/applicable OEM and/or UAS Operator maintenance policy and procedures.
- Reference to all manufacturing safety and technical bulletins.

6.3 Battery Handling

Batteries are considered to be separate to the UAS device due to their interchangeable nature. Subsequently, it is recommended that a UAS Operator has the following:

- A battery tracking system that identifies the use, exchange and performance of batteries, independent of the UAS device.
- Procedures for battery transportation that are considerate of work site requirements.
- Procedures for battery storage (including the safe charging and storage of batteries in fireproof containers).
- Procedures for battery inspection (including testing battery pack capacity and thermal runaway).
- Risk identification, rating and mitigation per battery make and model.

6.4 Alterations and Customisations

Any UAS that has undergone any changes that may affect UAS operations (i.e. hardware customisation or alteration, or software versioning, changes or patches) should be subject to a functional test flight, risk review and training to ensure modifications allow operations to be carried out safely and effectively.

6.5 Original Equipment Manufacturer Technical and Safety Bulletins

It is recommended that a UAS Operator should comply with all technical and safety bulletins issued by an OEM.

■ *Section 7* Operation of Unmanned Aircraft Systems

7.1 Pre-Flight Operations

7.1.1 Site Permission and Flight Planning

It is recommended that prior to any UAS operations, the UAS Operator should submit a plan of activities to the asset owner or shipowner's representatives and in accordance with any established procedures relevant to the flight area.

The plan of activities should include at least the following:

- Nature/objectives of the flights.
- Dates and times for all flights.
- Name and contact details for the UAS operations scheduling and management.
- Name and contact details for the UAS operations flight team (e.g. pilot-in-command and camera/payload operator).
- The product details and serial number of the UAS device to be used.
- Site visit/inspection reporting (recommended where possible).
- A description of the flight activity including:
  - Maps or diagrams of the flight area.
  - Infrastructure subject to inspection.
  - Planned altitudes for the UAS operation.
  - Planned take-off, recovery and return-to-home locations.
- Emergency scenarios and procedures for:
  - Loss of control.
  - Collision.
  - Mechanical or electrical failure.
  - Loss of line of sight.
  - Sudden changes to environmental conditions.
  - On site emergency situations (e.g. access for emergency services, fire and site evacuation).

7.1.2 Work Permits

An on-site work permit may be required (and is different from permission to fly). It is the responsibility of the asset owner or shipowner's representatives to assess whether a work permit is needed. All work permits should be approved by the asset owner or shipowner's representatives. If the ship or asset is hosted at a third-party location, the third-party location owner's authorised representatives may also be required to grant an on-site work permit. The work permit should be valid for each individual UAS operation and for the maximum duration needed to complete the inspection work (usually less than twelve hours).

The following criteria should be considered when assessing and implementing work permits for UAS operations:

- National, international, industry or company-specific prerequisites (e.g. permission to fly requests from national

aviation authority).
- Night-time operations.
- Limited visibility operations.
- Use of Visual Line of Sight (VLOS).
- Use of Extended Visual Line of Sight (EVLOS) for operations.
- Use of Beyond Visual Line of Sight (BVLOS) for operations.

7.1.3 Risk Assessment

Due to the inherent risks of UAS operations, it is recommended that a risk assessment is completed and documented before a UAS operation, and should involve the:
- UAS Operator.
- The asset owner or shipowner's representatives:
  - Subject matter experts on any safety-critical or operations-critical infrastructure or assets within the flight area.
  - Health and safety management.
- Any third-party location owner or authorised representative where the ship or asset is being held.
- The Inspection Data End-User responsible for the use and acceptance of any inspection results.

Multiple risk assessments may be required for the same flight area on the same day (e.g. due to weather conditions, changing inspection scope).

The use of pre-determined risk assessments designed to cover generic and/or historical conditions and variables is not allowed. Customised and specific risk assessments are considered industry best practise as each risk situation should be assessed on its own merits, and use of a generic assessment to cover all potential issues can lead to complacency amongst personnel.

The risk assessment should typically address the following criteria:
- Flight stability and accuracy risks:
  - Current weather.
  - Predicted weather during UAS operations.
  - Sea state and swell (offshore specific).
  - Environments with excessive hot or cold temperatures.
  - Air flow from ventilation fans, both intake and exhaust.
  - GPS denied areas.
- Drops risks:
  - Flying over areas occupied by personnel.
  - Flying over areas potentially occupied by personnel.
  - Flying over structurally vulnerable equipment or assets.
- Explosion risks:
  - Running or rotating machinery.
  - Areas where explosive gases or materials may be present.
- Collision risks:
  - Birds.
  - Unguarded ventilation fans.
  - Other UAS.
  - Piloted aircraft (e.g. supply helicopters).
  - Areas where line of sight cannot be maintained.
  - Confined or limited access spaces.
  - Height/flight ceilings.
  - Areas with falling debris or water.
  - Ship or asset structure.
  - Other vessels or vehicles (e.g. supply ships).
- UAS device communication drop-out risks:
  - Radio or signal transmitters that could affect communication with the UAS device.
  - High voltage cables or areas that may affect control signals or damage the UAS device.
  - Dense areas of structural steel.
- Is the area, infrastructure or asset being inspected in a "live" or "downtime" status.
- Any known/discovered design or operational limits of the UAS device.

For further information, refer to risk assessment principles and methods in IEC/ISO 31000 Risk Management Principles and Guidelines or ISO/IEC 31010 Risk Management - Risk Assessment Techniques.

7.1.4 Checklists

It is recommended that the following types of checklists be reviewed, completed and verified pre-flight:
- Location/on-site inspection.
- UAS device and equipment inspection and test.
- Ground control systems inspection and test.
- Pilot/camera operator readiness.

7.1.5 Pre-Flight Briefing

The flight team should conduct a pre-flight briefing no more than 30 minutes prior to the beginning of UAS operations (to minimise the risk of any subsequent changes to conditions and circumstances that may affect the UAS operation). The intention of the briefing should be to consider any changes to circumstances or conditions that were not considered in the risk assessment, any amendments required to the flight plan and UAS operations, reconfirm emergency procedures and reconfirm flight team roles and responsibilities.

7.1.6 Commencement of Flight Operations

It is the responsibility of the pilot to assess all available information and checklists before deciding to commence with UAS operations. No other party or entity should force the pilot to commence UAS operations.

The asset owner or shipowner's representatives should always have the ability to refuse permission to commence UAS operations regardless of any additional considerations.

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7.2 In-Flight Operations

7.2.1 Flight Team Size

It is recommended that all UAS operations include a minimum of two personnel:

- Pilot (responsible for control of the UAS device).
- Camera/payload operator (responsible for control of any attached inspection equipment).

It is recommended that the Inspection Data End-User reviews live video feeds to enable real-time suggestion and direction to the pilot.

Any personnel involved or in proximity to the flight team should avoid causing any unnecessary distraction to the pilot (e.g. communication, movement).

7.2.2 Take-off and Landing Zones

Take-off and landing zones should be visibly marked and cordoned off to avoid the risk of distraction and collision.

7.2.3 Communications

At a minimum, the pilot and camera/payload operator should remain in constant communication. It is recommended that other personnel within the flight team and pilot also remain in constant communication. Cell/mobile phones are not considered reliable for this intended communication.

If communication between the pilot and camera/payload operator is lost or significantly distorted for any amount of time, the predetermined emergency procedure should be followed.

Any member of the flight team should also have the ability to contact and communicate directly with the asset owner or shipowner's representatives and the UAS Operator.

7.2.4 Visual Line of Sight

All routine UAS operations should occur within VLOS. The use of EVLOS or BVLOS for UAS operations is subject to regulatory acceptance and risk assessment, and prior approval by the asset owner or shipowner's representatives and the Inspection Data End-User.

7.3 Post-Flight Operations

7.3.1 Flight Logbooks

A record of every UAS operation (including for training purposes) should be maintained by the pilot in a logbook.

7.3.2 Accident and Near-Miss Reporting

All accidents and near-miss incidents should be documented and reported to the asset owner or shipowner's representatives and the Inspection Data End-User as soon as possible.

All accidents and near-miss incidents should be captured and stored by the UAS Operator in a flight issue log.

■ *Section 8* Inspection Data

8.1 Photography and Videography Data Acceptability

It is recommended that photography and videography for use in inspection should provide a type, volume and quality of data that is equivalent or better than data captured using existing inspection procedures and methods accepted by the Inspection Data End-User.

The following criteria should be considered:

- Adequate image resolution.
- Adequate camera zoom.
- Adequate image size.
- Adequate lighting and contrast.
- Accurate date and time stamping of images.
- Uninterrupted or adequate visibility of ship or asset (e.g. lack of fog, rain, smoke).
- Adequate ability to position, angle and zoom camera on areas of interest.
- Limited previous or recurrent indications of abnormal deterioration or damage to asset.
- Training, experience or instruction of the camera/payload operator for the intended type of inspection (e.g. an inspection to examine weld joints has a camera/payload operator (or instructor) who is sufficiently knowledgeable and experienced in welding inspection).

Upon completion of the inspection, the inspection report should be issued to the Inspection Data End-User, as well as an additional media transfer of any original photograph files or video files that are referenced or copied within the report (to allow for further examination of the images without being affected by image compression).

8.2 Other Data Acceptability

Alternative methods of inspection may be considered for use with UAS and will be prescribed in future revisions of this Guidance Note.

Alternative methods of inspection will require the same procedures and level of qualification and certification that is currently required for use of these methods without a UAS (e.g. ultrasonic testing requires use of approved procedures).

Alternative types of sensors and data capture are recommended to be calibrated and tested beforehand, with consultation from the Inspection Data End-User.

8.3 Data Security

It is recommended that a UAS Operator adhere to appropriate data security principles, standards and methods to ensure that inspection data captured, transmitted and stored is secure and protected from manipulation or unwanted distribution at all times.

For further information, refer to data and system security principles and methods in ISO/IEC 15408 Information Technology - Security Techniques - Evaluation Criteria for IT Security and ISO/IEC 27001: 2013 Information Technology - Security Techniques - Information Security Management Systems.

■ *Section 9*
References

BS EN 61508: 2010	Functional Safety of Electrical/Electronic/ Programmable Electronic Safety-Related Systems
CAA CAP 722	Unmanned Aircraft System Operations in UK Airspace - Guidance
Section 333 FAA Modernization and Reform Act of 2012	Special Rules for Certain Unmanned Aircraft Systems
HSAC RP UAS RP 15-1	Helicopter Safety Advisory Conference UAS Guidelines
ICAO CIR 328	Unmanned Aircraft Systems (UAS)
ICAO Document 10019 AN 507	Manual on Remotely Piloted Aircraft Systems (RPAS)
ISO 9001: 2015	Certification for Quality Management Systems
ISO/IEC 15408	Information Technology - Security Techniques - Evaluation Criteria for IT Security
ISO/IEC 27001: 2013	Information Technology - Security Techniques - Information Security Management Systems
ISO/IEC 31000: 2009	Risk Management Principles and Guidelines
ISO/IEC 31010	Risk management - Risk Assessment Techniques
UK JDN 2/11	The UK Approach to Unmanned Aircraft Systems

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