VERGE AERO

Show Operations Manual

Verge Aero™ Show Operations Manual

Revised: April 2025

All product information and specifications mentioned in this document are subject to change.

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Note: Because Verge Aero frequently releases new versions and updates to its system software, applications, and Internet sites, images shown in this manual may differ slightly from what you see on your screen.

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Version History

Version	Revision Date	Changes
2021.1	8/26/21	N/A
2021.2	9/15/21	Night Operation Requirements, Visual Observers
2021.3	10/8/21	Geofencing, Safety Radius, Hub Settings Config
2022.1	1/25/22	Chapter Numbers, Charging Time and Power Needs charts (1.2), Environmental Operating Conditions (2.2), Black Base Station Layout (5.3), Spectrum Check (5.9), Trigger methods (5.11), Maintenance after Sand (Ap. B)
2022.2	2/1/22	Updated computer specs (4.0)
2022.3	6/9/22	Updated Night Operations Requirements (2.7), Added Flying Near Buildings (2.1)
2023.1	4/3/23	Updated IR Variation (1.2) & Operating Temperature (2.2)
2023.2	8/28/23	Fixed UN3481 link (1.2), Updated the following sections: Flying Near Fireworks (2.3), Spectrum Check (2.6), VO Test Link (2.8), Verge App Toolbox (4.0), Computer Specs (4.0), Individual Drone Information (4.4), Light Modes (4.5), Show Upload (5.8), Spectrum Check (5.9), Pre-Show Checklist (5.11), Emergency Procedures (5.12), and Show Day Checklist (appendix 4)
2024.1	5/1/24	Added X7 support
2025.1	1/7/25	Expanded environmental conditions info (2.2) Added footnote for ballistics model calculations (2.5)
2025.2	4/4/25	Expanded value table for ballistics model to include 800 ft

1. Hardware Overview & Handling

1.1 Drones

Specifications

Width (Prop-to-prop): 48 cm (18.9”)

Width (Hub-to-hub): 28 cm (11.2”)

Height (Flight Configuration): 14 cm (5.4”)

Height (Storage Configuration): 9 cm (3.6”)

Weight: 830 g (1.8 lb)

Landing Gear

Drones are stored with their landing legs in a collapsed configuration. The landing gear needs to be put into the flight configuration before flying.

Landing Gear Collapsed

Landing Gear Expanded

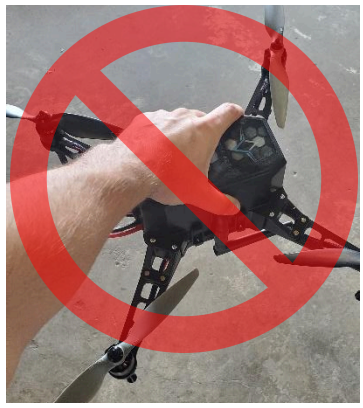
Handling

The X7 should be moved by grabbing the center hub of the drone and not by the landing gear or arms.

For X1, always hold drones by the arm. This can be done using either of the two different grips shown below. Do not carry drones by the lid.

Correct Grip

Correct Grip



Incorrect Grip

Plugged-In

When plugged in, drones should only be carried two at a time, and held parallel to the ground to minimize GPS disturbance. When plugged in, ***do not carry drones by the lid***. The GPS sensor is directly underneath the lid, and your hand can cause signal obstruction. The optimum handling method is pictured below left.

Unplugged

When unplugged, drones can be carried up to four at a time (two in each hand) using the grip pictured below right.

1.2 Batteries

!!! **!!!**

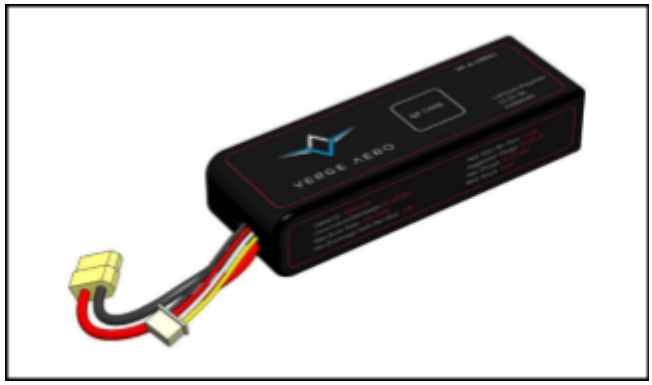
CAUTION: BATTERIES ARE HIGHLY FLAMABLE AND SHOULD BE TREATED AS EXPLOSIVES AT ALL TIMES. HANDLE WITH EXTREME CARE.

!!! **!!!**

X1 Drone Battery

Verge X1 Drones are powered using a 3-cell LiPo battery pack. Taking care of these batteries is of the utmost importance for both physical safety and show success.

Battery management requires focused attention. The batteries must be regarded with the same level of care as the drones themselves.



3S 5100mAh 11.1V RC LiPo with XT60 and balance connector.

X7 Drone Battery

Verge X7 Drones are powered using a Li-Ion battery pack. Taking care of these batteries is of the utmost importance for both physical safety and show success.

Battery management requires focused attention. The batteries must be regarded with the same level of care as the drones themselves.

4200mAh 45.4Wh 10.8V Smart Li-ion Battery Pack

Any battery that is dropped, dinged, or damaged in any way, should be retired from use and disposed of in a battery recycling facility. Damaged batteries are much more likely to fail and even catch on fire.

Charging Protocol

Never leave batteries unattended while charging. During and immediately after charging, batteries are most at risk of ignition. Monitor charging and recently charged batteries using a thermal camera. Batteries that are significantly hotter than the rest need to be removed from the charger and separated immediately.

Batteries should be charged no more than 24-hours before a show. Leaving batteries charged for significant periods can cause damage to the cells, increasing the risk of ignition and decreasing performance. The recommended charging protocol is listed below.

Note: These recommendations assume room temperature. Handling batteries at non-room temperature can produce variations in battery performance and measurements.

Charging Protocol Step-By-Step X1

1. Check the battery before connecting it to the charger. There are two conditions to watch out for:

- Problem: Cell imbalance greater than 50mV.
- Solution: Connect to ISDT battery checker and balance cells.

- Problem: Pack below 11.1V (3.7V per cell).
- Solution: Trickle charge pack to 11.1V (trickle charge uses current less than 0.5A).

2. If cells are balanced and the pack is at 11.1V, the batteries are safe to charge using a standard 1C balance charge. For the X1 battery, 1C charging occurs at 5.1A. Charging batteries at rates higher than 1C can damage cells and degrade cell performance.

- **During charging, monitor cells using a thermal camera. Any cells that are significantly hotter than the rest must be removed from the charger and separated immediately.**

3. After charging is complete, remove from the charger and check cells again for cell imbalance and cells above 4.25V. If a battery is unusually hot, isolate it from all others and monitor it regularly with a thermal camera.

4. Separate charged batteries and avoid clustering batteries together.

- **Monitor batteries regularly with a thermal camera, any battery that is significantly hotter than the rest must be separated immediately.**

5. Once a battery has been fully charged for an hour, check to ensure the pack is at a stable temperature using a thermal camera, then place it into safe transport containers.

Charging Protocol Step-By-Step X7

1. Inspect batteries for damage prior to charging.

- The X7 battery is housed in a durable PC+ABS enclosure that helps protect the internal cells from damage. However, batteries should still be visually checked prior to charging to ensure no punctures or other damage that may affect the battery is visible.
- Check battery's current charge state using the built-in battery level indicator located on the front of the battery. If no LEDs illuminate, do not attempt to charge the battery.

2. If the battery is not damaged and is showing status on the battery indicator, it is ready for charging. Insert and lock the battery into an X7 or standalone Verge Aero battery charger.

- **During charging, monitor cells using a thermal camera. Any cells that are significantly hotter than the rest must be removed from the charger and separated immediately.**

3. After charging is complete, remove from the charger and check battery again. If a battery is unusually hot, isolate it from all others and monitor it regularly with a thermal camera.

4. Separate charged batteries and avoid clustering batteries together.

- **Monitor batteries regularly with a thermal camera, any battery that is significantly hotter than the rest must be separated immediately.**

5. Once a battery has been fully charged for an hour, check to ensure the pack is at a stable temperature using a thermal camera, then place it into safe transport containers.

Charging Time

Each battery takes ~1 hour to charge using the recommended quad balance charger. Verge recommends at least (20) chargers per 100 batteries to complete all charging within five hours.

Total Batteries	Total Chargers	Batteries Charging at One Time	Time Required
100	20	20	5 hours
100	40	40	2.5 hours
200	40	40	5 hours
400	80	80	5 hours
500	25	100	5 hours

Power Needs

The recommended quad balance charger charges four batteries simultaneously, requiring 400W of power. On a standard 120V 15A circuit (4) quad chargers can run safely simultaneously.

Amps required per quad charger: [400W/120V = 3.33A]

Amps required for (4) quad chargers: [3.33A * 4 = 13.33A Total]

Number of Chargers	Power Required	Standard 120V 15A Circuits Required
5	2000W	2
10	4000W	3
15	6000W	4
20	8000W	5

Recommended Battery Charger X1

Verge recommends using ISDT BattGo battery checkers, which can be purchased here. This specific battery checker has the ability to balance cells as well as check voltages. Verge recommends using a QC3 Quad Balance Charger, which can be purchased here.
On a standard 120V AC circuit, a single quad charger with four batteries connected pulls 3A. Generally, four chargers can be connected to a single circuit, drawing a total of 12A and 1400W.

Recommended Battery Charger X7

Verge recommends using the X7 or the standalone multi-battery charger to charge the batteries.
Drone:

> Each drone has a USB type C port that can be connected to a standard 5V charger. This allows operators to set up a bank of X7s to be used as chargers. Recommended USB C charger.

Multi-battery Charger:

> Verge sells a standalone multi-battery charger for a more efficient charging setup. Each charger has a battery slide in port. This allows operators to chargeup up to eight batteries at once.

Battery Storage

Cells are in a storage state between 3.7V and 3.9V (pack voltage between 11.1V and 11.7V). The ideal storage voltage is 3.8V per cell and 11.4V per pack.

Batteries should undergo at least one full charge-discharge cycle monthly to maximize pack health and longevity.

Battery Transport (Charged)

When transporting charged batteries, minimize grouping batteries together. **Always put groups of batteries in LiPo/Li-Ion Safe bags (fiberglass bags with ventilation) and carry a Class B fire extinguisher.**

Battery Transport (Shipping)

Please take these instructions extremely seriously. Charged batteries are very dangerous. Transporting charged batteries can result in catastrophic accidents should they catch fire.

ALL BATTERIES MUST BE IN A STORAGE STATE FOR SHIPPING.

When shipping drones, each drone should carry a storage-state battery in its tray. All extra batteries must be individually packaged. Follow the United Nations regulation for shipping drones with batteries in accordance with UN3481.

Battery Health

X1 battery Internal Resistance (IR) is one metric to understand a battery's health better. The IR of each cell and IR variation between cells provides an indication of the battery's condition.

Cell Internal Resistance	Cell Condition
< 10 mΩ	Great Condition
10-15 mΩ	Good Condition
15-20 mΩ	Aged Condition
> 20 mΩ	Pack should be Retired
Pack IR Variation	**Pack Condition**
0-30 mΩ	Usable Condition
> 30 mΩ	Pack should be Retired

The X7 smart battery solution is designed to self-test and report the estimated flight time remaining so that each battery's health state may be visually checked through the Ground Control Station before each flight.

Final Note:

Batteries are a safe and effective method of powering drones when properly used and maintained. However, if proper procedures are not followed, batteries can be easily damaged and result in bad outcomes, such as thermal runaway or even catching fire. Batteries on fire can result in serious damage to property and people if they are in a vulnerable location.

Taking care of these batteries is of the utmost importance for both physical safety and show success. Please give it your closest attention with the same level of care—or greater than—the drones themselves.

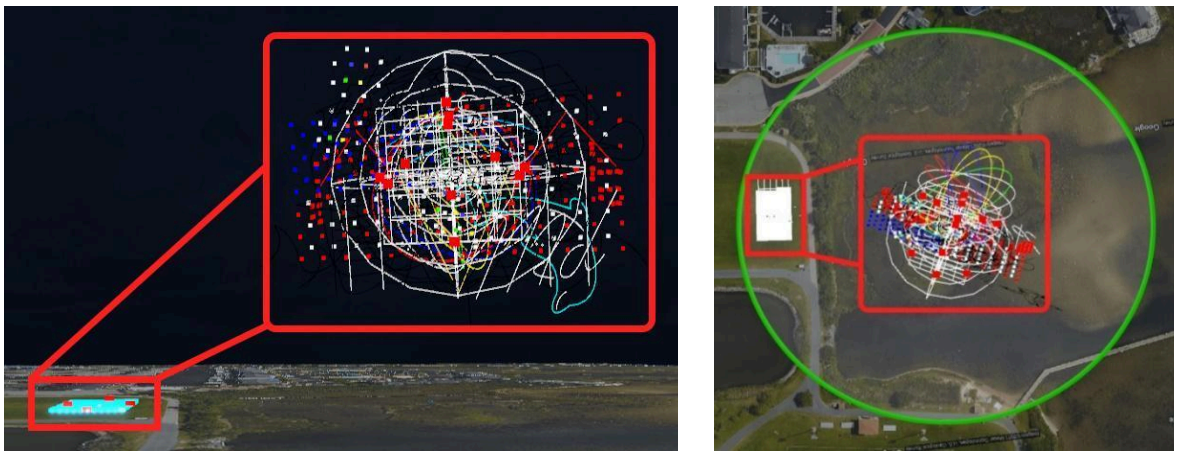
2. Show Planning

2.1 Location and Flight Time

Understanding the limitations of both the technology and your show location is essential to designing a safe and successful show. This document assumes the show will take place in authorized airspace.

Flight Operations Area

The Flight Operations Area consists of the Launchpad, Traversal Airspace, Show Airspace, and Restricted Zone. Drones should never fly directly above people, and an additional safety radius is highly recommended anytime drones are in flight.



(Left) Side View of Flight Operations Area. (Right) Top View of Flight Operations Area including Restricted Zone.

Launchpad

The Launchpad should be determined at the same time as the Show Airspace. Some guidelines for selecting an optimum launchpad are below.

- As close to directly underneath Show Airspace as possible. The closer the launchpad is to Show Airspace, the less battery is being wasted during traversal (cutting performance time).
- Away from trees and buildings. Any obstacle near the launchpad can obstruct GPS signal.
- On level ground that doesn't include tall grass, plants, or obstructions.

Traversal Airspace

Traversal Airspace is the designated three-dimensional corridor between the launch pad and the show airspace, essential for drone transit. Operators must be vigilant about maintaining safe altitudes and avoid any obstacles such as tall trees, power lines, buildings, or other structures that may interfere with drone passage. This airspace should be planned with precise boundaries and altitude limits to ensure uninterrupted and safe transitions between launch and show operations.

Show Airspace

The Show Airspace is the 3-dimensional space a show will occur within. Pay attention to the lowest show altitude and take extra precautions to avoid tall trees, telephone lines, buildings, etc.

Restricted Zone

The Restricted Zone is a designated area surrounding the drone light show where audience members and non-participating personnel are restricted to ensure safety in the event of an emergency landing or motor failure. This radius is calculated based on critical factors, including wind speed, maximum drone speed, and flight altitude. Establishing an appropriate Restricted Zone is essential to prevent unintended entry and to protect bystanders from potential hazards associated with unexpected drone descent or lateral drift. See section 2.5 for more details.

Flying Over Water

Flying over water introduces additional risk factors that need to be taken into consideration. The water will need to be free of spectators, be patrolled for safety, and have a recover plan in place in case a drone lands in water. If possible, have the Show Airspace and Traversal Airspace entirely over land. If flying over water is necessary, ensure that the length of the show is conservative to minimize the risk of an auto-landing due to low battery.

Flying Near Buildings

Flying near and/or below a large building significantly reduces the signal-to-noise ratio of the GPS satellite connections. When GPS signal decays, altitude is affected more than latitude and longitude, which can result in vertical accuracies decaying to upwards of 5m. For every one meter of the height of a building, you need at least one meter of lateral distance relative to the top of the building to avoid GPS signal decays.

Flight Time Determination

A critical part of managing a successful show is setting appropriate expectations for the client. The chart below lays out recommended and maximum flight times. Note that flight time is from launch to land and usually includes ~1 minute of traversals to/from Show Airspace.

This chart assumes fully charged batteries.

Powered Ground Time*	Recommended Max Flight Time	Absolute Max Flight Time**	Over Water Flight Time
15 min	16 min	20 min	15 min
30 min	15 min	19 min	14 min
1 hour	14 min	17 min	12 min
1.5 hours	12 min	13 min	10 min
2 hours	11 min	12 min	9 min
3 hours	9 min	10 min	7 min

*Powered Ground Time begins the moment the first drone is plugged in

**Absolute Max Flight Time should only be attempted with new batteries (less than 20 cycles).

2.2 Environmental Operating Conditions

Drones are not impervious to environmental factors. Normal weather patterns can be a cause for unsafe flights. Safe environmental conditions for operation are listed below. **Flying outside of these parameters is not recommended.**

Temperature: 14°F (-10°C) to 104°F (40°C).

Low temperatures have a negative impact on battery performance. When planning to fly in temperatures below 40°F (5°C), show day operations need to be adjusted. Batteries must avoid being unplugged in the cold for extended periods. Once batteries are plugged in at low temperatures, the drones' lights should remain on at full brightness to pull current through the battery. Additionally, aggressive show maneuvers can cause autolandings during a show in cold weather. Extra easing time should be factored into show design for cold weather performances.

Wind: Sustained 15mph, gusting 20mph.

Note that drones will use more battery life to combat wind. Flight times should be conservative when flying in high winds.

Rain:

X1 is not rated to fly in rain
X7 is designed to IP64 standards. However, it is not rated to fly in rain.

To minimize potential damage to drones, it is not recommended to fly in any level of precipitation. Doing so, however, will not result in behavior that causes the drone to exit the safety area. If you must proceed with flight in rain, try not to exceed light rain, or a precipitation rate of 2.5 mm/h. Flight in any amount of precipitation is not officially supported by Verge Aero.

Snow/Freezing Rain:

Freezing rain can be catastrophic to the mechanical components of the X1 or X7 drone. If the motors are not spinning and water is allowed to accumulate within the motor housing, expansion due to freezing may permanently damage the windings or casing. Additionally, ice sheeting may be shed in flight, leading to the release of fast-moving, uncontrolled debris. **It is strongly advised to never operate in these conditions.**

Snow *may* be acceptable if careful considerations are made. It is important that significant accumulation is avoided. Buildup on the top cover will negatively impact GPS reception and cause deterioration of the launchpad solution. Buildup in the motors can cause lockups or a failure to launch. Visibility and line of sight must be maintained in consideration of local rules and

regulations. Snowfall can have a strong detrimental effect on visibility. As with rainfall, flight in snowfall is not officially supported by Verge Aero, but doing so will not result in behavior that causes the drone to exit the safety area

2.3 Flying Near Fireworks

Choreographed shows that integrate both fireworks and drones can be extremely appealing to audiences. When flying drones near fireworks, drones must be outside the fireworks' blast radii. Including a buffer outside of the immediate blast radii is recommended to account for firework misfires and debris. **Flying within the blast radius creates the potential for drones to be damaged by shell bursts or other aerial projectiles and is not recommended.**

Fireworks discharged near the drone launchpad can cause drone sensor errors to appear on the Console. This includes the concussion from large shells and salutes or the heat produced by fireballs. These sensor errors will clear a few seconds after the firework is discharged.

2.4 Geofencing

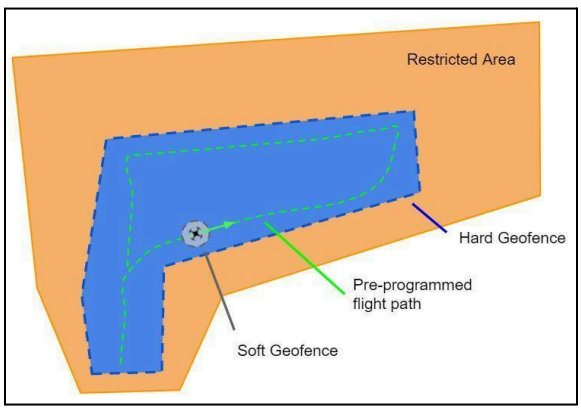
The Verge system utilizes a dual geofence system for maximum redundancy and safety. This system consists of a soft geofence and a hard geofence.

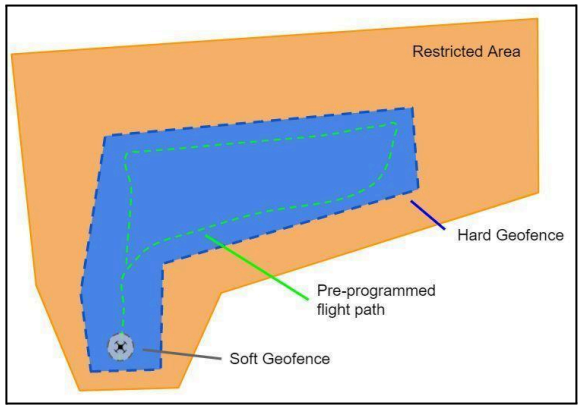
The soft geofence is a local 4m radius around each individual drone as it travels along its respective flight path. If a drone deviates from its flight path enough to breach that radius, that drone will autoland. When autolanding, a drone will descend vertically from the position where the autoland was triggered. The drone will descend in a controlled manner until it reaches the ground and the motors turn off.

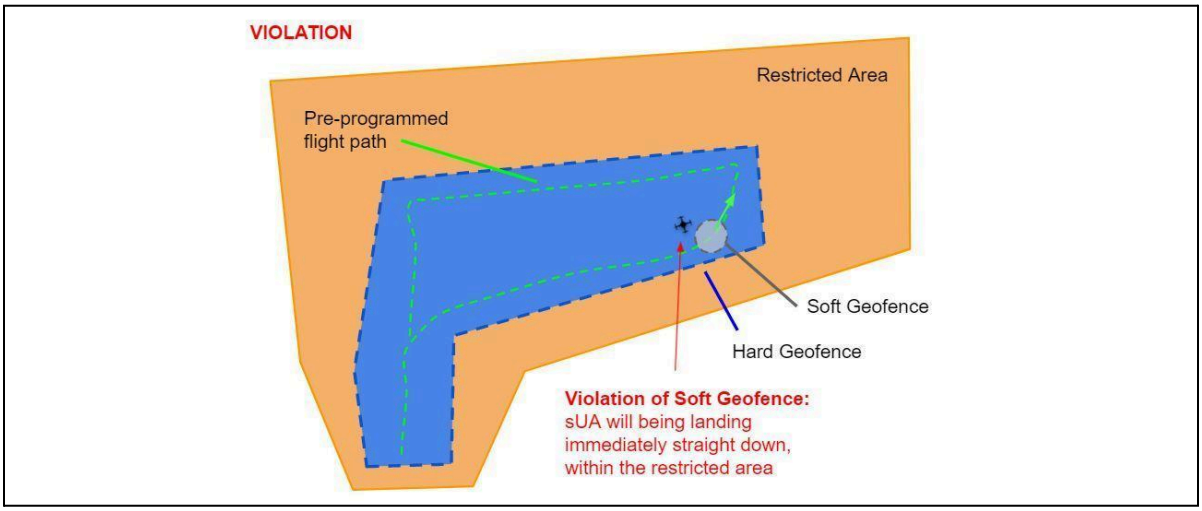
The hard geofence encompasses the entire show airspace. If a drone breaches this hard geofence, the drone will autoland below it's immediate location.

A restricted area is imposed outside of the hard geofence area. The restricted area represents the maximum distance a drone could stray in a worst-case scenario, plus an additional 50-foot buffer.

Geofence Diagrams





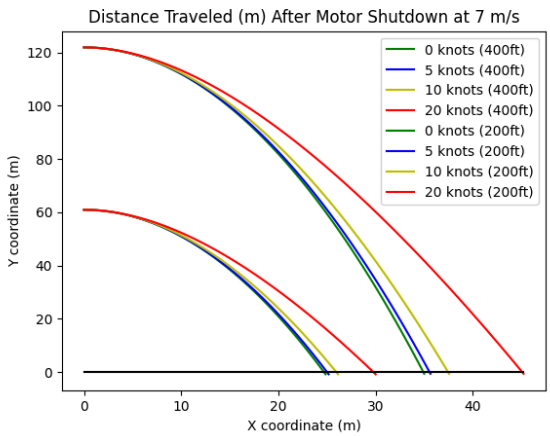


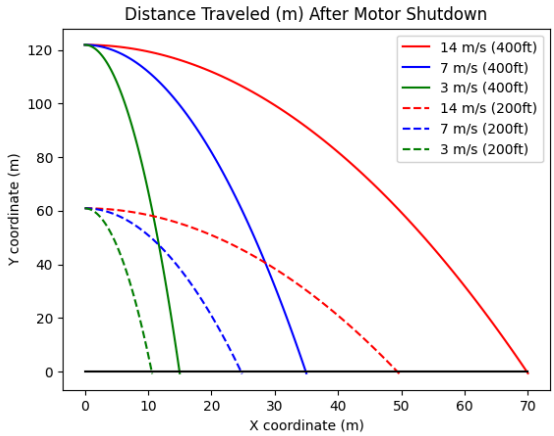
2.5 Restricted Area

To determine an appropriate restricted area, the maximum distance a drone could travel after breaching the hard geofence was calculated. The calculations utilized extremely conservative values and resulted in the following data.

As seen in the table below, even under a very conservative model, the restricted area (defined by the safe distance) is much smaller than a 2:1 altitude to lateral distance restricted zone. Furthermore, depending on the location of the multi-sUA light show, it is possible to modify both the maximum height and maximum speed of the sUAs to safely operate in more confined areas, such as urban areas.

The equations used are found in Appendix 5: Restricted Area Calculations.





Traversal Distance with variable Height

Initial Height (ft)	Initial Velocity (m/s)	Windspeed (knots)	Distance Traveled (ft)	Safe Distance +50 (ft)
400	7	5	115.64	165.64
350	7	5	108.65	158.65
300	7	5	100.51	150.51
250	7	5	91.22	141.22
200	7	5	81.94	131.94
150	7	5	71.5	121.5
100	7	5	57.62	107.62
50	7	5	41.44	91.44

Traversal Distance with variable Windspeed

Initial Height (ft)	Initial Velocity (m/s)	Windspeed (knots)	Distance Traveled (ft)	Safe Distance +50 (ft)
400	7	1	114.86	164.86
400	7	2	114.96	164.96
400	7	5	115.64	165.64
400	7	10	118.06	168.06
400	7	15	122.1	172.1
400	7	20	127.75	177.75
400	7	25	135.01	185.01

Traversal Distance with variable Initial Velocity

Initial Height (ft)	Initial Velocity (m/s)	Windspeed (knots)	Distance Traveled (ft)	Safe Distance +50 (ft)
800	14*	5	330.34	380.34
700	14*	5	306.8	356.8
600	14*	5	285.65	335.65
500	14*	5	259.85	309.85
400	14*	5	231.76	281.76
300	14*	5	201.39	251.39
200	14*	5	164.11	214.11
100	14*	5	115.35	165.35
800	7	5	167.29	217.29
700	7	5	155.23	205.23
600	7	5	144.41	194.41
500	7	5	131.24	181.24
400	7	5	116.93	166.93
300	7	5	101.49	151.49
200	7	5	82.59	132.59
100	7	5	57.94	107.94
800	3	5	74.11	124.11
700	3	5	68.61	118.61
600	3	5	63.7	113.7
500	3	5	57.75	107.75
400	3	5	51.31	101.31
300	3	5	44.4	94.4
200	3	5	36	86
100	3	5	25.13	75.13

*14 m/s is double the max traversal speed of the X1/X7. It is included merely for demonstration purposes

2.6 Site Visit

To validate a flight location, site visits are recommended for visual validation and testing. Below is a list of checks to perform during a site visit.

GPS Signal Obstructions

The RTK unit and each drone all receive data individually from satellites. Communication can be blocked by physical obstructions such as buildings or trees. The closer these obstructions are to the launchpad, the more significant their effect will be. A significant slope in the launchpad will tilt the drones' GPS ground plane off-level, risking the drones missing satellites near the horizon.

Test: Set up the RTK antenna and allow to survey. If the accuracy is not below 1.9m once the anchor begins streaming the location has bad GPS signal. Good RTK accuracy is below 1.65m. Move the RTK antenna to different areas around the launchpad and re-survey to find the best GPS location.

Once RTK is streaming, power on a few drones and place them in the launchpad to ensure they reach and maintain GPS fix. Test the corners of the launchpad and a few slots in the middle. If they maintain GPS fix the launchpad location has sufficient GPS signal for a safe flight.

Magnetic Field Interference

Objects containing iron (such as buildings, cars, rebar, etc.) create their own magnetic field that can interfere with the drones' magnetometer performance.

Test: Perform a heading check with multiple drones in multiple different launchpad positions. If they all point correctly north, the location does not have significant magnetic field interference. Failure to complete a successful heading check is a no-fly situation.

Radio Signal Obstruction

Any external radio waves that occur on our operational band can interfere with the communication between the drones and the base station.

Test: Use a spectrum analyzer to verify that the designated operating band has no signals before the base station is turned on. After turning the base station on, check that there are signals in the expected band. More details on the Spectrum Check can be found in section 5.9.

2.7 Night Operation Requirements

In accordance with your waiver to the FAA part 107.29 regulation, one or more of the following collision mitigation measures must be used during night operations to achieve alternate means of compliance. It is the responsibility of the customer to check the below information against their own waiver to ensure the information is correct.

Compliant Show Design

Verge's advanced show planning software automatically detects if the sUA swarm will be visible for at least 3 statute miles at times during flight. The PIC must review the show rendering created by the flight planning software to verify that the sUA swarm has sufficient luminous output to always be visible for at least 3 statute miles.

Outer Boundary Illumination

If a show design is not compliant, the show planning software will automatically activate four or more sUA operating in the Ground Safety Zone having anti-collision lights visible for 3 statute miles with an effective flash rate of no less than 40 but no more than 100 cycles per minute.

Automatic Anti-Collision Light Application

Utilize either local ADS-B receiver hardware and/or an ADS-B service provider to receive real-time flight information of nearby aircraft. Based on the input received, the ground station will automatically transmit a signal to toggle the swarm's anti-collision lighting mode. This feature is independent of show design and can be triggered to override show lighting at any moment.

2.8 Visual Observers (VO's)

A team consisting of both a Pilot in Command (PIC) and a Visual Observer (VO) is required for every flight. One VO is required for every 250 drones. Prior to flight, VO's must be trained and certified in night vision tactics. The Verge VO certification test can be found on our Knowledge Base.

During flight, the VO must have direct communication with the PIC. This can be accomplished using handheld radios, cell phones, or any other method of direct vocal communication. The VO

must be able to trigger the swarm's anti-collision lights at any time – either remotely or via direct communication with the PIC.

2.9 Checking Airspace and Filing for Waivers

Use the Air Control or equivalent app to check the airspace classification in your operating area. If the airspace is class G simply file a NOTAM, contact the nearest FSDO per your waiver, and you're ready to fly. If the airspace is anything other than class G, you will have to obtain an additional waiver to fly in that airspace. This process is done through the FAA Drone Zone website. You will file for airspace authorization with a temporary waiver to part 107.41.

2.10 Filing a NOTAM

A NOTAM (Notice To Airmen) must be filed at least 24 hours before any flight, regardless if it's a test flight, or a commercial flight, and for all airspace classifications.

Gather the following information and call 1-877-487-6867. Tell them you are calling to file a NOTAM for UAS operations. After a successful filing, the NOTAM can be found on the FAA's NOTAM website under the specified airport.

Location	Latitude and Longitude coordinates in degrees, minutes, and seconds.
Altitude	Surface to maximum flight altitude (FAA maximum 400 feet).
Operation Radius	Flight radius in nautical miles, minimum 0.1 nautical miles.
Time/Date (UTC)	Flight time and date in Coordinated Universal Time (UTC). Give yourself some buffer on both sides of the planned flight.
Airport Distance	Where your flight zone is relative to the nearest airport. The NOTAM call agent will help you find the closest airport to file with.
Operator Initials	Phonetic alphabet initials of the Pilot In Command.
NOTAM ID	Will be provided at the end of the call.

Example NOTAM Info

Location (deg, min, sec)	33°32'31.1"N 82°07'50.7"W
Altitude	Surface to 400 feet

Operation Radius	.1 nautical miles
Time/Date (UTC)	2200 (5/14/2023) to 0200 (5/15/2023)
Airport Distance	15 miles NW of AGS (Augusta Regional)
Operator Initials	“Mike Hotel” for Mason Hayes
NOTAM ID	IRQ05-212

3. Generating .Vbake Files

To convert a .show file (design file) into a .vbake (flight-ready file) use the Verge Aero Portal. You will create a Flight authorization before gaining access to the file conversion process.

Create a Flight Authorization

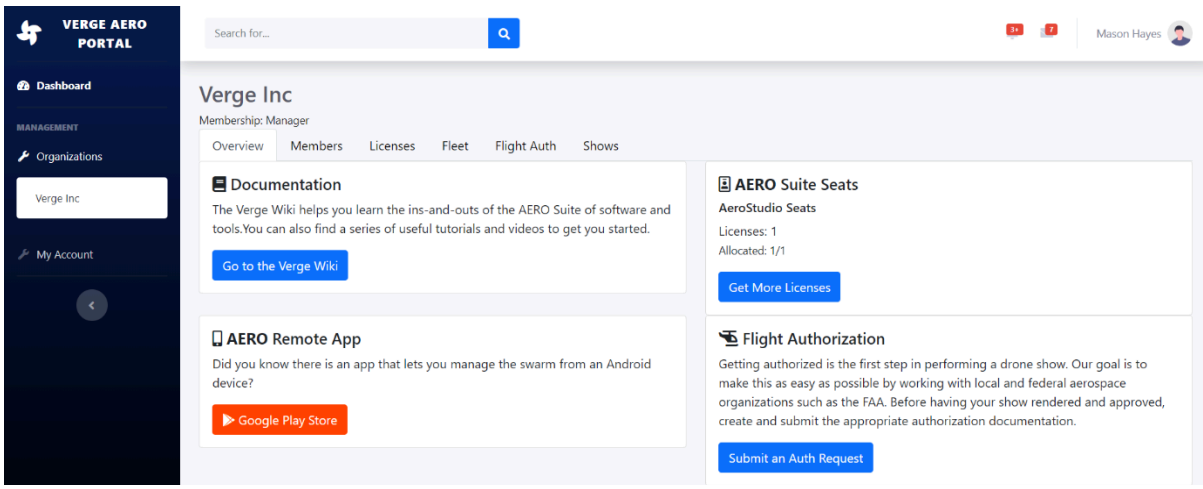
1. Visit www.droneshow.software/

2. Login

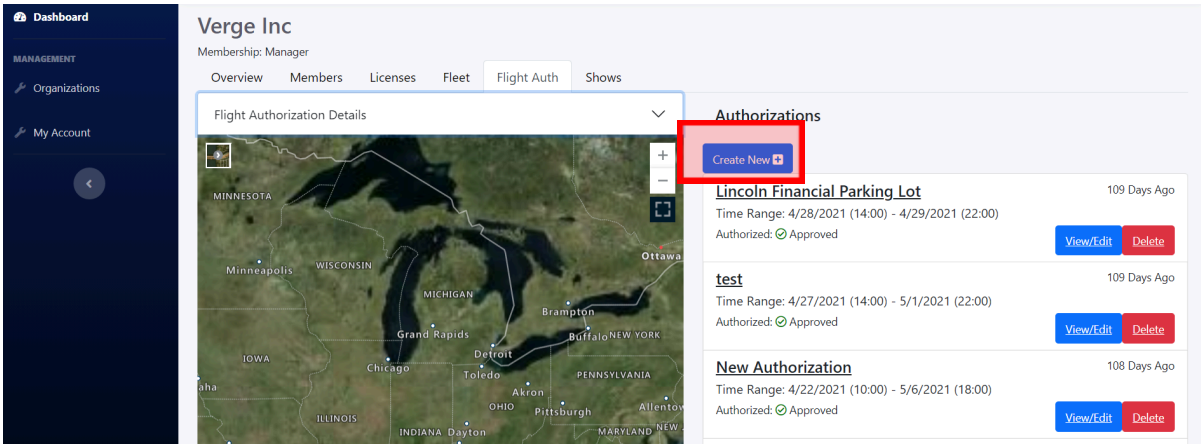
3. In the left column, navigate to *management* > *organizations* > **your organization name**

4. Selecting your organization will bring you to your organization's home page

5. Navigate to the “*Flight Auth*” tab



Verge Inc. homepage on the Verge Aero Portal.



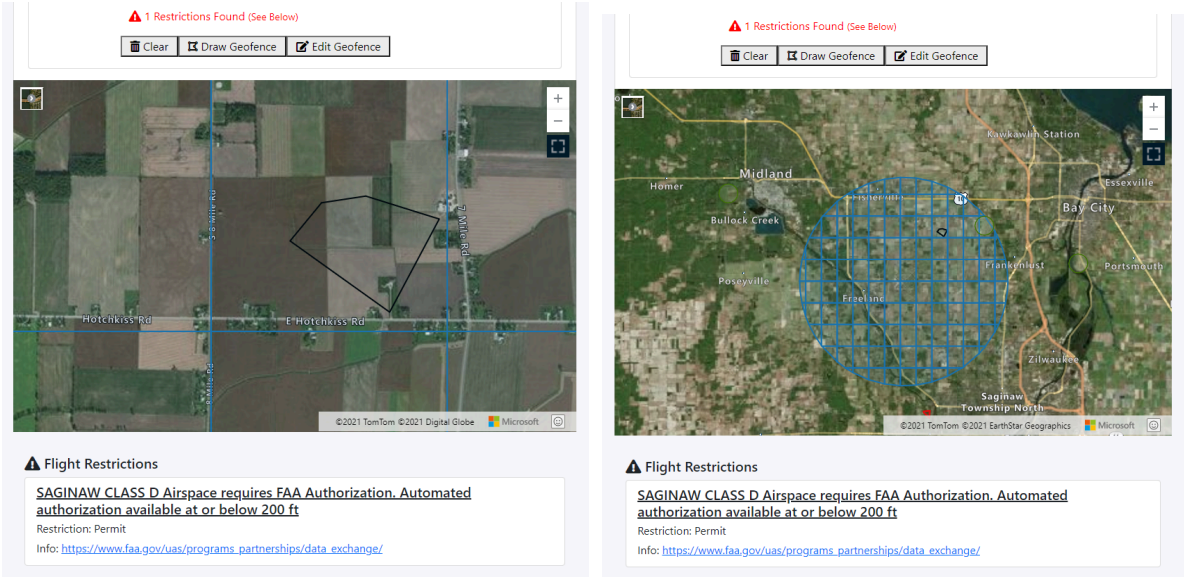
Flight Authorization tab with "Create New" button highlighted.

6. Select the "Create New" button next to the map to initiate a new flight authorization.

7. In the Flight Authorization Details dropdown, select *Draw Geofence* to overlay the proposed flight operations area onto the map (this includes both launchpad and show area), and provide the maximum altitude that occurs in the show. If the uploaded .show file exceeds the geofence in any capacity you will not be provided a Vbake file.

Note: double-clicking will close the geofence.

Controlled airspaces are designated on the map via colored grids. If your proposed flight location is within controlled airspace, a Restriction Warning will be issued with details provided below the map. The appropriate waiver will need to be uploaded before a Vbake file is provided.



Geofence located within restricted airspace. Restriction notice is provided above the map with details below.

8. Complete the *Parameters* tab within Flight Authorization Details. Give the authorization a name, designate whether it is a show location or a test location, and submit a time frame that you will fly the file during. Vbake files are time-sensitive and will not launch outside of the designated flight time under any specific flight authorization.

9. Submit the Flight Authorization. The authorization will appear in the right-hand column displaying its authorization status.

Preparing a .Show File for Cloud Conversion

Preview renders used for show design iteration are more lenient than production renders. To ensure the .Vbake received is as-designed, it is necessary to view the production render before uploading to the cloud. This is done within the studio as shown below.

Note: If the production render is not checked, it is likely the .Vbake file received will vary from the design observed in preview renders. This will cause unnecessary iterations of the file conversion process.

1. In the studio toolbar select *Render* > *Render Show* to open the Render Log window.

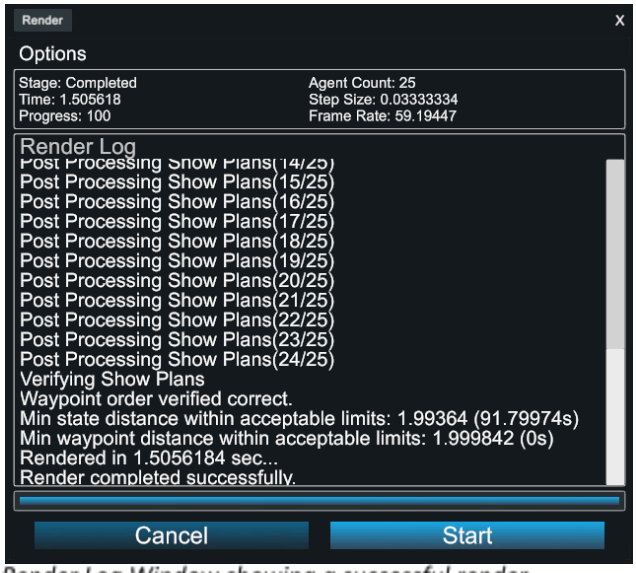
2. In the top left of the Render Log window select *Options* to open the Render Options window.

3. In Render Options set the Render Quality to Production. Close the Render Options.

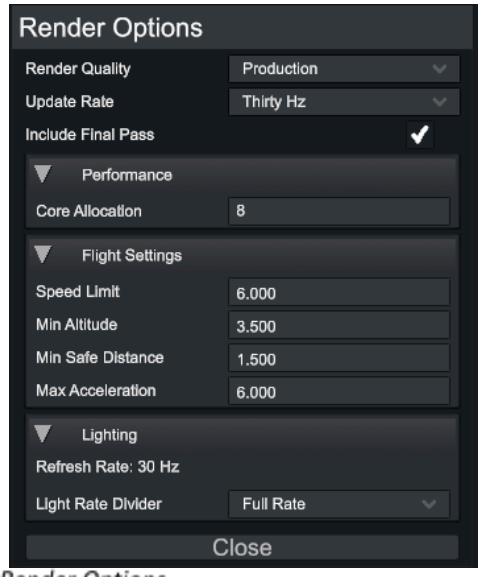
4. Select *Start* in the Render Log window and wait for the render to complete. If the render is successful, the final line will read “Render completed successfully”.

5. Watch the production render in real time to verify the show looks as desired.

6. Export the file as a packed show.



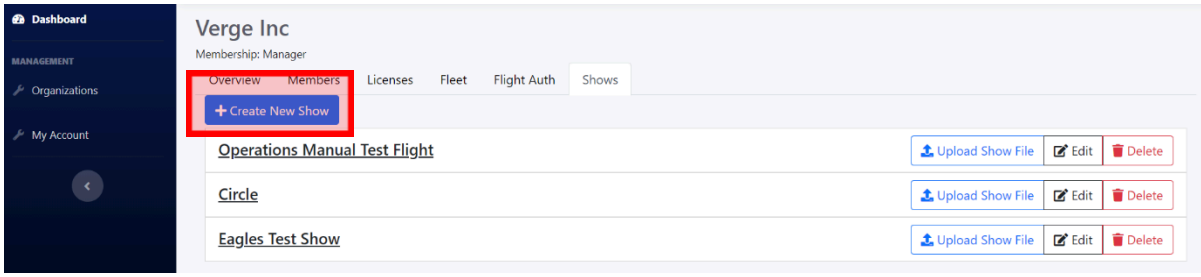
Render Log Window showing a successful render.



Render Options

Generate a .Vbake File

1. Once the flight authorization is approved, navigate to the *Shows* tab and select *Create New Show* to create a new show category.



Shows tab with "Create New Show" button highlighted.

2. Use the *Upload Show File* button to upload a packed show for conversion and click *Submit*. The render will be queued, then a status bar will display the progress of the render. Once the render is complete you will have the option to download the originally uploaded packed show, the render log, and the Vbake file.

Viewing Vbake Results

IMPORTANT: After downloading the Vbake, open the file in the designer to view the final result. Often the Vbake render is slightly different from the designer preview renders. Look over the show

carefully to ensure it is the exact flight paths you intended. The flight paths shown in the Vbake viewer are the exact paths that the drones will fly during that show.

To view a Vbake in the designer follow the steps below.

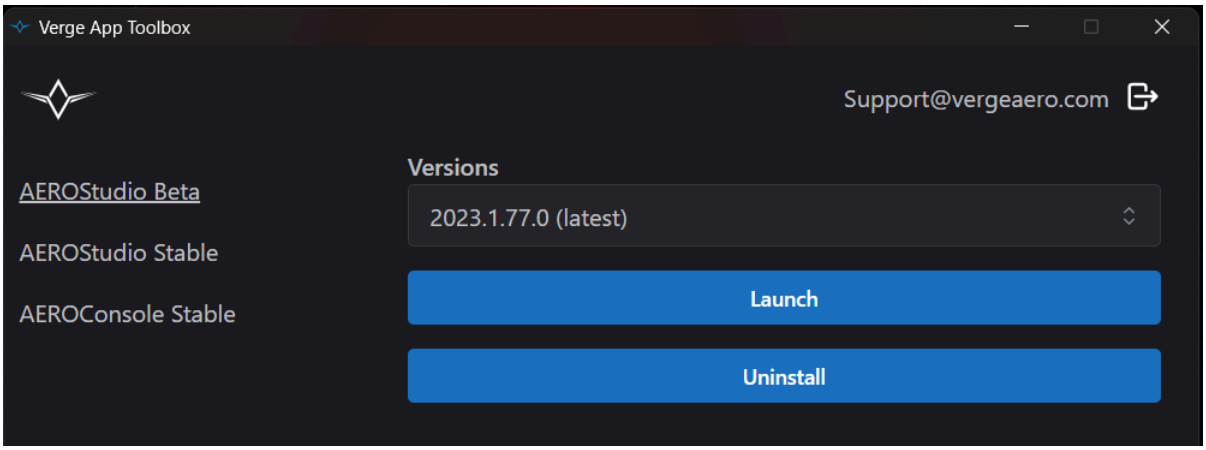
1. Open the associated .Show file in the designer.

2. In the toolbar select *Import* > *Vbake* and select the desired Vbake file.

3. In the hierarchy an object titled "Render Viewer Node" will appear, allowing the rendered Vbake to be viewed in the designer.

4. Verge App Toolbox

The Verge App Toolbox is the launcher that contains the Design Studio and Console applications. If you do not have access to the application you need, please email support@vergeaero.com to gain the proper access.



Launcher Window with the Design Studio and Console applications.

Computer Specifications

Laptops must have an ethernet port to run the system. To ensure seamless communication throughout the system configure the ethernet ports.

Specs	Minimum Windows	Minimum Mac
Operating System	Windows 11 64 Bit	M2 Pro
Memory	16 GB RAM	
Graphics	RTX 3050 or equivalent	
Processor	Intel® Core™ i7 10th Gen / AMD® Ryzen™ 7 3000 series or better	
Storage	2 GB available space	2 GB available space
Ports	Ethernet Required	Ethernet Required

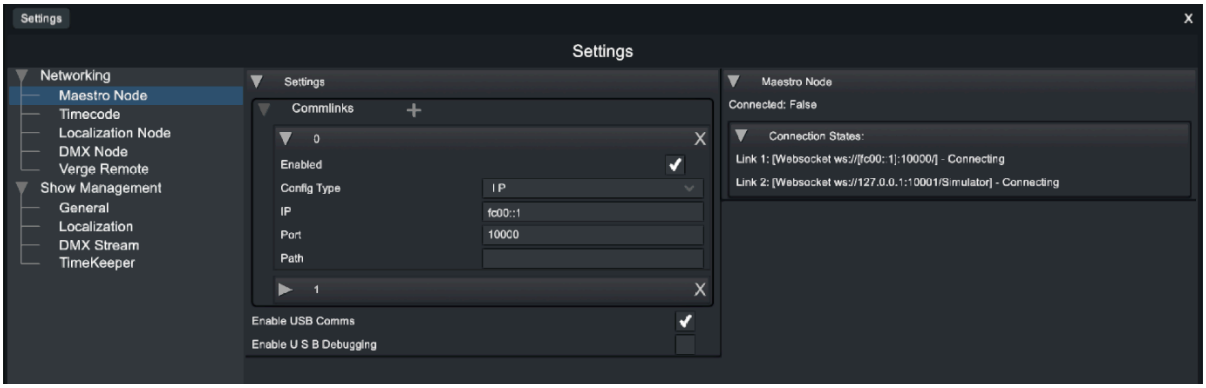
4.1 Console Settings Configuration

IP Address

If the IP address is incorrect the Maestro server will not be active and no devices will connect to the Console. Correct IP settings are found below.

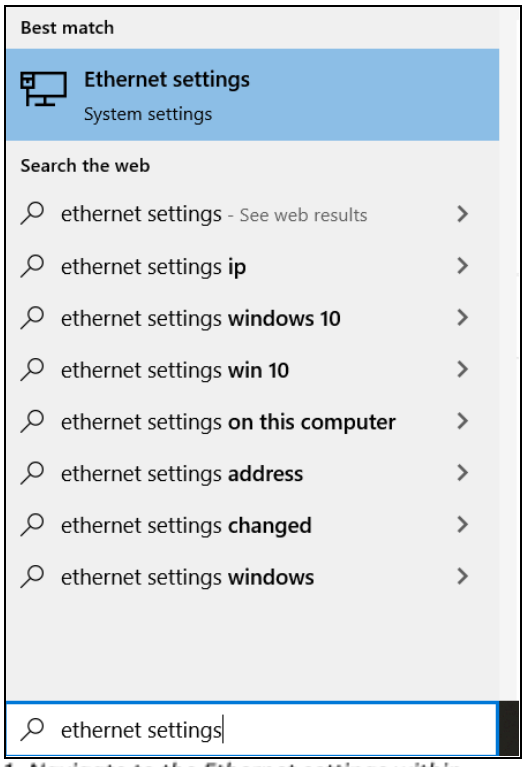
In the toolbar select *Edit* > *Settings* to bring up the settings window. Navigate to *Networking* > *Maestro Node.* Create a connection with the following settings:

Config Type: IP
IP: fc00::1
Port: 10000

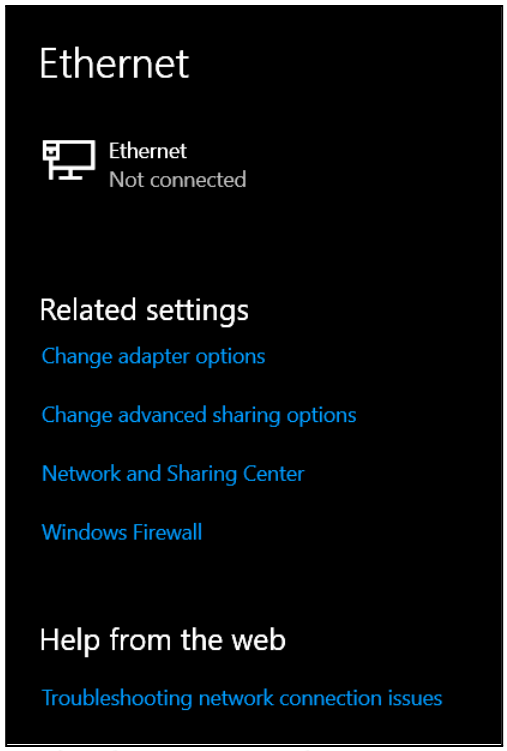


4.2 Ethernet Configuration

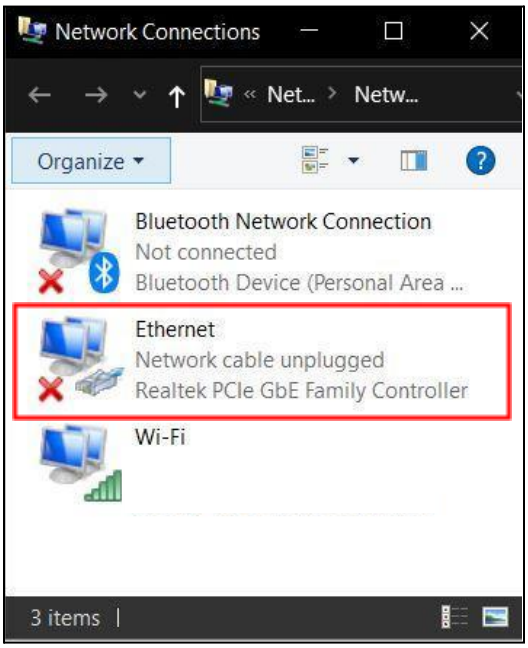
All ethernet connections besides IPv6 need to be disabled. Follow the step-by-step instructions below.



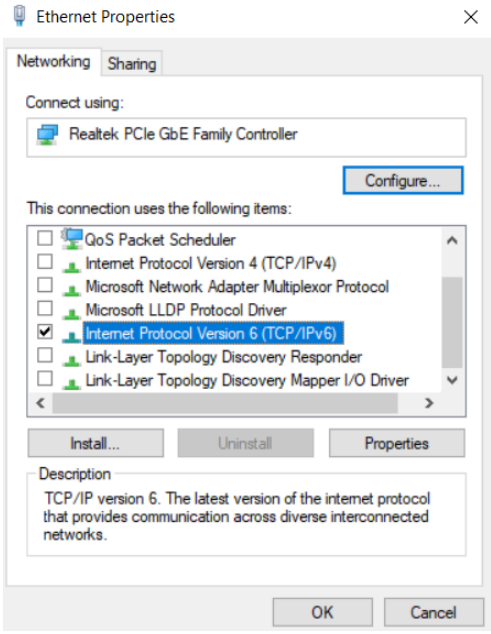
1. Navigate to the Ethernet settings within the System settings.



2. In the Ethernet settings select "Change adapter options".



3. Select "Ethernet" from the Network Connections list.

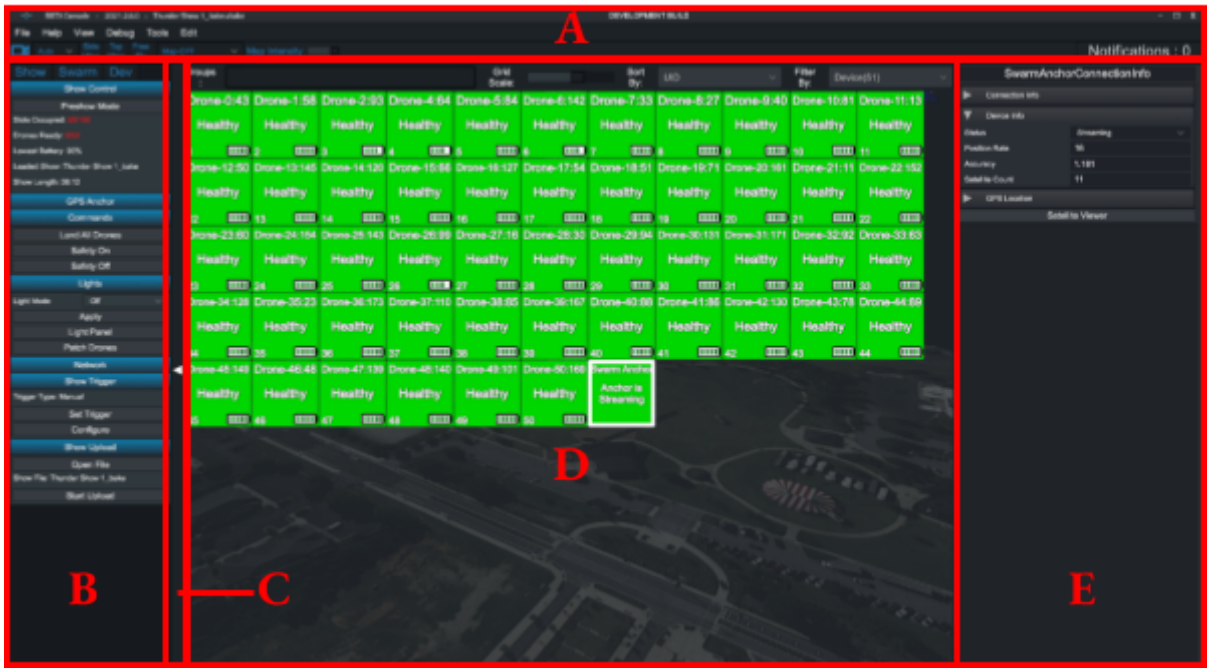


4. Uncheck every connection except "Internet Protocol Version 6" (IPv6).

4.3 Console Overview

The Console is the interface between the Pilot in Command and the hardware. The Console provides all information about the system and individual drone health, allows the PIC to send

commands to the drones (such as lighting, show uploads, calibrations), and launches the show. The Viewing Window can be toggled between Device View and Environment View, allowing the PIC to view either detailed health information or specific GPS locations of the drones and Launchpad.

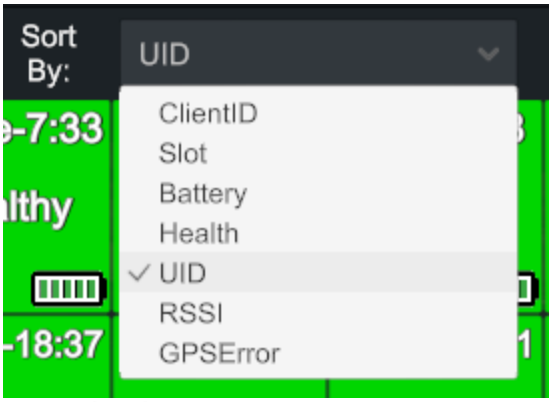


Console standard layout in Device View.

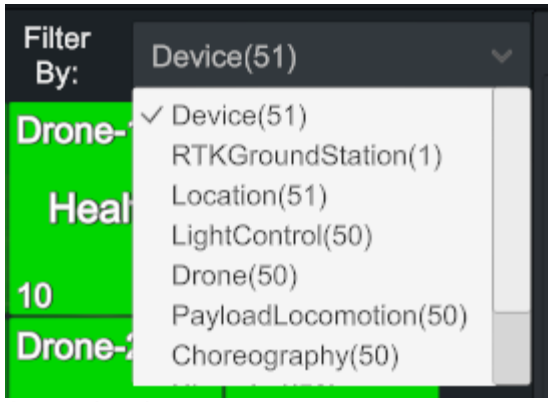
Section	
A – Toolbar	Standard Toolbar.
B – Command Panel	Contains all swarm-level command options. This includes show upload, lights, land-all, show launch, etc.
C – Toggle View Button	Switches between Device View and Environment View.
D – Viewing Window	Device View displays devices based on filter and organized by sort. Environment View displays the launchpad slots and active drone locations over their specific GPS locations.
E - Inspector	Displays all detailed information for a selected device.

Filter and Sort Devices

To help visualize the overall state of the system, connected devices can be filtered and sorted. Filtering changes what types of devices are displayed. Sorting organizes these devices based on the selected method.



Sort By dropdown menu

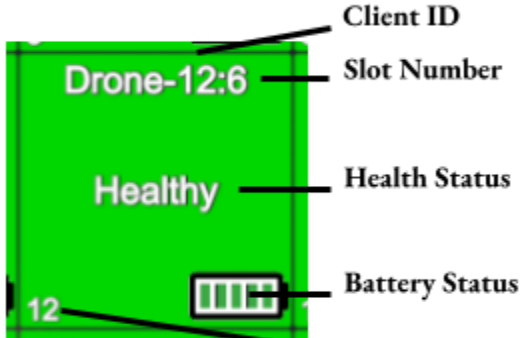


Filter By dropdown menu

SORT BY	
Client ID	Client ID is assigned on a first-come, first-serve basis as devices connect to the Console. The first drone connected will have a client ID of 1. Sorted lowest to highest.
Slot	Launchpad slots are numbered sequentially, beginning with 0. Drones that are slotted will display their specific slot number. Sorted lowest to highest, followed by drones without slots.
Battery	Sorted from lowest battery to highest battery.
Health	Sorted from unhealthy to healthy.
UID	Each drone has a unique ID number listed on the bottom cover next to the light. Sorted from lowest to highest.
GPS Error	Sorted from lowest GPS error to highest GPS error.
FILTER BY	
Device	Displays all devices connected to the Console (individual drones, RTK anchor, emergency box, etc).
Drone	Displays all drones connected to the Console.

4.4 Individual Drone Devices

Reading a Drone Device



The Drone device box displays specific identification and health information, as shown in the figure to the right. Selecting a drone device will display all the drone's information in the Inspector. Relevant Inspector fields are outlined below.

Last Packet Time: Displays time since the Hub has communicated with the drone. If the last packet time exceeds 60 seconds, the drone requires a power cycle.

Safety Switch: Displays the current status of the drone's safety switch. When the safety switch is enabled, the drone will not launch.

RSSI: "Receive Signal Strength Indicator" measures Telemetry communication signal strength. The smaller the value, the stronger the signal. -10 through -80 is a good signal.

Battery: Displays current battery percentage.

Errors: Displays a drone's relevant errors.

Hivemind & Autopilot Fw: These are the hash codes for the firmware that is currently loaded onto the drones.

Unique Identifier: Displays drone UID.

Slot: Displays launchpad slot number.

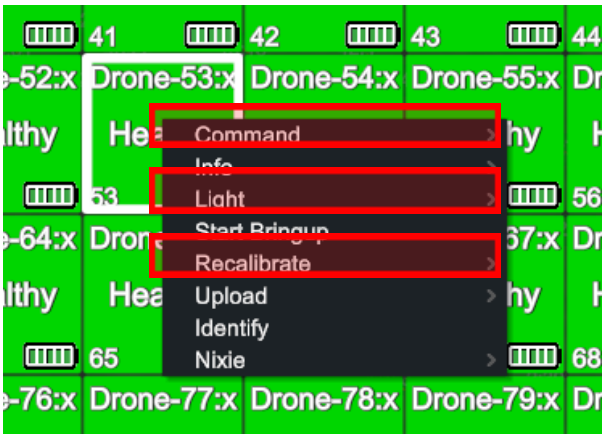
GPS Error: Displays the uncertainty of the drone's GPS location. Drones must have a GPS error below 0.04m (4cm) for safe flight. Once this threshold is reached, the Fix Type will switch from GPS Float to GPS Fix.

Relevant Drone Device Inspector Properties

Commands

To send commands to a singular drone, select its device box in the viewing window. Selected drones will have a white outline, as shown below. To bring up the commands window right-click on any drone. Multiple drones can be selected by holding ctrl and clicking on multiple devices.

The only three menu commands required during show operations are Command, Light, and Recalibrate. For detailed recalibration info, see Recalibrations.



Selected drone shown with white outline, including command box brought up with a right-click.

COMMAND	
Reboot Autopilot	Resets flight controller. Required after every recalibration.
Reboot Hivemind	Resets drone(s) to initial power-on state. Analogous to a physical power cycle. Rarely used.
Safety Switch On	Turns the safety switch on for the selected drone(s).
Safety Switch Off	Turns the safety switch off for the selected drone(s).
LIGHT	
Off	Turns light off for the selected drone(s).
Set Color	Allows a specific color to be set for the specific drone(s).
RECALIBRATE	
Level	Triggers level calibration.
Compass	Triggers compass calibration.
Gyroscope	Triggers gyroscope calibration.
Accelerometer	Triggers accelerometer calibration.

4.5 Light Modes

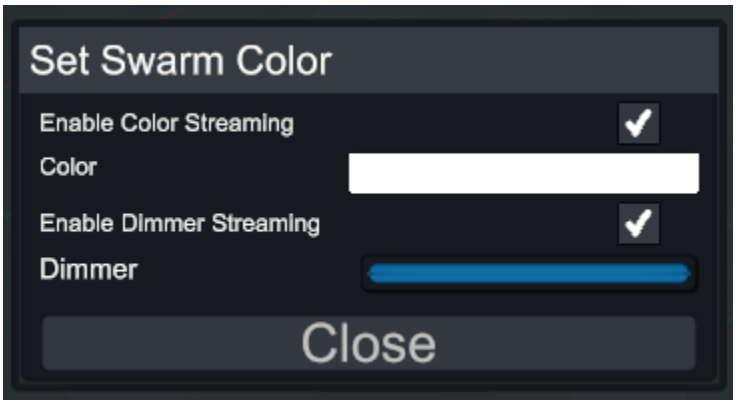
To apply different light modes to all online drones, select the desired mode from the Light Mode dropdown and click *Apply*.

Light Mode	
Off	Turns lights off.

Proximity	Lights turn green when they're in the GPS location of a launchpad slot. The further they are from a slot, the more red the light becomes. Note anytime you move a drone its GPS accuracy decreases, so be careful about trusting this method to be the only way you determine the launchpad.
Status	Lights will turn on to match the status of the drones in the viewing window.
RTCM	Lights will flash green and white indicating they are receiving GPS correction data from the RTK. Any drone that is not receiving correction data will flash red.
Heading Check	Lights will turn green when the drones are facing North. Any other direction and the lights will be red.
Time Sync	Drones will flash through all colors (RGBW) at the same time to verify that all drones are time-synchronized.

Light Panel

Check "Enable Color Streaming" to assign the designated Swarm color to all drones. Check "Enable Dimmer Streaming" to dim the light intensity. The dimmer option can be used to help preserve battery life during on-ground testing.

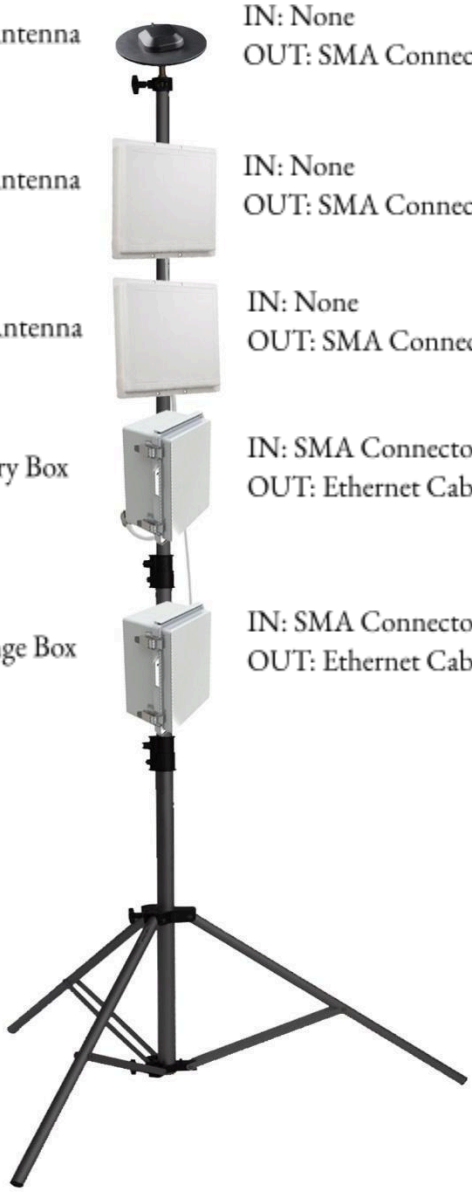


Light Panel with options to set color and brightness.

5. On-Site Operations

5.1 Tripod Layout

Connections



RTK Antenna
IN: None
OUT: SMA Connector to RTK Interface

Telemetry Antenna
IN: None
OUT: SMA Connector to Telemetry Box

Long Range Antenna
IN: None
OUT: SMA Connector to Long Range Box

Telemetry Box
IN: SMA Connector from Telemetry Antenna
OUT: Ethernet Cable to Base Station Box

Long Range Box
IN: SMA Connector from Long Range Antenna
OUT: Ethernet Cable to Base Station Box

Telemetry (AT86) Gateway

Long Range (LoRa) Gateway

SMA Connector from Patch Antenna 1

Ethernet Cable to Base Station Box

SMA Connector from Patch Antenna 2

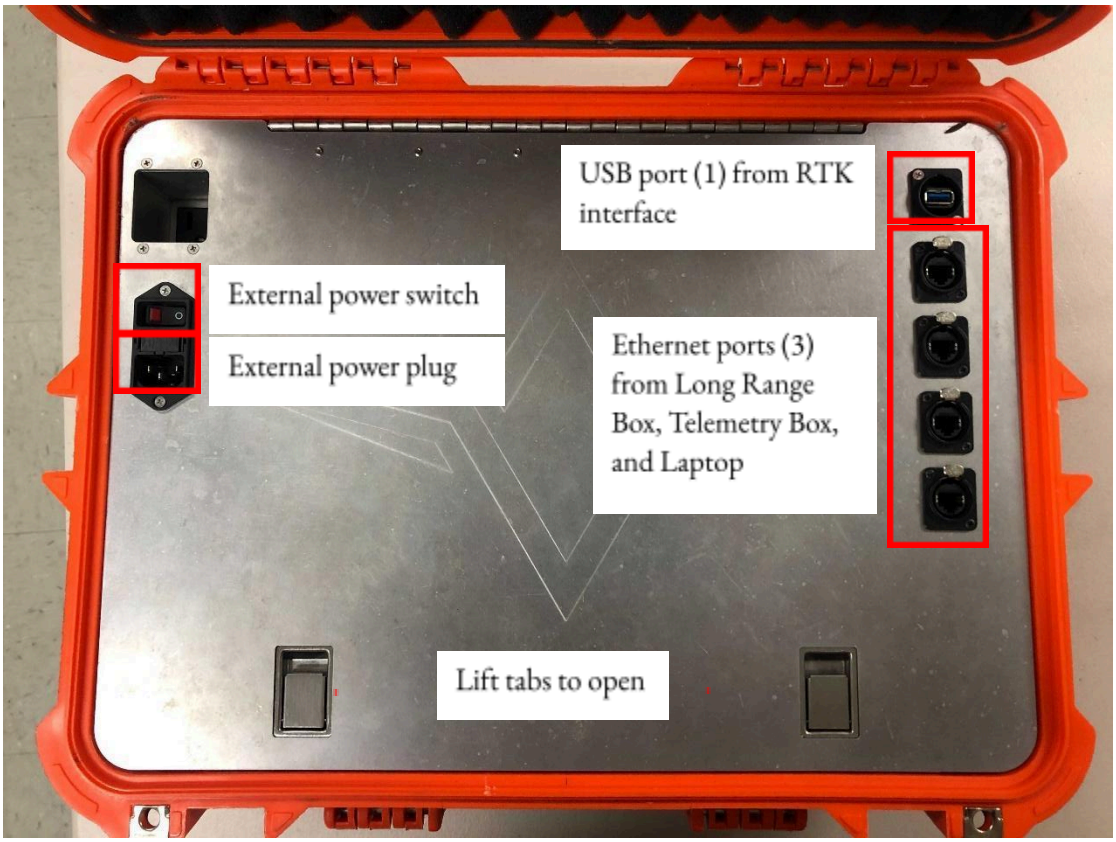
Ethernet Cable to Base Station Box

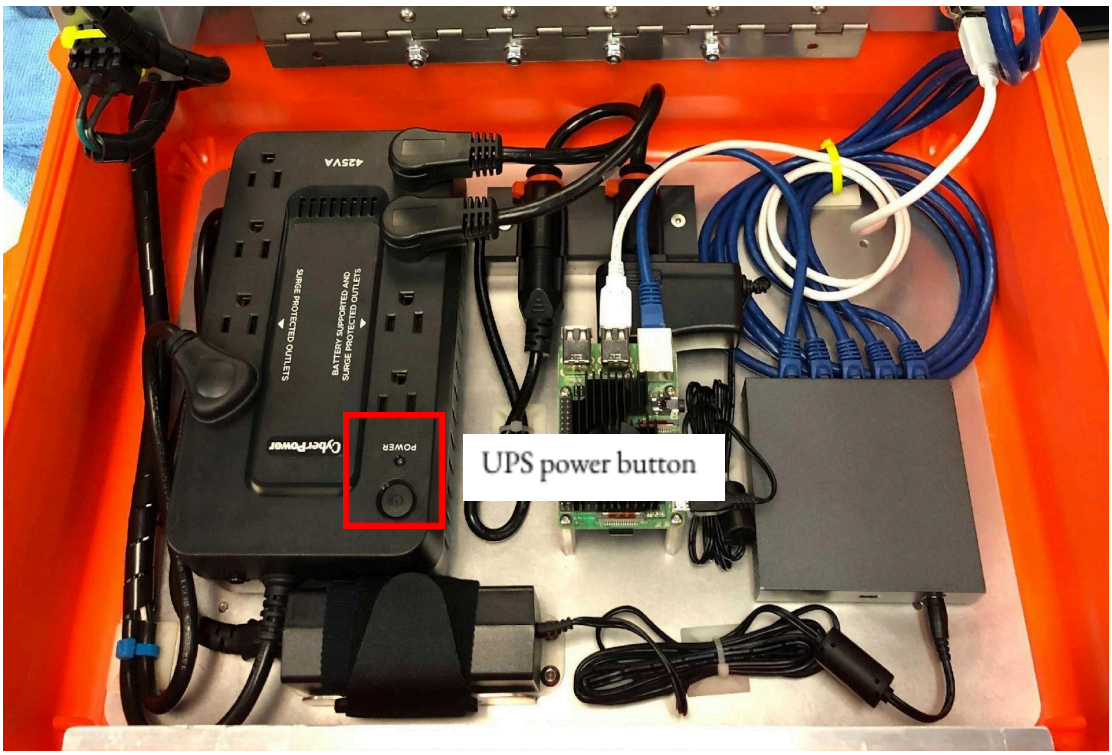
RTK Interface Unit

IMPORTANT:
The RTK interface unit CANNOT get wet. If water penetrates any of these connections the drones can lose GPS signal.

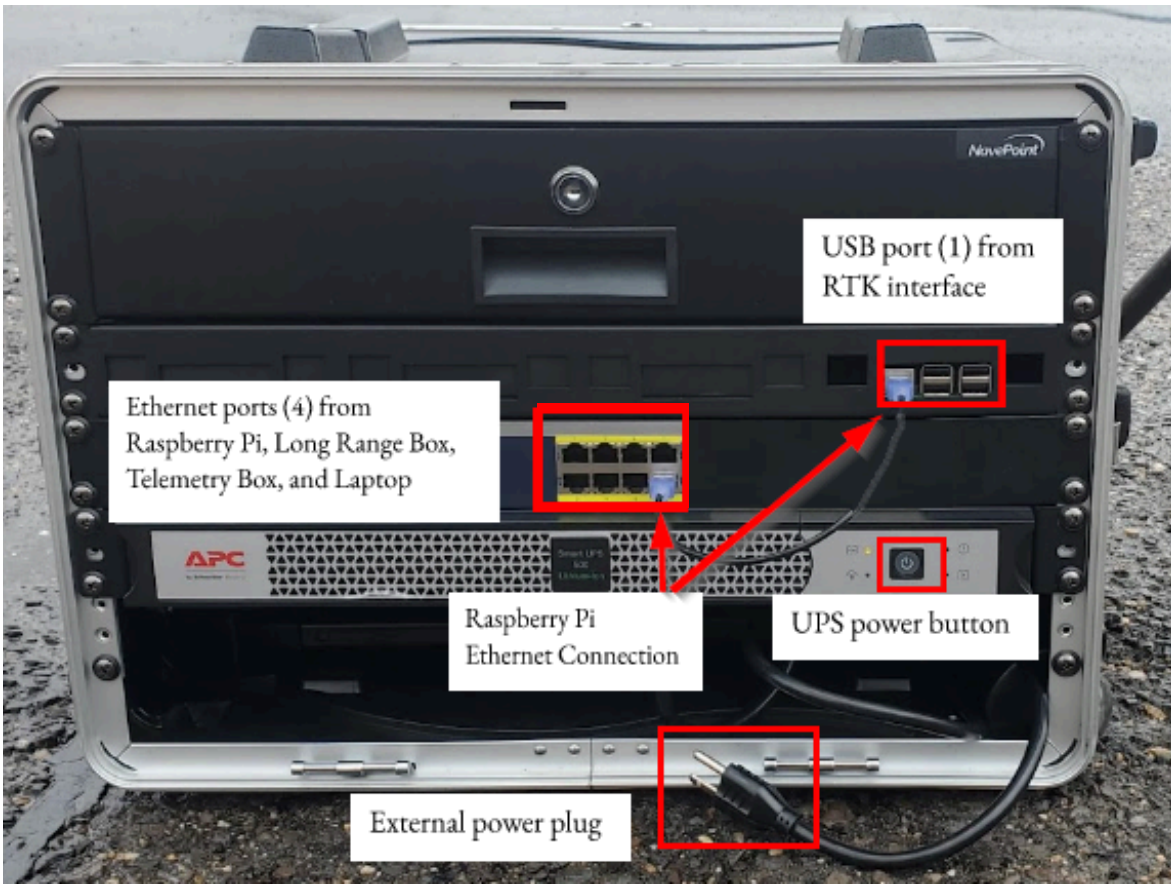
IMPORTANT:
The interface unit should be secured to some surface to minimize movement and possibility of broken connections.

5.2 Orange Base Station Layout





5.3 Black Base Station Layout



5.4 Ground Power

The base station is designed to operate using standard 60Hz 120VAC power in North American. A voltage converter is required when operating in the EU to convert 240VAC to 120VAC, or changing the UPS to an EU approved UPS is needed. Operating outside of this specification can cause interference with GPS signal. GPS units are sensitive to signal variation, and therefore it is critical the base station has a clean, grounded, power input.

The base station box utilizes an uninterruptable power supply (UPS) to act as a battery backup and signal neutralizer. When the battery is fully charged this power supply can run without external power for **up to** an hour. This should only be relied on in emergency situations. When the UPS is not receiving external power, audible warning beeps will occur every few minutes. If the UPS battery is low the warning beeps will be more rapid, occurring once every second. It is not safe to fly if you are observing the low-battery warning beeps. If the UPS on the base station dies, this means the drones are not receiving GPS correction data and will deviate from their prescribed flight paths causing potential for catastrophic failure.

If a generator is necessary to provide external power Verge recommends using an inverter generator to provide the cleanest signal.

Turning On the Base Station

Use lift tabs to open the tray. Press and hold the UPS power button to turn on. When the indicator light is green the UPS is on. Once the UPS is powered, the base station box is on.

Connect ground power via the external power plug and flip the external power switch. Ground power is connected if the orange light on the switch is illuminated.

Note: If the light on the external power switch is on *and* the UPS warning beeps are occurring the UPS is not being supplied sufficient/clean power and is not charging.

5.5 Launching The Console

Load Vbake

When the Console is opened the first step is to load the .vbake file for the show you will be flying. Select *Ok* and navigate to the .vbake in your local files.

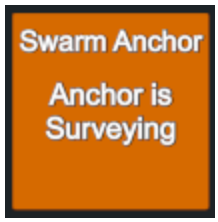
Load .vbake window. Appears when Hub is launched.

Ensure RTK is Streaming

When the Console first launches, the RTK antenna needs time to triangulate its local position. During this time the Swarm Anchor is Surveying (A). The survey needs to reach two thresholds to begin streaming. First, the survey requires a minimum of 5 minutes. Second, the accuracy must reach below 2m. If 5 minutes pass and the accuracy is still above 2m, the survey will continue. Once the Accuracy is both below 2.0 and 5 minutes have passed, then the Swarm Anchor will begin Streaming (B). Moving the RTK or tripod will require a new survey. **Do NOT move the tripod that the RTK is attached to while a show is running.**

Accuracy	Survey Quality
1.900 - 2.000	Poor
1.650 – 1.890	Acceptable
1.450 – 1.640	Good
Below 1.450	Excellent

RTK Survey Quality Index.

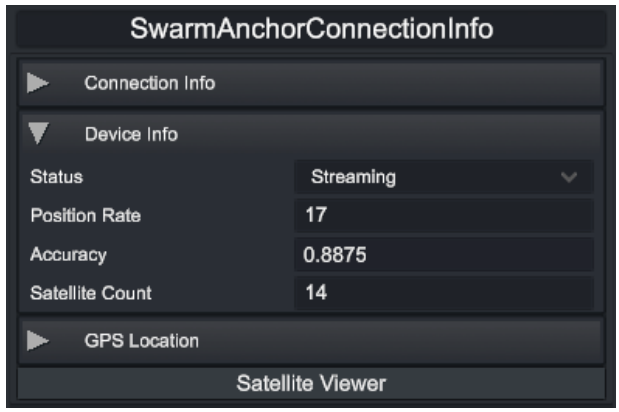


Anchor Surveying (A)

Anchor Streaming (B)

Reading RTK Device Inspector

With the Swarm Anchor device selected, detailed RTK connection information will be displayed in the Inspector. This is where you will find the streaming status, accuracy, and satellite count. To see the specific satellites you are connected to select *Satellite Viewer*.



5.6 Launchpad Layout

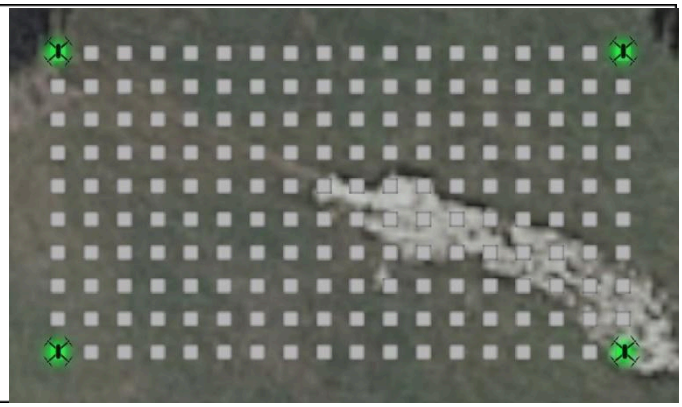
Recommended Launchpad (Standard Grid)

The standard launchpad is a grid with constant spacing. The Verge team uses 4 feet (1.2192 m) when doing a tray take-off or 3.28 feet (1.0001 m) when using staggered take-off. See the steps below to create a standard launchpad.

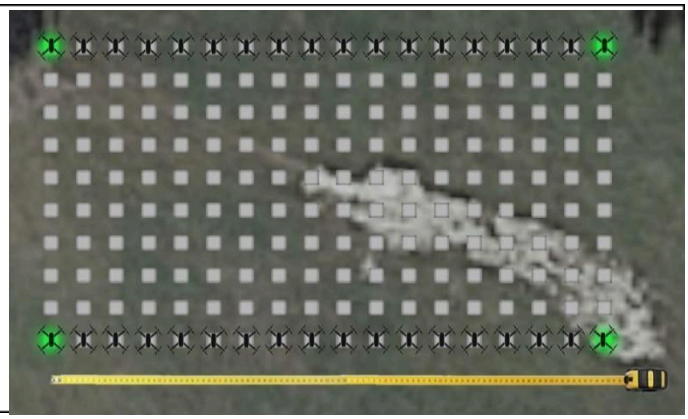
1. Power on 4 drones. Provide time for GPS error to settle.

2. Use proximity light mode to place a drone in each corner of the grid.

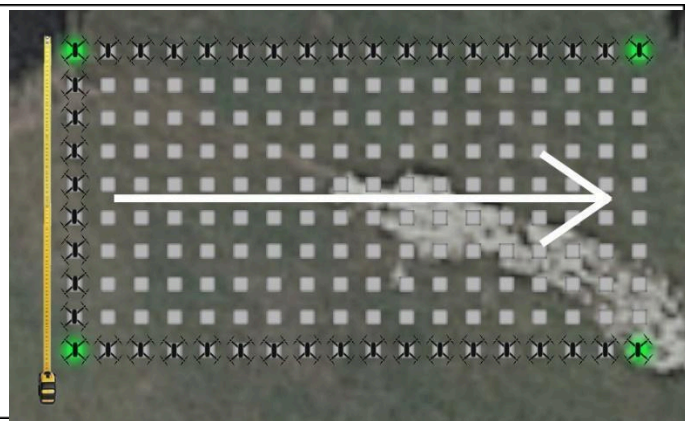
3. Adjust the drones' locations until they're perfectly in the corner slots.



4. Use a tape measure to lay out drones along two parallel sides of the grid. Filling the long edge first is recommended.



5. Once both rows have been placed, work row by row across the grid to fill the launchpad.



Alternative Launchpad Layout Methods

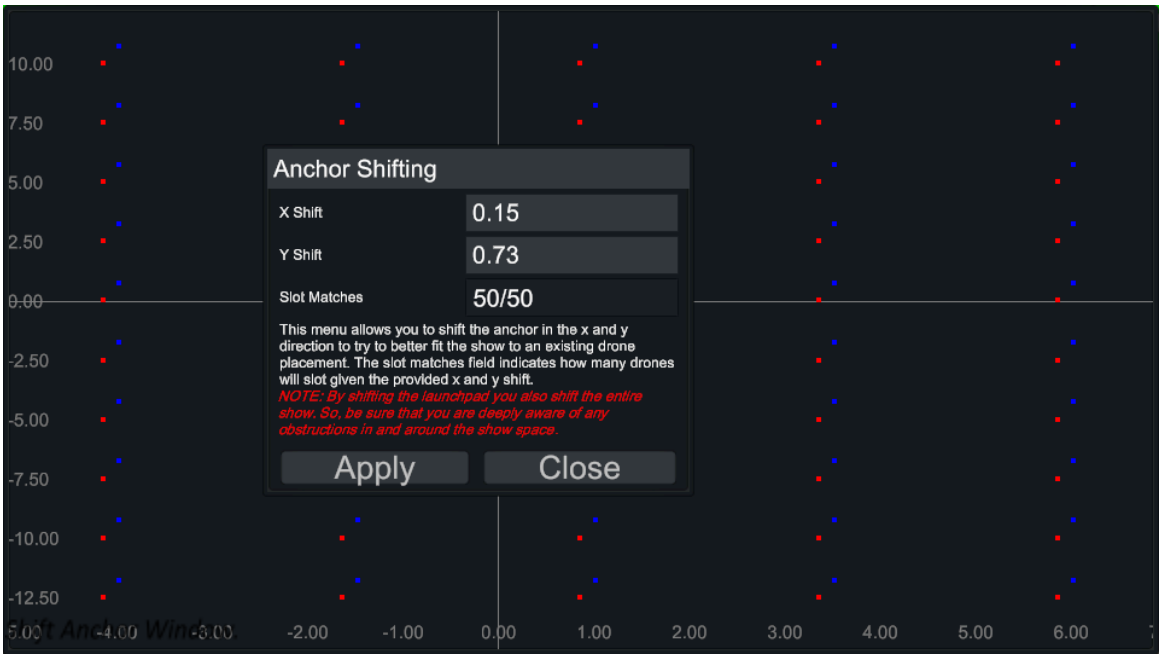
1. Plug in all drones and use proximity mode to place them in slots. Note that anytime a drone is picked up and moved its GPS error will increase. It is best to get a drone close to a slot and then come back and make minor adjustments later if necessary.

2. Layout and mark the grid the day before the show, or with spare batteries.

Fit Anchor

The GPS location of the launchpad can be shifted in the X and Y axes (latitudinally and longitudinally). This shift is caused by the RTK accuracy. **Caution: Shifting the Launchpad shifts the entire Flight Operations Area, be aware of your environment.**

To shift the anchor navigate to the GPS Anchor module of the Command Panel and select the *Fit Anchor* button. The red dots are the launchpad slot locations and the blue dots are drone locations.



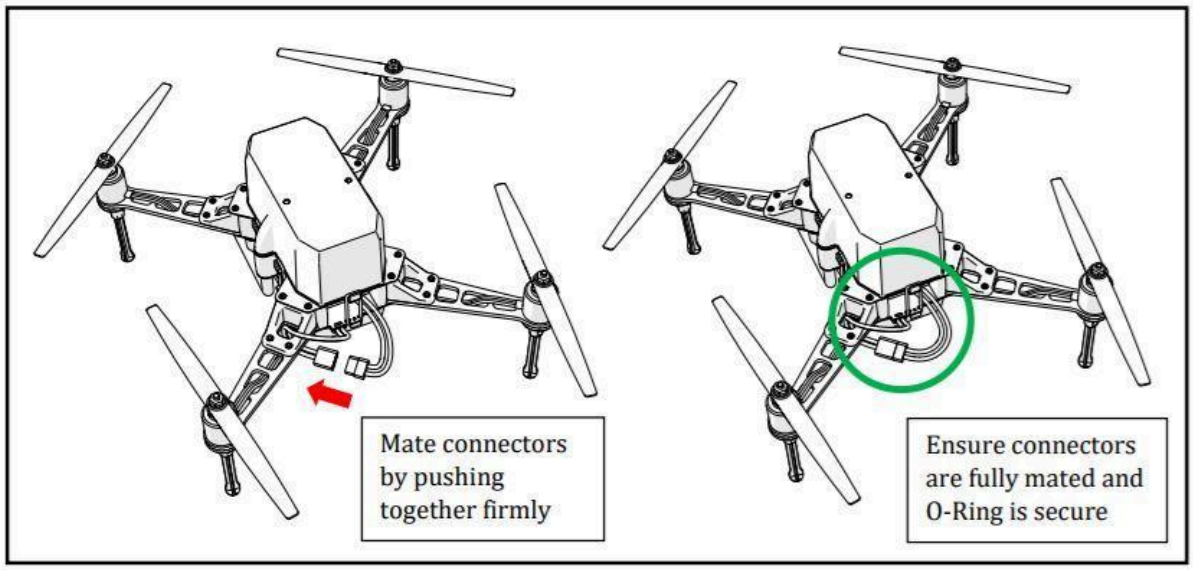
5.7 Turn on Drones

Seat Battery

Ensure the battery is fully seated in the drone before powering on. The battery lever will be in the unlocked position (pointing left) when inserting into the drone. Once the battery is pushed all the way in, turn the lever to the right to lock the battery in place. You will hear a click when the battery is locked in place.

Plug In All Drones

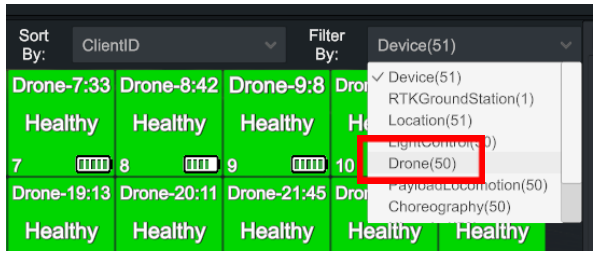
When plugging in X1s, ensure the cable loops through the arm and the connectors are fully mated. If the cable is not through the arm it can get hit by the propellor.



For X7, push and hold the power button for two seconds to turn on the drone. You will hear a start up jingle, as well as see the power button light turn on.

Check Number of Drones Online

When flying a show, you will know exactly how many drones you plan to power on. This includes both show drones and sideline drones. Open the "Filter By:" dropdown to see the number of drones online in parentheses.



Online drone count shown in Filter dropdown menu.

Identify Offline Drones

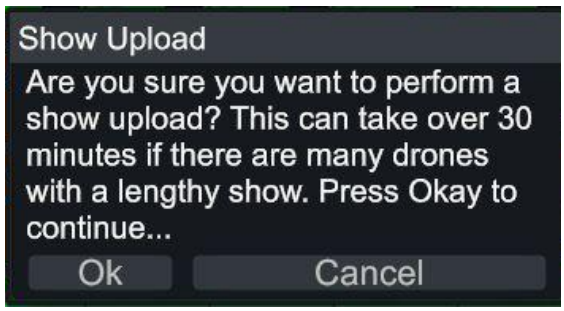
To quickly identify any drones that got missed during the plug-in process, turn the lights on for the entire group. Drones that do not light up either need to be plugged-in or power-cycled.

5.8 Show Upload

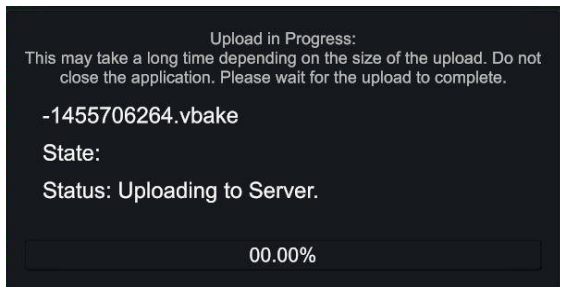
Note: It is strongly recommended to upload the show prior to arriving on site.

Start Upload

When all drones are online and ready for the show upload select the "Start Upload" button at the bottom of the Command Panel. When the show upload is in progress no other commands can be sent to the drones until it is finished. For this reason, you will be asked to confirm the show upload before it begins. Ensure all lights are turned off on the drones prior to loading the show to help conserve battery life.



Show Upload confirmation window.



Show Upload Progress Window.

The time required for a show upload depends on the length of show, number of drones, and distance from the Telemetry Antenna. Increasing any of these factors will increase the time it takes for the upload to complete. The show upload is a two-step process. The drones receive a compressed file, then each drone unpacks their file. The upload progress window will disappear after the compressed files have been received. Change lights to Status Mode to see the unpacking process. Drones blinking white are unpacking the show.

Reupload to Missed Drones

If there are drones that do not successfully receive the show, move them closer to the Telemetry antenna and reupload. Use ctrl+click to select multiple devices in the Hub and right-click on one of the selected devices. In the resulting menu select *Upload* > *Show.*

Switching Between Shows

Using the "Open Show" button at the bottom of the Command Panel allows you to change the show that is loaded in the Console. Drones store all show files, even if they are power-cycled.

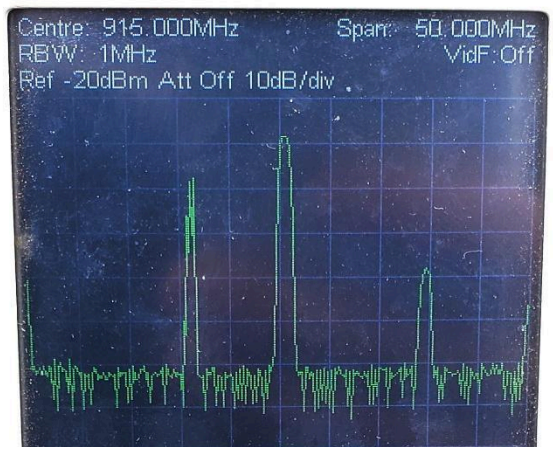
5.9 Health Checks

Spectrum Check

Having a clean spectrum for operation and communication to the drones is essential to efficient setup and successful performances. There are two radio signals that broadcast between the base station and the drones. If there is excessive noise on the spectrum communication between the drones and base station can be interrupted. This can cause slow show uploads, longer wait times for drones to reach fix, and interruption in RTCM signal.

The Long Range radio broadcasts at 915 MHz

The Telemetry radio broadcasts at 906.8 MHz



Spectrum centered at 915MHz with a span of 50MHz showing the Telemetry spike (A), Long Range spike (B), and unknown spike (C) with acceptable noise floor.

The radios support 868 MHZ and 2.4Ghz for countries that do not allow frequencies in the 900 MHz range.

The figure to the right exhibits a spectrum with Telemetry frequency (Spike A), Long Range frequency (Spike B), and an unknown frequency (Spike C).

To perform a spectrum check use a spectrum analyzer centered at 915MHz with a span of 50MHz and ensure the Long Range and Telemetry spikes are distinct and significantly above the noise floor. Watch the Video for more information on spectrum checks.

Heading Check

A heading check is required on-site before every show. If this check is not performed, drones launched with significant heading error will auto-land immediately after takeoff.

To perform a heading check set the light mode to *Heading Check* in the Lights section of the Command Panel. When activated drones facing directly north will turn green, in any other direction they will be red. Orient all drones until their lights are green. Once all lights are green, check for any drones that are greater than 20° from north. These drones require magnetometer recalibrations.

Sensor Errors and Recalibrations

The health status of each drone will be displayed on its associated Console device in the viewing window. Below is a list of possible errors and their solution. For detailed instructions on all calibrations please see Recalibrations.

After every recalibration autopilot must be rebooted for changes to take effect. To do this right-click on a drone device and select "Command>Reboot>Autopilot".

ERROR	SOLUTION
EKF Inconsistent	Wait until GPS fix. If drone reaches fix, reboot autopilot. If reboot does not fix, power cycle. If power cycle does not work, recalibrate accelerometer and gyroscope.
IMU Inconsistent	Recalibrate accelerometer. Recalibrate gyro.
Baro Failure	Power cycle.
Power Failure	Swap battery.
Mag Failure	Recalibrate compass.
Accel Failure	Recalibrate accelerometer.

Gyro Failure	Recalibrate gyroscope.
GPS is Invalid	This will occur right after powering on. Wait. Check if GPS is coming in. Wait. Power cycle.
Position is Invalid	Same as GPS invalid.
Connection Timeout	If longer than 60 seconds power cycle.
No Autopilot Heartbeats	Power cycle.
Low Battery	Swap battery.
RTCM Lost	Unplug and re-plug Telemetry Box ethernet cable.

Hover Test

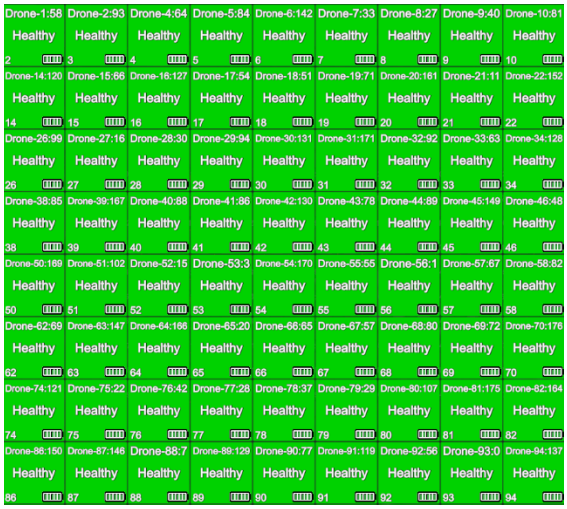
The hover test is a brief show for the entire launchpad that occurs in staggered groups. Drones will launch to 2m, hover for a few seconds, and return to the ground. This test is used as a final visual check on the health of the drones. The PIC should be looking for any drones that don't launch, exhibit toiletbowling behavior, or have significant altitude variation. A successful hover test verifies that each drone in the launchpad is healthy for takeoff.

The Hover Test is a separate show file from the full performance show file. Hover Test files and Show files must be created and uploaded to the drones separately.

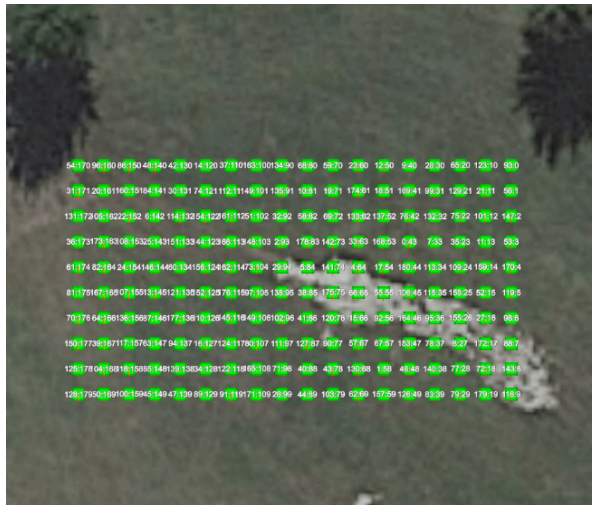
5.10 Final Pre-Flight Checks

Check Slots

Once the launchpad slots are full of healthy drones there are a few final checks. A full healthy launchpad and viewing window are shown below.



A) Fleet of healthy drone devices.

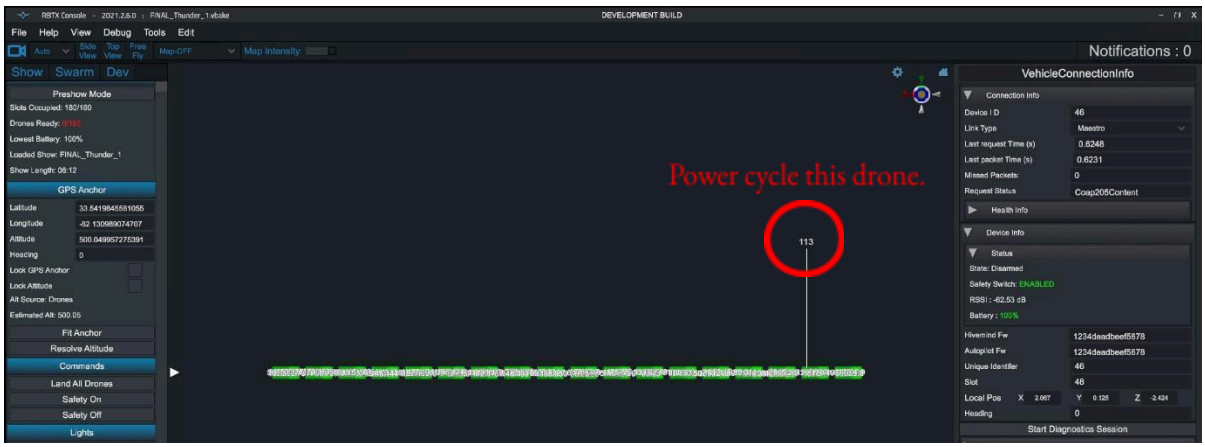


B) Launchpad full of healthy drones.

Check Altitude

This check ensures that all drones are at the same starting altitude, and that altitude is the "ground" as determined in the design studio.

To run this check use a side view in the Launchpad Viewing Window to ensure that all drones are at the slot altitude. There are two possible errors. One is that all the drones are equally above or below the slots. If this is the case select *Resolve Altitude* in the GPS Anchor tab of the Command



Launchpad Viewing Window displaying the side view of a launchpad with one altitude error.

Panel. The other is a singular drone that is above or below the slots. This drone must be power cycled.

Check Battery

This check ensures that all drones have full batteries prior to takeoff.

To run this check sort by Battery in the Devices Viewing Window to organize the devices from lowest to highest battery. Check the first device to see the lowest battery in the fleet. Any drones in the launchpad with less than 100% battery need to be supplied with a fully charged battery.

Check GPS Error

This check ensures that all drones are within the acceptable range of GPS error.

To run this check sort by GPSError and check the last device to see the drone with the largest GPS Error. If the Fix Type on the worst drone is GPS Fix, the entire fleet will be within the acceptable error range. If the Fix Type on the worst drone is GPS Float the GPS Error must be below 0.040 to fly safely.

Verify RTCM Signal

This check ensures that all drones are receiving GPS correction data.

To run this check apply Light Mode "RTCM". When a drone flashes green it has received the GPS correction data, if it flashes red it has missed the GPS correction data.

Verify Time Sync

This check ensures that all drones are on the same timing.

To run this check set the fleet light mode to *Time Sync*. Pull any drones that are not in sync and label them for further investigation. If the entire fleet is out of sync, a power cycle of the base station may be required.

Show File Test

This check ensures that all drones in the launchpad have the show file preparing to be flown.

To run this check, scroll to the bottom of the Command Panel to Show File Test and click Execute. The test takes 30 seconds to complete, and the results are displayed using the drones' lights.

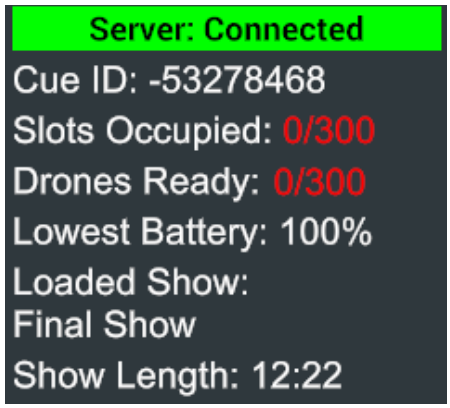
Green Light = Drone has show. This should happen to all drones in the launchpad.

Blue Light = Drone has show but is not in a launchpad slot.

Red Light = Drone does not have the show.

Reading the Show Control module

At the top of the Command Panel is the Show Control module. This module provides critical show information at a glance, displaying the active show file, the portion of launchpad slots filled by drones, and the lowest battery percentage of launchpad drones.



Show Control Tab in Preshow Mode

Show Control Info	Description
Slots Occupied	Number of drones in launchpad slots out of total launchpad slots.
Drones Ready	Number of healthy, slotted drones, with safety's off. (Ready to Fly)
Lowest Battery	Lowest battery of slotted drones.
Loaded Show	Show file that is currently open.
Show Length	Length of show from launch to land.

5.11 Launch Show

To launch drones into their prescribed show pattern, a series of four security barriers must be checked before the final trigger can be initiated.

1. Preshow Checklist

All checks on the Preshow Checklist need to be confirmed and the checklist needs to be signed before flight.

2. Turn Safety's Off

Each drone has a safety switch. If a drone's safety switch is on, that drone will not launch. During all pre-show activities, drones should have Safety On, and after the show has landed, they should be again set to Safety On.

Safetys for the entire fleet can be turned on and off in the Commands tab of the Command Panel using *Safety: On* or *Safety: Off*. Safety switches for selected drones can be turned on/off by right-clicking a drone device and selecting *Command > Safety On* or *Command > Safety Off*. The state of a drone's safety switch can be seen in the Inspector when a drone device is selected. When a drone is healthy and has the safety switch off, its device will read *Ready to Fly*.

When safety switches for the entire fleet are off, only drones that are healthy and hold a launchpad slot for the loaded show will launch. Drones without launchpad slots do not have a flight path and therefore will not launch or show in the Drones Ready count.

3. Enter Show Mode

The option to enter Show Mode is located in the Show Control Tab at the top of the Command Panel. Select the button that reads *Show Mode: Off* to switch to *Show Mode: On*. When entering Show Mode: On, the packet rate is reduced from 40 to 10 packets per second. If you enter Show Mode: On before turning safeties off, it will take longer for the drones to report their status' back due to the slower packet rate.

4. Arm System

Once steps 1-3 are complete, the option for Armed: NO can be changed. Clicking ARMED:NO will prompt a dialogue box allowing the PIC to verify the loaded show is the one intended to be launched and change to ARMED: YES.

5. Lock Trigger

Locking the trigger is the final barrier to launching a show. Once the trigger is Locked, the show can be executed using one of four trigger methods.

Trigger Methods

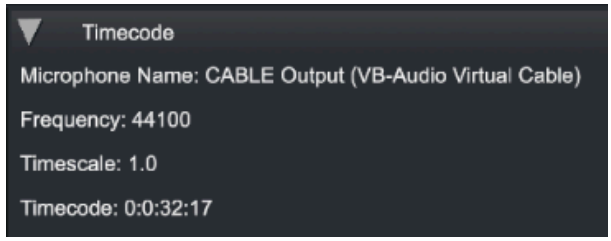
Select the trigger method by clicking *Set Trigger* in the Show Trigger Tab of the Command Panel.

1. Manual

The Manual trigger method allows the PIC to execute a show with the click of a button. This method has a built in 5-second delay. The Launch button will enable once all security barriers are selected. The show timeline will begin five seconds after the *Launch* button is pressed.

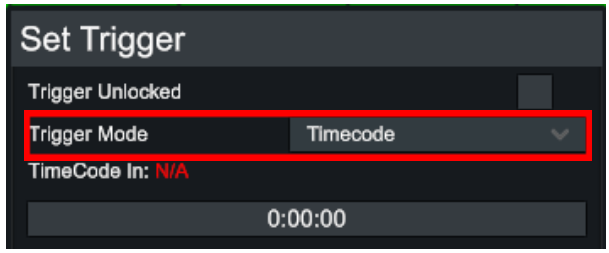
2. Timecode

The Verge Console accepts SMPTE timecode as a method for launch and requires an audio interface to feed a signal into the show laptop.



Timecode Window in Settings

Timecode settings can be modified by selecting *Configure* in the Show Trigger Tab of the Command Panel.



Uncheck the *Default Device* checkbox and select the device that will be providing the timecode signal. The details of this device are displayed in the Timecode window.

When Timecode is selected as the Trigger Mode a clock appears in the Trigger dialogue box. Click on this Trigger Clock to set the launch time. When Timecode is being streamed the current time will be displayed under after *Timecode In*.

Using the Timecode method the 5-second delay is accounted for before the trigger time and the performance timeline will begin at the time dictated by the Trigger Clock. Learn more about Timecode through our step-by-step tutorial.

3. Wallclock

The Wallclock trigger method is similar to Timecode. Instead of using an external signal it uses the internal clock on the show laptop. Setting the Trigger Clock will trigger the show based on the time inputted when your machine's clock reaches the trigger.

4. Verge Remote

The Verge app supports the ability to launch a show remotely. This feature is not yet available for public use.

5.12 Emergency Procedures

On rare occasions, emergency action may be required during flight. The PIC must carefully evaluate the situation and determine the appropriate action with safety in mind. It is extremely important to note that some emergency actions may result in drone damage, collateral damage, and could potentially lead to a worse outcome than the original emergency.

Warning Lights

Click *Warning Lights*

Turns on RTCM light mode to illuminate all drones in case of the need to warn incoming aircraft. All drones will flash green/white alternately. The Warning Lights button will flash when activated.

Click Warning Lights again to returns all drones to show lighting. The Warning Lights button will stop flashing.

Land All Drones

The Land all command will cause all drones in flight to auto-land directly below their present location. This command should only be used in absolute emergencies when drones need to vacate the airspace immediately. Using this command can cause collisions and undesirable landing locations. There are three safety barriers that a PIC will need to select before triggering the Land All command. This is to prevent accidental triggering.

Return to Home

A safe, deconflicted return to home feature. This option will leverage the existing show rendering system to construct metadata that can be used for the return to home, the same way the main show does today. Available in firmware version 1.5.0 and newer.

5.14 Post-Show

Count Drones

To ensure drones are not being left behind count drones as you pack up to make sure you leave with the same amount you arrived with. Doing a walk-through of the launchpad after the show has landed is another way to ensure that all the drones that launched returned to the launchpad.

For reference, a list of all drones that were online when Showtime Mode was initiated is compiled in an excel file found in Documents > VergeConsole > Logs > Showtime.

Pull Logs from Problem Drones

Any drones that do not fly as expected should be marked and have their logs pulled to identify the problem as soon as possible. For step by step directions see Appendix 3: Pulling Logs.

Turn Off All Drones

Batteries continuously discharge until they are completely dead. Any batteries that are in the critical battery life state, should be turned off immediately.

Discharge Batteries

Any batteries that are not used during the show must be discharged to a storage state. See Battery Handling for more details.

Appendix 1: Recalibrations

Videos showing sample calibrations can be found here.

Calibrations:

Level – Leave on flat ground. Don't touch.

Compass (Magnetometer) – Spinning an all 6 axis.

Gyroscope – Leave on flat ground. Don't touch.

Accelerometer – Stagnant on 6 axis.

Calibration Light Codes:

Blue: Calibration is active.

Red: Axis has already been completed.

Yellow: Searching for axis.

Green: This axis is complete.

Appendix 2: Maintenance

Pre-Flight Maintenance Checks

Prior to every show flight, both launchpad and sideline drones must go through routine maintenance checks. Pre-flight maintenance checks are listed below.

- Check for damaged props (visual test). Chips in props larger than 1/8in should be replaced. For reference, 1/8in is roughly the thickness of 2 quarters.
- Check for loose props (hand-tighten test)
- Check for crooked antennae (visual test)
- Check for flush battery connectors (visual test)

After Launching from Sand

An air compressor should be used to blow out all motors following flights from a sandy location. Taking off from surfaces such as deserts and beaches can cause sand to get stuck in components of the drone. Motors can get stuck and degrade quickly if sand buildup remains inside during flights.

Hardware Damage

Reference the X7 maintenance guide for directions on replacing legs, props, and arms. Any damage to the body will require the drone be sent to Verge Aero for further review.

Battery Maintenance

Batteries degrade over time and will need to be replaced eventually. This will depend on the care and frequency of use.

Please refer to the Battery Handling section of this manual for detailed battery best-practices and information on battery health checks.

Motor Lifetime

Motors need to be replaced every 100 flight hours (roughly 500 shows). Once your fleet is nearing this metric contact Verge to arrange a schedule for fleet-wide motor replacement.

Appendix 3: Pulling Logs

Issues with Specific Drones (Pulling Logs)

A drone's flight log provides information such as GPS, velocity, acceleration, vibration, sensor noise, and failsafe triggers. These logs are stored on the drone's micro-SD cards. Any time an error occurs on a specific drone (no takeoff, erroneous flight path, connection issues, etc) the logs should be pulled for that session and sent to the Verge team with a description of the problem.

There are two types of logs. First, the hivemind logs that capture on-ground activities. In the event of a no-take-off, the hivemind logs should be pulled. The second log is from the flight controller and captures all in-flight information. If a drone autolands, or exhibits other stange behavior in flight, the flight controller logs should be pulled. Video on pulling logs.

1. Follow this tutorial to configure your computer to connect to X7s.

2. Use QGroundControl to download the flight controller logs.

3. Use the Console to download hivemind logs.

4. Email logs to support@vergeaero.com for further review.

Appendix 4: Show Day Checklist

Setup

- □ Unpack drones
- □ Setup base station

Visual Inspection of all Connections

- □ Antennas to gateway boxes (fully screwed in)
- □ Ethernet cables fully plugged in to gateway boxes and base station box

- □ RTK USB (6-pin connector, USB into base station box)
- □ Ethernet cable fully plugged in to computer and base station box

Launch Console

- □ Load VBake
- □ Swarm anchor is streaming

Drone Initialization

- □ Place drones in launchpad
- □ Plug-In drones
- □ Check number of online drones
- □ Identify offline drones

Upload Show

- □ Upload show
- □ Reupload to drones that were missed

Drone Health Checks

- □ Heading check
- □ Device errors and recalibrations
- □ Routine maintenance check
- □ Routine battery connector check

Final Pre-Flight Checks

- □ Check altitude
- □ Check battery

- □ Check GPS error
- □ RTCM light mode test
- □ Time-sync test
- □ Show file test
- □ Final pedestrian check & TFR Check
- □ Laptop audio is on (for failsafe alerts)

Launch Show

- □ Launchpad drones are healthy and slotted
- □ Turn safeties off
- □ Go into Show Mode: On
- □ Arm System & Lock Trigger
- □ Launch show

Post-Show

- □ Final drone count
- □ Pull logs from any problem drones
- □ Discharge unused batteries

Appendix 5: Restricted Area Calculation

The Restricted Area is determined based on calculations of the maximum distance a drone could traverse when its motors are completely cut during flight. This is the scenario which would occur if a drone breached the hard geofence.

Freefall Equations

The following equations were used to model the trajectory of a drone breaching the second layer "hard" geofence. Please contact the Verge team for the full python script.

Position is calculated in each axis via:
$x = x_0 + v_0 * t + .5 * a_0 * t^2$

Wind force is calculated using F = A * P * Cd
A is Surface Area
P is pressure
Cd is coefficient of drag

A Cd of 1.05 was used based on the coefficient of drag of a cube. And the surface area is modeled as a flat plane. These are extremely conservative values considering the X7 drone is much more aerodynamic in reality with a Cd closer to 0.6 (reference).

Pressure is calculated using P = .00256 * V * V
V is velocity in mph
P is pressure in Pounds per Square Foot (psf)

Area is computed as a conservative cross-section of the largest part of the X7 drone: 0.015 m^2

P is converted from Pounds per Square Foot to Newtons per Square Meter using the conversion factor of 47.8803 (reference).

Acceleration due to wind is applied in the worst-case scenario, where the force is applied only in the same direction as the initial velocity of the drone with no wind resistance in the opposite direction.