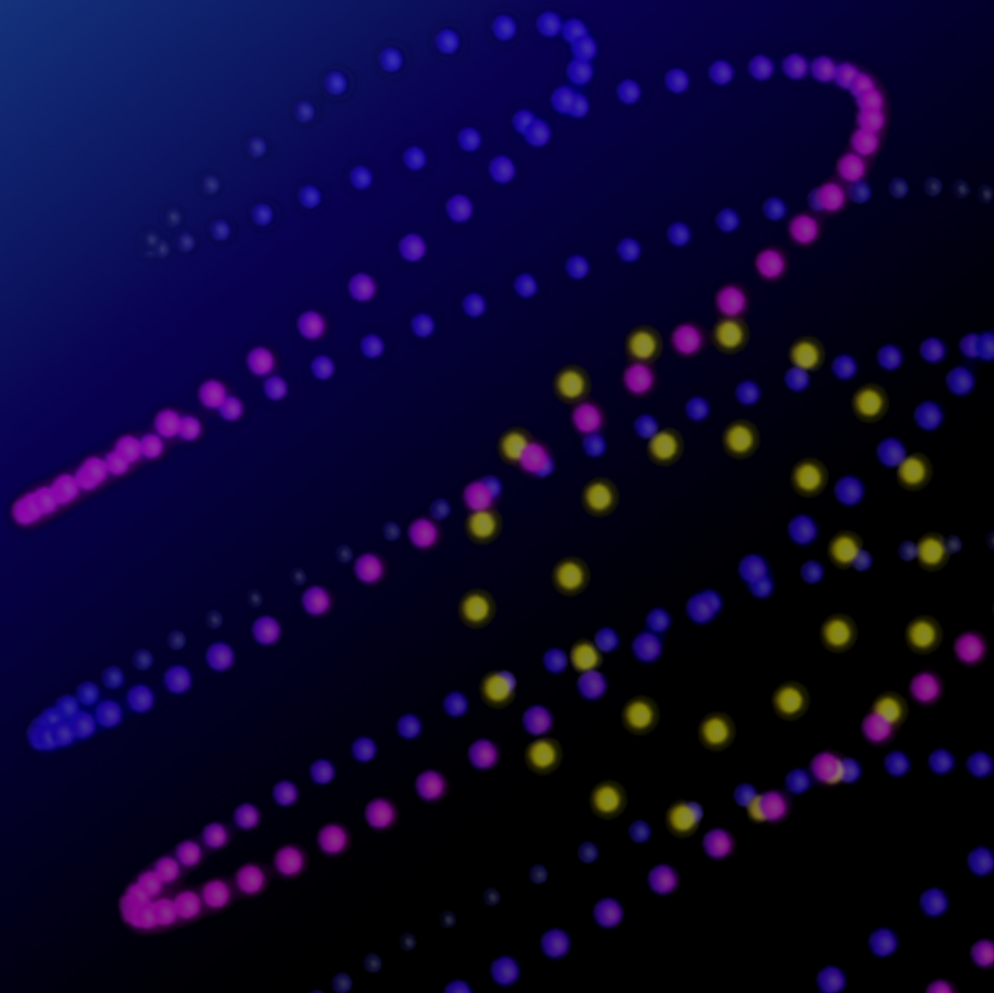
Drone Light Show Alliance

Standards for Outdoor Drone Light Shows Before an Audience

2025 Edition



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NOTICE OF AMENDMENT

Users of this document should be aware that this document may be amended from time to time through the issuance of official Amendments.

1 General

1.1 Scope. These standards shall provide recommendations for the protection of the National Airspace System ("NAS"), manned aircraft, property, operators, crew, support personnel, and the viewing spectators.

1.2 These standards shall apply to the use of small unmanned aerial vehicles in performing a drone light show in front of viewing spectators.

1.3 These standards apply to any outdoor drone light show in the United States.

1.4 These standards shall apply to the videotaping, audiotaping, or filming of any television, radio, or a movie production only where such production takes place before spectators who are not crew of the operation.

1.5 These standards shall apply to the rehearsal of any drone light shows.

1.6 These standards shall not apply to camera drones or other filming drones that are in flight during a drone light show.

1.7 The purpose of these standards is to conduct safe drone light shows.

1.8 Equivalency. Nothing in these standards is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, effectiveness, durability, and safety over those prescribed by these standards.

1.9 Definitions. The following definitions are use in these standards.

1.10 Active Show Area. The area of a show excluding the take-off and landing zone.

1.11 Audience. Spectators whose primary purpose is to view a performance.

1.12 Co-Remote Pilot in Command (CRPIC). A second to the remote pilot in command that is primarily responsible for ensuring all safety checks have occurred by the RPIC.

1.13 Crew (Support Personnel). Trained on-site personnel employed by the DLS operator or other authorized persons

1.14 Drone/sUA. Means a small unmanned aircraft and its associated elements (including communication links and the components that control the small unmanned aircraft) that are required for the safe and efficient operation of the small unmanned aircraft in the national airspace system. **14 CFR § 107.3**

1.15 Drone Light Show (DLS). An artistic performance involving multiple drones to form images or shapes in the sky.

1.16 Extended Kalman Filter (EKF). An algorithm that is used to estimate vehicle position, velocity and angular orientation based on rate gyroscopes, accelerometer, compass, GPS, airspeed, and barometric pressure measurements.

1.17 Exclusion Zone. A designated safety zone inclusive of the DLS flight area in which spectators are not permitted.

1.18 Federal Aviation Administration (FAA). Is responsible for safely integrating drones into the national airspace system.

1.19 Flight Area. An area limited by the size of the light show. The entire flight path from takeoff through landing is contained within the flight area.

1.20 Flight Path (Path). Is the preprogramed route, mission, or path that the drone will take during a show. This is the animated portion of the DLS, typically this is prepared in a 3D animation software such as Blender, Maya, Cinnema4D, or purpose built application.

1.21 Ground Control Station (GCS). A computer or multiple computers used to control drones for a drone light show.

1.22 Hard Geofence. An external barrier, larger than the soft geofence. If a drone breaches the boundary of the hard geofence, it immediately turns off the motors.

1.23 Failsafe. A software function that is initiated if prespecified conditions are met causing a drone to land or return home.

1.24 Land Command. A command that causes the drone to immediately land in place.

1.25 Minor Incident. Any unusual or unexpected flight behavior from the aircraft which does not result in damage or loss. Any failure of any drone which does not result in damage or loss.

1.26 Major Incident. Is any unusual or unexpected flight behavior which does result in damage or loss, any significant danger or damage to persons, possessions or property during flight operations. Any public encroachments or drone incursions which required preventative measures to avoid.

1.27 Path Based Geofence. A geofence that is based upon the vehicle's flight path rather than the perimeter of the show design area.

1.28 Primary Communication Channel. The primary, two-way connection that is used for communication between the drones and the GCS.

1.29 Real Time Kinematics (RTK). RTK stands for Real-Time Kinematics, a technique that improves the accuracy of satellite-based positioning systems. RTK uses a reference station to provide real-time corrections to satellite navigation data.

1.30 RTK Base station. Is the fixed refence station that provides correction data to the ground control station.

1.31 Rehearsal. A practice performance during which no audience is present.

1.32 Remote Pilot in Command (RPIC). A remote pilot in command must be designated before or during the flight of the small unmanned aircraft. The remote pilot in command is directly responsible for and is the final authority as to the operation of the small unmanned aircraft system. The remote pilot in command must ensure that the small unmanned aircraft will pose no undue hazard to other people, other aircraft, or other property in the event of a loss of control of the small unmanned aircraft for any reason. The remote pilot in command must ensure that the small UAS operation complies with all applicable regulations of this chapter. The remote pilot in command must have the ability to direct the small unmanned aircraft to ensure compliance with the applicable provisions of applicable laws. **14 CFR § 107.19**

1.33 Return to Home (RTH) Command. A command that initiates a function where the drone returns to its launch location.

1.34 Return to Launch (RTL) Command. Is the same as RTH Command.

1.35 Shall. Indicates a mandatory requirement.

1.36 Should. Indicates a recommendation or that which is advised but not required.

1.37 Single Point of Failure. A component within a system that, if it fails, will cause the entire system to stop working.

1.38 Secondary Communication Channel. The secondary communication channel that is used for communication between the drones and the GCS.

1.39 Security Staff. Individuals who’s job is to monitor the Exclusion Zone for unauthorized access.

1.40 Soft Geofence (Normal Geofence). Is the restricted area where UASs fly. If the sUAS violates the soft geofence, it executes a "Return To Home" command or a land command. The sUAS will have the lights illuminated during this process.

1.41 Takeoff/Landing Area. Is the location where the Drones start and end their flight paths. It is located within the Flight Area.

1.42 Visual Observer (VO). A person who is designated by the remote pilot in command to assist the remote pilot in command and the person manipulating the flight controls of the small UAS to see and avoid other air traffic or objects aloft or on the ground. **14 CFR § 107.3**

2 Transportation of Batteries

2.1 Scope. All batteries either charged or discharged shall be transported in accordance with any federal, state, or local regulations.

2.2 Transportation Container. If the Batteries are not installed directly inside the drones, batteries should be transported in a metal container that prohibits accidental ignition from heat or other such sparking source.

2.3 Charging in Transit. Batteries should not be charged while on active roadways. Charging should only occur at a stationary location.

2.4 Damaged Batteries. Damaged batteries shall be separated from nondamaged batteries during transport. The damaged batteries shall be placed in a fireproof bag located inside a secondary container. There should be two layers of containment when transporting a damaged battery.

2.5 Fire Extinguisher in Transit. A minimum of one fire extinguisher shall always be readily available during transit. The fire extinguisher must be capable of putting out a lithium-based fire. The chemistry of the batteries being transported shall match the rating and capability of the fire extinguisher.

3 Storage and Charging of Batteries

3.1 Scope. This section covers the charging and stationary storage of the batteries.

3.2 Charging Speed. All batteries shall be charged at a rate of no more than 1C to ensure the safest possible charging state.

3.3 LiPo and LION Charging Voltage. A DLS operator should follow recommendations for charging voltage, as a general rule, LiPo or LION batteries shall be charged no higher than 4.2v per cell.

3.4 LiHv Charging Voltage. A DLS operator should follow recommendations for charging voltage, as a general rule, LiHv batteries shall be charged no higher than 4.35v per cell.

3.5 Unattended Batteries. Batteries shall never be unattended while charging or discharging.

3.6 Dropped or Damaged Batteries. Batteries that have been dropped or otherwise damaged should be destroyed.

3.7 Thermal Event. If safe to do so, power should be shut off to the charger immediately. If safe to do so, a fire extinguisher should be used to reduce the temperature of or contain the thermal event. If safe to do so, battery / drone experiencing thermal event should be isolated from other drones / batteries and removed from any structures. Combatting thermal events is not required, if you do not feel safe doing so, evacuate and dial 911 immediately.

3.8 Storage Container. If the Batteries are not installed directly inside the drones, batteries should be stored in a metal container that prohibits accidental ignition from heat or other such sparking source.

3.9 Fire Extinguisher. A fire extinguisher capable of extinguishing lithium fires shall always be present and readily available while charging or discharging batteries. The chemistry of the batteries shall match the rating and capability of the fire extinguisher.

4 Waiver Requirements and Operator Qualifications

4.1 FAA's Authority. The FAA has exclusive authority over rules and regulations of drones and drone light shows. Nothing herein in an attempt to modify or limit that authority. Should questions or conflicts exist between the guidelines herein and FAA rules; FAA rules shall control.

4.2 14 CFR § 107 (Part 107). Contains the list of regulations as it relates to drones and their usage. Should a conflict exist between the guidelines here and Part 107; Part 107 shall control.

4.3 107 Certificate Required. Prior to conducting any drone light shows, all RPICs and CRPICs shall obtain a part 107 certificate in accordance with 14 CFR § 107.61.

4.4 Waiver Required. Prior to conducting any drone light shows a waiver shall be obtained from the FAA waiving 14 CFR § 107.29 (a)2 &(b) and 14 CFR § 107.35 to be eligible to perform drone light shows.

4.5 Waiver Standards. The FAA, in its sole discretion, shall determine that appropriate measures are established to meet minimum safety standards required for the granting of a DLS waiver.

4.6 Age Requirement for RPICs and CRPICs. All RPICs and CRPICs shall be at least 21 years old and licenses by the FAA in accordance with any and all applicable laws.

4.7 Age Requirements for Crew and VOs. All Crew and VOs shall be at least 18 years old.

4.8 Recurrency Certificate. All RPICs and CRPICs should take a Part 107 Small UAS Recurrent training every year.

4.9 Real World Experience Required. In addition to the classroom training below, all RPICs and CRPICs shall participate in a minimum of five drone light shows as a crew member or observer of an operation prior to being trained how to operate a DLS. This minimum experience should focus on all aspects of the DLS from site selection, security, and the DLS performance.

4.10 Operating Airspace. All drone light shows will only be conducted in Class G airspace unless a separate Certificate of Authorization is obtained in accordance with 14 CFR § 107.41. Such authorization must be obtained through the FAA Drone Zone portal, as required by the FAA.

5 Training

5.1 VO Training. VO's will be specifically trained in their role. The initial training will take place prior to show preparations to familiarize all crew with the equipment and standard operating procedures. There will be a required knowledge test at the end of training. The training materials will come from a variety of FAA-disseminated sources. Primarily, the training will be adapted from Chapter 11 of the Airplane Flying Handbook and Chapter 12 of the Helicopter Flying Handbook, both titled "Night Operations." Topics in the training shall include the following: (1) Autokinesis: Fixation on a stationary object may cause incorrect perception of motion, (2) Fixation / Fascination: Pilots may tend to fixate on a single point, making them less aware of other traffic. Scanning and off-center viewing techniques will be discussed. Reversible Perspective Illusion: Difficulty determining if an object is moving towards or away from you. (3) Size-distance Illusion: Objects may incorrectly seem closer when brightly lit and further away when dimly lit. (4) Flicker Vertigo: Viewing a flickering light can be distracting, annoying, and disorienting. Such training shall be documented and records kept for at least two years.

5.2 RPIC/ CRPIC Training. There shall be a minimum of 24 classroom hours. Prior to these in-classroom sessions trainees should review the DLS Software Manual and review the drone manual. The structure of the training should be as follows: Day 1: Classroom Training (8 hours) which will cover (1) Overview of FAA regulations; (2) Understanding the DLS waiver; (3) Detailed study of drone light show operations, including Navigating Exclusion Zones; (4) Show creation processes; (5) Show limitations; (6) Day-of-show logistics. (7) Comprehensive training in drone control software; (8) On-site inspection and planning for drone light shows; (9) Necessary permits; (10) Safe weather conditions for operations; (11) Maintenance and production aspects of the drone light show; (12) Advanced knowledge on the RTK (Real-Time Kinematic) system and Ground Control Station computing systems; (13) Emphasis on understanding various failsafes of the drone light show; (14) Training to identify and utilize failsafes to ensure safe operations at all times; (15) Training on emergency procedures and incident response and documentation. Day 2: Group Field Exercise (8 hours) (1) Collaborative design and setup of a drone light show; (2) Comprehensive step-by-step process walkthrough; (3) Deep dive into the software, exploring each section and component. Day 3: Final Examination and Practice Test (8 hours) which will explore: (1) Conducting a final exam to assess knowledge and skills; (2) A practical test to demonstrate the ability to set up and run a show independently, without intervention.

5.3 CRPIC to RPIC Transition. A CPRIC must serve as CPRIC for a minimum of five drone light shows prior to being allowed to being an RPIC.

5.4 **Increasing DLS Size.** A CPRIC and RPIC should begin with smaller DLS and work their way up to larger shows. There should be a crawl, walk, run, approach to familiarity with DLS of increasing size.

Detailed risk mitigation plan for possible problem solving

	Risk Name	Risk description	Risk identification	Suggested mitigation
1	Magnetometer failure	The main magnetometer (compass) of the UAV fails during the flight	During the flight a drone may start flying circles around its designated position	1)Perform full test repetition, 2)Perform take-off test before show, 3)Land/Disarm the drone during flight
2	GPS sensor failure	The GPS sensor of the 1 UAV fails during the flight	Warning in Alerts View (DSS 4.0), earlier versions Overview GPS profile	Disarm
3	RTK Base station failure	RTK Base station stops working	No RTCM messages over both comms channels in Detail View, check RTK Client	Land
4	RTCM stops over secondary channel	All involved drones loose RTCM signal over secondary channel	No RTCM on secondary channel in Overview profile or Detail view	Continue the show. Try to fix secondary channel
5	Main PC failure	Main PC stops working, could be power loss or hardware malfunction	PC has previous history of failure or Windows updates are enabled	Land from second computer (Redbutton)
6	Secondary PC failure	Secondary PC stops working, could be power loss or hardware malfunction	PC has previous history of failure or Windows updates are enabled	Use backup replacement PC.
7	VSM Failure	VSM crashes and DSS looses connection to all drones	All drones connected to this VSM will be disconnected and in Service manager VSM will be Stopped/Crashed	Restart VSM
8	GPS jamming	Intentionally caused GPS jamming with the intention to cause damage	Number of GPS satellites decreases on all drones, afterwards drones start flying away	Disarm all drones immediately
9	GPS Spoofing	Intentionally caused GPS spoofing with the intention to cause damage	All drones move sideways	Can be caused by GNSS spoofing, disarm all drones immediately
10	Red button fail	Redbutton crashes on secondary PC	Red Button application stops responding/updating	Try to re-open Redbutton
11	Problems with battery charge or connection	A drone may start losing altitude because of sudden battery discharge	One or several drones fall down	Continue show
12	Propeller failure	A drone may start losing altitude or become unstable	Drone starts losing altitude or flying unstable	Continue show
13	Several drone flyaway	One or more drones may fly away without immediate reason	Drones have previous history of GPS glitching	Continue show
14	WiFi connection performance critically low	On most of the involved drones, the WiFi connection drops below 25%	During full test repetition or small batch test flights, WiFi signal was weak	Check comms levels during preflight, continue dance if WiFi levels are low, but secondary channel is OK
15	Number of satellites becomes critically low	On most of the involved drones, the number of visible GNSS satellites drops below 11	UAV forecast showed tendency of deceasing visible satellites at show time	Reposition GNSS reciever prior to show. If during show monitor drone movement closely and return home if unstable flight.
16	Precipitation occurs during flight	Sudden precipitation occurs (that was not in forecast or could not be identified before flight)	Storm clouds were present in proximity before show or precipitation was in the forecast	Continue until rainfall increases critically.

6 Requirements of Drone Light Show Drones

6.1 Design of Drones for Light Shows. Drones used in drone light shows shall be specifically designed and manufactured for use in drone light shows.

6.2 Lighting Module. Each lighting module shall be visible for a minimum of three statute miles. This determination should be based on real world performance, not based off an LED rating from a spec sheet. It is not acceptable to add the LED values together and claim that is the brightness.

6.3 Firmware. Each firmware shall be capable of autonomous flight control of a drone. Typical firmware will use Ardupilot or PX4 as the base then add logic to support light shows. Each firmware revision shall be tested a minimum of 500 flight hours before being used in a DLS in front of Spectators. The firmware shall be capable of a redundant dual layer geo-fence.

6.4 Firmware Updates. A Drone's firmware should be updated in accordance with manufacturer recommendations. After a firmware update a test flight, not in front of Spectators, shall be performed for a minimum of three (3) minutes to verify functionality.

6.5 Primary Communication Channel. Each drone shall be equipped with a primary communication channel capable of two-way communication. This should be a reliable fast link such as WIFI operating at 5.8GHz or 2.4GHz, LoRA, LTE, etc. Drones during a DLS should remain connected to this channel for the duration of the DLS.

6.6 Secondary Communication Channel. Each drone shall be equipped with a secondary communication channel capable of long-range communication. This shall be a separate frequency from the Primary Communication Channel. Typically, this frequency should be 868MHz or 915MHz.

6.7 Encrypted Communication. Both the primary and secondary communication channels shall employ mechanisms that ensure the authenticity and integrity of the communication, including but not limited to encryption, signing, or other protective measures to prevent unauthorized access or tampering.

6.8 Breach of Encryption. If a DLS operator becomes aware of a breach of communication encryption, they shall immediately cease performing drone light shows until the encryption can be updated and security restored.

6.9 RTK GPS. All drones used in a DLS shall have an RTK GPS. The RTK GPS should be a quad-constellation GNSS chip with a u-blox f9p or equivalent to provider a greater level of accuracy, anti-jamming, and anti-spoofing algorithms.

6.10 Logging. Each drone shall record a flight log to an onboard physical medium. Flight logs shall not be recorded only in ram or other temporary storage.

6.11 Log Retention. A DLS provider should pull logs from drones in a show in a reasonably practical timeline. Logs should be retained for a minimum of two years.

6.12 Log Analysis. Logs should be reviewed in a frequency that is reasonably practical and monitored for abnormalities related to individual drones and the drone fleet. Drones that are indicated to be problematic from log analysis shall be pulled from operation, inspected, and test flown to verify safe operations.

6.13 IMU. Is an electronic device that measures and reports an object's acceleration, angular rate, and orientation.

6.13 Propeller Guards. A physical barrier that protects the drone's propellers from obstacles.

7 Requirements of Ground Control Station

7.1 Redundant Computers. A minimum of two computers must be used to conduct a DLS. Each computer should be organized and configured in a way that there is no Single Point of Failure should one computer fail.

7.2 Enterprise Grade Networking Equipment. Enterprise grade networking equipment shall be used for conducting a DLS. Enterprise grade means a system capable of handling thousands of clients and that is easily scalable. A consumer or homebased networking equipment setup is not acceptable.

7.3 RTK Base station. The RTK Base station used in a DLS shall be a quad constellation RTK such as a u-blox f9p or equivalent. The accuracy of the base station shall be a minimum of .5 meters.

7.4 Wired Connection. Computers and the RTK Base station shall be hard wired and not connected over a wireless link.

7.5 Emergency Commands. All software used to conduct a DLS at a minimum shall have hold, land, RTH, and disarm functionalities. Hold shall issue a command to the drones to stop and hold position. Land shall issue a command for the drones to land in place. RTH shall issue a command to the drones to return to home. Disarm shall issue a command to terminate the motors causing the drone to fall.

7.6 Secondary Channel Independent. The secondary channel shall be capable of being used even when the primary network fails. All emergency commands shall be available regardless of network status.

7.7 Location of GCS. GCS should be placed in a central location where the RPIC and CRPIC can clearly observe the show and show related operations both on the ground and in the air.

7.8 Constant Communication. RPIC and CRPIC should have instant and constant communication with all VO's, Security Staff, and other relevant parties. For example, a two-way radio headset.

7.9 Redundant Power. GCS computers shall have redundant power. For example, a laptop where if power is cut, the internal battery keeps the GCS powered.

7.10 Uninterruptable Power Supply. Networking equipment should be on a uninterruptable power supply (UPS) or other battery system such that if shore power is cut the network remains active

7.11 Shore Power. Shore power is not required but should be used when available.

7.12 Remaining Battery Power. Enough battery capacity should be available at the time of launch to provide power to equipment at minimum for the duration of the show.

7.13 Redundant Access Points. A minimum of two access points be used for all DLS operations as to not allow for a single point of failure.

7.14 Placement of Access Points. Access points should be placed at locations close to the drones and flight area to maximize coverage and minimize risk of disconnections during flight.

7.15 Flight Video Recording. The primary flight control computer shall be equipped with an internal or external screen recorder. The preference should be for an external screen recording unit as to not tie up resources on the main show computer. Recording of the secondary computer is recommended but not required as such recordings would have very limited value given the primary computer would have to fail. Screen recordings should contain all setup and flight operations. Screen recordings from shows with any abnormalities should be retained for two years.

7.16 Minimum Computer Specifications. GCS computers should meet or exceed any and all software manufacturer's minimum specifications.

7.17 Other Programs. All GCS computers should only run the GCS software while conducting DLS operations. No other programs or resource intensive activities should be running in the background that are not related to the DLS operation.

7.18 Protection. GCS and all relevant equipment should always be protected from the elements.

7.19 GCS Passwords. Any access system or network should be protected by nondefault passwords.

7.20 RTK Antenna Placement. The RTK antenna should be mounted in such a way that it is not easily affected by outside forces such as wind, people, or other environmental factors.

7.21 Independent Emergency Commands. All emergency procedures and commands should be able to be executed from all computers independent of each other.

7.22 GCS Updates on Site Prohibition. Updates to GCS should not happen on site unless critical safety flaws are detected.

8 Requirements of DLS Animation

8.1 Drone Show Animator. A DLS drone flight path shall be pre-animated using Blender, Cinema4D, Maya, Houdini, or other similar animation program including purpose-built standalone applications. The animator that creates the path should have experience with 3D animation and be proficient in 3D animation.

8.2 Safety Checks. Drone paths shall be checked for maximum speed, distance between drones, and collisions in its native 3D animation format as well as in its exported drone compatible format.

8.3 Maximum Speed. During a DLS a drone shall not be animated to go any faster than 7 m/s or the drone's maximum rated speed determined by the manufacturer, or the real world tested maximum speed minus the acceptable wind threshold. Should the design call for faster speeds the safety distance shall be increased by distances determined in 10.14, or a rate specified by the FAA, whichever is greater.

8.4 Minimum Drone Separation Distance. DLS drones shall always be minimum of 1.5 meters apart during a DLS, but should be typically 2 meters or more apart or the separation recommended by the manufacturer. This distance does not apply to the ground configuration of the drones if the drones are taking off in multiple waves.

8.5 Designed with Site in Mind. A DLS should be designed with the location/environment in mind. Considerations for the Exclusion Zone and natural barriers should be implemented from the beginning of the design phase. A DLS shall not be designed to be larger than the determined flight zone which accounts for all safety aspects. Should a design require more space, the site plan shall be updated to match.

9 Site Selection

9.1 Site Selection. Sites should generally be free of obstructions such as tree overhang, power lines, cranes, or light poles, and shall provide adequate room to safely conduct the DLS including drone layout and flight area. Sites should be selected with safety in mind.

9.2 Control of Site. A site should be selected that is able to be fully controlled from both an access and restriction standpoint. All the flight area should be approved by the property owners as to allow sufficient access and restriction.

9.3 Exclusion Zone. Each site must establish and maintain an exclusion zone throughout the flight operation.

9.4 Elemental Protection. Sites should have adequate facilities and protection from the elements for all personnel

9.5 Site Topography. The site should have a large enough flat area or a reasonable slope to safely setup drone launch and landing areas with adequate spacing between drones.

9.6 Site Specific Hazards. If a site has hazards such as sand or mud, necessary precautions should be taken to protect the drone and prevent drone malfunctions.

9.7 GPS Obstructions. Sites should be selected to account for any GPS based obstructions such as glass buildings, tall buildings, trees, and other such obstacles.

9.8 Magnetic Interference. If possible, sites with large amounts of metal should be avoided, such as parking garages, metal barges, piers, or other such structures. If they cannot be avoided, the RPIC shall take necessary precautions to limit the effect of magnetic interference, such as elevated platforms or disabling the drone compass and using fix heading.

9.9 Site Visit Review. A site will be thoroughly reviewed to ensure it meets the criteria necessary for safe operations. An in-person site visit shall occur prior to the day of the show and/or the show design process beginning for any sites that are abnormal, are in locations that may substantially impact the show design or may have hazards that need further review or clarification.

9.8 Daylight Inspection. On the day of the show the RPIC and CRPIC must confirm that no hazards or other obstacles are present prior to setting up the show. This inspection should occur immediately upon arriving on site during the daylight.

9.9 Site and Setup Photographs. Photographs should be taken of the site prior to setting up GCS or drones and after setup is completed.

9.10 Site Records. Site information (site plan, photographs, video recordings) shall be stored for a minimum of two years.

9.11 Site Plan. A site plan shall be generated that contains the flight area, exclusion zone, nearest airport, date, address, as well as location of the spectators and security, points of ingress and egress, and acceptable thresholds for sustained winds, gusts, clouds, and visibility.

10 Conducting a DLS

10.1 Insurance Requirements. All persons conducting a DLS shall hold aviation insurance with specific coverage for drone light shows in an amount no less than five (5) million dollars per occurrence. Such policy shall be in the form of an "occurrence" policy not a "claims made" policy.

10.2 Minimum Number of VO's. A minimum of one VO shall be on site for each 250 drones being flown in the DLS. Visual observers shall complete training prior to the DLS operation.

10.3 Minimum Number of Security Personnel. An appropriate number of security personnel shall be on site to effectively lock down the Exclusion Zone. When determining the number of security personnel needed many factors must be considered including but not limited to site plan, site size, number of ingress and egress points, number of attendees, proximity to crowd, level of foot traffic, and if alcohol is being consumed by attendees.

10.4 Crew Briefing. A crew briefing shall be conducted prior to set up of the DLS and shall include details on the tasks of the day, site specific hazards and details, safety items, and responsibilities and duties of crew members.

10.5 Communications. Effective communication shall be established between all members of the crew, security, and the client to ensure that operations are well planned and executed in a safe and predictable manner.

10.6 Number of Part 107 Holders. A minimum of two-part 107 Certificate Holders shall be present on each DLS site to ensure that there is not a Single Point of Failure, both the RPIC and CPRIC shall be licensed and have completed a 107 recurrency course in the last 24 months.

10.7 Lock Down the Exclusion Zone Before The DLS. The exclusion zone shall be locked down prior to any lift off of the DLS operation and an appropriate time shall be allowed to confirm that the Exclusion Zone is cleared of any non-participating individuals.

10.8 Check of Weather and Other Environmental Factors. Prior to any DLS operations environmental factors such as wind and visibility shall be checked to confirm that conditions are safe to proceed.

10.9 Maximum Wind Speed. A DLS should only be performed in winds that meet the manufacturers specifications. As a general rule, a DLS should not be performed in sustained winds that exceed 25MPHs or wind gusts exceeding 35 MPH.

10.10 Safety Responsibility. The RPIC and CPRIC shall both be responsible for safety of a site and the DLS.

10.11 Loss of RTK Corrections. During a DLS if the RTK correction signal is lost on the drones and cannot be re-established within one (1) minute, the drones must be issued the hold command

and the RPIC will land the drones starting from the bottom of the formation to the top of the formation.

10.12 Loss of Drones. If at any point during flight five (5) of the drones or 1%, whichever is greater, are behaving abnormally the RPIC shall hold the show and land the drones. Abnormal behavior shall not include the drones entering a failsafe response as intended. Examples of expected failsafe conditions include landing because of a low battery because of battery voltage sag, battery overheating, or landing because of loss of GPS. Should three (3) of the drones impact the hard geofence, or if there is an inflight fire, or multiple drone to drone collisions, the show shall be landed immediately. Should one (1) drone not respond to the hard geo-fence the show shall be landed immediately.

10.13 Drone Breach of Exclusion Zone: If a drone breaches the Exclusion Zone during a DLS, the RPIC shall immediately hold the show initiate drone landing.

10.14 Size of Exclusion Zone with a Show Perimeter Based Geofence. For any DLS with a flight height from 0-400 feet above ground level (agl) the Exclusion Zone around the entire perimeter of the active show area will based on the following formula to calculate horizontal range of a falling object. An additional 33 foot buffer will be used beyond the horizontal trajectory. Additionally, a 33 foot buffer will be added for each 100 feet above 400 feet.

$$r = v * \sqrt{(2 * h / g)}$$

r = horizontal range in meters

v= velocity in m/s

h= initial height

g= gravity (9.8m/s^2)

Exclusion Zone Size for 400 Foot Flight Height		
Fastest Speed in Show	**Horizontal Trajectory**	**Recommended Exclusion Zone**
6 m/s	98 feet	131 feet
5 m/s	82 feet	115 feet
4 m/s	65 feet	98 feet
3 m/s	50 feet	83 feet
2 m/s	33 feet	66 feet
1 m/s	16 feet	39 feet

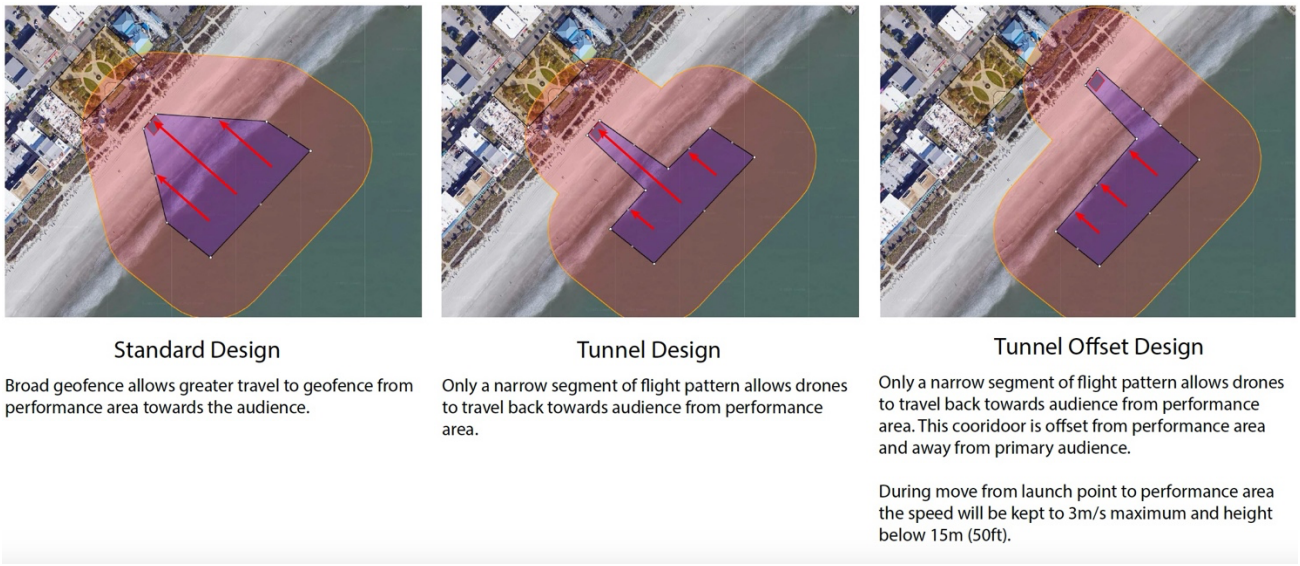
Exclusion Zone Size for 300 Foot Flight Height		
Fastest Speed in Show	**Horizontal Trajectory**	**Recommended Exclusion Zone**
6 m/s	85 feet	118 feet
5 m/s	71 feet	104 feet
4 m/s	56 feet	89 feet
3 m/s	42 feet	75 feet
2 m/s	28 feet	61 feet
1 m/s	14 feet	47 feet

Exclusion Zone Size for 200 Foot Flight Height		
Fastest Speed in Show	**Horizontal Trajectory**	**Recommended Exclusion Zone**
6 m/s	70 feet	103 feet
5 m/s	57 feet	90 feet
4 m/s	46 feet	79 feet
3 m/s	34 feet	67 feet
2 m/s	23 feet	56 feet
1 m/s	11 feet	44 feet

Exclusion Zone Size for 100 Foot Flight Height		
Fastest Speed in Show	**Horizontal Trajectory**	**Recommended Exclusion Zone**
6 m/s	49 feet	82 feet
5 m/s	40 feet	73 feet
4 m/s	32 feet	65 feet

3 m/s	24 feet	57 feet
2 m/s	16 feet	49 feet
1 m/s	8 feet	41 feet

10.15 Size of Exclusion Zone with a Show Perimeter Based Geofence and Restrictive Show Design. If DLS is designed to have a restrictive show design area that will allow the drones to move away from spectators at a slow pre-set speed and altitude and a perimeter based geofence, the Exclusion Zone around the Takeoff/Landing Area shall be 1:1 to pre-set takeoff height. The Hard Geofence shall be set as tight as possible around the Takeoff/Landing Area. When the drones reach the active flight area the standards above shall apply. An Example of acceptable restricted show design is the example below using a tunnel offset design.



10.16 Size of Exclusions Zone with a Show Perimeter Based Geofence and Path Based Geofence. If the drones performing the DLS have both a GPS based show perimeter geofence as well as a EKF triggered Path Based Geofence then the Exclusion Zone shall be based on the following formula.

V_1= maximum exit velocity from the geofence without delay

$$V_1^2 = u^2 + 2ad$$

V_2= exit velocity after breaching and one second delay

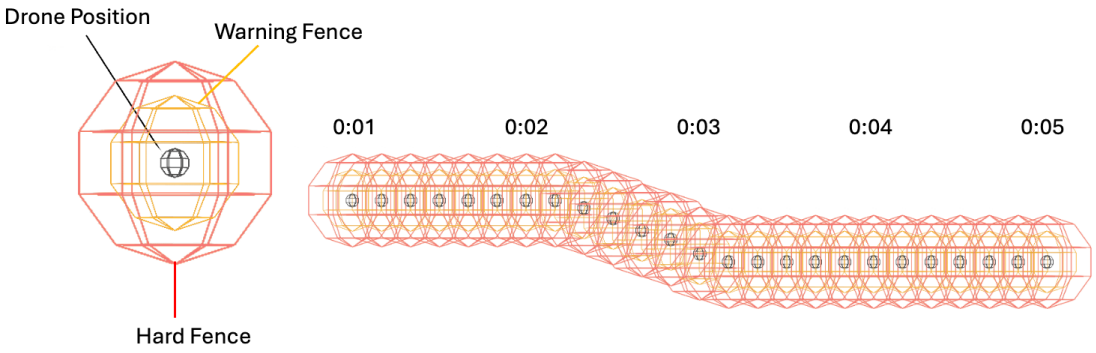
$$V_2 = \sqrt{(u^2 + 2ad)} + a$$

d_2= distance covered during one second delay

$$d_2 = \frac{1}{2}(V_2 + V_1)$$

$$x = \frac{\left(V_2^2 \sin(2\theta) + V_2 \cos(\theta) \sqrt{((V_2 \sin(\theta))^2 + 2gh)}\right)}{g}$$

θ = launch angle assumed to be ≅ 45 degrees
x = horizontal distance covered until impact from
g=-9.8m/s^2
h= altitude (AGL)
Total horizontal distance = x + d_2



10.17 Vertical Geofence. A vertical geofence shall be set no less than 4 meters above the maximum flight height.

10.18 Hazardous Conditions. The DLS shall be stopped whenever an RPIC or CRPIC identifies a hazardous condition and shall not resumed until the condition is corrected.

10.19 Crowd Control. If the RPIC or CRPIC believes the lack of crowd control poses a hazard, the DLS shall be postponed or discontinued immediately until the situation is corrected.

10.20 Unsafe Conditions. If any unsafe condition is detected, such as drones crashing into the audience or sudden change in weather conditions, the RPIC shall immediately terminate the DLS.

10.21 Drugs and Alcohol. No person shall be present in the Exclusion Zone with alcohol in his or her system or while under the influence of drugs that are not over-the-counter or prescription medication used in compliance with manufacturer's or physician's written instructions.

10.22 Over-the-Counter Medication. No person shall be present in the exclusion zone while under the influence of over-the-counter or prescription medication that impair the judgment, mobility, or stability of the user to such degree that he or she cannot understand and conform to the requires of applicable laws, regulations, and standards governing the DLS.

10.23 Armed Drones Safety. At no time shall any part of the body be over top of an armed drone awaiting take-off.

10.24 Maximum Operating Temperature. A DLS should not occur when the temperature is above 112F. Batteries should be stored between 65-75F before flight and after flight.

10.25 Minimum Operating Temperature. A DLS should not occur when the temperature is Below 10F. Precautions shall be taken when a DLS is occurring in temperatures below 32F. Batteries should be stored between 65-75F before flight and after flight.

10.26 Fog, Snow, or Rain. A DLS shall not occur in fog, snow, moderate or heavy rain. Moderate rain is rain falling at a rate greater than 2.5 mm per hour, but less than 7.0 mm per hour.

10.27 Thunderstorms. A DLS shall not occur with a thunderstorm within five (5) miles.

10.28 Failsafe Lighting. During a failsafe state on the drone, the LED light shall produce a visual indicator that it has entered a failsafe state. This color shall be obvious and clear that such failsafe event has occurred. The main show LED shall remain at a minimum of twenty percent brightness during a failsafe descent.

10.29 Drone Lights During Abort. If the RPIC is required to abort out of the flight, the RPIC shall light up all drones to a minimum of fifty percent brightness while performing the emergency landing.

10.30 Fifteen Minute Rule. RPICs and CRPICs shall be "show ready" a minimum of fifteen minutes prior to showtime. If pilots fail to meet this deadline for any reason, they shall push the DLS by a minimum of fifteen minutes.

10.31 Pre-Flight Inspection. A preflight inspection shall occur prior to the DLS. The preflight inspections involve a visual condition inspection of each drone and the drone components, and the hardware associated with the DLS system. The RPIC will be responsible for ensuring the completion of the pre-flight inspection. The preflight inspection will at a minimum include: (1) Visual inspection of the whole structure of the drone body; (2) Registration markings, for proper display and legibility; (3) Sufficient lighting and pre-assessment of operational area conducted; (4) Moveable control surface(s), including airframe attachment point(s); (5) Motor(s), including attachment point(s); (6) Install the battery and lock the battery compartment; (7) Verify all systems (e.g., aircraft and control unit) have an adequate energy supply for the intended operation and are functioning properly; (8) Avionics, communication/navigation equipment, and antenna(s); (9) Calibrate drone compass as needed; (10) Control link transceiver, communication/navigation data link transceiver, and antenna(s); (11) Check ground support equipment, including takeoff and landing systems for proper operation; (12) Check onboard navigation and communication data links; (13) Check flight termination system; (14) Check battery levels for the aircrafts; (15) Check that the drones are arranged according to the diagram of the drone grid; (16) Verify communication with UAS and that the UAS has acquired GPS location from at least twelve satellites; (17) Start the UAS propellers to inspect for any imbalance or irregular operation; (18) Verify all headings and altitude; (19) Verify geofencing setup.

10.32 RPIC Responsibilities. The RPIC shall oversee the entire DLS operation from start to finish. The responsibilities include: (1) Ensuring all crew members are aware of their responsibilities by giving a Crew Briefing; (2) Ensuring all required paperwork is completed; (3) Ensuring a thorough on-site assessment is completed; (4) Ensuring the drones are only operated within their limitations; (5) Ensuring all commercial work is completed within the limitations stated by Part 107; (6) Ensuring that the drone(s) used are airworthy by completing a pre-flight checklist; (7) Ensuring that the welfare of themselves or others is not compromised by any planned operations; (8) Ensuring that they are of sound body and mind to operate the aircraft; (9) Full understanding of all equipment for setup and adherence to the pre-flight checklist; (10) Ensure that all take-off/landing zones are free from obstructions and people; (11) Full understanding of all warnings and indicators of a malfunction and landing protocols in the event of an emergency; (12) Full understanding of each site location and operational guidelines with respect to flight operations in each location; (13) Ability to identify signs of night illusions or fatigue; (14) Ability to recognize and overcome visual illusions caused by darkness and understand physiological conditions which may degrade night vision; (15) Full understanding of equipment breakdown, storage, and battery charging; (16) Assess operating environment including: (a) Local weather conditions; (b) Local airspace and any flight restrictions; (c) The location of persons and property on the surface, and other ground hazards; (17) Ensure the geo-fence systems and GCS operate properly; (18) Ensure that each drone's sensors and flight control systems operate as intended; (19) Confirm a Notice to Airmen (NOTAM) 24-72 hours prior to proposed operation. The NOTAM will include location, altitude, operating area, duration and nature of the activity; (20) Confirm all requirements are met in the airspace authorization if flying in anything other than Class G airspace; and (2**1**) Identify and address any site-specific issues that could impact the DLS.

10.33 CRPIC Responsibilities. The CRPIC is the assistant to the RPIC and plays a critical role in supporting the successful execution of the DLS. Their duties shall include: (1) Organizing the crew on-site to ensure efficient and effective operations; (2) Oversees the accurate layout of the drone setup grid as part of the show setup process; (3) The CPRIC assists the RPIC in completing the pre-flight checklist, ensuring all required procedures are followed; and (4) Must agree with the RPIC on the readiness of the show and show safety.

10.34 Visual Observer (VO) Responsibilities. The VO will assist the RPIC and CRPIC. Their responsibilities include: (1) Informing the RPIC of any other aircraft entering the show flight path; (2) Assisting in observing and noting the heading of the aircraft in the event of a 'Fly Away' scenario; (3) Ensuring that all take-off/landing zones are free from obstruction and people; (4) Assist in the setup operations and placement of drone into their starting grid; (5) Assisting in the event of any emergency, and aid in an emergency landing; (6) Fully understanding the site location and aid the RPIC in keeping line of site throughout the show; (7) Full understanding of equipment breakdown, storage, and battery storage; (8) Ability to identify signs of night illusions or fatigue to recognize and overcome visual illusions caused by darkness and understand physiological conditions which may degrade night vision personally and within crew; (9) Ability to effectively communicate: (a)

the drone location, attitude, altitude, and direction of flight; (b) the position of other aircraft or hazards in the airspace; and (c) be able to determine that the drone does not endanger the life or property of another.

10.35 Security Staff Responsibilities. Security Staff shall be responsible for: (1) Monitoring the Exclusion Zone perimeter for unauthorized access; (2) Securing the premises by patrolling Exclusion Zone and access points; (3) Immediately make attempts to remove any unauthorized person(s) from the Exclusion Zone should a breach of the Exclusion Zone; (4) Should unauthorized person not be able to be removed or should there be a risk to that person's safety the security personnel shall immediately notify the RPIC, who will pause or stop the display to ensure the safety of all persons.

10.36 Identifying the Exclusion Zone. The Exclusion Zone perimeter will be identified with caution tape, traffic cones, or other similar items to clearly indicate it is an area not accessible to the public.

10.37 GCS or Drone Updates. GCS or Drone updates should not occur while on site setting up for a DLS.

10.38 Staff Clothing. All staff participating in the DLS shall have climate appropriate clothing that identifies them as members participating in the DLS. The staff should wear high visibility vest and other appropriate personal protective equipment.

10.39 Fire Extinguisher. A fire extinguisher capable of extinguishing lithium fires shall always be present and readily available performing a DLS. The chemistry of the batteries shall match the rating and capability of the fire extinguisher.

11 Post DLS

11.1 Post Show Report. After the DLS, the RPIC shall document the number of drones that successfully took off and landed, any issues that occurred during the DLS, and any other important information. This report will also include the name of the visual observers to ensure a 250/1 compliance ratio.

11.2 Mandatory FAA Reporting. The RPIC shall report to the FAA, in a manner acceptable to the Administrator, any operation of the drone involving at least: (a) Serious injury to any person or any loss of consciousness; or (b) Damage to any property, other than the small unmanned aircraft, unless one of the following conditions is satisfied: (1) The cost of repair (including materials and labor) does not exceed $500; or (2) The fair market value of the property does not exceed $500 in the event of total loss. This report shall be made no later than 10 calendar days after a DLS that meets the criteria of either (a) or (b) of this section. **14 CFR § 107.9.**

11.3 Incident Investigation. Any incidents and occurrences will be investigated by the DLS operator, as well as following Part 107 rules and regulations where applicable.

11.4 Incident Handling. In the event of any incident the severity must be assessed. The severity of the incident will dictate the proper response and handling.

11.7 Incident Logging. A DLS operator shall log any and all Major Incidents and take all necessary steps as required by Part 107. The DLS operator shall perform an investigation procedure to ensure that all proper logging and handling of the incident has been completed. All minor incidents should be taken care of swiftly and tested with a thorough flight test before entering back into operations.

11.8 Investigation Procedure. A DLS operator shall create a major incident report document prior to the next drone show. The guideline for the investigation procedure is as follows: (1) Introduction; (2) Description of Events including a thorough timeline of the events and actions taken up to and after the incident; (3) Analysis of the event should describe what occurred and also knowledge on how to fix the situation so that it does not happen again; (4) Conclusions as to how the operations that caused a major incident will not happen again. The report should also include any recommendations on how to improve the drone operations in the future.

11.9 Accident Response Policy. If an accident causing severe injury is to occur, a RPIC shall immediately (chronologically) call 911 and the NTSB (following the procedure outlined below). Within ten days the RPIC is to fill out the drone zone incident form.

11.10 NTSB reporting. Contact the NTSB's 24-hour Response Operations Center (ROC) at 844-373-9922 to file a report. Contacting the ROC satisfies 49 CFR 830.5. A phone call is sufficient initially, but a written follow-up may be required. When you contact the NTSB, 49 CFR 830.6 spells out exactly what needs to be reported to them. The notification required in § 830.5 shall contain the following information, if available: (a) Type, nationality, and registration marks of the aircraft; (b) Name of owner and operator of the aircraft; (c) Name of the pilot-in-command; (d) Date and time of the accident; (e) Last point of departure and point of intended landing of the aircraft; (f) Position of the aircraft with reference to some easily defined geographical point; (g) Number of persons aboard, number killed, and number seriously injured; (h) Nature of the accident, the weather and the extent of damage to the aircraft, so far as is known; and (i) A description of any explosives, radioactive materials, or other dangerous articles carried.

11.11 Reporting Requirement for an Exclusion Zone Breach without Injury or Damage. If a drone breaches the Exclusion Zone and does not result in injury, the RPIC shall immediately notify the responsible person of the waiver. The responsible person will then immediately notify the FAA waivers team that there has been an Exclusion Zone breach that has not resulted in an injury and will generate a report which shall be provided to the waivers team within seven days.