Evaluation and Application of Fotokite Tethered Drones in Rural Areas of California and Washington

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Acronyms Table

Abbreviation	Meaning
WSDOT	The Washington State Department of Transportation
Caltrans	The California Department of Transportation
CCTV	Closed Circuit Television
IP	Ingress Protection
SIM	Subscriber Identity Module
LTE	Long Term Evolution
Wi-Fi	Wireless Fidelity
GPS	Global Positioning System
COA	Certificate of Authorization
URL	Uniform Resource Locator
AC	Alternating Current
DC	Direct Current
TMC	Traffic Management Center
MOSFET	Metal-Oxide-Semiconductor Field-Effect Transistor
RMA	Return Merchandise Authorization
ID	Identification
FAA	Federal Aviation Administration
TIM	Traffic Incident Management
DOT	Department of Transportation

Background

The Washington State Department of Transportation (WSDOT) Southwest Region collaborated with the California Department of Transportation (Caltrans) to pilot tethered drone technology, funded through the Western States Rural Transportation Consortium (WSRTC). The initiative aims to enhance situational awareness and improve traffic monitoring in rural areas.

Presentation Overview

1. Introduction
    - Rural Area Challenges and Proposal
    - Fotokite Background
        - System Overview
        - Manufacturer Specifications
        - How Fotokite Works
    - Use Cases
        - Deployment Locations
2. Evaluation
    - Field Trial Issues
    - Issue Resolutions
    - Caltrans Successes and Lessons Learned
    - WSDOT Successes and Lessons Learned
    - Fotokite in Action
3. Overall Conclusion and Next Steps

Challenges and Proposal

- Challenges
  - Lack of power, infrastructure and cameras in rural areas
  - Incidents outside CCTV coverage
  - Commercial drones require a certified Part 107 pilot and have limited flight duration
- Proposal
  - Use of ground powered tether drone (Fotokite)
    - Part 107 is not required (Caltrans still requires their pilots to be licensed)
    - Can fly continuously for hours while connected to a ground power supply
    - Live streaming function with the ability to remote control camera
      - Note: remote control camera feature was added in 2025

Fotokite System Overview

- Material Overview
  - Drone: Carbon fiber
  - Tether: Two copper cables wrapped by dual Kevlar strands
  - Ground base: IP55 rating material
    - Protection against solid: Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the satisfactory operation of the equipment
    - Protection against liquid: Water projected by a 6.3 mm (0.25 in) diameter nozzle against enclosure from any direction shall have no harmful effects
    - Can be operated in light to medium rain and snow

Fotokite System Overview

- Communication Overview
  - Communication is established via a Fotokite-provided global SIM card embedded in the ground base
    - Communicates with the Fotokite Cloud to synchronize drone operations
    - Automatically selects the strongest available signal (AT&T, Verizon, T-Mobile) to optimize livestream performance
    - Users may opt to use their own LTE service. Fotokite will configure the system for the carrier of choice with a fee
  - For live streaming capabilities, Fotokite system requires a connection to an upstream network, either through a customer-provided Wi-Fi/Ethernet connection or via the integrated LTE modem
    - Starlink network has been successfully utilized in areas with little to no cellular coverage
  - The system can operate without a connection to the Fotokite Cloud. However, if the firmware is not up-to-date and data is not synchronized, Fotokite may have limited ability to provide troubleshooting support, as they rely on this data for diagnostic insights

Fotokite Manufacturer Specifications

Figure 1: Fotokite cradle and flight unit

Dimensions: 20.2 x 13.7 x 8.4 in
Ground Base Weight: 22.2 lbs
Flight Unit Weight: 2.78 lbs
Power Source: 110-230 (50-60 Hz) VAC
Flight Power Consumption: 300-400W
Weather Ratings: light to medium rain/snow, wind up to 25 mph
Operating Temperature: 14°F to 104°F
Flight altitude: 150 ft (with GPS), 82 ft (without GPS)
Flight time: 24 hours +
FAA Compliance: No Part 107 pilot license, waiver or authorization (COA), or aircraft certification needed for Public Safety Officers

Fotokite User Interface

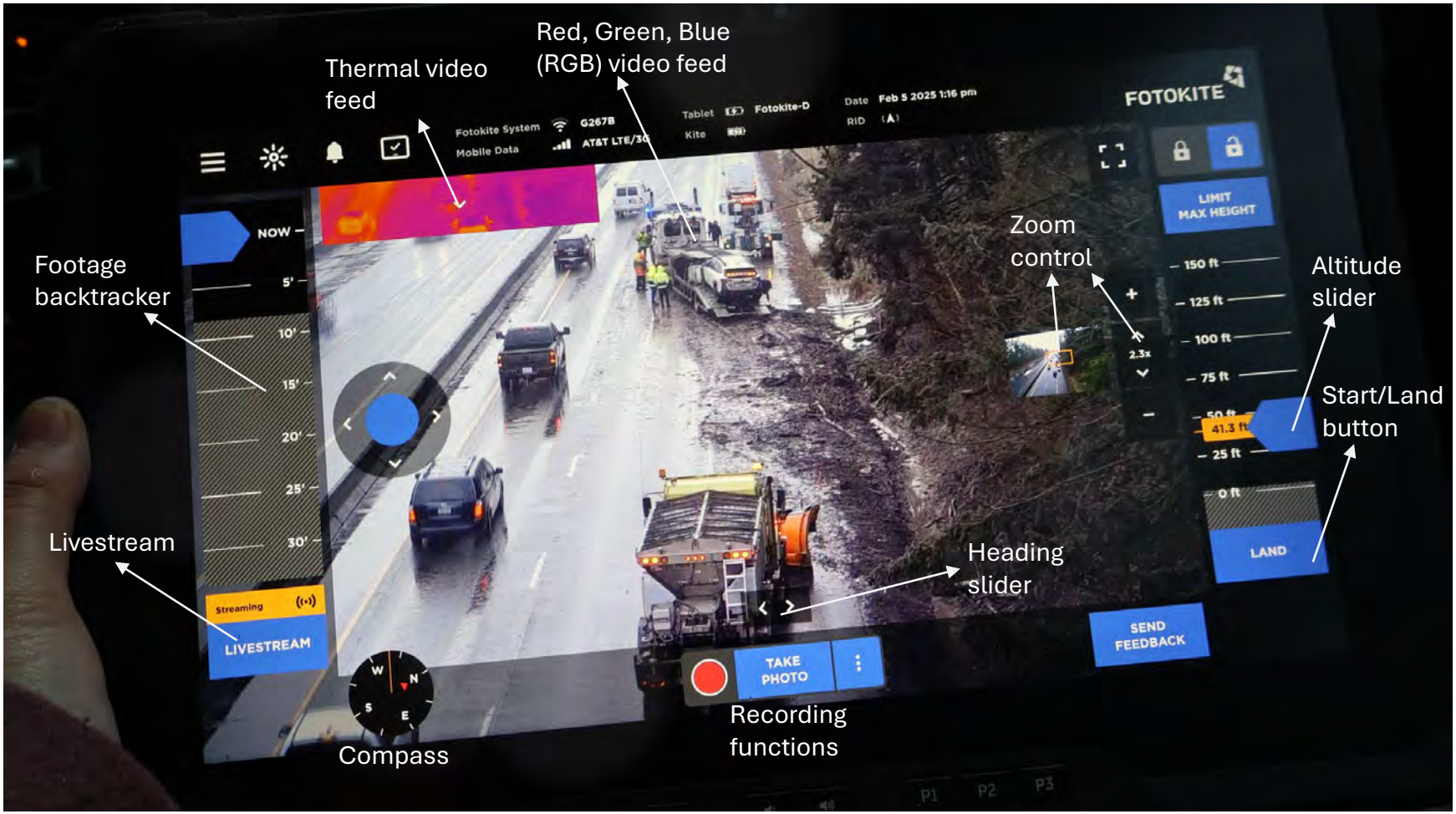
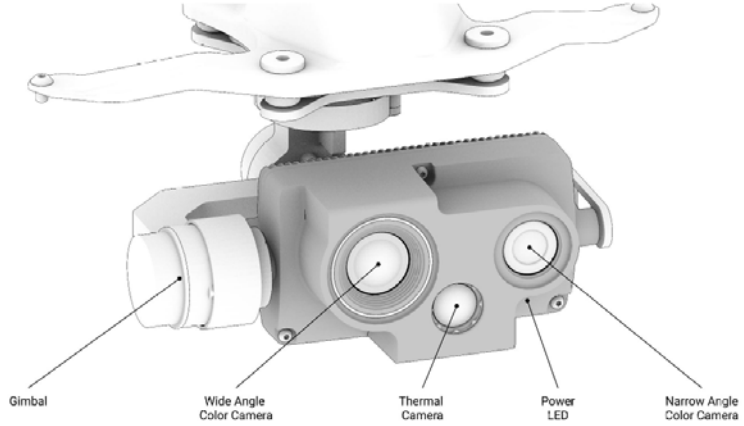


Figure 2: Fotokite controller user interface

Fotokite Camera



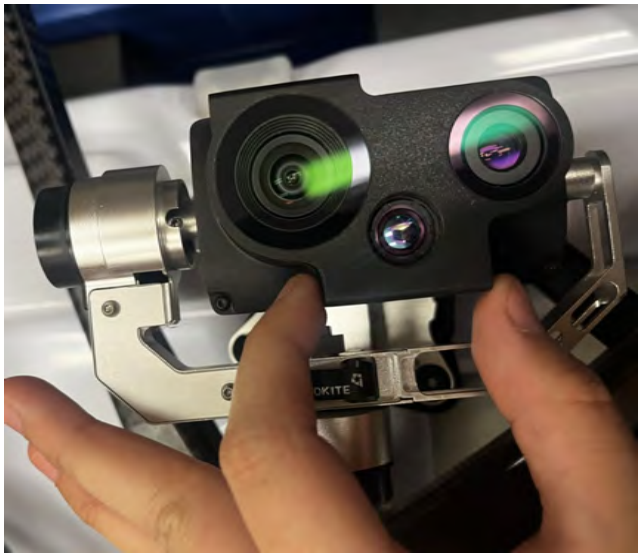


Figure 3: Fotokite camera configurations

Dual color camera zoom color video feed: 0.5x – 16x hybrid optical and digital zoom

- Optical zoom ranges: 0.5 – 1x and 2.3 – 4.6x
- Digital zoom ranges: 1 – 2.3x and 4.6 – 16x

Fotokite Power Rating

AC Power Supply Requirements

Power Specification	Value
Nominal Input Voltage	110 - 230 (50-60Hz) VAC
Operational Input Current	Peak 3.5A
Operational Input Current: Continuous	2.6A
Operational Input Current	Idle 1.8A
Idle Power Consumption (not flying)	220 - 260W
Maximum Power Consumption in Flight*	300 - 400W
Min Ground Fault Circuit Interrupter Rated Current**	15A

* If connecting to an inverter or generator, always ensure you are connecting to a power source rated for a minimum 900W continuous output.
** Rated Ground Fault Circuit Interrupter (GFCI) Cable is included with every new Fotokite System.

Fotokite Power Rating

DC Power Supply Requirements

Power Specification	Value
Nominal Input Voltage (DC)	12 - 24 VDC
Operational Input Current	Peak 55.0A
Operational Input Current	Continuous 50.0A
Operational Input Current	Idle 6.7A
Peak Idle Power Consumption (not flying)	40 - 80W
Maximum Power Consumption in Flight	400 - 500W
Sleep Mode Input Power Consumption*	0.25W
Max Path to Power Resistance Required**	0.065 Ohm
Circuit Breaker / Fuse Min Current Rating***	60A

*The Fotokite Roof Mount System enters Sleep Mode after 5 minutes running without alternator (car battery voltage reading <12.4V) and exits Sleep Mode once the alternator is running (car battery voltage reading >13.1V). Battery saving feature is not currently supported for 24V vehicles.
**A low-resistance path of power is required. Use 6 AWG wire (silicone sheath and a high strand count preferred) at a maximum length of 16ft (5m) from the battery or power supply.
***A 60A circuit breaker or fuse is required to be installed as close to the power supply as possible.

How Fotokite Works

Fotokite Drone

External Viewer

Generate a URL and access code for live-streaming

Tether
(Power 300-400 W)

Control drone & camera

Tablet

Wi-Fi Comm

Fotokite Cradle
(Comm Hub)

Fotokite LTE connection

2025 Feature Remote Control Camera

110 to 230 VAC Power

Power Inverter

12 to 24 VDC Power

Recommend 1000W inverter

Sync Flight Data and Provide Info to Fotokite

Gas/Hybrid/Electric Vehicle

Fotokite Setup for Caltrans Network

Fotokite Drone

Tether (Power 300-400 W)

Cradle has modem internally for comm, and Caltrans proposed to put their SIM in here for convenience

Internal Viewer

Fotokite Cradle (Comm Hub)

Hardwire

Cellular Comm

Cellular Modem (Caltrans SIM)

TMC

110 to 230 VAC Power

Power Inverter

12 to 24 VDC Power

Wi-Fi Comm

Control drone + camera

Tablet

Access the Fotokite footage directly via Caltrans network instead of Fotokite network

Gas/Hybrid/Electric Vehicle

Fotokite Setup for Caltrans Network

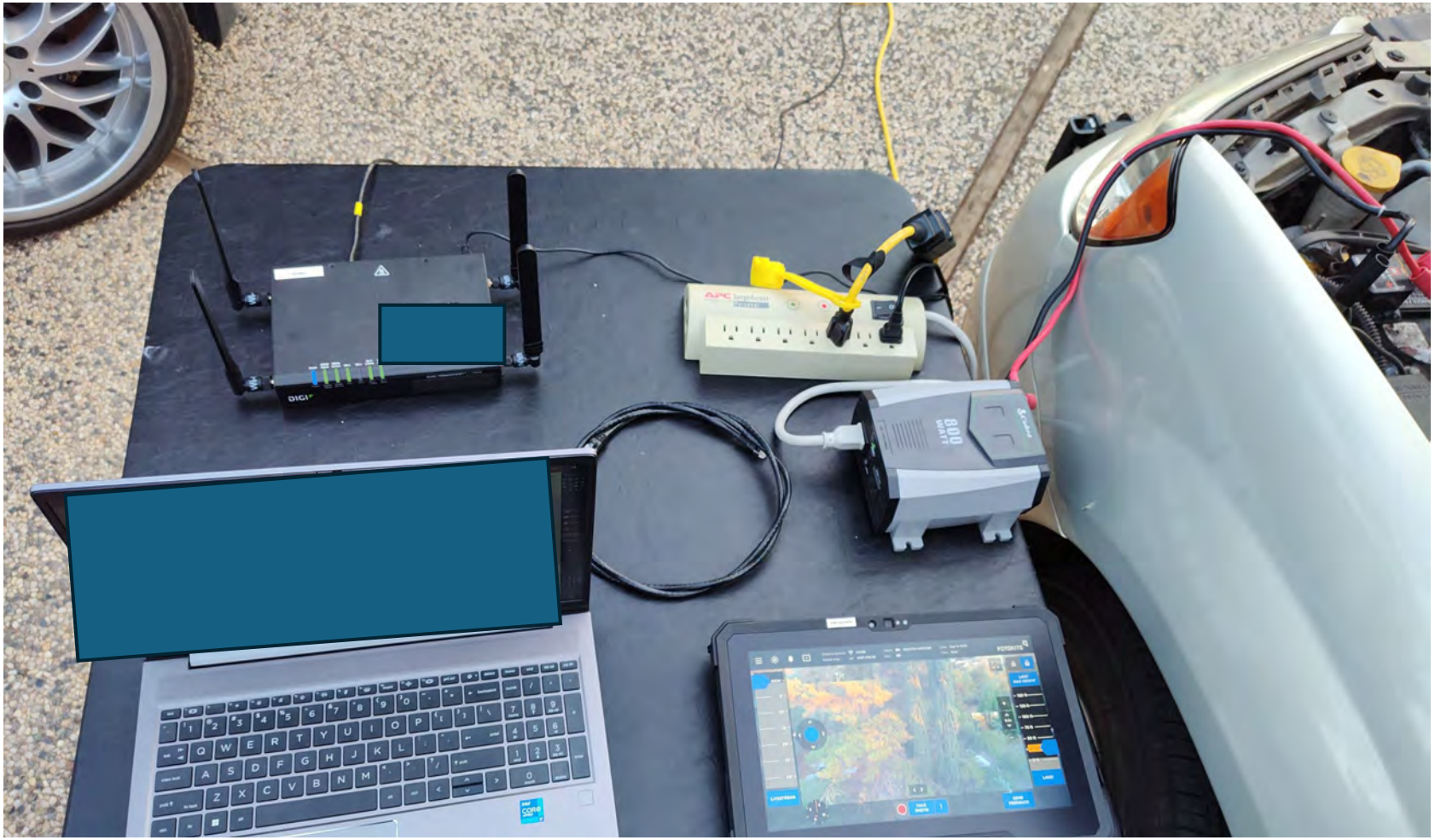


Figure 4: Fotokite system setup to communicate with Caltrans TMC

Rural Use Cases

1. Incident Management: **chain control**, **traffic volumes/queues**, **situational awareness**, **special events** (air shows, etc.), **accident management.**
2. Maintenance: **bridge**, fire, or flood damage, **temporary closure**, dam management.
3. Construction: timelapse, **traffic lookout**.
4. Surveillance: **CCTV (live streaming)**, security.
5. Others: tracking animals, fire management.

• Note: bold indicates scenarios have been tested

WSDOT Deployment – Southwest Region Only

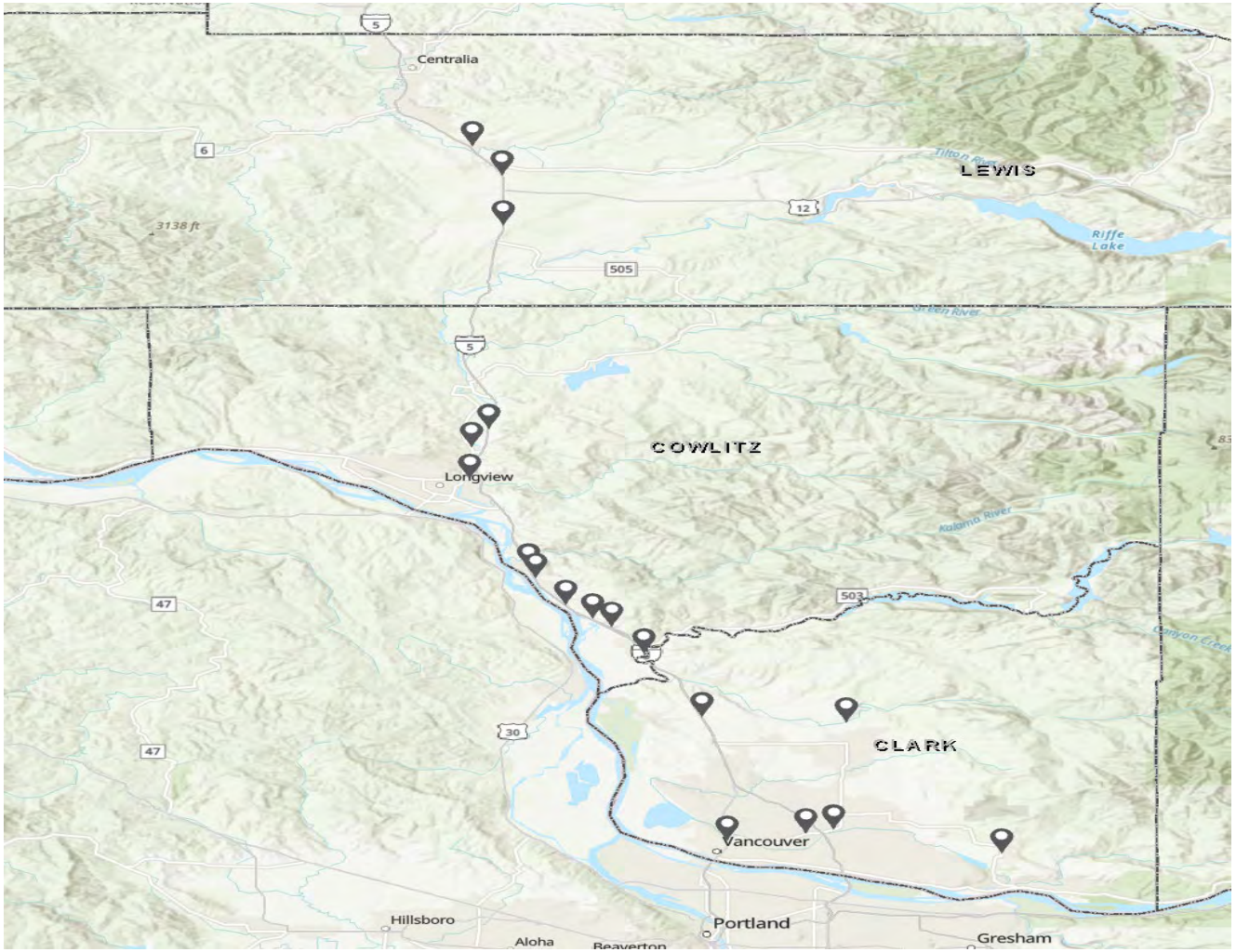


Figure 5: Fotokite deployment sites in the Southwest region of Washington

Caltrans Deployment – Northern and Central Region of California

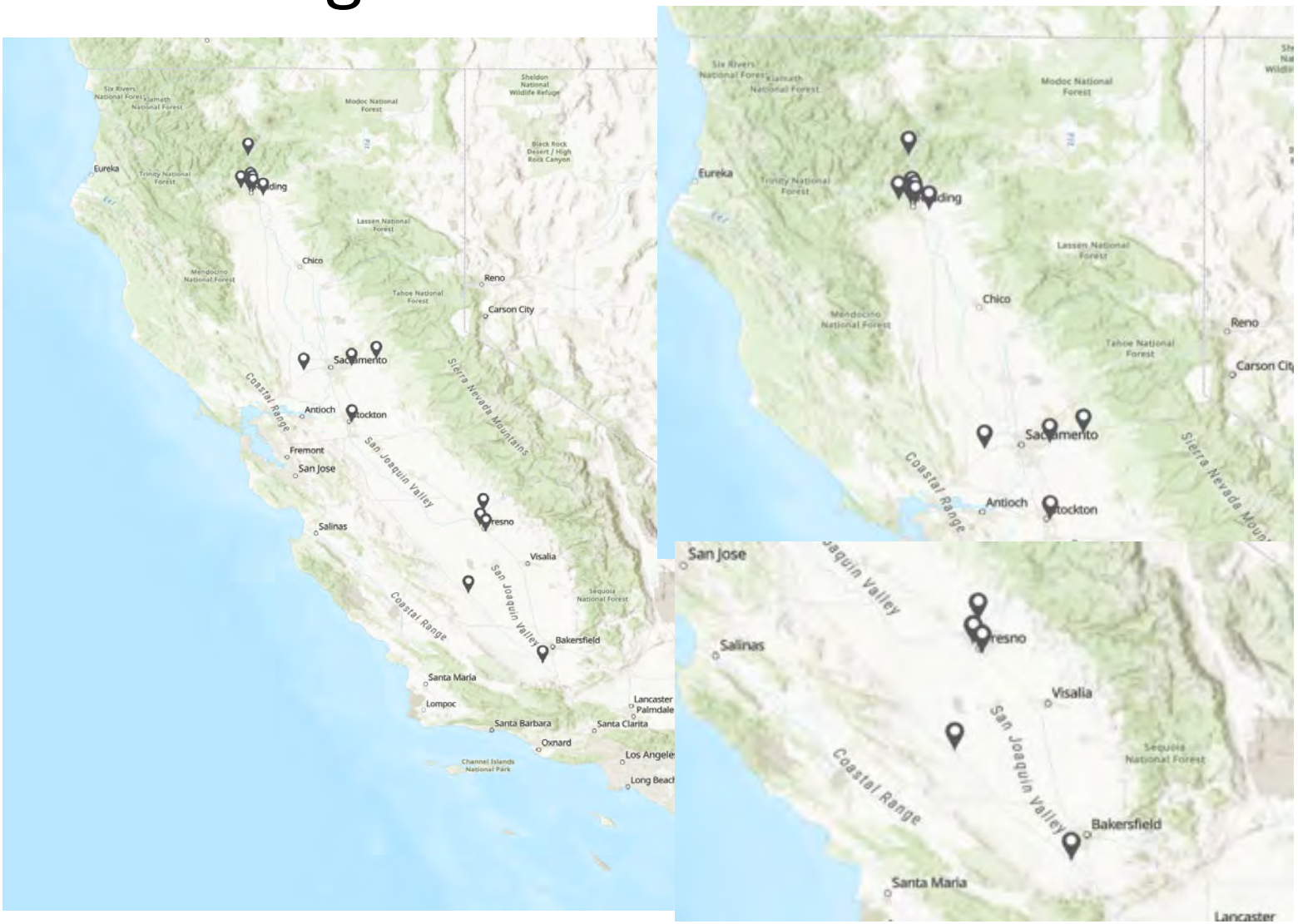


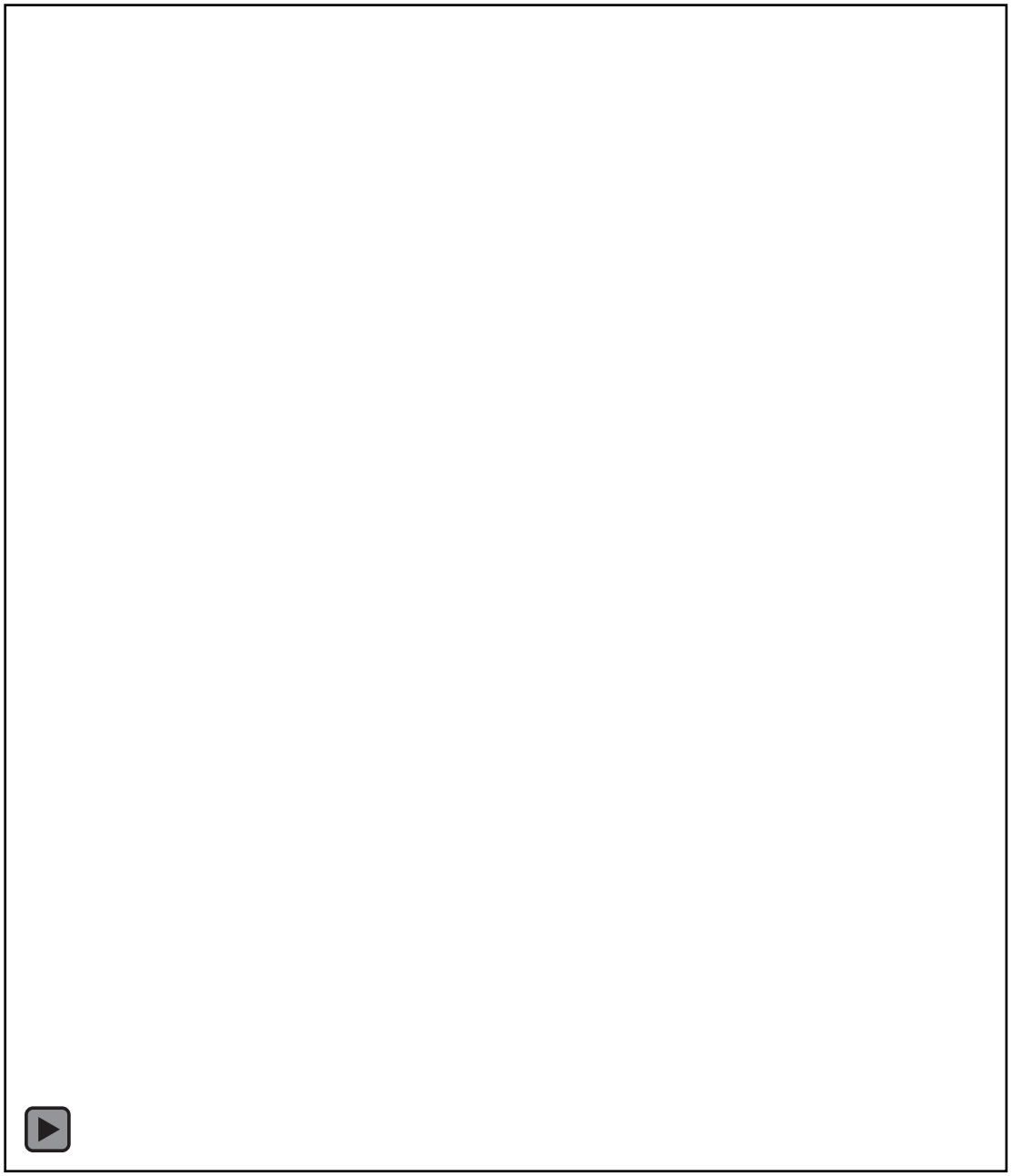
Figure 6: Fotokite deployment sites in California

Evaluation Timeline

- July to October 2023
  - Procurement period.
  - 3 units procured for California
  - 2 units procured for Washington
- End of October 2023
  - Motor malfunction issue experienced by WSDOT
- November 2023
  - Camera lens condensation experienced by WSDOT

Figure 7: Condensation at the Fotokite camera lens

Video 1: Motor malfunction



Evaluation Timeline

- End of November 2023
  - In California, a second Fotokite unit experienced the same motor failure causing it to crash. Fotokite crashed upside down, thus only the frame and propellers were damaged.

Figure 8: Damages sustained from the crash

Evaluation Timeline

- December 2023
  - Power supply failed to meet the minimum standard 11.83V required to fly the drone. As a result, the drone was not able to launch. The Fotokite cradle had to be fixed at Fotokite headquarter in Colorado. The cause was due to malfunctioning battery.

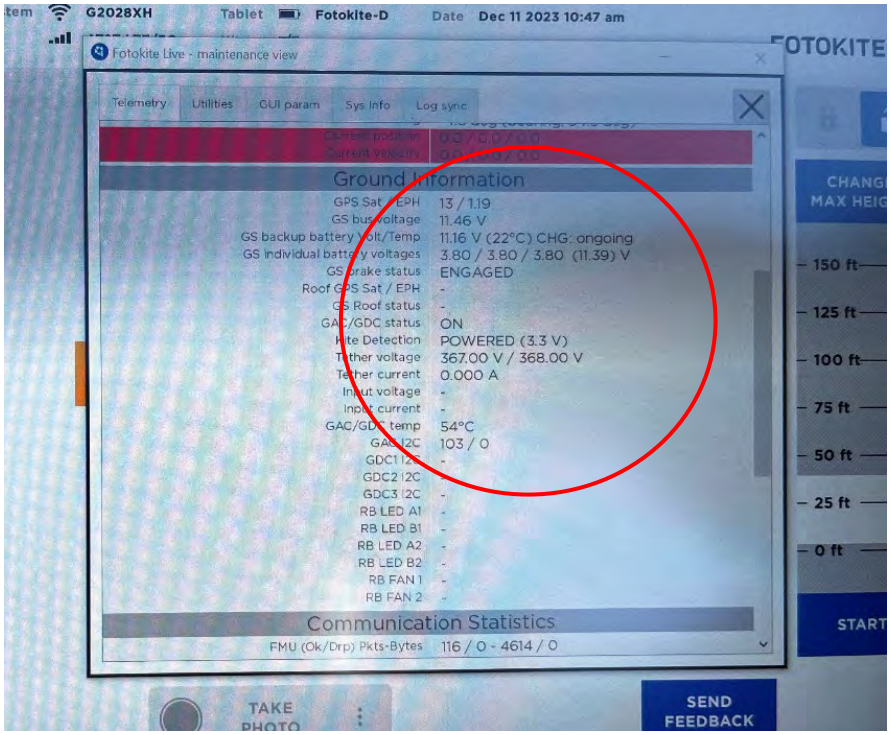


Figure 9: User interface shows cradle voltage failed to meet the standard

Evaluation Timeline

- January 2024
  - Recalled all units due to motor malfunction issue. Root cause was identified as MOSFETs from different manufacturer. All units were sent back for RMA repairs. Four of the 5 units were affected by this issue.
  - Insufficient voltage issue was caused by a malfunctioned charging circuit.
  - Lens condensation was caused by a crack in the lens.
  - Downtime for all units was about a month.
- February 2024
  - Two tablets had a software issue experienced by WSDOT. One table was fixed remotely. The second unit was replaced by Fotokite.
- March 2024
  - Wind caused by passing trucks affects Fotokite stability. Control algorithm did not react as intended during the drone flight.
- May 2024
  - Live stream experienced delays.
  - Fotokite was tested and could perform self-leveling and descending during strong wind.

Evaluation Timeline

- June 2024
  - Pre-mature landing triggered due to cradle overheating (ambient temperatures ranged from mid to high 90's Fahrenheit).
- June 2024 to August 2024
  - Focus on the pre-mature landing issue. The unit was sent back after a month in service. Vendor recommended monitoring backup battery temperature and to place cradle in shade.
- End of August 2024
  - The pre-mature landing issue was resolved by replacing the cradle battery.
  - Remote ID functionality was introduced, which introduced lockout issue.

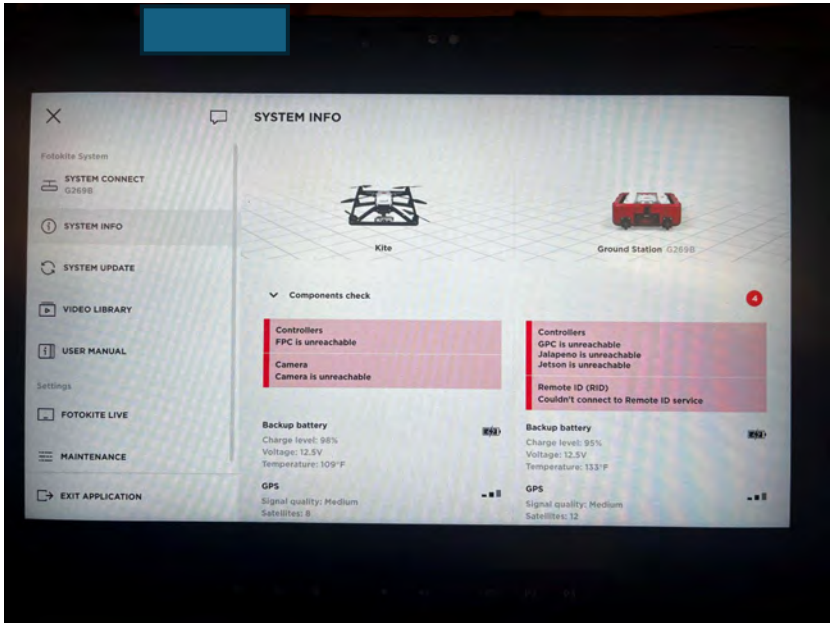


Figure 10: Remote ID error codes

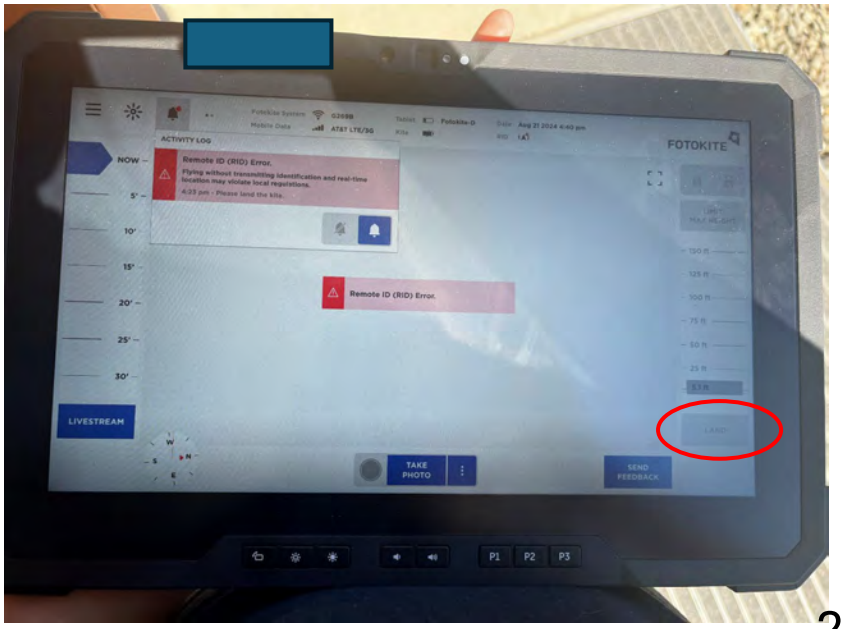


Figure 11: Remote ID caused user lockout

Evaluation Timeline

- September 2024
  - Vendor investigated and identified remote ID issue. Possible software fix identified. Software changes must be FAA compliant.
  - Unable to power from newer model trucks for more than 30 minutes. Root cause was identified as malfunctioning auxiliary battery switch and an idle kill switch on the truck. Solution was to manually disable the idle kill switch and replace the auxiliary battery switch.
- October 2024
  - Caltrans tested the Fotokite using Starlink network. The test was successful.
  - Remote ID issue was still pending. Fotokite was in the process of modifying the code logic to prevent user lockout.

Figure 12: Malfunctioned auxiliary battery switch

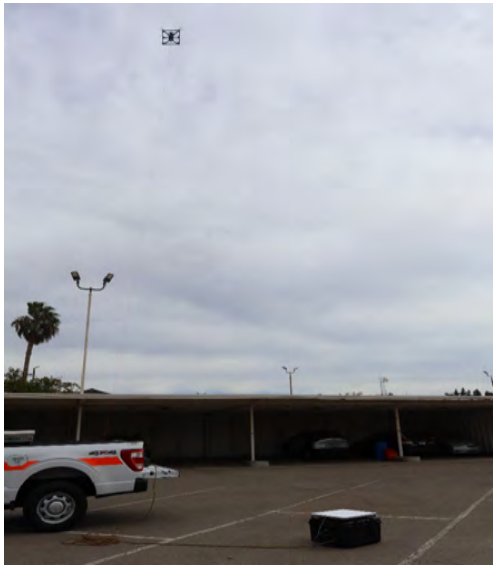


Figure 13: Fotokite using Starlink network

Evaluation Timeline

- November 2024
  - Although Fotokite had software release to mitigate remote ID issue, DOTs still experienced remote ID issue, and it prevented the Fotokite from being launched.
- December 2024
  - Issue with the camera's vertical movement (unable to control its up-and-down motion). A loose shaft was suspected to be the cause. However, when the issue was tested and attempts were made to replicate it, the problem resolved itself. Regardless, Fotokite replaced the camera.
  - Cradle failed to provide power to the drone due to internal short during cold weather testing. Fotokite downtime was about a month.

Figure 14: Fotokite operated in cold weather conditions the day prior to the tether power failure

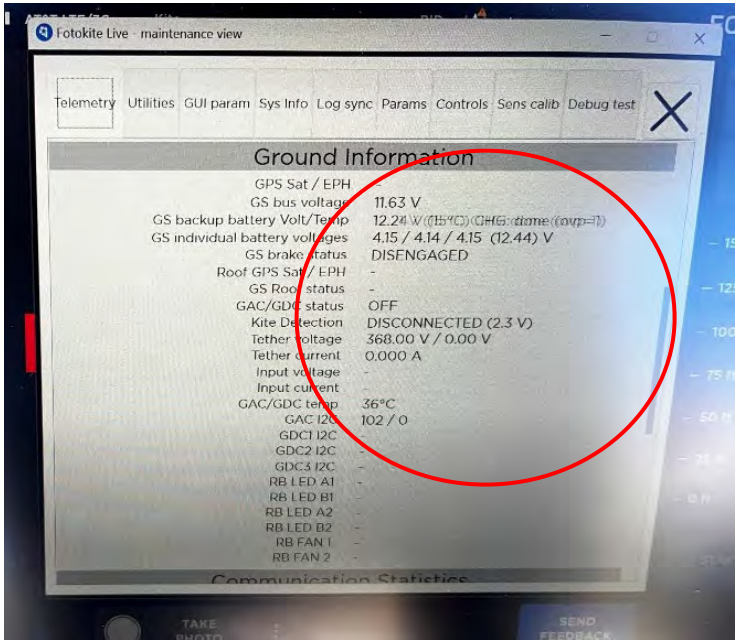
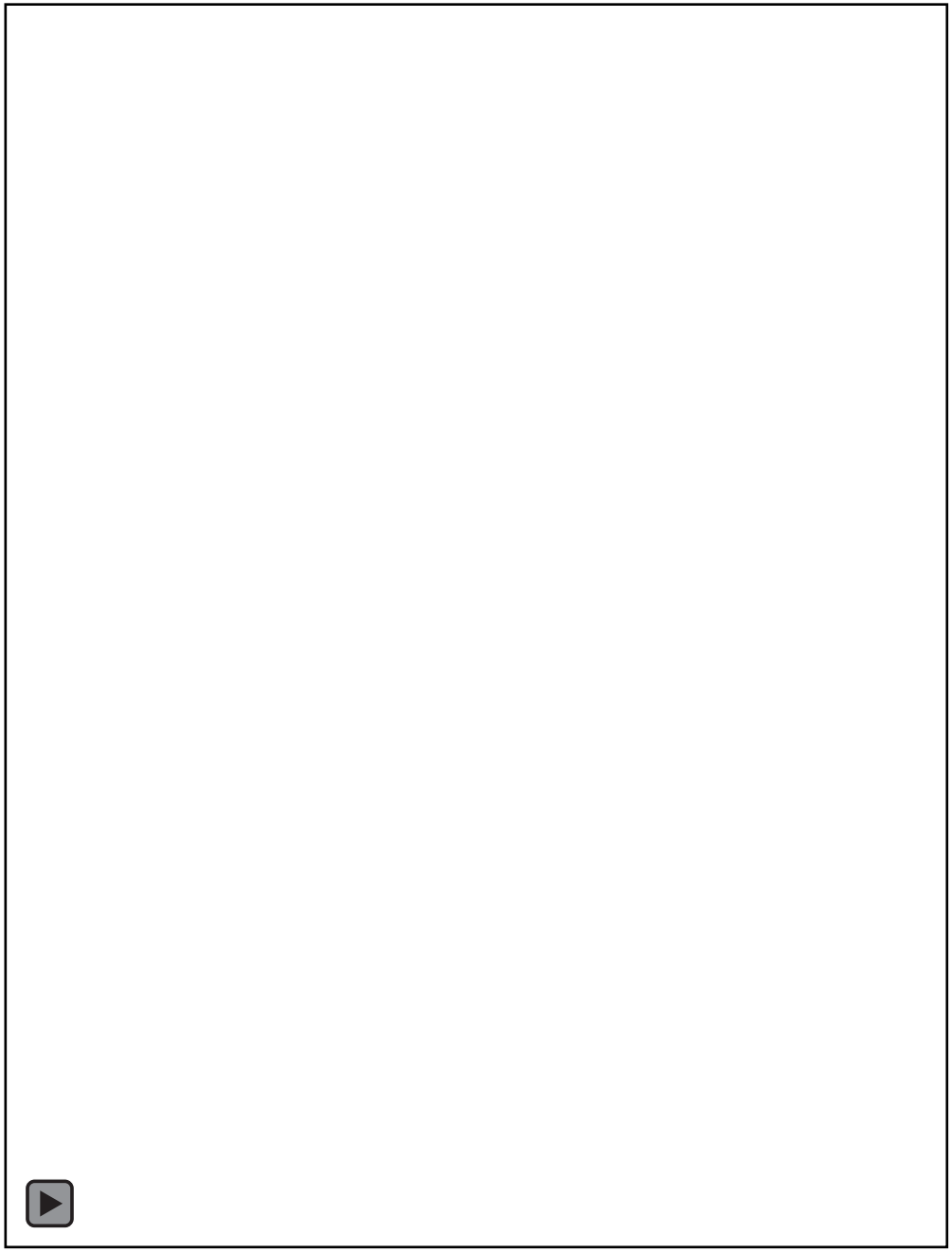


Figure 15: Fotokite user interface show that the flight unit was unable to take off due to a disconnected tether power supply

Video 2: Demonstration of the camera issue



Evaluation Timeline

- January 2025
  - Remote camera control was introduced via firmware upgrade.
  - The heating issue with the backup battery was traced to the internal system layout. Specifically, the tether retraction motor was positioned too close to the temperature sensor. As the motor heated up during operation, it influenced the sensor's readings, leading to inaccurate and corrupted temperature data.
  - Premature landings in high-temperature conditions were addressed by improving the temperature monitoring process. A software update was implemented to enhance the accuracy of temperature readings and prevent false positives caused by heat generated from the motor.
  - Remote ID issue: partially addressed. Fotokite needs recertification from the FAA to make significant changes.

Figure 16: Remote control camera feature demonstrated via a user phone

Evaluation Timeline

- February 2025
  - A forced software update occurred during field operation due to an incomplete prior update. Once a software update is initiated, it must be completed to avoid operational issues. The Fotokite application does not initiate updates on its own; however, users should ensure that auto-update settings on the tablet are properly configured to prevent unintended updates during missions.
  - External magnetic disturbances detected due to initialization bug and/or significant amount of steel affecting the magnetometer embedded in the unit.
  - The tablet experienced a hardware failure where the screen remained blank despite the device being fully charged. The tablet was replaced.
  - Under windy conditions (around or greater than 15 mph), Fotokite deviated from the base further than expect, suspect GPS issue.

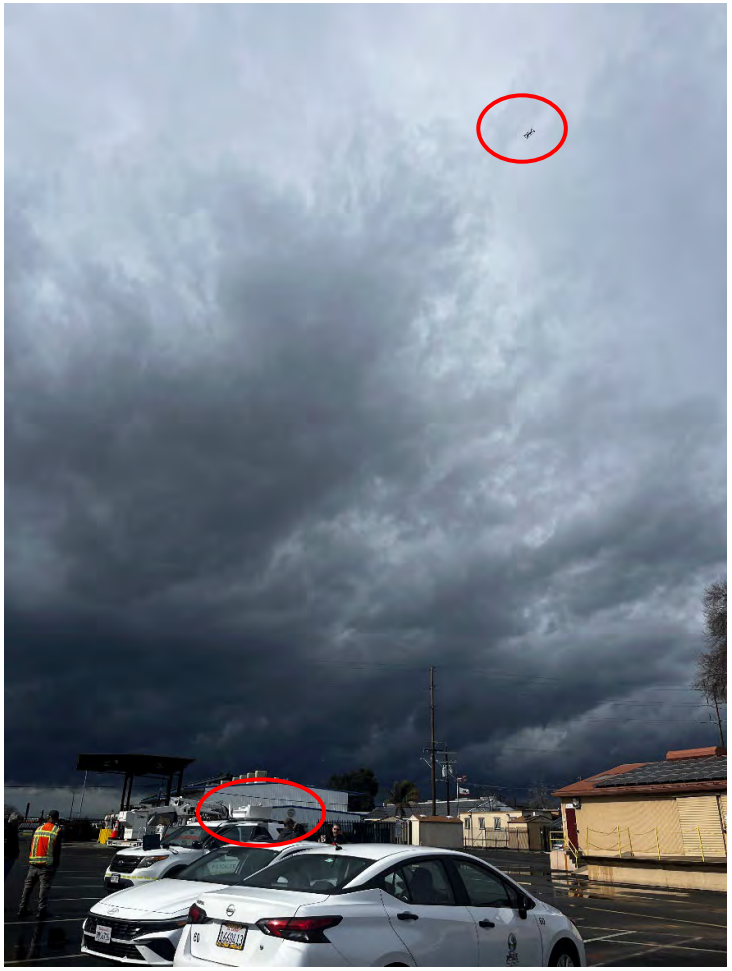
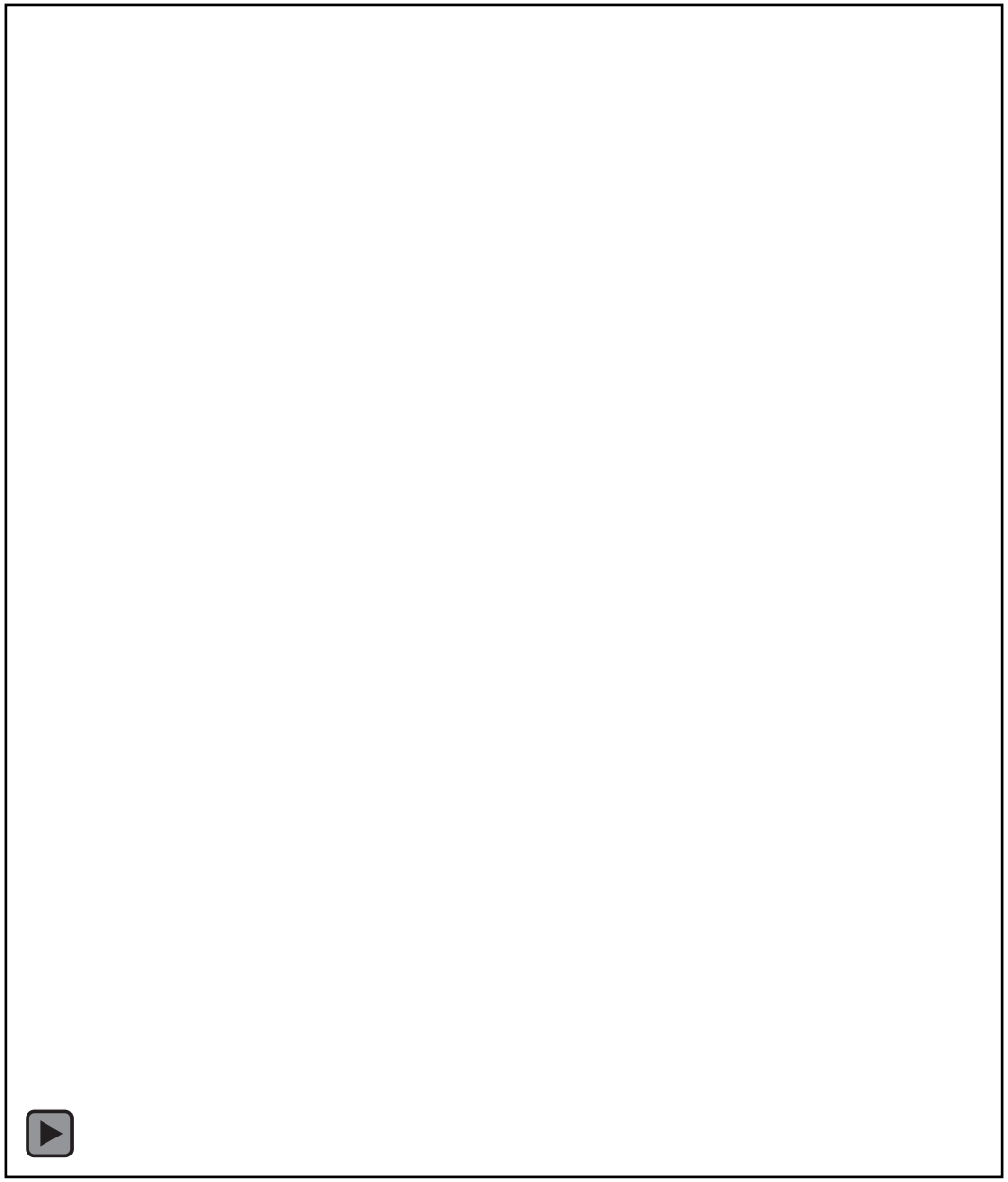


Figure 17: Fotokite deviated from its base in 15 mph wind

Video 3: Demonstration of Fotokite deviated from its base in windy conditions



Evaluation Timeline

- March 2025
  - Livestreaming was unstable in the Dunsmuir, California region due to limited cell coverage.
- April 2025
  - The Remote ID issue remains unresolved. While recent firmware updates have partially mitigated the problem, remote ID issue still persists. A complete solution is pending.
- May 2025
  - WSDOT Unit E392K remains under repair, with a current downtime of approximately three months.
  - The unit E392K also experienced a camera issue that was not discovered until the unit is in repairs. The cause was due to water ingression

WSDOT Experience with Fotokite

What Has Been Successful and Lessons Learned for WSDOT

- Successful
  - Live-stream implementation for traffic operation and management
    - Costco opening
    - Situational awareness
    - Birds eye view of the accident scene
  - Easy of use
    - Straightforward control interface
  - Responsive customer support
- Lessons Learned
  - **Limited Troubleshooting Capability**: Unable to independently resolve issues; reliant on vendor support for troubleshooting.
  - **Repair Downtime**: Typically take a month.
  - **Lack of Need**: WSDOT Southwest Region is already well-equipped with cameras.
  - **Combability**: Not suitable for rapid incident response (limited truck space and the nature of the work).

Livestream Event – Unscheduled

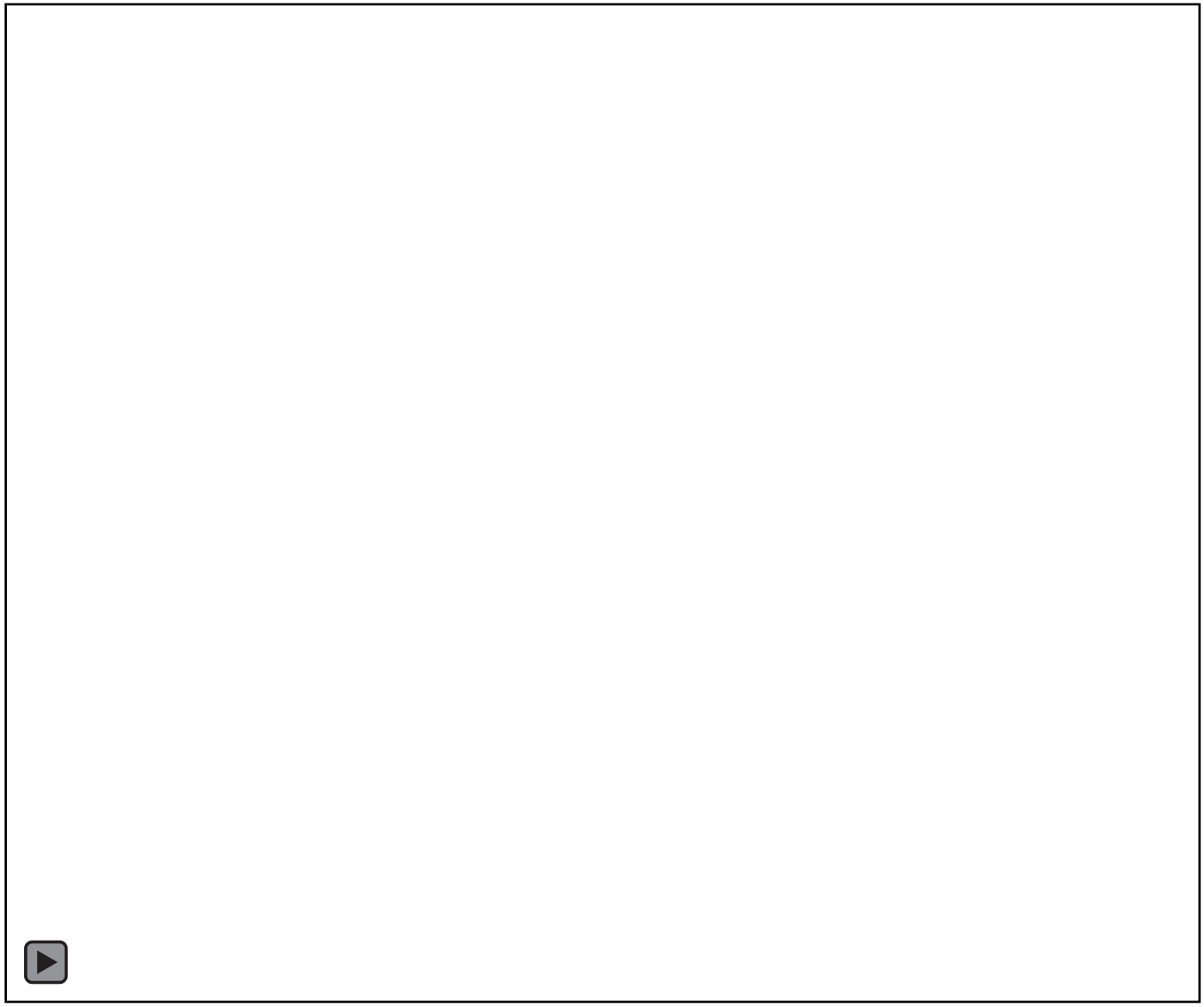
- On February 5, 2025, at approximately 10 AM on I-5, a vehicle accident occurred when a car veered off the road and into a ditch.
- An emergency lane closure was implemented because of the accident. The WSDOT Rapid Response Team documented the scene for safety and insurance purposes. In addition, WSDOT TMC utilized the Fotokite livestream to monitor traffic conditions in real time.
- Another incident was captured by the Fotokite system for the TMC; however, the exact location of this incident is unknown.

Figure 18: Approximate location of the collision on February 5, 2025

Livestream Event – Unscheduled Example

Figure 19: Crash site captured by Fotokite

Video 4: The Fotokite livestream was broadcast within the WSDOT TMC



Livestream Event - Scheduled

- Fotokite was used to monitor a Costco opening for approximately 5 hours.
- The livestreaming was broadcast in the TMC room for traffic monitoring.
- Fotokite required a 30-minute rest period in the shade one time between flights. After cooling down, it was re-launched and successfully completed the mission.

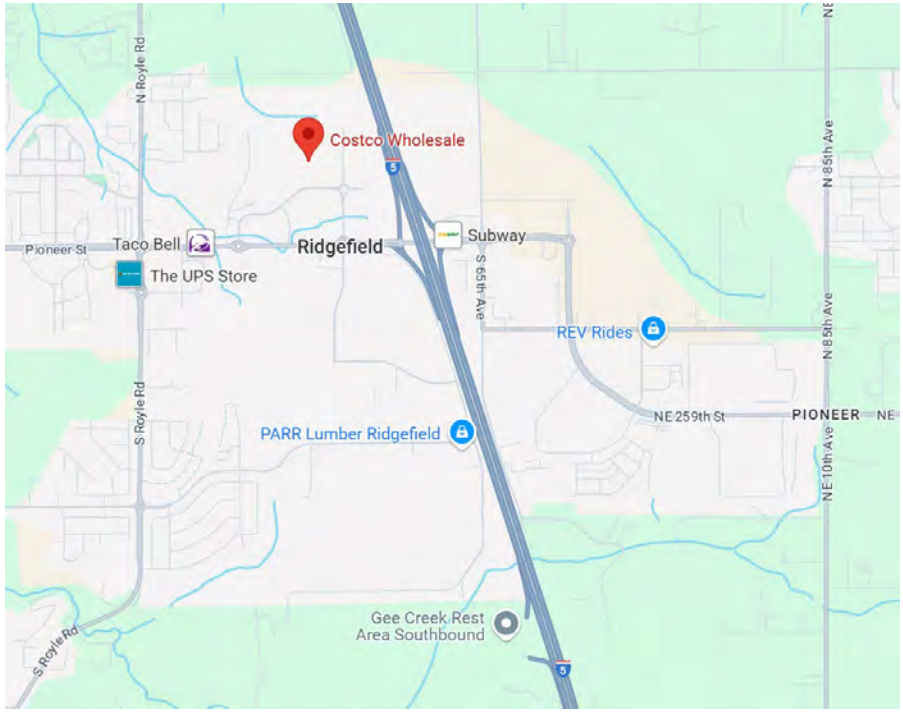


Figure 20: WSDOT monitored the Costco opening on Pioneer Street/I-5 Southbound

Livestream Event – Scheduled Example

Figure 21: Monitoring of Costco opening

WSDOT Rapid Incident Response Truck

- The size of the portable Fotokite unit poses a challenge for storage and deployment for WSDOT incident response trucks.
- Out of approximately 20 incidents per day and around 400 incidents per month (excluding off days), Fotokite is deployed about twice a month, resulting in a usage rate of less than 1%.

Figure 22: Fotokite and WSDOT rapid incident response trucks

Caltrans Experience with Fotokite

What Has Been Successful and Lessons Learned for Caltrans

- Successful
  - Live-stream implementation for Traffic Incident Management (TIM)
    - Chain control
    - Unscheduled and Scheduled major events
    - Use of Starlink Satellite Internet
  - Easy of use
    - Straightforward control interface
    - Recently – Remote operation
  - Responsive customer support
- Lessons Learned
  - **Limited Troubleshooting Capability:** Unable to independently resolve issues; reliant on vendor support for troubleshooting.
  - **Repair Downtime:** Typically take a month.
  - **Bandwidth Limitations:** High-resolution bandwidth constraints prevent Caltrans from obtaining smooth video footage for TMC.

Livestream Event – Unscheduled

- On January 6, 2024, at approximately 7:30 a.m. on southbound I-5 at Millux Road, roughly 100 miles north of Los Angeles, a multiple vehicle collision occurred:
  - Involving a total of 35 vehicles: 17 passenger vehicles and 18 big rigs
  - Resulting in 2 fatalities and 9 injuries
  - Closed southbound I-5 for over 24 hours
  - Included a hazardous material gas leak

Figure 23: Location of the collision on the map

Livestream Event – Unscheduled Example

Figure 24: Crash site captured by Fotokite

Livestream Event – Unscheduled Example

Figure 25: Crash site captured by Fotokite

Livestream Event – Unscheduled Example

Figure 26: Crash site captured by Fotokite

Livestream Event - Scheduled

- On October 17, 2024, Caltrans held its Annual Great Shakeout Earthquake Exercise Statewide. D6 was tasked to use the Fotokite to livestream a mock structure inspection Statewide.
- The Fotokite used a Starlink satellite internet connection to achieve this.
- The Fotokite was flown for 2 continuous hours livestreaming to a maximum of 38 viewers, with a continuous 25 viewers at all times.

Figure 27: Fotokite used Starlink network in a rural area

Livestream Event – Scheduled Example

Figures 28, 29, and 30: Fotokite used Starlink network in a rural area

Livestream Event – Scheduled Example

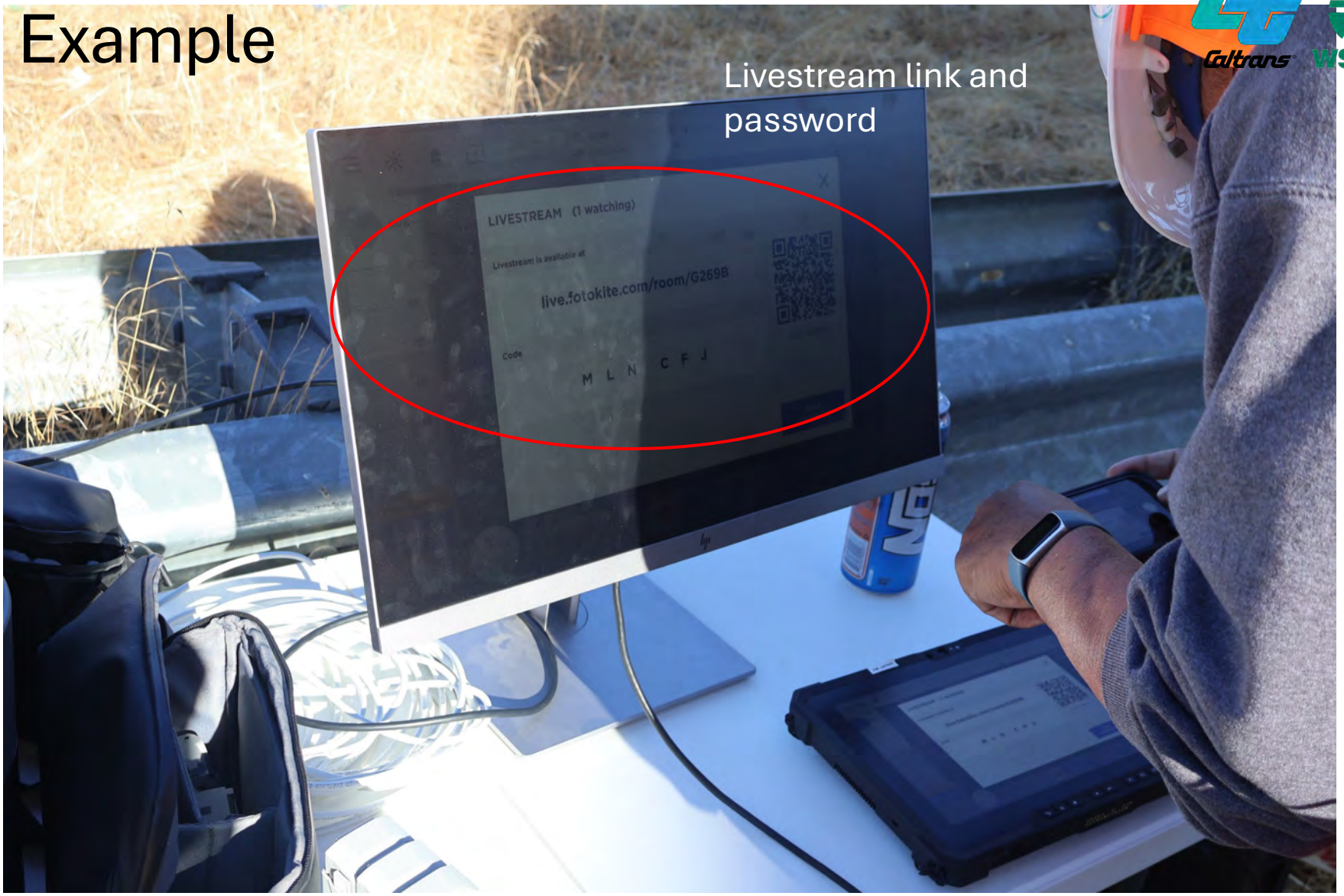
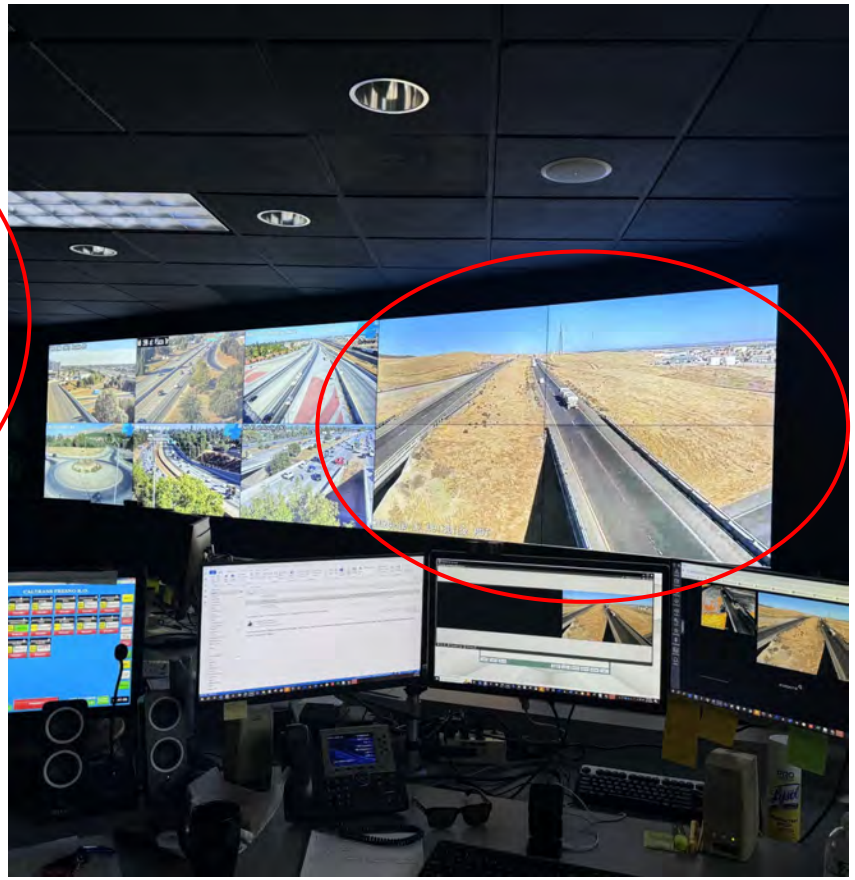


Figure 31: Setting up livestream for Fotokite

Livestream Event – Scheduled Example



Figures 32 and 33: Livestream images inside Caltrans TMC

Traffic Surveillance

Recording/Monitoring traffic patterns during peak hour(s)

Figures 34, 35 and 36: Fotokite used for traffic surveillance

Figure 37: Fotokite in action

Conclusion and Next Steps

- Fotokite live-streaming and remote-control camera functions are well-received by both DOTs
- For WSDOT, not needing a certified pilot is great
- Issues arise almost every month, with all five units having experienced at least one problem
- Fotokite began deploying units in 2019, so there is currently no long-term data available to assess performance over a 10-year span. As of April 2025, the vendor estimates the life expectancy of a Fotokite unit to be approximately 5 years.
- For livestreaming, requirements are
  - Bandwidth: 2 MBit/s or greater
  - Max. 0.6GiB of data usage/hour
  - Latency: < 200ms
  - It is recommended to utilize Federal Communications Commission National Broadband Map as a part of your deployment planning process
- Next steps:
  - Concern that DOTs need to rely on the Fotokite troubleshooting service indefinitely
  - Will the vendor continue to improve their product over time?
  - Caltrans is moving forward with expanding the number of Fotokite systems and is researching the development of self-contained mobile units that include Starlink for internet communication during long-term events

FAA Reauthorization Act for Fotokite 2024

- Operation in Zero-Grid Airspaces: Public safety organizations may now operate Actively Tethered UAS in areas where traditional drones can not be flown without specific waivers and prior approval from the FAA. This includes urban areas and near airports, wherever public safety operations are needed.
- No Remote Pilot Certification: Public safety personnel, including all volunteer firefighters, are not required to hold a Part 107 Remote Pilot Certificate to operate an Actively Tethered UAS.
- No Certificate of Authorization (COA): Public safety organizations, including volunteer fire departments, are not required to obtain a COA for Actively Tethered UAS operations.
- Securing Growth and Robust Leadership in American Aviation Act's language can be found below, with Actively Tethered UAS language found in Section 926: https://www.congress.gov/bill/118th-congress/house-bill/3935. This language amends US Code Title 49 Sections 44801 and 44806.
- More details: New FAA Reauthorization Act Unlocks Operational Freedom for Public Safety Teams with Actively Tethered UAS | FOTOKITE %

Federal Communications Commission (FCC) National Broadband Map

- Link to the FCC Broadband Map: [Home | FCC National Broadband Map]

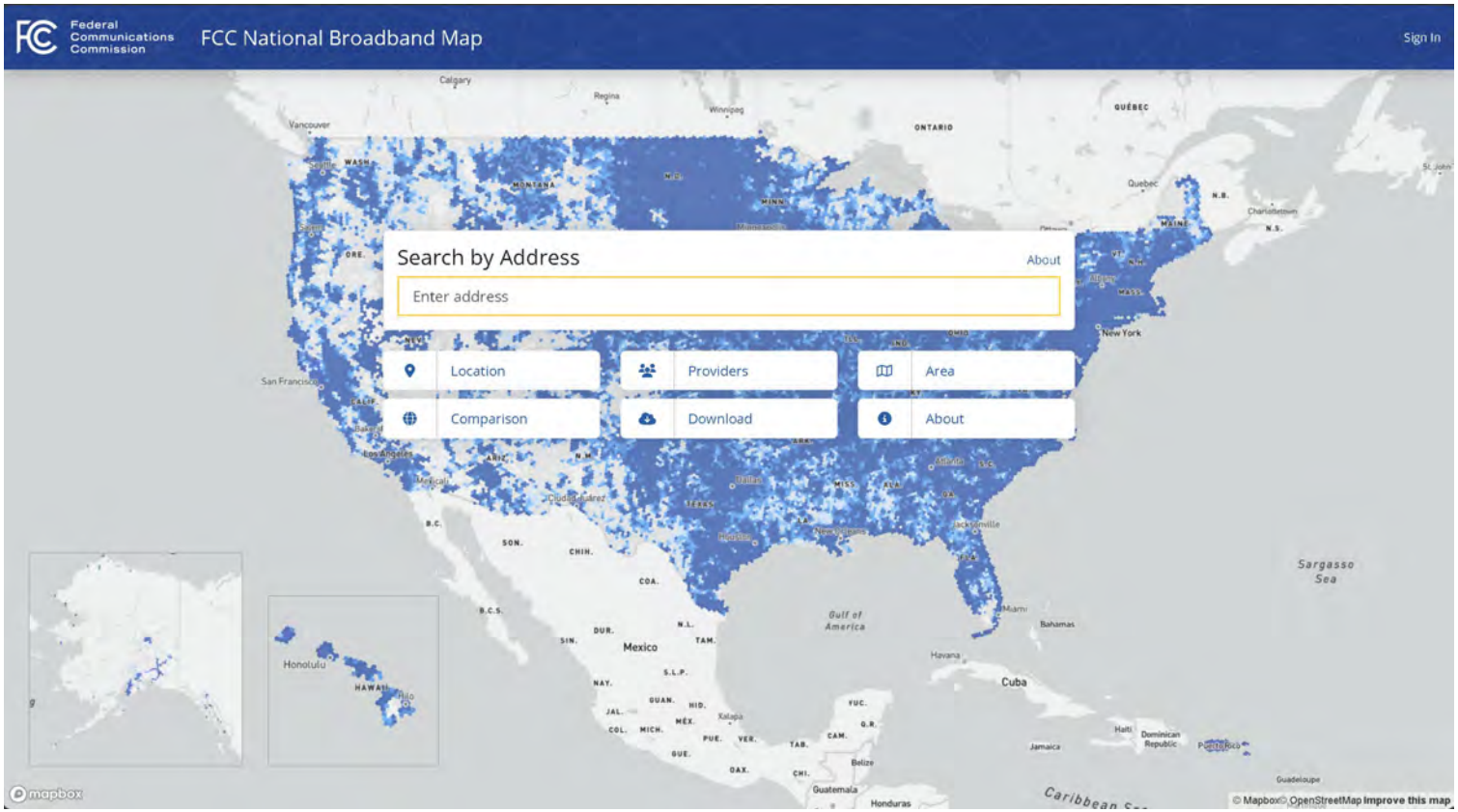
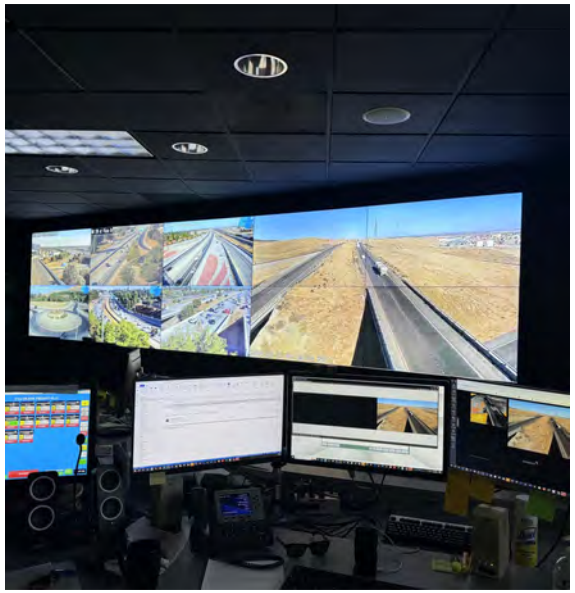
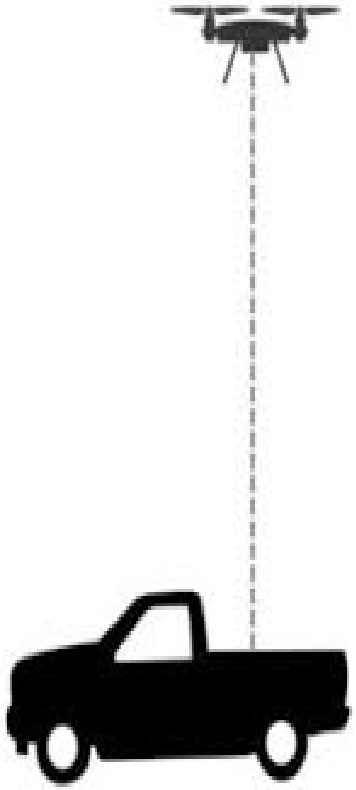


Figure 38: FCC National Broadband Map User Interface





Thank You, and Any Questions?