ASME MUS-1–2024

Use of Unmanned Aircraft Systems (UAS) for Inspections

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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Two Park Avenue • New York, NY • 10016 USA

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The next edition of this Standard is scheduled for publication in 2027. This Standard will become effective 6 months after the Date of Issuance.

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FOREWORD

The use of unmanned aircraft systems (UAS) has become increasingly popular in various industries. The energy, manufacturing, medical, and public safety industries have demonstrated how UAS have positively impacted their businesses by improving personnel safety and boosting efficiency. The inspection and maintenance sectors have also benefited from implementing UAS programs to perform inspections and repairs of infrastructure to replace conventional methods.

UAS will continue to provide more opportunities.

It is recognized that the Federal Aviation Administration (FAA) is the governing body to fly outdoors; however, there is no governing body to fly UAS indoors. This Standard aims to cover flying under the FAA as well as provide more guidance to those who fly indoors.

The ASME Mobile Unmanned Systems (MUS) Standards Committee was formed in 2019 and oversees three subcommittees: Unmanned Aircraft Systems/Unmanned Aircraft Vehicle for Inspection, Crawlers/Ground Robotics for Inspection, and Remotely Operated Vehicles/Autonomous Underwater Vehicles for Inspection.

This Standard is available for public review on a continuing basis. Public review provides an opportunity for additional input from industry, academia, regulatory agencies, and the public-at-large.

ASME MUS-1–2024 was approved by the American National Standards Institute as an American National Standard on May 8, 2024.

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(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Standard

(4) to permit the use of a new material or process

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(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Standard and the paragraph, figure, or table number

(4) the editions of the Standard to which the proposed case applies

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USE OF UNMANNED AIRCRAFT SYSTEMS (UAS) FOR INSPECTIONS

1 INTRODUCTION

Unmanned Aircraft Systems (UAS) offer the potential to mitigate risks associated with manned inspection techniques and improve efficiency and viability. The use of these systems for inspections of infrastructure has become popular; however, the methods of performing these inspections using UAS have not been defined. Figure 1-1 demonstrates the different aspects of conducting an inspection using UAS for the purpose of obtaining quality data and maintaining safety within the inspection environment.

The intent of this Standard is to encompass operation and safety of not only the vehicle but the whole system. It is the goal of the UAS for Inspection Subcommittee to address operation of UAS using other nondestructive examination (NDE) methods.

NOTE: Throughout this Standard, "UAS" refers to all essential elements associated with the unmanned aircraft system, including but not limited to the pilot, control station, aircraft vehicle, command and control datalink, launch and recovery equipment, etc., whereas "UA" refers to the unmanned aircraft only.

1-1 Scope

This Standard provides the requirements for the use of UAS to safely and reliably perform inspections to obtain quality data and repeatable results. It is the responsibility of the user of this Standard to determine whether using UAS to perform the inspection is the proper method for the desired outcome. The vehicles used for the inspection of assets may involve rotary, vertical take-off and landing (VTOL), fixed winged, or hybrid platforms. In some conditions, the use of a tethered system is recommended.

This Standard was written to be used by many industries and not only comply with ASME code-related inspections. The use of this Standard provides the basis of using UAS safely and reliably when carrying out inspections and can be applied to the inspection.

Figure 1-1-1 shows the different inputs the Standard incorporates toward the goal of providing high-quality, repeatable inspection results while encompassing best safety practices.

This Standard provides guidelines for the following:

(a) Outdoor Inspections. The jurisdictional authority applies to performing outdoor inspections. The owner operator can use this Standard in conjunction with applicable regulatory and industry operational and inspection standards [i.e., beyond visual line of site (BVLOS), detect and avoid, etc.].

(b) Indoor Inspections. The jurisdictional authority typically does not apply to indoor inspections. The operator can use this Standard to perform inspections to apply applicable codes or standards for obstructed/unobstructed examinations.

The best practices, procedures, and equipment are dependent on which type of inspection is being conducted. Figure 1-1-2 illustrates the overview of the ASME MUS-1 structure and applicability based on the different environments for conducting the inspection (i.e., indoor and outdoor).

1-2 Definitions

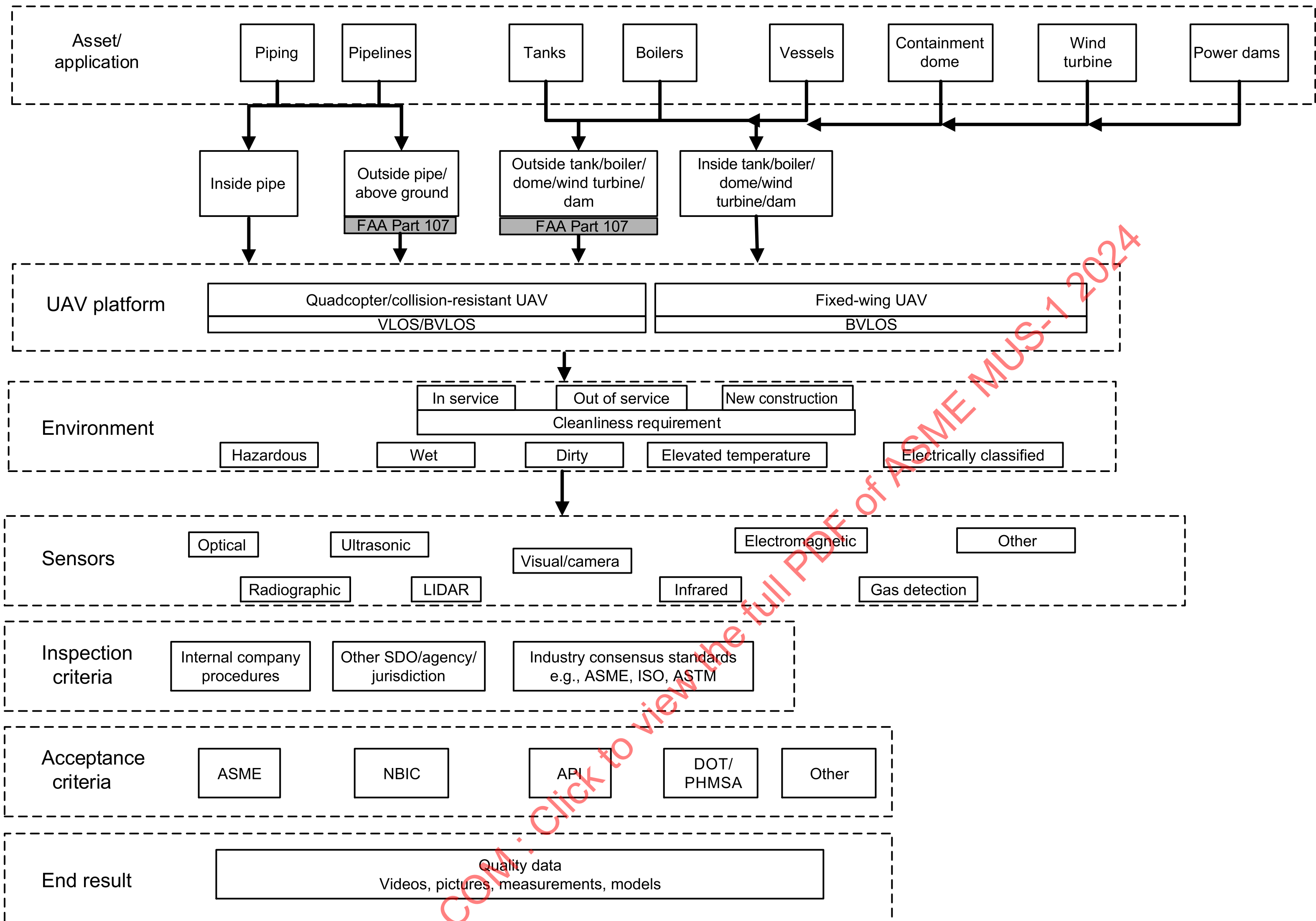
abused: any form of explicit or implicit treatment that damages the integrity of the unmanned aircraft system (e.g., operation in adverse weather conditions).

airworthiness: the condition in which the unmanned aircraft system conforms to its certification type and is ready for safe operation.

autonomous: the ability or behavior of a robotic system to operate within its environment by implementing predetermined decisions or plans with no additional input from the pilot. Not controlled by others or outside forces; independent judgement.

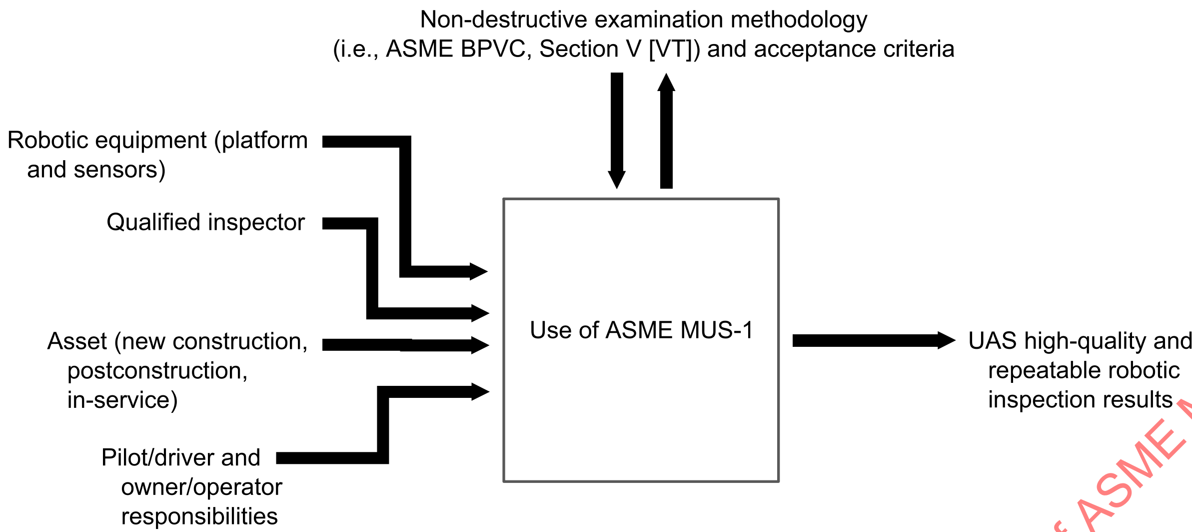
auxiliary lighting: an artificial light source used as a visual aid to improve viewing conditions and visual perception.

Figure 1-1
UAS for Inspection Landscape



GENERAL NOTE: See para. 1-3 for definitions of abbreviations.

Figure 1-1-1
Input and Outputs of ASME MUS-1



beyond line of sight (BLOS): the condition in which the unmanned aircraft and control station are unable to maintain a direct datalink between the two subsystems. This condition could require an additional source of transmission or link (i.e., tower, repeater station, etc.).

beyond visual line of sight (BVLOS): the condition in which a direct line of sight (unimpeded with no obstacles) is beyond the ability of the pilot in command/visual observer to physically see the unmanned aircraft.

command/control link: the systems supporting the exchange of information data between the ground control station and the unmanned aircraft.

control station: a transmitting controller interface device used by the pilot to control and monitor the flight path and telemetry of the unmanned aircraft.

corrective lenses: eyeglasses or contact lenses.

crew resource management: the effective use of all available resources (e.g., personnel, hardware, procedures, information) that are involved in decisions essential to safe and effective operations that are required to operate a safe flight.

current edition: the edition of the referenced code or standard that is in effect at the time of use of this document.

damage (deterioration) mechanism: any type of deterioration encountered in the refining and chemical process industry that can result in flaws and defects that can affect the integrity of vessels (e.g., corrosion, cracking, erosion, dents, and other mechanical, physical, or chemical impacts).

damage (deterioration) mode: the physical manifestation of damage (e.g., wall-thinning, pitting, cracking, embrittlement, creep).

direct visual examination: when access is sufficient to place the eye within 24 in. (600 mm) of the surface to be examined and at an angle not less than 30 deg to the surface being examined.

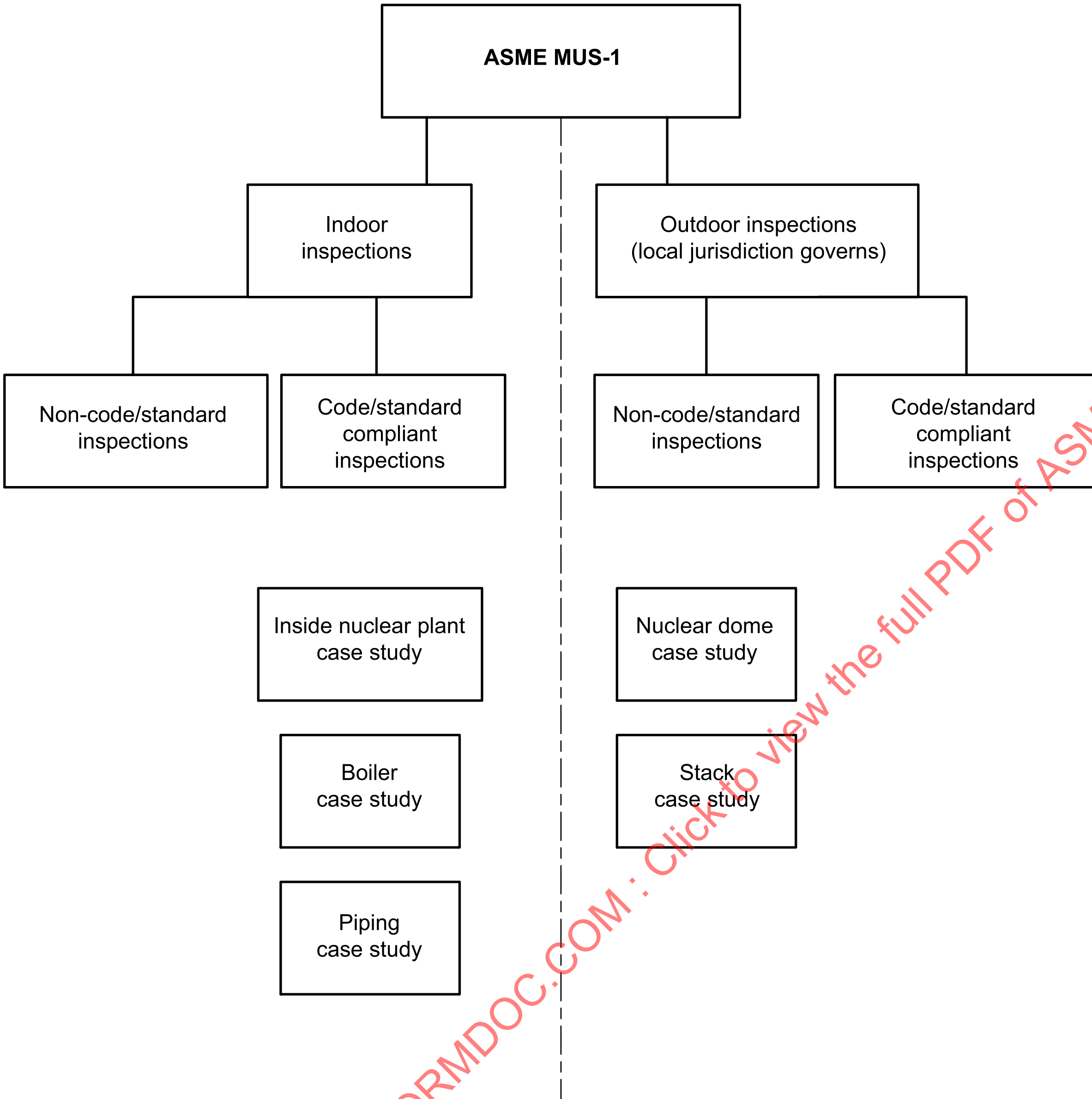
enhanced visual examination: a visual examination technique using visual aids to improve the viewing capability.

examination: the process of determining the condition of an area or item per established code, standards, or owner's specifications.

extended visual line of sight (EVLOS): the condition in which the pilot in command and/or visual observer is not able to maintain direct visual contact with the unmanned aircraft. This scenario requires methods or procedures to be used to maintain situational awareness of the unmanned aircraft and operational domain.

Federal Aviation Administration (FAA): the national aviation authority of the United States, with powers to regulate all aspects of American civil aviation.

Figure 1-1-2
ASME MUS-1 Structure



first person view (FPV): using the camera-enabled view from the unmanned aircraft's perspective as the means of flight operation (i.e., not using visual line of sight).

global positioning system (GPS): satellite mapping coordinate acquisition.

hazardous space: a space with an atmosphere that may expose personnel to the risk of death, incapacitation, impairment of ability to self-rescue (i.e., escape unaided from a permit space), injury, or acute illness.

hazard identification: process that is part of the risk analysis to identify all known and unknown hazards that can cause harm during the mission; is often assigned a numerical ranking that results in a decision to mitigate or terminate the mission.

inspection: activities performed by a subject matter expert to verify that materials, fabrication, erection, repairs, etc., conform to an applicable code or standard, engineering best practice, and/or owner's written specification requirements.

inspector: a subject matter expert who performs inspection/examination tasks to verify that materials, fabrication, erection, repairs, etc., conform to an applicable code or standard, engineering best practice, and/or owner's written specification requirements.

job safety analysis (JSA): a technique that focuses on job tasks to identify hazards. It focuses on the relationship between workers, tasks, tools, and work environment. It also includes steps to eliminate or reduce the hazards to an acceptable regime.

jurisdiction authority: applicable federal and civil regulations (e.g., International Civil Aviation Organization, geographic aviation authority).

latest edition: the latest edition in effect at the time of reference.

line of sight: the line of direct datalink communication between the control station and the unmanned aircraft without the use of a secondary transmitting device (i.e., tower, repeater, etc.).

lost link: the interruption or loss of control link, or pilot unable to effect aircraft control, and the unmanned aircraft is not operating in a predictable or planned matter. A condition in which the unmanned aircraft's flight telemetry is no longer controllable by means of direct pilot intervention or preprogrammed autonomous commands.

lux (lx): a unit of illumination equal to the direct illumination on a surface 1 m from a uniform point source of one fc intensity, or equal to 1 lumen/m^2.

may: verb used to indicate an action that is permitted but not required.

mitigation: activities performed to lower the assessed risk of continued operation by reducing the probability of failure, the consequence of failure, or both.

oblique lighting: light source positioned at a low or shallow angle on opposing sides used to show more detail by creating shadow on surface or object being inspected.

owner/user: the company, organization, or entity that owns or is responsible for the equipment being inspected and is accountable for public safety and compliance.

payload: the carrying capacity of a unmanned aircraft in terms of weight. It normally refers to the reserved lifting ability of the unmanned aircraft to perform additional operational missions excluding the basic systems required for flying.

payload operator: the person responsible for controlling the unmanned aircraft onboard payload.

personal protective equipment (PPE): protective clothing, helmets, goggles, or other garments or equipment designed to protect the person from an injury or hazard.

pilot in command (PIC): the rating required of the pilot/operator in charge to conduct and oversee flight operations in accordance with the governing body (see FAA regulations 14 CFR Part 61 and 14 CFR Part 107).

process safety management: as outlined in OSHA 29 CFR 1910.119.

qualification program: a program that is used to qualify the pilot in command, all aspects associated with unmanned aircraft flight, and the inspections performed by the inspector.

qualifying organization: an organization that undertakes the training, demonstration, and practical examinations to qualify a pilot in command (see FAA regulations 14 CFR Part 61 and 14 CFR Part 107).

remote pilot certificate (RPC): a certificate with a unmanned aircraft system/unmanned aircraft rating that is issued in accordance with the governing body (see FAA regulations 14 CFR Part 61 and 14 CFR Part 107).

remote visual examination: substituted for direct visual examinations when access is insufficient to place the eye 24 in. (600 mm) from the surface and requires the use of visual aids (e.g., use of cameras).

risk: combination of the probability of an event and its consequence. In some situations, risk is a deviation from the expected. When probability and consequence are expressed numerically, risk is the product.

risk analysis: systematic use of information to identify sources and to estimate the risk. Risk analysis provides a basis for risk evaluation, risk mitigation, and risk acceptance. Information can include historical data, theoretical analysis, informed opinions, and concerns of stakeholders.

risk-based inspection (RBI): a risk analysis and management process that is focused on loss of containment of pressurized equipment in processing facilities, due to material deterioration. These risks are managed primarily through equipment inspection.

safety data sheet (SDS): includes information such as the properties of each chemical; the physical health and environmental health hazards; protective measures; and safety precautions for handling, storing, and transporting the chemical.

semi-autonomous: the ability or behavior of a robotic system to operate within its environment by implementing predetermined decisions or plans with little additional input from the pilot. Not controlled by others or outside forces; semi-independent judgement.

service provider: a person or group (either within the owner/user organization or a third-party vendor) that provides unmanned aircraft system inspection services.

shall: verb used to indicate an action that is mandatory and must be followed.

should: verb used to indicate an action that is a recommendation, the advisability of which depends on the facts in each situation.

subject matter expert (SME): an individual considered knowledgeable in a particular field or discipline; should be able to produce documentation to support their knowledge.

surface glare: reflections from artificial light that interfere with visual perception and/or cause overexposure of imagery and video being captured.

sterile cockpit: no crewmember may engage in, nor may any pilot in command permit, any activity during a critical phase of flight that could distract any crewmember from the performance of the crewmember's duties or interfere in any way with the proper conduct of those duties. (See FAA AC 120-71.)

unmanned aircraft (UA): the aerial vehicle including everything that is on board or otherwise attached to the vehicle.

unmanned aircraft systems (UAS): all components that are associated with the unmanned aerial equipment, including radio controller, aerial vehicle, launch and recovery equipment, etc.

vertical take-off and landing (VTOL) aircraft: an aircraft that can hover, take off, transition into forward fixed-wing flight, and then retransition to land vertically. This classification can include a variety of types of aircraft including fixed-wing aircraft as well as helicopters and other aircraft with powered rotors, such as cyclogyros, cyclocopters, and tiltrotors.

visual examination: an examination method used to evaluate an item by observation such as assembly, surface condition, and operational condition.

visual line of sight (VLOS): the condition in which the pilot in command and/or visual observer is able to maintain direct, unaided (other than corrective lenses) visual contact with the unmanned aircraft. This may provide sufficient means to monitor the flight path in relation to other aircraft, persons, vehicles, and structures. Given ideal weather conditions, visual line of sight operations are normally accepted to a maximum distance of one-half nautical mile horizontally and 400 ft vertically from the unmanned aircraft pilot in command; however, many variables can reduce these distances.

visual observer (VO): a trained competent person specific to the operational needs of an unmanned aircraft system mission and is designated by the pilot in command to assist in maintaining visual line of sight of the unmanned aircraft, provide security of the landing zone, provide weather and battery level updates to the pilot in command, and fufill any ancillary needs during flight operations while also maintaining direct communication with the pilot in command.

visual test (VT): visual inspections that are performed by API certified inspectors, AWS certified welding inspectors, NDT technicians per ASME Boiler and Pressure Vessel Code Section V, Subsection A, Article 9, and other subject matter experts.

1-3 Abbreviations

API = American Petroleum Institute
ASME = The American Society of Mechanical Engineers
ASME BPVC = ASME Boiler and Pressure Vessel Code
AWS = American Welding Society
BLOS = beyond line of sight
BVLOS = beyond visual line of sight
DOT = U.S. Department of Transportation
FAA = Federal Aviation Administration
FPV = first person view
ICAO = International Civil Aviation Organization
LAANC = low altitude authorization and notification capability
LIDAR = light detection and ranging
NBIC = National Board Inspection Code
NDE = nondestructive examination
NDT = nondestructive testing
OSHA = Occupational Safety and Health Administration
PHMSA = Pipeline and Hazardous Materials Safety Administration
PIC = pilot in command
PPE = personal protective equipment
SDO = standards development organization
TOI = target of inspection
UA = unmanned aircraft
UAS = unmanned aircraft system
UT = ultrasonic thickness
VLOS = visual line of sight
VO = visual observer
VTOL = vertical take-off and landing

1-4 References

14 CFR Part 61. Certification: Pilots, Flight Instructors, and Ground Instructors. https://www.ecfr.gov/current/title-14/chapter-I/subchapter-D/part-61
14 CFR Part 107. Small Unmanned Aircraft Systems. https://www.ecfr.gov/current/title-14/chapter-I/subchapter-F/part-107
29 CFR 1910.119. Process Safety Management of Highly Hazardous Chemicals. https://www.ecfr.gov/current/title-29/subtitle-B/chapter-XVII/part-1910/subpart-H/section-1910.119
API 510. Pressure Vessel Inspector. American Petroleum Institute.
API 570. Piping Inspector. American Petroleum Institute.
API 653. Aboveground Storage Tank Inspector. American Petroleum Institute.
API 1160. Managing System Integrity for Hazardous Liquid Pipelines. American Petroleum Institute.
ASME Boiler and Pressure Vessel Code, Section V. Nondestructive Examination. The American Society of Mechanical Engineers.
FAA AC 120-71. Standard Operating Procedures and Pilot Monitoring Duties for Flight Deck Crewmembers. Federal Aviation Administration.
FAA Part 107 (see 14 CFR Part 107).
NFPA 70. National Electrical Code. National Fire Protection Association.

2 PURPOSE OF INSPECTION

The primary purpose of inspection is to provide the client or asset owner with an independent, objective, and impartial visual or evidential report regarding the current condition of the asset, process systems, subsystems, and components. The owner shall be informed of damage (as defined by the asset owner or applicable standard) to the assets, component, or subsystems identified by the inspections results. These findings may be unexpected but could affect the asset if not addressed. These conditions should be prioritized by potential impact to personnel safety and the environment. These considerations may be influenced by equipment condition and age, personnel or other assets in the area, impact of equipment outage, or any other relevant conditions.

Primarily, an inspection by UAS will be used as a remote visual inspection, with the UA camera as a substitute for the human inspector's eyes. Multiple inspectors or experts will have the ability to view the inspection simultaneously, with reduced risk and better access to the asset. Another advantage is the collection of large amounts of data more safely and efficiently, which facilitates improved decision-making by the inspector and provides an easily referenced historical record.

2.1 Site Overview

2.1.1 Internal. For confined space inspections, such as boilers, stacks, or pressure vessels, the inspector must wait for the ambient conditions of the equipment being inspected to adjust to a level considered safe for confined space entry. A job safety analysis (JSA) shall be conducted prior to operation to help ensure visual inspection can occur on the targeted equipment locations.

(a) First Person View or Point of View. The internal inspection may not allow for direct line of sight (e.g., inside a pipe or tank). Inspectors may consider the use of first person view (FPV) display, which could include a built-in viewing screen, a ground station monitor, an additional remote viewing screen, etc., for completing a safe flight.

(b) Hazards. To minimize the risks and potential hazards to infrastructure, personnel, and the environment during interior UAS operations, site planning and preparation should be completed.

2.1.2 External. UAS may be used to complete or facilitate exterior visual inspections on equipment to avoid risks associated with personnel working at heights, improve the area of coverage and efficiency of visual inspections, and enable on-stream inspection of target equipment.

(a) First Person View or Point of View. The external inspection should be aided or supplemented with multiple observers and first-person displays (e.g., inside a stack, flare, and vessel or tank structures). Inspectors may consider the use of FPV display, which could include a built-in viewing screen, a ground station monitor, an additional remote viewing screen, etc., for completing a safe flight.

(b) Hazards. To minimize the risks and potential hazards to infrastructure, personnel, and the environment during interior UAS operations, site planning and preparation should be completed.

2.2 Verification Flight

In certain circumstances when the pilot in command (PIC) may not be familiar with environmental conditions (e.g., particular components, equipment, structures, type of inspection, sensor packages, changes that are different from previous inspections, or when required to support preflight risk evaluation/risk analysis), the PIC should conduct a verification flight. The need for a verification flight should be addressed in section 3.

3 PREPARATION FOR INSPECTION

3.1 Preliminary Mission Planning

3.1.1 Purpose. The purpose of this section is to establish open lines of communication between the PIC, internal/external client, and the participating crew members that are consistent with crew resource management and site-safety practices at an early stage of the mission planning. The preparations practices in this section apply to confined space, internal, and external inspections.

3.1.2 Component of the Mission to Identify. The PIC in combination with other subject matter experts (SME) shall clearly define the upcoming mission by determining the following:

(a) type of inspection for which the UAS will be used
(b) purpose of the inspection (e.g., routine operations and maintenance, commissioning, problem site, hazardous environment)
(c) vital documentation of asset process and product (e.g., current drawings)
(d) asset and asset area cleanliness and readiness for requested inspection
(e) a safe deployment area, crew assignments, and needs of client request with named SMEs
(f) need for verification flight
(g) crew members' roles, responsibilities, and required qualifications
(h) identification of the object of inspection and flight plan
(i) equipment (resolution) and payload details
(j) inspection objective deliverable requirements (i.e., data format, media delivery, and security of deliverable)

(k) risk analysis and mitigation (e.g., establish appropriate protocol for adverse and unplanned events)

3.2 Pre-Mission Evaluation and Planning

3.2.1 General. The owner operator and the UAS service provider shall complete pre-mission evaluation and planning before continuing other activities. Pre-mission evaluation and planning should be consistent with the UAS being flown within the manufacturer's published performance limitations for the given model. UAS operators shall document in their preflight assessment that the UAS selected meets the prerequisites for safe operation of UAS and required conditions for each flight of the mission. If the UAS manufacturer's performance limitations are not published or if the UAS are flown outside the published limitations, then the UAS shall be assessed in accordance with para. 3.2.2 to validate its inflight performance profile.

3.2.2 Operational Performance Validation. The PIC shall follow the manufacturer's published limitations. For all UAS flown outside the manufacturers' published limitations, or if no limitations are published, the following shall be validated:

(a) Required operating conditions shall be flight tested to validate performance and control prior to the first inspection flight. These conditions are to be tested and validated in a test flight that meets or exceeds the conditions required for the actual inspection flights.

(b) All payloads at their actual location on the UAS may be simulated for flight performance characteristics.

(c) Operating conditions, such as

(1) environment performance: wind, temperature, altitude, atmospheric effects, visibility, ceiling, hazardous environment, etc.

(2) site-specific factors: electronic magnetic interference, control/video bandwidth congestion or limitations

(3) payload compatibility: signal emissions from payload that may limit performance, flight time reduction for weight and use of onboard power

These validation steps can also be used to validate a pilot's qualifications to operate in extreme conditions as well as to validate onboard payload sensors.

It is the responsibility of the owner/user to establish the scope, quality level, and acceptance criteria of the inspection. The owner or owner-designee will select the equipment that is appropriate for the intended inspection. Equipment selection is dependent on what image quality and georeferencing accuracy is required and based on the intended application of the UA.

3.3 Selection of a UAS Service Provider, UA Device, and Equipment

The owner operator should review and understand the following requirements and recommendations before selecting a third-party service provider:

(a) Safety Features

(1) The UAS and onboard modules shall be used specifically and only for the intended operational environment.

(2) The UAS materials and onboard modules shall be nonhazardous to the object of inspection under normal operating conditions in case of an unexpected event or failure that results in device loss.

(3) The UAS device shall possess a proven structurally strong (e.g., carbon fiber, carbon-filled composites), protective component to minimize potential damage to the structure and coatings for internal inspections (e.g., protective cage, propeller guards, collision-avoidance system).

(4) Critical UAS spare components (e.g., motor, battery, controller, viewing screen) should be available to minimize risk from completion of inspection.

(5) The UAS should have multiple failsafe modes in the event of unexpected malfunctions or failures.

(6) The UAS should have power-up self-testing of critical components, such as motors and various sensors. The self-testing diagnostic should display on a user interface that the equipment is ready to perform under specifications.

(b) Accessibility/Use

(1) The UAS manufacturer shall provide specifications verifying the UAS device is designed for the intended environment (e.g., maximum operational wind speed, temperature, humidity).

(2) The UAS manufacturer shall specify the minimum access requirements for safe UAS operations, so that end-users can select equipment with sufficient access requirements that meet the desired use-case (e.g., manhole opening too small, confined spaces, size of the openings, and structural limitations within the space). Note that these dimensions may be affected by varying asset characteristics.

(c) Operability

(1) The PIC shall have clear access to the UAS control station to easily operate the UA.

(2) The UAS device shall have onboard flight control modules that allow for stable and accurate maintaining of UAS position, altitude, and speed control on all axes.

(3) The UAS shall have onboard localization and navigation modules [e.g., GPS for external inspection, which is not applicable for indoor operations or visual line of sight (VLOS)].

(4) The PIC should ensure battery power is sufficient to support the planned operation.

(d) *Data Acquisition*

(1) The UAS shall have an onboard camera that provides the required visual quality of still images, livestream video, and recorded video. Any onboard sensors or payload shall have been previously tested and can provide the required data while operating in its current environment and UAS platform. The data should be identified in the planning stage as a critical data requirement or alert that would terminate a mission.

(2) When applicable, the UAS device shall have onboard sensors that can provide additional information (e.g., geotag information, anomaly measurement).

(e) *Communication/Transmission*

(1) The UAS should provide and maintain an interference-resistant communication channel.

(2) The PIC shall ensure that reliable interpersonal communication equipment is available and provided for each team member, as applicable.

(3) Range and channel-hopping capability of communication equipment is appropriate for most missions. When the system does not have this capability, the crew should employ a radio frequency meter to monitor channel interference.

(f) *Data Display*. The UAS should have the capability to use additional viewing equipment to display and replay visual data, including still images, live video feed, and recorded video to the inspector to reduce any distraction of the PIC.

3.4 Site Planning

3.4.1 Site-specific Considerations. Operation at specific locations at a facility or plant shall also be taken into consideration when planning and validating proper operation conditions. At a minimum, the following factors shall be considered:

(a) terrain
(b) asset structure and adjacent structures
(c) water factors
(d) work permit requirements
(e) local regulatory requirements
(f) general access
(g) local airspace
(h) site-specific safety training requirements
(i) personal protective equipment (PPE) requirements

3.4.2 Atmospheric and Environmental Considerations. Operational conditions due to atmospheric and environmental conditions at the location, including internal conditions of asset for confined space inspection activity, shall be taken into consideration. A site readiness checklist that directly affects operational performance validation shall be completed prior to the activity. At a minimum, the following factors shall be considered when planning an activity:

(a) local general seasonal conditions
(b) day of operations forecast
(c) wind
(d) precipitation
(e) cloud cover and height
(f) visibility
(g) asset readiness for confined space and internal (interior) inspection (e.g., blocked openings to prevent wind intrusion as well as safety barriers on all openings)
(h) rotor wash (dust, gases, or debris both toxic and nontoxic due to air movement provided by the UA)

3.4.3 Additional Considerations. Additional considerations shall be evaluated for the safe operation of the UA and onboard payload sensors. An on-site survey or job walk shall be completed prior to the activity to account for conditions that may not be apparent during the initial planning. The following factors, at a minimum, shall be considered and assessed for the safe operation of UAS:

(a) primary and secondary takeoff and landing zone compatibility
(b) induced turbulence of unknown openings, air movers, or other equipment that can disturb the known weather conditions
(c) magnetic interference
(d) spectrum analysis
(e) GPS or navigation availability

(f) noise
(g) temperature challenges
(h) humidity changes, both exterior and interior that can affect the UAS and crew (misters, cleaning equipment that require water and can affect the known humidity)
(i) hazardous chemical contact known to asset process or used to clean asset prior to mission
(j) radioactive areas
(k) electrically classified areas (intrinsically safe)
(l) cell power generation areas
(m) locally reduced visibility (dust, steam)
(n) vehicle and pedestrian activity
(o) simultaneous operations (including UAS and robotic crawlers)
(p) job safety analysis or job hazard identification and analysis review
(q) lighting for internal inspection

3.5 Sensors and Aircraft Selection

Sensors being used to perform inspections shall meet acceptance criteria based on the owner/user inspections needs, criteria specifications, or referencing code. When acceptance criteria is based on code requirements, the sensors shall be initially tested independent of being installed in the UAS and shall meet the equivalent code requirements for use. The camera used for visual inspections shall satisfy human eye equivalency or have the required resolution (camera and monitor) for inspection acceptance criteria (e.g., ASME BPVC requirements) by meeting a required Jaeger 1 visual equivalence and/or the 1951 U.S. Air Force resolution test chart.

The effective range to the item being inspected, or surveyed using the sensors, shall be determined to provide accurate and meaningful results. UAS performance and safety will be taken into consideration in determining the effective sensor ranges. Successful validation and operation requirements of onboard imaging sensors shall be documented. Revalidation of onboard sensors shall be consistent with equipment calibration specifications required by code or sensor manufacturer's specification.

All onboard sensors or modules carried by UAS, which the UAS was not originally designed for, shall be tested for their intended operational environment.

3.6 Flight Plan

A flight plan for the specific activities shall be approved by the PIC and reviewed by the owner/user. The flight plan shall be based on inspection or survey requirements specific to meeting the acceptance criteria of the owner's specifications, operation performance considerations, payload/module/sensor limitations, jurisdictional and flight requirements, and any additional safety considerations specification to the flight. As a minimum the following considerations shall be addressed:

(a) Flight and inspection crew shall be identified, and their duties and qualifications completed and documented in accordance with section 5. A methodology of communication shall be set up between the remote operator, inspector, visual/safety observers, and any individual involved in the activity to maintain constant communication between among all crew members.

(b) Flight plans (maps) for each inspection with area designations shall be developed. Each flight plan shall include the date and time of the flight in question, UAS equipment used, the takeoff and landing locations, the area surveyed, the type of imagery collected (video or photos or both), the file and folder names where this imagery can be found and the corresponding URLs. Consider using current satellite imagery, flight-planning applications specific to UAS operations approved by the FAA, or drawing from the geographic aviation authority templates/forms (e.g., filing flight plan on an aeronautical chart or flight map).

(c) Identify the safe return-home battery/fuel level and primary and secondary take-off/landing zones based on factors such as wind speed, direction, temperature, flight distance, operating altitude relative to the takeoff location, obstruction heights near the takeoff/landing location, and the mission flight path.

(d) Verify and ensure flight clearance (FAA requirement) by knowing in which airspace class they are operating in along with any additional specialized classes in their area. Use the low altitude authorization and notification capability (LAANC) or most current mission operation approval system when operating in these airspaces.

(e) Ensure calibration of all equipment and perform test flights before launching inspection mission according to equipment manufacturer.

(f) Review preflight checklist and emergency checklist.

(g) Acquire documented permission to operate UAS from official authorities (e.g., site security, site management, asset owners/operations). It is the responsibility of the PIC of the UAS service provider to be aware of the client's UAS operations, local UAS laws, and the country's most current aviation and UAS laws.

(h) Obtain permission when operating in airspace that requires approval by using LAANC or the most current mission operation approval system. Contact air traffic control when approval systems are not available.

3.7 Risk Analysis

The owner shall perform a risk analysis and hazard identification to provide a risk mitigation strategy before operating UAS. The hazard identification is a critical step in the risk analysis to help identify hazards that can affect the mission and provide a clear path for mitigation strategies. For each identified hazard, ensure the UAS mission can be conducted safely. The assessment shall include

(a) identification of the primary and secondary takeoff and landing areas before carrying out mission. Identify alternative landing sites if the initial site is no longer available in the event of having to perform an emergency landing. Takeoff and landing sites shall be clear of buildings, trees, people, power lines, telephone lines, busy roads, and anything that can obstruct safely landing the UA.

(b) development of a plan for flying over people and for crowds that are not part of the inspection. This can be supplemented by email communications to production leaders or supervision as well as posting signage on the day of the mission that UAS operations are in progress. Ensure that a safe zone and barrier is identified and identify a safety observer to monitor the mission plan, potential risks, and who is aware of the emergency protocol. The safety observer shall notify the PIC it is unsafe to carry out the mission if the observer feels the safety procedures are not in compliance. Any member of the UAS mission crew shall have the ability to terminate the operation in the event that conditions suddenly change that affect the crew or operating area. The plan should include a briefing with the crowd notifying them of the physical risks and emergency procedures. This can include pictures of UAS dangers and potential injuries and posted billboard procedures.

(c) at least one visual observer (VO) for UAS operations, unless performing approved beyond visual line of sight (BVLOS) operations subject to relevant jurisdictional authority (see para. 5.6).

(d) consideration of other risk concerns such as collisions, dropped objects, dust, foreign material exclusion, and potential of explosion in operation environment.

(e) confirmation that a proper failsafe feature and protocols are in place, such as appropriate return-home altitude, geofence, lost-link operating sequence, and low battery/fuel settings.

3.8 Documentation

The service provider/operator is to possess at all times an operations and safety manual specific to UAS with an organized documentation system to confirm that service-related records are maintained within the guidelines of this Standard and referencing code. The records shall include but not be limited to the following information:

(a) documentation of an effective organization, safety management structure, and employer's written practices or procedure and each named pilot's logged flight time on all equipment to be used.

(b) Statutory and Regulatory Authorizations. Required authorization/waivers granted on behalf of national/local aviation authorities, if applicable, shall be included.

NOTE: Although some states do not have UAS laws, it would still be good practice to notify local authorities.

(c) Equipment Registry. The service provider shall obtain a registry of each operational device with original equipment manufacturer specifications, serial number, technical bulletins, hardware alteration and customization history, software versions, etc.

(d) Training Record. The training record shall include all applicable information of all personnel in terms of personal portfolio, training hours, dates, scores, personnel certifications, and other company-specified categories.

(e) Pilot/Operation Logbook. The service provider shall maintain a logbook to record all applicable operational flight/training information such as flight date, time, duration, malfunction incident, accident, emergency procedures, flight plan, etc.

(f) Maintenance Logbook. The service provider shall maintain a logbook (hard copy or electronic) to record maintenance procedure and practice of each device, maintenance test flights, and payload modules.

4 EQUIPMENT USED FOR INSPECTION

4.1 Selection of Equipment

There are a variety of UAS types and optional UA payloads. Depending on the purpose of inspection, the asset owner shall select the type of UAS and UA payload that will best satisfy the intent of inspection. The asset owner shall also determine compatibility of the UAS and payload for any environmental conditions. These environmental conditions can include, but are not limited to, NFPA 70 hazardous areas, radioactive areas, lightning conditions, confined space entry, etc.

4.2 Inspection Planning

The asset owner, inspector, and PIC shall discuss the inspection goals prior to flight and record inspection goals in the inspection plan. The inspector shall ensure all necessary aspects of the inspection are achievable. All problematic inspection goals should be discussed with the asset owner as soon as they are realized.

4.3 UAS and UA Platform Requirements

The combined weight of the UA and payload cannot exceed what is determined by the jurisdictional authority, [e.g., 55 lb (25 kg)]. The UA shall be registered with the regional jurisdictional authority (see, for example, FAA's registration website).

4.4 Visual Inspection Equipment

The most common inspection method using UAS is a remote visual inspection (RVI). RVIs may be for informational purposes only and/or to meet the requirements of an inspection code or standard (e.g., API 510, API 570, API 653, ASME BPVC). When performing a remote visual inspection, the quality of the camera/picture/video shall comply with the applicable codes/standards. When an inspection code or standard does not provide means of remote visual requirements, a methodology for the use of the camera/picture/video must be used to show equivalency to visual examination and be approved by the owner/user.

The camera payload being used to perform the remote visual inspection shall meet the operator's/client's requirements for resolution, adequate lighting, stability of image, and distortion-free image quality. Methods to test, calibrate, and verify camera acuity can vary depending on the code, standard, or asset owner requirements. These can include, but are not limited to, the 1951 USAF resolution target, light meter, pixel count, lens focal length, gimble mount, and maximum viewing angle from the UA to the inspected surface.

4.5 Advanced Nondestructive Examination Equipment

Further advanced nondestructive examination (NDE) methods can be completed with the aid of UAS, such as ultrasonic thickness (UT) measurements, thermal inspections, LIDAR measurements, multispectral monitoring, and multi-gas sensing.

(a) Ultrasonic (Volumetric). Typically the UA will fly in very close proximity to and in direct contact with the asset being inspected. A UT probe or secondary vehicle containing the UT probe will be attached to the asset by making surface contact with the asset. Once the UT measurements are complete the UA will fly away from the asset and move to the next measurement location. These inspections are currently semi-autonomous. This type of inspection can either be used to find the thickness of the base metal of an asset or the dry film thickness — the coating thickness remaining on the surface of the asset. Typical industry-accepted thickness probes are used to collect and analyze the data.

(b) Thermal (Infrared) Inspections. These flight profiles are typically medium altitude and dependent upon the sensor suite mounted to the UA. Thermal inspections are used for checking for adequate levels of insulation of either hot or cold assets, monitoring the health of rotating equipment, or monitoring side-by-side assets for load balancing. Visual detection software systems can be used to find changes over time.

(c) LIDAR Measurements. Light detection and ranging (LIDAR) uses a range of projected, focused light and the resulting backscatter to digitally measure the geometry of an internal or external surface with high resolution and accuracy. This can be used in real-time flight control systems for object avoidance or to digitally reconstruct an accurate 2D or 3D model of an asset.

(d) Multispectral Monitoring. This broad class of inspection entails capturing images across the light spectrum from ultraviolet light through the visible range and into the infrared range. This type of inspection has been used for detecting faults in electrical systems and the identification of production process spills and leaks.

(e) Multi-gas Sensing. This type of future integration will monitor the immediate flight environment for dangerous lower explosivity limit situations in which the UA is operating. This type of monitoring will be used to ensure the operational environment of the UA is safe for continued operations.

4.6 Optional Payloads

It is not the intent of this Standard to identify all optional payloads a UAS manufacturer could offer. Depending on the purpose of inspection, the asset owner shall determine the payload that best satisfies the intent of inspection. The payload that is chosen shall comply with applicable FAA Part 107 requirements, applicable NDE standards, applicable lighting requirements, and other applicable codes/standards that would encompass the chosen payload. Carriage and transportation of hazardous materials is not permitted.

5 DUTIES AND RESPONSIBILITIES

5.1 Asset Owner/User Roles and Responsibilities

The asset owner/user shall

(a) define the inspection objectives and prepare a document outlining inspection scope, schedule, and logistics. Include any practical constraints such as adjacent locations where flying is not permitted.

(b) define the inspection deliverables to ensure the flight plan and desired results are in alignment with the desired scope.

(c) select the appropriate UAS service provider whose qualifications, certifications, and capabilities are acceptable for the intended inspection/examination application.

(d) ensure UAS service provider compliance with owner/user requirements and all applicable regulations.

(e) ensure all required licenses, work permits, and authorizations are issued prior to UAS flight.

(f) ensure an emergency response plan is implemented and a risk analysis or job safety analysis is conducted prior to UAS inspections being performed.

5.2 UAS Service Provider Roles and Responsibilities

The UAS service provider shall

(a) ensure the PIC and other UAS crew members have the appropriate training, certifications, and accreditations to successfully complete the mission at hand. The UAS flight crew should be knowledgeable of the following factors:

(1) safety of ground personal
(2) safety of the asset being inspected
(3) emergency procedures
(4) limitations of UAS
(5) operational use of UAS
(6) requalification and continued training

(b) ensure the PIC and other UAS crew members have the appropriate flight experience, determined by the owner operator, to successfully and safely complete the inspection. The UAS service provider shall have written policies regarding all personnel training and UAS proficiency.

(c) keep a record of credible flight and mission experience. The records can be hard copy or electronic and should document the experience and background of the PIC, the operator, and the UAS. The information should include, but is not limited to, the following:

(1) logbook of hours flown
(2) types of aircraft flown (to include supporting regulatory documents)
(3) types of missions flown
(4) training and certifications
(5) maintenance and inspection/repairs

(d) ensure that personnel involved with UAS activities adhere to a duty time. For safety concerns, duty time should not exceed 12 hr per day. Duty time activities can include, but are not limited to, the following:

(1) on-site training prior to mission
(2) job briefing and hazard assessment
(3) preflight operations
(4) flight and inspection
(5) postflight operations
(6) data review

(e) ensure the qualified inspector has the appropriate experience and applicable certifications to perform the asset inspection.

(f) assign the appropriate personnel and crew. Examinations that use UAS are considered unique because each examination can include and involve a variety of payloads, inspection methods, and experienced personnel. A UAS inspection team should include, at minimum, the following individuals:

(1) PIC

(2) qualified inspector (as required)

Depending on the size and/or complexity of the inspection flight path, other crew members may be used, such as a camera/payload operator, VO, or safety spotter.

5.3 PIC Roles and Responsibilities

The PIC is the person who is in direct control of the UAS flight operations. Competency of the PIC affects the safety of personnel and the asset being inspected. The PIC shall

(a) ensure UAS flight operations are compliant with applicable federal and civil regulations.

(b) meet the regulatory flight training hours and experience to maintain the required certifications.

(c) be responsible for all aspects of the flight plan, flight, airworthiness of the UAS, and safety of the flight.

(d) develop an emergency plan per UAS manufacturer recommendations, when applicable, as needed for the flight objectives.

(e) ensure all persons involved with the UAS flight are trained and understand the emergency plan.

(f) consider and account for the following:

(1) compliance with local jurisdiction (e.g., country, state, province, county, city)

(2) UAS maintenance

(3) completion of flight checklist

(4) personnel and equipment safety

(5) hazard identification

(6) coordination with the UAS inspection team

(7) weather limitations

(8) inspection goals

(9) UAS limitations

(10) indoor flight hazards (if applicable) that are not addressed by FAA/ICAO

(g) hold a valid FAA Part 107 certificate for Small Unmanned Aircraft, or equivalent national civil aviation organization or ICAO-applicable credentialing commensurate with commercial operations, when flight is performed outdoors. When flight is performed indoors, while not always required, the PIC should hold a valid FAA Part 107 certificate for Small Unmanned Aircraft, or equivalent national civil aviation organization or ICAO-applicable credentialing commensurate with commercial operations.

5.4 Qualified Inspector Roles and Responsibilities

The qualified inspector shall

(a) hold the knowledge, skills, ability, and certifications (as applicable) to perform inspections of the specific asset

(b) be responsible for the aspects pertaining to the asset inspection

(c) meet any specific requirements of the owner/user

(d) consider and account for the following:

(1) hazard identification

(2) coordination with the UAS inspection team

(3) weather limitations

(4) inspection goals

(5) UAS limitations

5.5 Camera/Payload Operator Roles and Responsibilities

The role of camera or payload operator is typically served by one person whose primary role is to control the onboard camera and other data collection devices when these tasks cannot be performed by the PIC or qualified inspector. The camera/payload operator shall

(a) be familiar with flight operations and mission objectives

(b) hold the knowledge, skills, ability, and certifications (as applicable) to properly use and control the camera/payload

5.6 VO Roles and Responsibilities

The VO role is typically served by one person whose primary role is to support the PIC with flight safety and can act as a communication link to minimize distractions to the PIC. The VO shall be

(a) familiar with current flight operation and mission objectives

(b) able to easily detect and communicate weather conditions, ground hazards, airborne hazards, etc., at established intervals during the flight

When required, the VO can serve as an additional crew member to keep line of sight.

5.7 Safety Spotter Roles and Responsibilities

The safety spotter role can be filled by an employee of the client that is most familiar with the area, or several people depending on the size of the flight area, whose primary function is to keep non-essential personnel away from the PIC and other crew. The safety spotter shall

(a) help to ensure the flight area remains clear of hazards and onlookers

(b) be familiar with flight operations and mission objectives

6 CONDUCTING INSPECTION

6.1 Initial Discussion

The initial discussion should be performed with all involved parties, including the UAS service provider and the asset owner personnel responsible for the asset, site safety, and inspection. The initial discussion can be done by phone, web conference, or with an in-person meeting.

The initial discussion should be summarized in a document that is read and approved by all the involved parties.

6.1.1 Scope of Inspection. The asset owner shall communicate the scope of the mission and all known potential hazards to the UAS service provider. The scope should include the area to be inspected, the assets to be inspected, and the sections of the assets to be inspected when relevant. The asset owner should also communicate which areas must not be entered or touched by the UAS when in proximity to the area of interest.

When possible, the asset owner should provide the UAS service provider with relevant maps and current drawings or original blueprints to illustrate the scope of the inspection, as well as documents from past inspections that are both manned and unmanned. The scope should set a timeframe in which the inspection should be accomplished, including an estimation of the time needed to gather and process the data.

The scope shall also determine whether the UAS service provider's mission is to provide an inspection report or simply gather auxiliary data that can later be used as a support for the inspection by the asset owner.

6.1.2 Involved Personnel. The asset owner shall decide which personnel are needed for the mission, such as an inspector, an engineer, or a safety specialist. The UAS service provider shall also decide when an observer or additional pilot is needed and have final say on the amount of people allowed to be inside of the secured flight operations area. See section 5.

6.1.3 Deliverables. Ensure the deliverables, as required in para. 3.1, have been met.

As stated in para. 3.1.2(j), the asset owner shall communicate to the UAS service provider the final deliverable type expected from the inspection. The deliverable type should be expressed in terms of data format (such as video, picture, 3D model/map, distance measurement, thermal measurement, etc.) of defined points of interest. The method of transfer of deliverable shall also be agreed upon and usually predetermined by the asset owner's IT security requirements (e.g., thumb drives, SD cards, cloud storage URL).

When the UAS service provider is conducting a code inspection, both parties shall agree on the final format in which the UAS service provider will deliver the report. The parties shall furthermore agree on how the data should be handed over, such as via the cloud, USB key, or SD card, paying special attention to the asset owner's IT security policies.

6.1.4 Acceptance Criteria. The UAS service provider and asset owner shall work together ahead of the flight to identify acceptance criteria the inspection will satisfy. The UAS service provider inform the asset owner of the projected quality of the data so they can define which standards are capable of being met. The service provider shall ensure that the standard allows for remote visual tools to satisfy the inspection requirements. Emphasis should be placed on the ability to locate data of interest in or on the asset.

6.1.5 Mission Environments. The asset owner and the UAS service provider should discuss the particularities of the setting in which the mission will be conducted. The service provider should thoroughly communicate the operational limitations of the aircraft to be used as well as the importance of weather and environmental changes that can immediately affect or terminate the flight.

For outdoor operations, this could include wind speeds and direction at ground level and aloft, or obstacles such as power lines, high-power generation areas (cell farms), wildlife, birds, bats, or large stinging insects that can damage the aircraft or affect the crew. Environments that are regulated by a national airspace administration, such as those with crowds or the area around an airport, could also affect the flight.

For indoor environments, this could include dust concentration, birds, bats, or large insects that can damage the aircraft, hanging objects like sprinkler systems, significant clutter, hazardous substances, internal temperature, or pooling, for example.

The UAS service provider should ask relevant questions on environments that may disturb the safe operation of the UAS, such as

(a) sources of electromagnetic interference, such as high voltage lines or cell generation farms

(b) sources of GPS disturbance, such as large steel structures or overarching structures

(c) steam or condenser vapor or potential hydrocarbons that could cause damage to the UAS or directly impair or harm to the crew

Ensure a current rescue or asset entry plan is in place and essential personnel are available to enter asset in the event the UAS need to be recovered. When any disruptions are identified, mitigation plans should be put in place.

6.1.6 Feasibility Test. The UAS service provider shall inform the asset owner of the feasibility of the inspection and the deliverables based on the hardware, experience, and capabilities of the UAS service provider.

The UAS service provider should also evaluate if the hardware is adapted to perform in the given environment.

When the scope, deliverables, environment, or acceptance standards are unrealistic, the UAS service provider should provide the asset owner with suggestions to modify the standards in ways that will suit the asset owner's needs.

6.2 Pre-mission Plan

Pre-mission planning should be done after the initial discussion and include the asset owner. The pre-mission planning contains steps for the asset owner and the UAS service provider.

The UAS service provider shall create a document from the pre-mission planning — the mission plan — and share it with all involved personnel. The document should be read and approved by the asset owner.

The mission plan should be used by all involved parties during the mission.

6.2.1 Operational Hazard Identification and Risk Analysis. Prior to the start of a mission, evaluate on-site conditions to ensure there are no changes to risk factors addressed in the planning phases. The asset owner shall ensure any site entry requirements have been met by all parties to the mission. The asset owner and PIC shall ensure all required permits and work process documentation are approved and available for inspection. The PIC shall ensure all persons directly involved in operations have received any required training prior to the mission.

The PIC shall verify that contingencies are in place should the UAS experience a failure, power loss, or loss of signal. The PIC shall continually reassess risk issues during operation for unexpected atmospheric conditions, wildlife behavior, malfunctions of UAS, and unauthorized and authorized personnel. The asset owner and PIC have authority to stop operations at any time due to safety, security, performance, or inspection quality issues. However, any other parties to the mission should promptly report any issues to the asset owner or PIC even if the other parties do not have stop-work authority.

6.2.2 Operational Needs Assessment. The UAS service provider shall confirm all items identified by the needs assessment during planning are available for the mission, including

(a) UAS with needed flight time, weight capacity, collision prevention systems for VLOS indoor operations, collision resilience systems for BVLOS indoor operations, and lighting

(b) internal and attached payloads

(c) data storage device with needed space and retention

(d) ground control station location

(e) crash mitigation systems, such as parachutes

(f) maintenance tools and spare parts

(g) sufficient number of batteries and charging stations to allow uninterrupted operations

(h) communication hardware, if flight will be performed in a loud environment

(i) transportation to site

(j) PPE, first-aid kit, heat, or water as needed
(k) sheltered area for charging, data review, personnel comfort, or other purposes as established

The UAS service provider and asset owner shall ensure planning documentation (see section 3) is followed.

6.2.3 Method Statement. The UAS service provider and asset owner shall ensure the following relevant procedures were followed:
(a) acquisition of permits
(b) training
(c) pre- and postflight checks
(d) data management
(e) decontamination of site

6.2.4 Permits. When the UAS service provider is an external party, or when needed by the internal UAS service provider, the asset owner should take measures to obtain the permits needed for the UAS service provider to access the site.

When the mission is performed in confined spaces, the UAS service provider should be properly trained and accredited for such a mission.

The UAS service provider shall be responsible for obtaining any other permits necessary to perform the flights in the airspace used for the mission.

6.2.5 Personnel. See section 5.

When the UAS service provider is an external party, or when needed by the internal UAS service provider, the asset owner shall schedule a site-specific safety walk down, ensure personnel have background checks and drug screenings, and a pre-job safety briefing for the UAS service provider in advance.

The asset owner should communicate to the UAS service provider any special security measures and insurance amount requirements that need to be taken ahead of the UAS service provider arriving on-site. The asset owner should also communicate to the UAS service provider how much time will be needed for on-site training and registration.

6.2.6 Data Management. The asset owner and the UAS service provider should define how the data will be managed following the inspection. This includes the format in which the data should be delivered, how the data will be identified, how the data will be localized, how the data will be handed over, and if archive retention is needed to protect against data loss.

In cases where the UAS service provider is a third party, they should also decide if the UAS service provider may leave the site with the data for postflight processing, known as "Off-Site Reporting." For example, when high resolution data like LIDAR is captured, it can easily take a week or more to process and create the final deliverable. This also must be done on high-powered computers capable of processing this data. Even now, with 4K video cameras or 40-plus megapixel image captures, the processing can take as long as the LIDAR data, for the same reasons. The method of delivery discussion can become very important because there may be terabytes of data.

6.2.7 Data Security. In cases where sensitive assets are inspected, special security measures should be agreed upon, such as recording data only locally on the UAS and ground control station with no local caching enabled. Data storage and requirements for storing data shall be the responsibility of the asset owner. The data security, including cybersecurity, shall comply with the previously agreed-upon parameters.

6.3 Inspection

6.3.1 Arrival on Site. The UAS service provider shall follow the asset owner's instructions regarding registration and training prior to entering the site. The service provider should also possess a JSA specific to UAS, which covers standardized areas of concern and should accompany any client JSA.

A briefing and JSA should be held with all involved personnel and include
(a) confirmation of the scope, risk analysis, and method statement
(b) review of the various responsibilities
(c) review of risks and mitigation plans
(d) review of emergency procedures specific to site
(e) review of permits
(f) review of weather forecast and asset operation status
(g) review of PPE
(h) confirmation that the asset is ready for the inspection

6.3.2 Mission Plan Review. The UAS service provider shall review each point of the mission plan on-site and determine if its parameters match the reality of the site and their operational ability. The scope should also be reviewed to ensure its feasibility.

Any variations or discrepancies shall be discussed with the asset owner and noted. When the feasibility is affected by the changes, the asset owner and UAS service provider should agree on mitigation measures or delay the mission, when necessary.

6.3.3 Outdoor Missions. When the mission is performed outdoors, the UAS service provider should ensure that the weather conditions, including wind and precipitations, do not pose a risk to the mission. The mission plan should be adjusted as needed when the current operational status of the asset being inspected, or nearby assets, differs from the plan.

The asset owner should ensure that the UAS can safely be flown in the area of interest by ensuring the area is cleared or that all personnel who may be in the area briefed on the potential risks if the UAS undergoes a failure.

6.3.4 Indoor Missions. When the mission is performed indoors, the UAS service provider shall ensure that the obstacles and layout of the asset match those that were planned for.

The asset owner shall ensure that potentially ongoing operations poses no harm to the UAS service provider or equipment, that asset operators are aware of the mission, and that the mission team and personnel on site discuss the site's current operational status and potential risks should the UAS undergo a failure.

The UAS service provider shall be cognizant that the UAS will be operating in a hazardous environment and shall execute any necessary procedures to rectify the situation. All indoor missions that have the potential for coming in contact with workers should be attempted at break times or lunchtimes when personnel presence is minimal. When this is not possible, the minimum remaining battery life should be adjusted higher to ensure the UAS returns to the primary landing zone with power to spare.

6.3.5 Additional Safety Check for BVLOS Indoor Missions. When the mission is performed BVLOS indoors, the UAS service provider should perform a visual check of the entrance of the asset with a flashlight to make sure there are no hazards.

When the mission is performed BVLOS outdoors, refer to FAA regulations for BVLOS.

6.3.6 Confined Space Entry. When the mission is performed in a confined space, special attention should be paid to safety procedures, such as ensuring that operators are aware of the mission scope, the UAS service provider is trained and has any necessary certifications for confined-space work, and that the asset and connected hazard sources are isolated in accordance with asset owner/regulator requirements.

6.3.7 Hardware Check and Payload Check

6.3.7.1 Prior to turning the UAS on, the UAS service provider should check the hardware, including the

(a) structural integrity of the UAS
(b) charge of the ground control station
(c) charge status, physical condition of the batteries, and the amount of flights on each battery
(d) tightness of the propellers and motors

6.3.7.2 After turning on but prior to arming the UAS, the UAS service provider should check that the

(a) UAS and the ground control station are transmitting within acceptable parameters
(b) storage space for data on the UAS is sufficient to record the different flights
(c) payload, including lighting, sensors, etc., are functioning in accordance with manufacturer specifications

6.3.7.3 After arming the UAS and after taking off, the UAS service provider should check that the

(a) UAS is flying as expected
(b) transmission is working as expected
(c) payload and sensors are responding as expected

In any case, the UAS service provider shall follow the UAS manufacturer's checklist during all aspects of the mission.

6.3.8 In-flight. While conducting the mission, the UAS service provider shall proceed as planned and deviate as little as possible from the method statement unless unknown hazards are discovered. The UAS service provider should pay particular attention to referencing the flights as planned to ease data localization. Extra steps can be taken in this regard, such as writing the flight number, names of the PIC and VO, asset number and date, and a diagram, when possible, on a flight documentation card and showing it to the camera before taking off.

The UAS service provider shall follow the UAS manufacturer's operational safety guidelines, guidelines established by relevant authorities, and monitor the critical performance indicators, such as

(a) the signal strength
(b) the battery status
(c) the ground control station charge

For indoor BVLOS flights, the UAS service provider should perform an evaluation flight prior to conducting the mission to ensure that the area to inspect matches the flight plan and that there are no unplanned obstacles that could damage the UAS.

In case of an incident or an unforeseen perceived risk, the UAS service provider should abort the mission, land the UAS in the nearest safe landing zone, and immediately report to the asset owner.

6.3.9 Postflight Hardware Check. Once all planned flights were performed, the UAS service provider should perform a visual check of the hardware to ensure no parts were damaged or lost. When any issues are noticed, the UAS service provider should immediately inform the asset owner to ensure the lost parts or damages do not affect the safety processes of the asset.

When the mission was performed in an asset that contains hazardous materials, the UAS service provider should handle the UAS with necessary caution and ensure that the UAS contain no signs of contamination. When contamination is present, the UAS service provider shall clean the hazardous contamination on-site or dispose of the UAS in accordance with applicable regulations and client and provider procedures.

6.3.10 Postflight Data Check. Before packing up the hardware, the UAS service provider should do an overview of the collected data with the asset owner to ensure that all planned flights were performed, that the necessary points of interest were observed, and that no critical data for the inspection is missing.

Additionally, the UAS service provider should check that the quality of data is sufficient to make a meaningful assessment and perform a code inspection when relevant. This includes ensuring the image is in focus, that the vibrations of the UAS do not make the images unusable, and that the lighting is sufficient.

6.3.11 Debriefing. After the mission but prior to leaving the site, the UAS service provider should report to the asset owner on the success of the mission, on any critical findings that require immediate attention, and on any incidents that may have occurred.

6.4 Postmission

The postmission processes can be done on-site when agreed upon by the UAS service provider and the asset owner.

This should also include decontamination and cleaning of the UAS especially when a confined space inspection is performed. This prevents cross-contamination to other sites and also ensures safe handling for the service provider. The proper disposal of the cleaning items should be on-site. When there is the potential for UAS coming in contact with materials like asbestos or other known carcinogens, there should be a plan in place prior to arriving on-site. This shall be performed by a certified, competent crew. The service provider shall instruct this crew on battery changing and handling, and on areas of the UAS that can be damaged by cleaning so the appropriate steps are taken.

6.4.1 Data Management. The UAS service provider should handle and transfer the data as agreed upon with asset owner and delete it prior to leaving the site. The UAS service provider should take care to duplicate the data prior to processing to have a backup if needed.

6.4.2 Report. The UAS service provider should provide the asset owner with a report in the agreed-upon format. For heavy data files such as videos and 3D models, the UAS service provider should share them via online storage or in a physical copy to ensure that the quality is preserved and that the files are not compressed.

The UAS service provider should ensure that the data is appropriately named and classified so that the asset owner can use it to identify points of interest with precision. When there are any interruptions in the data, the UAS service provider should notify the asset owner in the report.

When the UAS service provider performs a code inspection, the UAS service provider should report the findings to the asset owner according to the referenced code.

When the UAS service provider is providing the asset owner with indications, such as measurements of distances, sizes, or temperature, the UAS service provider should provide the asset owner with a description of how the measurements were obtained, as well as a margin of error.

6.4.3 Physical Documents. The following physical documents and characteristics shall be considered:

(a) hazards plan
(b) proper risk analysis
(c) flight plan
(d) JSA