LUERA TREX WILDFIRE INCIDENT – JUNE 1-7, 2017 – MAGDALENA, NM – UNMANNED AIRCRAFT SUPPORT OF OPERATIONS

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OVERVIEW

The Luera TREX (training exercise) prescribed fire (Type 3 organization) was a wildfire training assignment designed to burn up to 10,000 acres of New Mexico State Trust Land southwest of Magdalena, NM, at the same time providing wildfire training opportunities to newer firefighters. Through a presentation with the Pikes Peak Fire Learning Network, Mike Caggiano / CSU invited Mike, Greg, and Steve to attend this TREX, with the specific goal us using Unmanned Aircraft to facilitate the Operations Section during this incident. A 'Drone Module' was add to the Type 3 organization. Between June 1 and 7, 2017, almost 70 hours of flight time was accumulated, with many practical missions and scenarios executed. This document is a summary of those lessons learned.

Our intent is to make these lessons available to any/all other wildland fire department/agencies who have an interest in using Unmanned Aircraft in support of wildfire operations. Firefighters help Firefighters: currently there is a dearth of real experience on this topic in the fire community. We have all heard from industry about the practical uses of UAS technology, but the reality is that almost no vendors have any real experience in wildland fire operational use of UAS. We currently believe the best way to acquire this experience is at the departmental level. Federal agencies are limited in their ability to innovate quickly due to policy and organization structural limitations. Many federal agencies are stretched thin financially and UAS is not an operational priority. This group, by providing a solid operational and policy base at our department level, and buy-in from our department for this Luera TREX activity, were able to mobilize quickly and efficiently.

Also note, the Unmanned Aircraft we used during this incident were all pilot-owned. Each of our departments are moving forward towards a UAS program in their own way. But our departments do not own these aircraft. We do. One of our goals was to verify the usefulness of essentially 'off the shelf' Unmanned Aircraft for wildland operations. In this way costs can be kept relatively low, and the entry point for a department exploring the use of UAS can be very reasonable (less than a Motorola 800 radio - $3500 – typical radio carried by a structure firefighter).

Base Camp Luera

VIDEOS & PHOTOS

https://tinyurl.com/luera-youtube

https://tinyurl.com/luera-photos

UNMANNED AIRCRAFT & SOFTWARE

Aircraft: DJI Inspire 1 with X3 visible camera, FLIR Zenmuse XT

DJI Mavic Pro

DJI Phantom 3 Professional

3DR Solo

Take away: Each aircraft flew a number of missions for many hours, all without a single failure. We replaced propellers after some missions where exposed to ash or heat. Each pilot/aircraft performed a pre-flight/post-flight. In the evenings we cleaned all equipment, often did test flights at base camp, and prepared the equipment for the next day missions.

Fixed wing aircraft were brought but never flown. All missions requested by Operations were from locations that only a VTOL aircraft operate. Also, these larger fixed-wing aircraft did not have suitable cases that could be used to safely carry this equipment to the field. If launch locations were such that a pickup truck could be used then these larger fixed-wing aircraft could be utilized.

Software: IOS versions: DJI GO for calibration, Litchi for general flights including waypoints and circle-point-of-interest (includes on-screen GPS coordinates), Autopilot for complex grid style missions (like SAR), Map Pilot for actual aerial survey missions (NADIR photos generating Orthophoto or Digital Elevation Models).

Android version: Tower-3DR Solo telemetry

Take away: know your software and how to use it for specific missions. Software is key to making the most use of the hardware. This is generally where vendors fail: they do not understand the public safety mission, or how available software can be utilized to successfully fly the hardware.

ORGANIZATIONAL / ICS NOTES

Understand ICS and where the UAS (Drone Module) fits into Operations plans/intentions for drone use. Work with Incident Command before the incident to clarify and prepare the assignment.

Request the Drone Mod leader attend the daily operational planning/briefings meetings to facilitate mission planning.

Establish LCES – It is imperative we operate as 'YOU ARE A FIREFIGHTER FIRST'. In many cases we were independent and responsible for our own safety. LCES and general situational awareness is mandatory. Do not place 'best spot to fly from' higher on your list than 'safe spot to fly from'.

Operations Contact - a nice-to-have would be a specific contact within Operations to coordinate UAS missions/usage/ideas/feedback.

Communication with DIVISIONS – where drones will be operating is essential information. Crews still need to be on the lookout for rogue drone operators. If crews are unsure they should call an unknown drone into their Division Sup.

Request a TAC channel for the Drone Module in the Communications Plan I205.

Provide Plans Section with the 'UAS 1 Page Safety Sheet' for inclusion in the IAP. Doing this can educate firefighters about the sights/sounds a drone can make (it is not a swarm of bees), and the potential hazards that drones can bring (spinning propellers, LIPO battery fires).

Be self-sufficient with regards to generator power, tools, and even food/water for the first 72 hours.

Know how 'camp life' works on an incident. In our opinion, a person with no field/camp experience would be a burden to the team. At least pairing/preparing a newcomer is in order to help function effectively.

Experienced Wildland Firefighters as UAS Pilots – having experienced firefighters is an obvious advantage to the incident. Understanding the ICS command structure, establishing LCES, communicating on the radio system, recognizing and mitigating fire environment hazards, understanding tactics & trigger points when performing missions as directed by Operations. Also, experienced people teach newcomers. You would not place a new firefighter as a lookout, same principle applies here.

author Mike Fontenot - 2005 & 2017

Small Incident Organization Structure (Type 3) UAS Team (Drone Module / DRONE MOD) attached to Operations for a small incident. For Luera it was a Type 3 organization, and having the Drone Mod report directly to Operations (Burn Boss/Ops Chief) facilitated communications and clarity of mission. In this way the Ops Chief could assign the Drone Mod to specific divisions for desired missions. Then Drone Mod could tie in directly with that Division.

Larger Incident Organization Structure (Type 1 or 2) – prior discussions led to placing the Drone Mod under the Situation Unit. But after this incident I question that structure. The need for specific mission requests comes from Operations, and being tied directly to them would facilitate that timely communication. I suspect adding the extra layer of Plans/Situation Unit would impede communicated needs and Drone Mod mission timeliness and clarity. The Situation Unit could still request specific

missions/data from the Drone Mod if necessary. I believe the missions from the Situation Unit would be less time-critical than from Operations.

Need for more than one Drone Module – Even on Luera TREX, a Type 3 incident, there was a need for numerous drone/aircraft to fly in different locations. This breakdown of flights could include:

1. Planned flights for Operations – discussed & briefed in morning (find access, locate flank, etc)
2. Immediate Need flights for Operations – basically 'on call' type of flights as directed by Operations (check for spots, did fire jump a road, etc)
3. Planned flights from Situation Unit – flights that assist a FOBS or Lookout (how many homes threatened, what is a good division break, etc)

UAS Education – in some cases the Ops Chief did not know what to request from the Drone Mod simply because the technology is so new. A document & discussion outlining the Drone Mod capabilities would be useful for all parties. Possible UAS demonstrations at ICP with the Ops Chief and Divisions would be useful. During one AAR the Ops Chief said: "in five years we will all be using drones on wildfire, we're just not sure what that is going to look like". Well said!

LOGISTICS & EQUIPMENT NOTES

Tablet/IPad – use replaceable screen protectors. Hot ash will pit the screens, have an easy-to-replace protector. We all used IPad/IOS devices for flying DJI drones. Have a way to shield from glare.

Tablet/Transmitter Neck Strap – during long days of flying it will be tiring to hold the transmitter/tablet combination. Have a way to attach a neck strap to relieve strain. Or some other way to support the weight of these components. Most prior flight experience for our pilots did NOT include hours upon hours of field flying. Fatigue can take a toll, be ready for this.

Internet DISCONNECTED Environment – Be able to operate in a remote area with no cell/data coverage. This means using all of your flight and mapping software in this disconnected way. In some cases you can cache your maps for different software BEFORE you leave the Internet-connected world. Research/test your software to find out.

Field Generator (field & camp) – a small, portable gas generator is a MUST HAVE for recharging batteries in the field. Examples include: Harbor Freight Predator 2000, Honda EU2000. These are also very quiet.

Equipment Cases – every aircraft and support components should be in a waterproof, dustproof hard case. Simply put, transportation of unprotected equipment to/from the field can destroy it. You must take steps to protect the equipment.

Field DRONE MOD TV Set & WIFI– having a field TV set great facilitates Operations being able to view your flights in real-time. Much more convenient that having them try to look over the Pilot's shoulder at the IPad screen. Using an HDMI-out cable, or WIFI Miracast dongle (@ 5.8 Ghz) that can also wirelessly link the RC Transmitter to the TV set. The only down-side we found with this arrangement is that the built-in Screen Recorder function of Litchi/Autopilot on IOS do not work when screen mirroring is enabled on the IPad. This is an Apple/IOS limitation.

Field of View (FOV) – of various camera. Different lenses/cameras provide different FOV. This should be explained to anyone viewing post-flight view, real-time TV set. Especially when your visual vs. thermal camera have widely different FOV.

Power for Components – IPads, TV sets, RC Controllers/Transmitters – have a way to provide field power to all of these. USB power sticks, generator.

SD Cards – have enough SD Cards to swap out for flights in the field. Best would be to download the video from a flight AFTER EACH FLIGHT. If you do this you will be assured of at least retaining the flight video you have taken in case the aircraft crashes on the next flight.

Common Labeling System – should be established beforehand. And in use by the entire Drone Module. Numerous videos are going to be recorded over a number of days. Being able to quickly and efficiently sort through these is essential.

Video Playback in the Field – have a way to play back your flight videos in the field. On your IPad or TV set. Find an easy way to view the video on the Micro SD Card directly.

Battery Chargers – multi-battery chargers are necessary to efficiently keep multiple aircraft batteries charged and flying in the field. Often the TV set is sitting on the back of a UTV or truck, with the Generator/Charger located some distance away for noise reduction/location in a shaded area/etc. Position the battery charger/generator in shade. Hot batteries must cool before charging.

Battery Management – have enough field batteries to keep flying AND rotate them through the charging process. Rough estimate is: 1 battery = 15 minutes flying, having 6 to 10 batteries will allow continuous flights with recharges ongoing. Be aware that a HOT BATTERY will not immediately accept a charge, and must be left to cool before being placed on the charger. Having these in a shaded area will facilitate this cooling.

Emergency Battery Concept – we believe there should be a 'standby/emergency battery' carried for each aircraft. If an emergency of some kind arises, having that 'ready to go' battery to fulfill that mission could be a lifesaver (ex: Ops Chief calls to say 'sawyer in Div A has cut his leg. Find me a good place to cut an LZ for medivac!')

ICP/Camp– have a place to work out of the weather (rain/sun/wind). You will be processing data/video files to your computer in the evenings. You cannot do that in your tent…… easily.

Camp Test Flights – find a suitable area in/near camp that you can conduct test flights.

Go Anywhere Capability – for a Drone Module to be successful we need to be ready to 'go anywhere'. Including getting on a helicopter. Keep in mind how your aircraft equipment is stored/carried, and how those batteries would be carried in a protected way onto a helicopter.

Small Dry-Erase 'Flight Board'– a small dry erase board with labels: Date/Time, Location, Aircraft, Mission. Before each flight fill in the details and hold this in front of the aircraft camera. Record a short video of this information. This method allows you to separate each flight at the end of the day, when you are sorting through all of the video/flight files found on the SD Cards. This is in addition to your own flight log notes.

MISSIONS SUITABLE FOR SMALL UAS

Field Accessibility & Route Reconnaissance - use the UAS to fly in search of specific access to areas of the fire. Operations often needs to drive to work locations in rough terrain with no clear roads. Being able to get into the air and let Operations view this recon flight on a field TV can save time and make the process safer by NOT having firefighters do this exploration in unknown terrain. This can be a critical life-safety mission.

Division Break Determination – aerial recon to help Operations determine suitable division breaks by finding geographic/terrain features that facilitate that separation of Divisions, and they work they do. Specifically relaying GPS coordinates (via Litchi) to Operations on the ground, these coordinates can be cross-checked via Avenza Maps right on the ground by Ops.

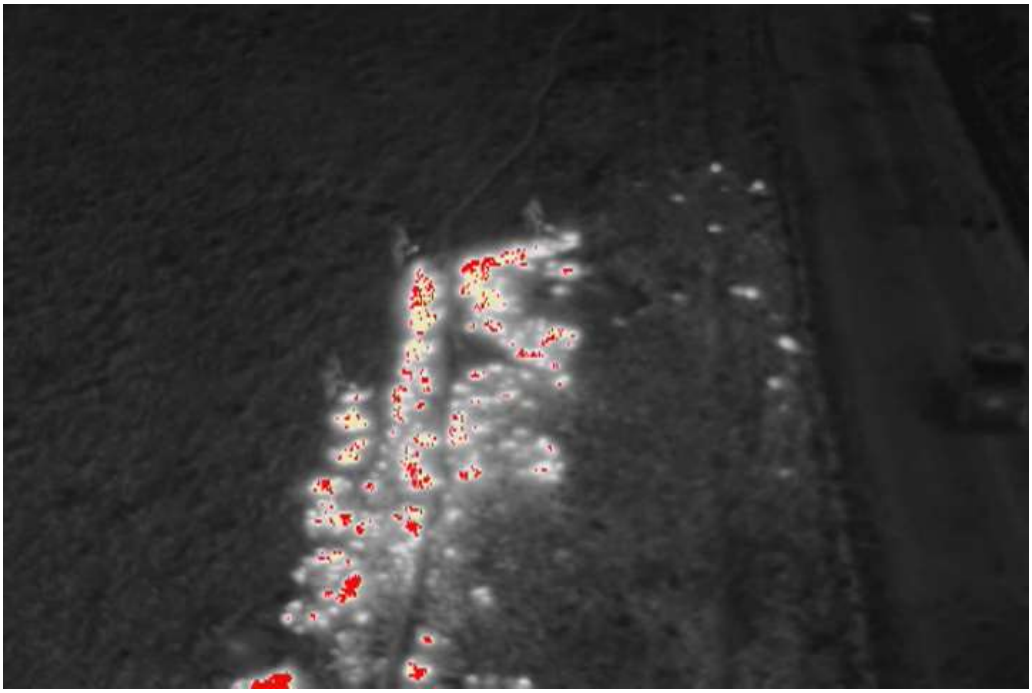
Division break along natural features and old trail/road

Fire Front Movement/Tracking in relation to Resources – monitoring the flame front movement towards resources/assets can help Operations decisions making. Knowing how far the flame front is from important assets can facilitate quick decision making. Examples: Flame front distance from parked Engines – by monitoring this on a regular basis you can determine how fast the flame front is moving.

Also being able to visualize multiple flame fronts in relation to each other helped Operations make decisions about where to quickly deploy resources.

Training Feedback – During TREX and other training events, aerial video/photos of the exercise can be used to further educate firefighters on the effectiveness of their techniques.

FLIR of drip torches pattern training



Patrolling Fire Line - flight of the UAS along a fire line perimeter can be used to monitor spots outside the line. To do this well you may need two UAS: so that you can always have an aircraft in flight, you would swap out UAS based on battery life. Also know that this kind of flying can be mentally taxing over time. Concentration of flying for long periods while watching a relatively tiny screen is mentally

exhausting. Using FLIR and Visual camera would be a productive combination: being able to use FLIR to look outside the line for hot spots, and having the visible camera to facilitate actual flying and recognition of a specific location/landscape features. This is an area that could be improved using machine vision to detect hot spots. In practical terms, you can fly your fire perimeter and drop waypoints. Then use that waypoint mission to repeat the flight over and over.

Assist FOBS/Lookout – in scouting suitable locations for the Lookout to position themselves. This save lots of hiking time and potential dead ends. It also gives the Drone Mod an idea of suitable launch sites away from smoke, and with good line-of-site for the current mission. The FOBS could also co-locate with the UAS and view flight video on the field TV set. Even direct the UAS for flights to specific locations. The UAS can also assist the Lookout at determining sky conditions when the Lookout location is obscured by smoke. By flying above/or to the side of smoke we can see the distant clouds and make a determination regarding cumulus build up, etc.

Fire Effect Monitoring – flying a specific area and taking photos (either manually or via survey – Map Pilot) can give Fire Ecologists an idea of percentage burned in specific areas.

Small Area Mapping – for determining the area burned, as in a black line or burn-out operation, flying the UAS along the perimeter can give an accurate area measurement without putting people at risk, normally done by walking that perimeter. The UAS can probably be flown faster than it can be walked, saving time.

Smoke Dispersion Monitoring – the UAS can be flown at altitude and visualize the smoke column dispersion given the current winds and terrain.

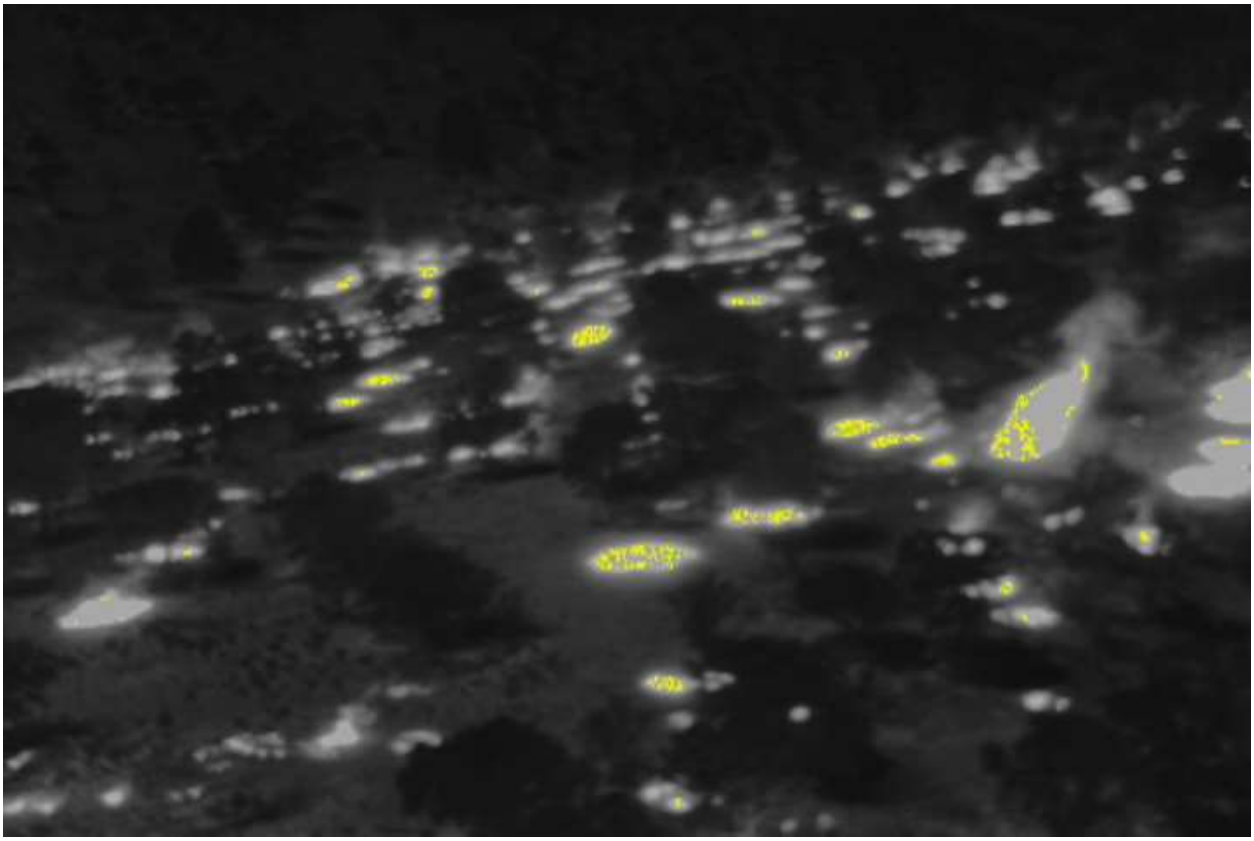
Search for livestock – ranchers near the incident may have released livestock, and might need assistance finding them. UAS can be tasked to assist these ranchers, while not taking personnel away from Operations resources/crews.

ICP/Base Camp Map – UAS can take aerial photos of the camp, which could then be used to provide a 'camp map' in the IAP.

Keystone Fire – Base Camp at Cinnabar Park, WY – July 2017

THERMAL / FLIR USE – DJI XT THERMAL CAMERA on INSPIRE 1

Overall FLIR Comments – While FLIR was useful at detecting 'hot spots', the situation of having a lot of heat on the ground overwhelmed the FLIR sensor and made reasonable analysis almost impossible.



Finding a Single Hot Spot – picking out a single hot spot from a relatively cool background was something FLIR was good at.

FLIR Camera FOV vs Visible Camera – The narrow FOV of the XT camera (19mm) made it difficult to fly the aircraft accurately. Especially when the visible camera was a much wider FOV. A better solution would include dual camera capability: visible and FLIR side-by-side. With both cameras of approximately the same FOV. This way you can avoid the large perspective shift when switching between the two cameras.

FLIR & Visible Camera Combination – see above, this feature would be an outstanding one, and make flying/searching/analyzing much easier and productive.

Suggested Missions for FLIR – picking out a single hot tree in a cool background, as with a lighting strike in a remote location. Searching for hot spots outside of the fire line where no other heat exists. This could be a fire line patrol with the camera focused well outside the line. Combined with a waypoint mission, this could be very useful.

MISSIONS NOT SUCCESSFUL WITH SMALL UAS

Large scale mapping missions, an example includes finding the fire perimeter of the overall incident. Due to line-of-sight limitation, potential smoke, relatively short battery life, using small UAS to fly these large geographic missions are not efficient. Or maybe not even possible. Under the limitations listed, to try and fly this type of mission would require relocation many times, in potentially inaccessible terrain. Where this mapping could work would be in a relatively small area in specific section of the fire.

Searching for Firefighters on the ground – While this may be possible in some situation, we found this was not successful for several reasons, even when the firefighter on the ground gave the UAS pilot a specific GPS coordinate. The terrain itself is often the same color as the firefighter uniform, green and yellow. Thus the firefighter is essentially camouflaged. If the cameras used are wide angle, without being able to get close to the terrain due to potential crash into trees or mountainous terrain, it is very hard to pick out the small person in the wide field of view.

We discussed the possibility of adding a strobe to a helmet, this needs more testing. Also we experimented using a mirror flash to get the attention of the flying drone. This was not very successful, mainly due to the narrow field of view of the drone camera. The mirror required extremely precise pointing to be seen by the drone camera. Very difficult to consistently achieve.

LIMITATION OF UAS THEMSELVES, AND FAA REGULATIONS

Battery Life – clearly being able to stay in the air longer would increase the usefulness of UAS missions. This would also reduce the need to manage battery recharges in the field. Mitigating this by having many charged batteries, and a way to keep batteries charged in the field is useful.

Wind Capability – Producing stable video/photos in higher winds would be a plus. While at Luera TREX we did not suffer excessively high winds (over 20 mph), but having a wider operational wind range would increase usefulness.

Limited Software Capability – we used IOS-based software, and none of these would allow the direct input of a GPS coordinate. Then have the drone fly to that coordinate. That would be an incredibly useful feature.

Flying in/around Smoke – This may be obvious but there was a lot of smoke in the air once burning started. We were able to work around much of this due to the location of actual burning material vs. launch and observation locations of the drones. Once burning started it often obscured specific geographic area while leaving other locations clear. We sought out those clear locations to launch from. And subsequently observe the flight of the drone itself.

Strobes to Aid Visual Orientation – using strobes on these aircraft did aid in providing better visualization of the flying aircraft. Often a dark aircraft would disappear when flying up a dark, burned mountain side. Having strobes on four sides would definitely improve this situation.

Also, asking a firefighter on the ground to give the drone pilot 'orientation' information was challenging. The normal method of telling a helicopter 'we are off your 1000' simply does not work for a drone. The firefighter cannot adequately see the 'drone nose', to make this orientation statement. We developed a method of 'flying forward'. In this way firefighters could orient and give useful position feedback.

Line-of-Sight Limitation – The FAA limitation of line-of-sight / LOS is a fairly severe restriction to full usefulness of UAS in this specific wildland environment. Often a day would start with little to no smoke, but get progressively smokier with time. This required a reposition of the UAS launch site to maintain LOS. In one case a dog-leg canyon required the Visual Observer/firefighter to walk out into a 'hot zone' of fire to maintain LOS with the UAS, and verbally relay information to the pilot standing some feet away. Because the Pilot could actually fly above the canyon and see terrain quite well, the VO was at some risk by their positional line-of-sight requirement, and provided little safety increase.

The reality of the situation during this incident was:

There were no other air resources flying on this fire, so a deconflict of manned aircraft was unnecessary

Multiple simultaneous UAS in the air were co-located in terms of Pilots and launch locations, and were easily able to deconflict by direct communication.

If any non-incident aircraft were to stray into the incident area the chance of them flying at 400' AGL or below were virtually non-existent due to the smoke and mountainous terrain. No sane manned aircraft pilot would venture into such dangerous conditions.

All firefighters on this incident were briefed regarding the UAS operations, and wore PPE, and were considered 'participants' to this UAS operation.

Every effort was make to not fly directly over firefighters.

The location of the incident was so remote there were no 'heavily trafficked roadways' to fly over.

The technical capabilities of the UAS we used were tested at some distances up to 5000' (strobes facilitated these LOS flights) from the controller with no degradation of flight control or video signal. Clearly the technology supported BVLOS flights.

This opinion about BVLOS flights will not be popular with the FAA, but truly considering the situation in the wildland fire environment, and the benefits of life safety this tool can provide, we strongly urge the FAA to take a more realistic approach in the wildland environment. One method would be the timely issue of an emergency waiver specific to an incident. The FAA is notorious for taking an unreasonable amount of time to issue an emergency waiver, doing so only long after the actual event has passed.

Given this reality, flying BVLOS would have been a very low risk and highly useful endeavor. No personnel or manned aircraft would have been put at risk. Only the UAS itself would have been risked if it crashed in the rough terrain of this incident. Risk of fire from a crash was very low, since most of the fire ground was already burning.

If there were manned aircraft as a part of the incident, the UAS team would communicate with Air Attack / Helibase, to call and request a flight centered on a specific GPS coordinate/launch location, out to 1 mile radius and up to 400' AGL of the highest terrain in that 1 mile radius. Air Ops does this on a regular basis and understands the process, and manned aircraft know to stay clear of this flight area.

Q & A OF INCIDENT PERSONNEL

Our intent is to produce a survey for Operations personnel assigned to this incident, with questions specific to the use of UAS.

FLIGHT-SPECIFIC NOTES

Fire Progression in Bathtub Basin/Three Fingered Canyon - Recon

'Bathtub Basin' area – 3 fingered canyon. We flew numerous missions with Burn Boss/t to evaluate the burned area, and fire spread within these canyons. Launching at the base of this '3 fingers', pilots had a direct LOS view up each canyon, and were able to provide real-time reconnaissance to Operations.

Division Break Recon

Search for suitable natural features from which to divide the incident into various Divisions.

UTV Access Route Recon – Using the drones to scout UTV access to different areas of the fire can save time, wear and tear on equipment, and reduce the driving risk for responders.

Luera – north black lining operations

MISSION: a. Primary mission on this day was to monitor and patrol the black lining operations on the north side of Luera Peak. Using the saddle between DP 5 and 6, follow the burn crew to the west as they created a black lined area between the saddle and DP 6.

b. Assist FOBS/Lookout with monitoring of smoke column produced, and how that smoke was spreading aloft. Assist FOBS with finding him a suitable location(s) to observe the black lining operation. That meant finding an initial position, and a later position as some increased due to burning operations.

c. Measure area burned by the black lining operations at end of day. ANSWER: 4.3 acres (approx. 1900' x 100' – I flew a Litchi waypoint mission, then later downloaded the DAT file using DJI Assistant 2. Converted that to a KML and imported to GE. Used GE to draw a polygon around the flight track to measure acreage.

POSSIBLE SOLUTIONS TO:

Patrol for hot spots outside containment lines: - fly the UAS with a pattern that follows the entire burn unit outline, have a FLIR camera focused on that area outside the line. Along with some thermal/image detection software, have the drone alert/stop when it 'sees' a potential hot spot (away from the major hot area of the black/burned area inside containment lines.

Luera Peak Radio Tower Road Recon Flight

Flight video board used, Litchi used.

0930 arrived (split road at DP 4) - Drove to a suitable launch early in day, before heating would ignite more fuel. Already hill was smoking and a lot of fire had come down from the top of the peak, from firing operations the day before.

Flight 1 – Launch location found, LCES established. Flew to closely follow the road to the top, goal is to examine visually the road for trees which had fallen and were potentially blocking access, up to the radio tower. Use of the drone vs people was a specific life-safety mission, time critical.

I found two trees down on the road, with one being about ¾ of the way across. Recorded the GPS coordinates of that (via Litchi) and relayed to Burn Boss Trainee.

I was able to follow the road to a split, and was not sure which way to proceed (prior examination of GE could assist). Called Burn Boss on radio to get clarity. This took precious time. Marked the road fork with a Litchi waypoint.

Took the left fork and flew down that road. Stayed high and observed a lot of smoke and some fire on top to the south. At that point I had to return to launch due to low battery.

Flight 2 – we moved a bit further up the mountain on the road and found another launch point. Note that the road was rougher at this point, and we passed a long stretch of green, unburned fuel on either side of the road. We reestablished LCES in this new launch location with plenty of good black across the road and down the slope.

I launched and flew directly to the road fork waypoint, then began moving toward the radio tower. It turned out the tower was just a bit further than I had flown during flight 1. I was able to observe the road fully and found no obstructions in this section. Still a lot of smoke to the south, with more smoke and flame increasing as the day heated up. Relayed observations to Burn Boss/t.

After this flight it took 30 minutes to drive from this launch location to DP 4.

DEFINITIONS

Android – computer operating system

AGL – above ground level

BVLOS – beyond visual line-of-sight

COMT – Communications Technician

COML – Communications Unit Leader

CSU – Colorado State University

FOV – field of view

IOS – Apple computer operating system for tablets & phones

LOS – line of sight

MEDL – Medical Unit Leader

VO – Visual observer

VTOL – vertical take-off and landing