UNMANNED AIRCRAFT SYSTEMS BRIDGE INSPECTION GUIDANCE

Document Title

Unmanned Aircraft Systems Bridge Inspection Guidance

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Document Introduction and Discussion

Advancements in UAS (Unmanned Aircraft Systems) have resulted in highly capable modern drones and sensors. When used by a qualified and experienced inspector, this equipment can be leveraged to locate and quantify various anomalies that are present in bridge elements, often before it reaches an advanced stage of deterioration.

Document Description

This guidance is not intended to be an exhaustive training manual for the use of UAS in bridge inspections. Instead, its purpose is to help promote understanding of regulations, inspection techniques, tools, and best practices for incorporating UAS into SCDOT's existing inspection workflows and policies. While these guidelines offer a solid foundation, it is important to recognize that site-specific conditions, engineering judgment, or unusual circumstances may necessitate additional measures. The inspector may need to implement requirements that go beyond what is detailed in this guidance to ensure the safety, effectiveness, and comprehensiveness of the inspection process. These additional considerations might include specialized equipment, tailored flight plans, or more stringent safety protocols based on the unique challenges of each inspection scenario.

1.0 ROLES AND ABBREVIATIONS FOR UNMANNED AIRCRAFT SYSTEMS

BIGD Chapter 3 defines Bridge Inspection roles, but the following are specific to Unmanned Aircraft Systems:

- Pilot in Command (PIC) – The PIC is responsible for the overall safety and execution of the flight operation. This includes conducting pre-flight checks, ensuring safe control of the UAS during the flight, and making real-time decisions in response to any issues that arise. The PIC is required by the FAA to have a Remote Pilot Certification, maintained through recurrent training and testing as required by the FAA. The PIC should be familiar with the UAS and have studied the owner's manual and received training on the operation of the UAS before attempting to fly near a bridge. The pilot is responsible for adhering with all Title 14 of the code of Federal Regulation (14 CFR) Part 107 requirements.
- Visual Observer (VO) – The VO assists the PIC by maintaining visual contact with the drone. The VO alerts the PIC to any potential hazards or obstacles and helps monitor the drone's position relative to the environment.
- Support Personnel (SP) – Support personnel may include data analysts, safety officers, and equipment technicians. Their roles include preparing equipment, monitoring data collection, ensuring compliance with safety protocols, and providing technical support as needed. They may also be required to monitor pedestrians and the public, wildlife, or provide additional VO support in congested areas.

BIGD Chapter 1 defines Bridge Inspection Abbreviations, but the following are additional abbreviations specific to Unmanned Aircraft Systems:

Table 1 – Abbreviations and Acronyms

BVLOS	Beyond Visual Line of Sight	PIC	Pilot in Command
CCR	Component Condition Rating	RTH	Return-To-Home
FAA	Federal Aviation Administration	SFRA	Special Flight Rules Area
GCS	Ground Control Station	UAS	Unmanned Aircraft System
GPS	Global Positioning System	VLOS	Visual Line of Sight
MOA	Military Operation Area	VO	Visual Observer

UAS, commonly known as drones, are rapidly becoming essential tools in various industries, offering new capabilities and efficiencies in tasks such as aerial photography, surveying, inspection, and more. In the context of bridge inspection, UAS should be viewed as a valuable tool for a Bridge Inspection Team Leader (BITL), particularly when a hands-on inspection is either unnecessary or not required.

It is SCDOT policy that all drones must be operated for SCDOT business activities in accordance with all applicable laws and regulations, following manufacturer instructions, and in an ethical and safe manner.

Drones must not be used:

- To monitor or record areas where there is a reasonable expectation of privacy.
- To monitor or record areas with sensitive, confidential, controlled unclassified and classified information without prior approval by the Bridge Management Office (BMO).
- For recreational use.

2.0 FEDERAL AVIATION ADMINISTRATION REQUIREMENTS

The Federal Aviation Administration (FAA) retains ultimate jurisdiction over all civil aviation, including UAS. State and local regulations are supplementary to FAA rules and policies. All bridge inspections conducted for SCDOT using UAS must adhere strictly to state, local, and FAA regulations. The following key aspects of FAA compliance are particularly pertinent:

- Certification and Registration: Operators must hold the appropriate certifications, including a Part 107 remote pilot certificate with a small UAS rating. Additionally, all UAS units employed in bridge inspections must be registered with the FAA, and their registration markings must be clearly displayed on the aircraft.
- Operational Limitations: Inspections must be conducted within the operational limits set by the FAA, including altitude restrictions, maintaining visual line of sight (VLOS), and adherence to no-fly zones unless specific waivers are obtained. For operations that require deviation from standard Part 107 regulations such as flying within security sensitive airspace, over people, or beyond visual line of sight, operators must secure the necessary waivers or authorizations from the FAA and/or military installations in advance.

- Safety Procedures: UAS operators must follow all prescribed safety procedures and risk mitigation strategies as outlined by the FAA. Pre-flight checks, operational briefings, and emergency procedures are essential components of safe UAS operations.
- Data Privacy and Protection: When UAS are equipped with cameras or other sensors that collect data, operators must ensure that all data collection, storage, and dissemination practices comply with FAA guidelines and respect privacy laws. This is particularly critical when flights are conducted over areas where individuals could have an expectation of privacy.
- Environmental Considerations: Operators must also consider impacts to the environment as part of their compliance, particularly when flying in sensitive ecological zones or near protected wildlife areas, adhering to both FAA regulations and environmental protection laws.

Title 14 of the Code of Federal Regulation (14 CFR) Part 107 is summarized below in Table 2 and serves as the legal or regulatory basis for drone-related operations.

Table 2 – Summary of FAA UAS Requirements

Type	Requirements
Pilot Certification	• Pilots shall pass an initial aeronautical knowledge test at an FAA-approved knowledge testing center to obtain a Remote Pilot Certificate with a Small UAS rating. • Pilots shall be at least 16 years of age.
Aircraft Requirements	• Aircraft shall be less than 55 lbs. • Aircraft shall be registered online with the FAA if over 0.55 lb. • Aircraft shall undergo pre-flight check prior to each flight to ensure UAS is in condition for safe operation.
Location Requirements	• Class G airspace can be flown under part 107 without an FAA waiver. • Classes B, C, D, and E airspace can be flown with an FAA waiver. FAA waivers shall be uploaded as part of the structure BSIP to the Bridge File.
General Operating Rules (Deviations require approval from FAA and/or SCDOT)	• Pilots shall keep the aircraft in sight (VLOS). • Pilots shall fly under 400 feet. • Pilots shall fly during the day. • Pilots shall fly at or below 100 mph. • Pilots shall yield right of way to manned aircraft. • Pilots shall not fly over people or moving vehicles. • Pilots shall not fly from a moving vehicle.

3.0 SCDOT UAS BRIDGE INSPECTIONS REQUIREMENTS

Drones allow a BITL to obtain data, models, surveys and to capture high-quality images and video of even the hardest to reach places of a bridge without other access equipment. The use of a UAS does not significantly increase the amount of time used to inspect a bridge and should only be used as a tool during the already scheduled and planned execution of the inspection. The SCDOT specific requirements for incorporating the use of UAS's during bridge inspections is provided in the following subsections.

3.1 UAS Structure Limitations

A UAS should not be the only access equipment to inspect a bridge if any of the conditions Table 3 are met. The BITL is responsible for determining when a UAS can be utilized and ensuring proper access methods are utilized.

Table 3 – UAS Applicability for SCDOT Bridge Inspections

Type	Requirements	Example
Poor CCR	Elements/components with a CCR(s) that are 4 'Poor' or lower shall not be inspected solely by the UAS (except when the components in 4 'Poor' or Worse condition are not the subject of the inspection).	If the superstructure is in 4 'poor' condition, a UAS may not be the sole access method to inspect the superstructure elements but may be the sole access method to inspect the deck if the deck condition is greater than poor (4).
Condition States 3 or 4	Elements in Condition State 3 (CS3) or Condition State 4 (CS4) excluding Bridge Management Elements (i.e. joints, wearing surfaces, protective coatings and deck protection systems) or for inspections where the elements in CS3 or CS4 are not the subject of the inspection. These elements in CS3 or Cs4 are not to be inspected by UAS.	A UAS may discover CS3 or CS4 deterioration on a beam, pier cap, columns or deck, for which the inspection team must use an alternative access method to properly assess and document the deterioration. CS3 or CS4 deterioration discovered in a protective coating, or joint does not require the team to deploy alternative access methods to assess and document the deterioration, providing the UAS collected sufficient detail regarding the deterioration.
10 Year Limit	A UAS cannot be used exclusively for any one element or component for more than 10 consecutive years.	Elements or components inspected using a UAS can continue to be inspected using a UAS for up to 10 years, but must use an alternative access method at least once every 10 years.
Inspection Procedures	Specific access/equipment are included in the Bridge Specific Inspection Procedure (BSIP) that prohibit the use of a UAS, or indicate closer hands-on testing and inspection is needed.	If the BSIP for a bridge requires an aerial lift to measure transverse and longitudinal movement between adjacent slabs, the drone may not be used as a replacement for the lift.
Inspection Type	A UAS cannot be used to inspect any portion of a NSTM member, moveable element, or a component subject to an in-depth inspection.	SCDOT does not permit the exclusive use of drones during the assessment of Nonredundant Steel Tension Members (NSTMs), movable (electrical and mechanical) bridge components, and other components requiring hands on or in-depth inspection.
Other	Any areas that require sounding, cleaning, etc.. would not be applicable for UAS.	Steel corrosion, delaminated concrete, and some crack widths would require closer assessment to properly inspect. These defects would not be suitable to inspect soly with a UAS. A UAS can be used to indicate defect areas but the UAS cannot be the sole inspection access method.

3.2 UAS Equipment Limitations

Inspectors responsible for performing UAS bridge inspections must rigorously ensure that all equipment adheres to industry standards and is configured correctly for the specific inspection tasks. This involves selecting appropriate drones, cameras, and sensors tailored to the inspection's requirements, as well as maintaining the equipment to prevent malfunctions during operation. The BSIP may contain UAS requirements unique to a structure, but to be used during a SCDOT bridge inspection, a UAS must meet the minimum criteria listed in Table 4.

Table 4 – UAS Criteria for SCDOT Bridge Inspection

Criteria	Requirement
NDAA Compliant	• All UAS utilized for commercial bridge inspections must strictly adhere to NDAA compliance standards and comply with the American Security Drone Act of 2023 (ASDA) and OMB Memorandum M-26-02 which prohibit the use of UAS manufactured by covered foreign entities.
Aircraft Requirements	• Powered by rechargeable batteries, • Controlled either autonomously or with a remote-control device. • Use GPS to track location. • Contain fail safes such as return to home technology. • Contain proximity sensors and awareness. • Ability to preprogram autonomous missions (if operating autonomously). • Ability to fly under bridges or in GPS denied environment and within confined spaces. • Ability to look up to view the underside of a bridge deck. • Equipped with reliable onboard data storage, such as SD cards or solid-state drives (SSD), capable of storing large volumes of high-resolution images, video, and sensor data. • A secure and efficient method for transferring data from the UAS to a external storage device.
Controller / Ground Control Station Requirements	• Include robust flight control interface with real-time monitoring and control of the UAS. • Display critical flight data, including altitude, speed, battery levels and GPS position. • Minimal latency to ensure accurate piloting and data collection. • Have the capability to start and stop data collection during flight operation. • Collect telemetry data for post-flight analysis.

3.3 Camera and Sensor Requirements

The camera or sensor on a UAS may limit its bridge inspection functionality. The BITL is responsible for determining what type of data is collected, and ensuing the UAS meets the minimum requirements for that type shown in Table 5. A UAS only needs to meet the camera/sensor requirements for the specific type of data collection being conducted.

Table 5 – Camera and Sensor Criteria for SCDOT Bridge Inspection

Type	Requirement	Functionality
High-Resolution Camera	The UAS shall be equipped with a high-resolution camera capable of capturing detailed imagery of the bridge structure. The camera must offer adjustable focus, zoom, and aperture settings to adapt to different inspection scenarios.	The camera should be able to capture clear images and video, even in challenging lighting conditions. The ability to record in 4K resolution or higher is required for capturing fine details that may indicate structural issues.
Thermal Sensors	Infrared or thermal imaging sensors are critical for detecting temperature variations that could indicate underlying structural problems, such as moisture intrusion, material degradation, or thermal bridging.	The thermal sensor shall be capable of providing accurate temperature readings of the inspected areas with high sensitivity capable of detecting subtle temperature differences.
LiDAR Sensors	For inspections requiring precise measurements and 3D modeling, a LiDAR sensor can be leveraged. LiDAR is useful for survey and mapping but can be used to support bridge geometries.	The LiDAR system shall be capable of capturing high-density point clouds with sufficient accuracy to generate detailed 3D models of the bridge.

3.4 Team Requirements

Bridge inspections that utilize UAS should not deviate from FHWA and SCDOT requirements for inspector qualifications. The minimum size of a crew should be two people, one to operate the aircraft and one to act as a VO. The crew should not operate with a medical condition that could interfere with safety. The BITL shall assign specific roles to all team members and ensure everyone understands their duties and the mission objectives.

If the pilot has not flown within the previous 30 calendar days, the pilot shall perform a 20 minute long maintenance flight with minimal hazards before using the UAS for a bridge inspection.

All UAS inspection activities shall be conducted under the supervision of a BITL who is qualified for both the structure and inspection type present. If possible, the BITL should be the PIC. If the BITL is not the PIC, they should work in concert to ensure all FHWA, SCDOT, and FAA rules are followed.

3.5 Documentation and Record Keeping

3.5.1 UAS Bridge Procedure and Equipment Reporting

Structures with previous UAS inspections should have an inspection procedure and Equipment listing which details both the scope of UAS inspection, and type of UAS previously used. The BITL is responsible for reviewing the inspection procedures and equipment listings and ensuring any unique requirements or capabilities are included in the current inspection activities. Updates to the inspection procedure and equipment listings may be made by the BSIP based on finding during the inspection event. Where a UAS is being used for the first time, the BITL is responsible for developing the new inspection procedure and equipment listing within SCDOTs report management software, as part of the inspection event.

3.5.2 UAS Mission Log

Every UAS Inspection shall have a Mission log created and uploaded to the Bridge File. The mission log documents the scope of UAS use, the results of a pre-flight risk assessment, flight log, and the follow-up items performed by the team during the UAS inspection. The PIC is responsible for completing the mission log in the field, and the BITL is responsible for ensuring the completed form is uploaded to the procedures folder of the Bridge File.

Attachment A provides a mission log SCDOT pilots shall complete for every inspection using a UAS. Consultants can use Attachment A or shall create their own mission plan that meets federal requirements and includes all provisions from this document. An example of a consultant UAS mission is provided in Attachment B.

3.5.3 UAS Inspection Data

Inspection data collected using a UAS may result in varying file formats based on the sensor type or collection methodology. The BITL is responsible for reviewing all the data collected by the UAS and exporting the portions relevant to the inspection as JPG photos to be used in the inspection report. UAS data used in an inspection report must meet the appropriate quality standards equivalent to a visual inspection.

All data collected by the UAS must be archived per SCDOT file retention policy, not just the data which is referenced by the inspection report.

If a UAS was used during an inspection, a Quality Control Reviewer or Quality Assurance Reviewer may opt to request the BITL to provide the files produced by the UAS inspection.

3.6 UAS Incident Reporting

This section provides the requirements for UAS related incident reporting, any incident occurring during a UAS mission that is not directly caused or related to the use of the UAS should follow established SCDOT or Consultant program reporting requirements.

3.6.1 Immediate Actions following an Incident

In the event of a UAS related incident, the following immediate actions should be taken:

- Ensure Safety – The first priority is to ensure the safety of all personnel and the public. If anyone is injured, provide first aid and contact emergency services, if necessary.
- Secure the Area – Safety land the drone if it is still in flight and secure the area to prevent further incidents or injuries. This may involve setting up barriers or warning signs around the affected area.
- Report the Incident – See reporting procedures.

3.6.2 Incident Reporting

Incidents meeting any of the Any of the following criteria shall be considered reportable to SCDOT.

1. Serious injury to any person or any loss of consciousness, or
2. Damage to any property other than the UAS unless one of the following conditions is satisfied:
    a. The cost of repair (including materials and labor) does not exceed $500, or
    b. The fair market value of the property does not exceed $500 in the event of a total loss.

3. Any event that involves a breach of regulatory requirements, such as flying in restricted airspace without authorization.

SCDOT BITL's shall report UAS incidents meeting the above criteria to their supervisor within 24hrs. Consultant BITL's shall report UAS incidents to the Bridge Inspection Program Manager (BIMP), or Bridge Management Quality Engineer (BMQE) within 24hrs. Items 1 and 2 above require reporting to the FAA under 14 CFR Part 107.9. The PIC is responsible for initiating the FAA notification within the FAADropZone portal, and a copy of the accident report should be included in the notification to SCDOT.

4.0 UAS PLANNING AND RISK ASSESSMENT

The first step when developing a flight plan for UAS operations is to determine the inspection scope, operational area, and perform a risk assessment.

The BITL is responsible for developing and documenting the inspection scope in section 2 of Attachment A. The PIC is then responsible for building a flight plan incorporating the inspection scope and outlining the flight path, altitude, speed, and waypoints the UAS will operate within. The plan should account for potential obstacles, no-fly zones, and environmental conditions like wind and weather. The BITL shall document the takeoff and landing zones determined by the PIC in Section 2 of Attachment A. The flight plan shall be kept on site during the duration of the use of UAS but is not required to be included in the mission log.

The BITL shall update section 1 of Attachment A after completing the UAS operation if there is a reduction in scope. The scope of the UAS operation may not be increased without first landing the UAS, updating the flight plan, and performing a new risk assessment based on the additions to the scope.

The purpose of this assessment is to identify a level of risk associated with the inspection of a specific bridge/asset, by a specific crew, on a specific day. The PIC shall perform an on-site assessment to identify all potential hazards such as power lines, traffic (vehicular, boat, train), pedestrian activity, and environmental factors. The PIC shall complete the risk assessment, incorporating both site observations and details from the flight plan using section 3 of Attachment A. This fillable performs a risk assessment based on the PICs inputs to determine if the flight is within SCDOT's parameters for SCDOT pilots to self-perform. If the flight is outside parameters, the pilot shall contact the BMO for potential approval with additional restrictions. Details for each risk category are detailed in the following subsections.

Some structures may have site specific hazards that results in additional risk to any UAS operation. The SCDOT pilot shall survey the operational area and identify any unique risks within the site. The PIC shall consult the BITL to alter the flight plan or produce site-specific UAS procedures to mitigate both the probability and severity of the risk. The PIC shall document any site-specific risks and the procedure used in its mitigation in Section 4 of Attachment A.

Consultants can use an internally developed scope and risk assessment procedure, but it must address all the risk categories detailed herein and be uploaded as part of the mission log similar to Attachment A.

4.1 Flight Conditions

The following risk categories are associated with the inspection team, and planned UAS mission.

4.1.1 Mission Type

UAS inspections generally require the UAS to operate near the structure and have an inherent risk of collision or loss of signal. Operating within a confined space, adds additional risk due to the reduction in separation and likelihood of GPS and control signal issues. Using UAS to capture inventory photos such as the structures profile, or approach photos allows for greater separation from the structure and thus a reduced risk of collision or loss of signal.

4.1.2 Team Composition and Experience

The minimum size of a crew should be two people, one to operate the aircraft and one to act as a VO. Adding an additional VO or Support person to the team provides reduces the workload on the PIC and VO and provides a reduction in risk to the UAs operation. More experienced PICs, support personnel will reduce some risks associated with these efforts.

A PIC with less than 5 hours of logged hours, or a significant gap in UAS flight time should not be the PIC for a bridge inspection. Pilots may build or maintain experience levels by conducting practice flights in a lower risk area away from structures, or obstacles.

4.1.3 Emergency Landing Area

If the PIC should identify at least one alternative landing location that could be used in the event of emergency, or an encroachment at the planned landing area. A site where no alternative landing area can be designated imposes a greater risk on the UAS mission.

4.1.4 Flight Time

FAA defines night operation as operating between the end of evening civil twilight and the beginning of morning civil twilight. Operations within that time carries additional requirements such as aircraft lighting and pose additional risks. Night operations will be considered on a case-by-case basis and require additional approval by the BMO for SCDOT pilots. Pilots shall also consider the anticipated flight duration and planned takeoff time to ensure the entire flight is conducted during daytime conditions.

4.2 Airspace Conditions

The PIC shall utilize FAA sources such as the UAS Facility Maps, to identify the type of airspace the UAs will be operating within. If authorization, either through the LAANC system or the FAADroneZone Waiver and Authorization system is used to access the airspace for UAS bridge inspection activities, it shall be included in the mission log uploaded to the Bridge File.

4.2.1 Airspace category

In general, operation in class G airspace with no other restrictions in place will present the simplest set of considerations for the PIC. Operating in controlled airspace will always require airspace authorization from the FAA.

4.2.2 Airspace Restrictions

When UAS operations are required in other types of airspace, like special flight rules area (SFRA) and Military Operational Area (MOA), additional coordination may be required with the facility/agency that operates in that space. While submitting for and achieving FAA authorizations and waivers is outside the scope of this document, the FAA has documentation of the process, and FAA Facility Map will often list the Point of Contact for the facility within the restricted spaces.

4.3 Weather Conditions

Weather plays a crucial role in the success of a UAS inspection. Adverse weather conditions, such as high winds, rain, fog, or extreme temperatures, can compromise the stability of the drone, the quality of the data collected, and the safety of the operation. The recommended source of accurate forecast information is NOAA's weather.gov. It's important to understand that a weather forecast has a descending amount of accuracy as the lead time increases. It may be necessary to re-assess the weather as the operation gets closer.

4.3.1 Cloud Ceiling and Visibility

Fog, mist, or low clouds can severely limit the drone operator's ability to maintain visual line-of-sight (VLOS) and capture high-quality data. In such conditions, it may be necessary to postpone the operation until visibility improves. high humidity levels can impact the quality of imaging sensors and lenses, potentially leading to fogging or condensation. UAS operations must be postponed if visibility is below 3 statute miles, or the ceiling would cause the UAS to encroach 500ft vertically or 2,000ft horizontally with clouds.

4.3.2 Wind Gust Speed

High winds can affect the stability of the drone, making it difficult to maintain a steady flight path, especially near bridge structures where wind currents can be unpredictable. PICs should establish wind speed limits for safe operation and monitor wind conditions continuously during the flight.

4.3.3 Temperature

Extreme temperatures, whether hot or cold, can affect drone performance, particularly battery life. Cold temperatures may reduce battery efficiency and flight time, while excessive heat can lead to overheating of the drone's electronics, the ground control station or both. PICs should monitor battery performance closely in extreme temperatures and plan for shorter flight durations if necessary.

4.3.4 Precipitation

Rain or snow can not only damage sensitive drone equipment but also reduce visibility, making it challenging to capture clear images or video. Flying in precipitation heavier than a light mist should generally be avoided unless the drone is specifically designed to withstand such conditions.

4.3.5 Kp Index

Kp is an index of space weather conditions and has impacts on GPS positioning. These forecasts are provided by NOAA at the Space Weather Prediction Center up to three days out. Higher values of Kp means it may be more difficult or impossible to achieve GPS positions on the UAS.

4.4 Site Conditions

Site considerations also extend to the surrounding airspace and infrastructure. Bridges are often located near roads, waterways, or urban areas where additional precautions must be taken.

4.4.1 Flying Over Water

When flying over rivers or other bodies of water, PICs should be prepared for the potential loss of equipment due to a water landing. This includes ensuring that the drone is equipped with flotation devices, if necessary, and planning for safe retrieval methods in the event of an accident.

4.4.2 Flying over People, Vehicles, Railroads

While the FAA has more recently allowed for a wider range of operation over people and moving vehicles, these types of mission would pose a much higher risk.

4.4.3 Private Property

While most bridge inspections are performed in areas where the public does not have a reasonable expectation of privacy, the privacy of the public should still be respected. When possible, avoid flying the drone over private property to minimize concerns about privacy. If it is necessary to fly near private property, ensure that no unnecessary footage is captured, and respect the boundaries of private spaces.

4.4.4 Wildlife

Bridge inspections often take place in areas where natural habitats and wildlife are present. It is important to consider the potential impact of drone operations on local wildlife, particularly birds, which may be disturbed or even threatened by the presence of a drone. PICs should:

- Identify Wildlife – Constantly survey the area to identify any sensitive wildlife species or nesting areas that could be affected by the drone's presence.
- Minimize Disturbance – Plan flight paths that avoid known nesting sites or habitats. If wildlife is observed reacting to the drone, consider altering the flight path or pausing the operation until the animals have moved away.
- Compliance with Regulations – Ensure that the operation complies with any local, state, or federal wildlife protection regulations, which may include restrictions on drone flights near certain protected species or habitats.

4.4.5 Air Traffic

PICs must be aware of any nearby airports, heliports, or restricted airspace. It is critical to obtain any necessary permissions or waivers before operating in controlled or congested airspace. If airspace waivers are required, they should be obtained from the FAA prior to mobilization. Temporary Flight Restrictions and Notices to Airmen should also be checked just prior to mobilizing for the inspection.

4.4.6 Obstacles

Powerlines, towers, and any guywires supporting such structures can pose a collision hazard to UAS operations. Like low hanging branches or vegetation, these items may be hard to see by the PIC or VO and too small for a UAS obstacle avoidance system to detect. The BITL and PIC shall survey the operational area for these hazards and include the presence of these hazards in the risk assessment.

4.4.7 Population Type

Select the type of landscape the mission is being performed in. Moderately and highly populated areas, and confined spaced, will present additional operational hazards. The distinction between rural, moderate, and highly populated areas can be subjective, but should roughly break down by suburb and urban boundaries.

5.0 SCDOT UAS OPERATIONAL REQUIREMENTS

A uniform operating procedure is required for conducting drone-based bridge inspections safely, efficiently, and effectively. This section provides operating requirements specific to UAS operations and shall not supersede existing FHWA, OSHA, FAA, SCDOT Safety manual or internal procedures. The PIC shall use these requirements as a baseline for all UAS operations and should develop additional procedures when necessary to ensure that inspections are carried out with precision, that safety risks are minimized, and that the collected data meets the required standards for thorough analysis. Section 4 of Attachment A shall be used by SCDOT pilots to indicate that all required procedures have been completed and document site specific procedures developed by the team when necessary.

Consultants can use Attachment A or develop their own UAS procedure, but it must meet or exceed the procedures detailed herein. A description of and verification of completeness shall be attached to the consultant mission log and uploaded to the procedures folder of the Bridge File.

5.1 Required Documentation

Ensure that all necessary permissions and waivers have been obtained from relevant authorities, particularly if operating in controlled airspace or near populated areas. These documents shall be on-site during all UAS operations.

5.1.1 PIC Certification Card

Operators must hold the appropriate certifications, including a Part 107 remote pilot certificate with a small UAS rating.

5.1.2 Airspace Authorization

For operations that require deviation from standard Part 107 regulations, such as flying within security sensitive airspace (e.g. military bases, national landmarks or certain critical infrastructure), over people, or beyond visual line of sight (BVLOS), operators must secure the necessary waivers or authorizations from the FAA and/or military installations in advance. Authorization documentation when applicable, shall be on-site and the PIC is responsible for ensuring UAS operations do not exceed prior authorization.

5.1.3 UAS Insurance and FAA Registration

All UAS units employed for SCDOT bridge inspections must be registered with the FAA with their registration markings clearly displayed on the aircraft. All UAS units must be insured with current proof of insurance kept with the unit and on-sire during every UAS mission. The PIC is responsible for verifying the registration and insurance documentation as part of the pre-flight checklist.

5.1.4 UAS Manual and Logbook

UAS Manufacturer user manuals contain troubleshooting guides and detailed setup and function guides that should be followed to ensure safe operation. Included in the UAS manual or maintained separately a UAS logbook that details any maintenance work, and a flight record shall be reviewed as part of the pre-flight checklist by the PIC.

5.2 Team Status and Assessment

The PIC shall ensure all team members perform a self-assessment and report any of the following situations that may affect the safety of the UAS mission or team. The PIC shall postpone UAS operations if a team member reports a violation of one or more of the following items.

5.2.1 Illness and Medications

All team members shall be free of any illness or medications that can affect their ability to perform their assigned UAS mission tasks. Even the common cold, or sinus issues may lead to a temporary VLOS with the UAS and affect the safety of the UAS mission.

5.2.2 Stress, Fatigue, and Emotional Wellness

Stress Fatigue and emotional state can affect team members decision making during nominal UAS operations and have a much greater impact should an emergency occur. The PIC shall postpone any UAS operations should a team member

report external pressures on the UAS mission that would affect safety.

5.2.3 Alcohol and Drugs

No team member shall have consumed alcohol within 12 hours of the UAS operation, and any team member who reports or shows signs of drug use shall be removed from the UAS mission team.

5.3 Emergency Procedures

The PIC shall discuss the following emergency procedures with the team prior to takeoff. The PIC shall ensure every ream member knows their roles and responsibilities for each situation. The PIC may reassign team members if they feel they cannot fulfill their duties in any way.

5.3.1 Loss of Signal to UAS

If the drone loses connection with the GCS, the PIC shall follow the pre-programmed return-to-home (RTH) procedure or initiate manual recovery if possible.

5.3.2 Lost VLOS with UAS

A video feed loss of signal can occur if the aircraft is out of range, or if it briefly flies behind an object that interrupts the signal (a carveout exception to the VLOS rules). Maintaining visual contact is the preferred method to re-establish control of the aircraft, with the pilot seeing the aircraft, and using a visual observer. Yawing the aircraft can help signal reception if the body of the aircraft is blocking the line of sight between the transmitter and receiver antennas. If video feed signal or visual contact cannot be maintained, the PIC shall terminate the UAS operation.

5.3.3 Collision with Manned Aircraft

Shall immediately announce visual sightings of any manned or unmanned aviation activity.

At all times during the flight, the PIC and the VO shall scan the airspace where the UAS is operating for any potential collision hazard; and maintain awareness of the position of the PIC through direct visual observation. Communication between PIC and VO shall allow for the PIC to maneuver the UAS with enough time to yield right-of-way in accordance with the following provisions:

- The UAS must yield the right of way to all aircraft and airborne vehicles.
- No person may operate a UAS so close to another aircraft as to create a collision hazard.
- The PIC shall ensure theirs and the VO's ability to scan the airspace where the UAS is operating for any potential collision hazard is not hampered by clouds or visibility.
- The PIC shall be able to determine the position, speed, attitude, altitude, and trajectory of the UAS during operations (visually or via electronic monitoring).
- The PIC shall have awareness of the operating area in which the UAS will fly.
- The PIC shall assess the potential for terrain obstruction for the VO.
- The PIC shall assess the proximity of the planned operation to manned aircraft activity.

If an aircraft is within a 3.5-mile horizontal radius and at an altitude less than 1,000 feet, the PIC shall take deconfliction maneuvers:

- Flight Crew members detecting the aircraft shall utilize the Voice Communication Protocol discussed before the flight.
- Upon identification of a potential conflict, the UAS shall immediately and rapidly descend to an altitude not higher than the nearest trees, buildings, or ground where manned aircraft are not expected to operate (generally less than 60 feet).
- If the PIC or a VO estimates a collision is imminent, the VO with visual contact should announce to the PIC to kill the motors of the UAS to initiate an immediate and rapid descent to the ground.

5.3.4 Collision with Structure

Unintentional collisions with a structure can occur during a UAS inspection due to sudden wing gusts, signal issues, or

other factors. The PIC shall immediately terminate any UAS mission where a collision with the structure occurs and inspect the UAS for damage before continuing. The additional considerations should be weighed and included in the mission planning to avoid unintentional collisions with structures:

- Use Collision Tolerant Drone or Propeller Guards
- Utilize UAS Collision Avoidance Technology
- Additional Visual Observer(s)
- Increase Stand Off Distance

5.3.5 Encroachment or Collision with Pedestrian, or Vehicle

Prior to every flight, the crew should ensure the area is clear and free of non-participants. The VO or other project personnel are responsible for monitoring the flight area for the duration of the flights. The crew can use cones or markings to block off takeoff/landing area. If possible, the PIC, VO, or crew member should alert the non-participant before they enter the flight area. Also, the VO is to notify PIC if a member of the public has entered the operations area. Then, the PIC shall pause the operation. The crew shall inform the member of the public that they are in a flight area and request that they remain in position to enable the pilot to safely land the aircraft or ask them to leave the area, if applicable. The PIC should land the aircraft as soon as possible, if operations cannot continue safely due to pedestrian encroachment.

In any case where the UAS crosses a road, the following apply:

- The VO or other crew must communicate to the PIC whether it is safe to cross, using language established by the communication protocol.
- The PIC may resume the mission once the observer gives the “All Clear” command using language established by the communication protocol.
- Relative direction of collision risk shall be conveyed as clock position with respect to the UAS with heading/direction of flight of the UAS as reference to 12 O’clock.

For UAS missions that have a high probability of encroachment into the operational area, the PIC shall consider adding the following considerations during the mission planning:

- Limit Size and Weight of UAS
- Increase Horizontal Distance from Public
- Redundant Battery Systems
- Clearly Delineate Landing Area
- Shut off Motors if Crash is Imminent
- Preplanned Ditch Procedures and Locations

5.3.6 PIC or VO Become Incapacitated

An incapacitated pilot is a PIC who is not consciously or physically able to control the UAS during flight operations. Consider during the Safety Briefing designating a back-up pilot and make them aware of the RTH function. In most cases, the VO should be designated as the backup pilot.

If able, the PIC should warn the crew of his/her status if able. Alternatively, VO may notice PIC incapacitation or impairment. The backup pilot shall take over control of and land the UAS in a safe location as soon as possible by activating the RTH function, or by flying the aircraft manually.

5.3.7 Change in Weather or Site Conditions

Weather is dynamic and may change during the UAS flight. The PIC shall assign a team member with the role of monitoring the weather conditions and responsibility to notify the PIC of any changes. If the PIC determines the changing conditions exceed those considered during the risk assessment, the UAS flight must be terminated and a new risk assessment completed prior to continuing and UAS operations.

5.3.8 UAS or Controller Battery Issue

Unforeseen controller or UAS battery issues may occur during the UAS flight and are generally detected with a sudden drop in charge due to unseen electrical or battery issues. The UAS flight shall be terminated if a sudden change in UAS or controller battery levels are observed. The UAS and controller shall be removed from inspection activities unit a test flight can be performed. This test flight shall be in a safe area with minimal structures or people.

5.4 Communication Protocol

The PIC and VO should have voice communication available between them from the start until the end of operations. Voice communication shall be accomplished either unaided, or using a hands-free radio or equivalent technology, and shall follow the guidelines below:

- Shall perform a radio check prior to launch to signal safe operation
- During the team briefing, discuss the roles and responsibilities as outlined in pre-flight planning.
- Establish clear communication protocols, including radio frequencies, hand signals, vocal signals, and emergency procedures.

5.4.1 Flight Plan Deviations

If the UAS has a failure or is unable to operate properly, for example due to an external source of interference (e.g., radar emissions, or erroneous position transmitted from the GPS), the PIC and the VO shall:

If operating in automated flight mode, activate the Smart Return-To-Home (RTH)

If operating in manual mode, activate RTH; or

If the UAS continues uncontrolled flight, activate the Kill Switch.

In the event of equipment failure or an unforeseen obstacle or hazard arises the PIC shall immediately pause the operation and reassess the situation. The PIC shall safely navigate the UAS to a landing zone and recover the UAS. A thorough equipment inspection must be completed before the UAS operation may continue.

5.4.2 UAS Checkpoints and Inspection Milestones

The PIC shall communicate with the team as the UAS mission progresses. This communication shall help VOs maintain VLOS with the UAS and anticipate the sudden movements performed as the UAS transitions between sections or elements of the structure. The PIC shall review the flight plan and determine what milestones or checkpoints should be vocalized using the team's communication protocol.

5.5 UAS Equipment Procedures

Due to the weight of equipment, the inspection team should use proper lifting techniques and Protective equipment when moving and operating UAS systems.

5.5.1 UAS Equipment Inspection

The PIC shall perform a comprehensive preflight inspection of the equipment, including all UAS components such as propellers, motors, batteries, cameras, and sensors. Ensure that all systems are functioning correctly. In addition, PIC shall ensure that the camera or sensor payload is securely mounted and properly configured for the inspection task. The PIC shall calibrate any necessary sensors or cameras before the flight.

Post-flight, the PIC is responsible for conducting a comprehensive inspection of the UAS and associated equipment and components to check for any damage or issues that may have occurred during the flight. Document and address any concerns before the next operation.

5.5.2 UAS Data Storage Devices

All UAS inspection units shall have a secure storage device to hold inspection photos, videos, or other data formats during the flight. Typically, this consists of a removable SD card. All SD cards should be installed or removed from the UAS when the UAS battery has been removed. The PIC shall review the manufacturer's operating manual and ensure the storage device has the correct formatting for the UAS unit and data type being collected.

5.5.3 Preflight Calibration

During every UAS preflight the PIC shall verify the UAS and controller have the most recently released firmware. If firmware version cannot be verified or is outdated the UAS mission shall be postponed.

After arming the UAS and prior to takeoff the PIC shall verify compass, gyroscope, and RTH settings are calibrated. Any repositioning or UAS adjustments required to correctly calibrate these systems shall be completed by the PIC while all other team members remain clear of the area.

The PIC shall verify all other UAS systems, such as camera or video functions are operating correctly prior to takeoff.

5.5.4 UAS Specific procedures

UAS systems may have unique systems or equipment for which the manufacturer has developed specific procedures regarding flight, maintenance, or storage of the UAS system. The PIC shall review the manufacturer's operating manual and incorporate any system specific requirements into the UAS operation.

5.5.5 Battery Management

Proper storage plays a crucial role in maintaining the health of drone batteries. To ensure optimal battery life, the PIC should store the batteries in a cool, dry environment, shielded from heat sources, moisture, and direct sunlight with batteries stored between 40% and 60%. The PIC should follow all manufacturer instructions regarding the safe storage, use and charging of UAS components.

The following guidelines will help ensure batteries perform as designed. Specific care tips can also be found in the instruction manual:

- Never fully discharge a battery
- Do not store batteries fully charged
- Only charge batteries in areas free from flammable materials
- Never charge batteries unattended
- Never store batteries in extreme temperatures
- Protect batteries from punctures or impact damage

5.6 UAS Flight Procedures

The following in-flight procedures are applicable to all UAS inspection operations but shall not supersede manufacturer or system specific procedures.

5.6.1 Arming and Disarming UAS

Arming and Disarming a UAS consists of the initial activation or deactivation of the UAS unit where the propellers are not activated. The PIC is responsible for the arming and disarming of the UAS unit and shall announce each operation to the team using "Armed" and "Disarmed" or other terms as defined by the team's communication protocol.

To avoid being struck by injuries during takeoff/landing, once the PIC is on-site, the PIC should take notice which direction the wind is blowing. The inspection team should be standing upwind 15 feet away from the drone during arming, disarming, takeoff, and takeoff due to malfunction or environmental disturbance. The PIC and BITL should coordinate on takeoff and landing locations and establish a perimeter around the inspection area to ensure public safety and prevent unauthorized access. This includes establishing no-fly zones if needed.

5.6.2 Takeoff and Landing UAS

Before takeoff the PIC shall ensure the takeoff area is clear of obstacles or unauthorized personnel. PIC is to announce "takeoff" before launching the UAS flight. At the conclusion of inspection activities, the PIC shall execute a controlled and gradual descent to the designated landing area. A final check of the landing area shall be conducted by a team member to ensure it is clear of obstacles and personnel. Once the landing area is verified as safe, the PIC is to announce "landing" before initiating the final landing procedure.

5.6.3 Flight Control Checks

Immediately after UAS takeoff, and before any inspection tasks are initiated, the flight controls of the UAS shall be checked. The PIC shall follow all manufacturer flight control checks, but at a minimum the following system checks

should be completed:

- Hover for 5 seconds
- Look and listen for indications of issues or defects
- Yaw right and left
- Pitch forward and backwards
- Roll left and right
- Test gimbal movement in all available directions
- Check UAS position and altitude holding

5.6.4 In-Flight Battery Monitoring

The PIC shall ensure that all batteries are fully charged and in good condition. The inspection team should have enough batteries or charging capability to complete the mission as planned and monitor battery levels during the operation to prevent mid-flight power loss.

All UAS batteries shall be charged 90% or greater prior to use in a bridge inspection flight. The controller shall have a battery charge of 60% or greater. The PIC shall regularly check battery levels and plan for a timely return to the landing zone before reaching critical battery levels. The BITL shall monitor battery life and plan to land the UAS before the capacity drops below 22%. After completing the UAS mission, batteries shall be removed from the UAS and stored safely based on the manufacturer's instructions.

5.6.5 In-Flight Signal Monitoring

The PIC shall confirm a strong and stable connection between the drone and the ground control station (GCS) is established before takeoff. The PIC should determine a minimal signal strength parentage or strength. The range of the UAS from the controller shall be limited to ensure the signal strength remains above this preplanned minimal value.

5.6.6 In-Flight Maintaining Line of Sight

The PIC shall maintain the drone at the planned altitude and speed, avoiding sudden movements or abrupt changes in direction unless necessary for safety. The PIC shall ensure the UAS always remains within the visual line of sight (VLOS) of the PIC or VO. The team should review the emergency VLOS procedure and apply updates based on any site-specific considerations when necessary.

While walking on the job site, all team members should keep eyes on the walkable surface and not look up at the drone while walking. The PIC should not operate the drone while walking. Never walk while you type or text on the GCS. Stand still, finish the entry, then proceed with walking. Be cautious of holes in the ground and their coverings.

5.6.7 Team Debrief

A post UAS operation debriefing session should be held to review the operation, discuss any challenges encountered, and identify areas for improvement. The PIC shall review the mission log and complete all applicable sections. Any challenges specific to the structure should be documented on the flight log, and operational areas of improvement shared internally and used to advance UAS operational procedures. If any incident occurs during the operation, report them immediately following the established incident reporting procedures.