A White Paper

The Memorial Day Floods
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Wimberley, Texas

Using Unmanned Aerial Systems During a Natural Disaster in Texas

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White Paper Objective

This White Paper will describe the 2015 Wimberley Flood, and the experiences observed first-hand by members of the Wimberley Fire Department's aviation unit and members of the Austin Fire Department's Robotic Emergency Deployment (RED) Team. Lessons learned from this emergency response will reflect specific experiences from the deployment of Unmanned Aerial Systems (UASs). It is the hope that future UAS emergency responses will benefit from and be enhanced by these experiences.

This paper covers the various tasks and missions asked of the UASs and emphasizes potential uses to improve utilization of these systems in future events of this magnitude. Included are support requirements from the Federal Aviation Administration (FAA) and local agencies in order to institute a temporary flight restriction (TFR) for safe, thoughtful integration with manned assets, as well as interactions and responses from private citizens and property owners, and other factual data.

The obstacles chronicled herein are based on first-hand participation by the authors in their roles as Pilot in Command (PIC), Pilot at Controls (PAC), and Visual Observer(s) (VO), collectively known as the "Flight Crew."

It should be stated that the Flight Crew adhered to the "First Protocol of Unmanned Aircraft Use" during this entire scenario, which dictates that unmanned aircraft (UA) will ALWAYS defer to the manned asset and give way, to the point of disposing of the UA in the most expeditious manner necessary to adhere to the protocol.

Introduction to the Incident

The 2015 Texas Memorial Day Floods are now being labeled a "millennial flood"; they surpassed the standard of what would be considered the severest flood that could occur in a 500-year span. The Blanco River, and its upstream wet and dry creeks, became engorged with rainwater from a heavy, slow-moving downpour. On the Blanco River in Wimberley, water rose rapidly, reaching what was described by first-hand observers as a "wall of water" estimated to be 40 feet high. This gives the small town of Wimberley the dubious honor of playing host to the highest flood--from normal river flow stages to peak flood levels—in all of the United States. It is estimated that at peak flood level, water was flowing at 230,000 cubic feet per second, nearly twice the flow of Niagara Falls. More than 350 homes were destroyed, and more than twice that many residences required demolition due to flood damage. Tragically, 12 people lost their lives, including one family whose vacation home was swept away, floating down the river until smashing into the Ranch Road 12 Bridge that leads into Wimberley.

Warnings began on the evening of Saturday, May 23 as reports came from upstream that the Blanco River was beginning to flood. The Hays County Emergency Management office initiated the reverse 911 call system to warn residents along the river of the approaching danger. Wimberley Fire Department swift water teams

deployed to begin door-to-door warnings to those individuals staying in vacation homes along the river; there was a potential that many of them did not have landline phones and could not be contacted via reverse 911. The first calls for help came into the station from Dispatch at approximately 9:30 p.m.. By 5:00 a.m. the following morning, the Wimberley Fire Department had received nearly 100 calls for emergency assistance, overwhelming their resources. Mutual Aid assistance was requested from surrounding community swift water response teams, including the City of San Marcos.

An Incident Command was established at Wimberley's Central Fire Station to coordinate and manage in-bound resources that had been requested. By daylight on Sunday, May 24, the National Guard was contacted to assist in water extractions using two Blackhawk helicopters. Resources from Hays County and other State agencies began filtering into the scene, but were hampered by high water and damage done to the main bridge into Wimberley. All resources had to take alternate routes that were longer and subjected to their own flooding.

Communications became the biggest initial issue as mainlines for telephone, internet, and even power were severed by the debris-filled flood waters. Many officials were relegated to using cell phone text messages to request help and attempt to detail situations in a rapidly evolving scene. Voice communication was limited to very short-range tactical radios. Assistance to re-gain the local communication network was delayed by repair technicians' inability to reach their destinations.

The event could be categorized in six major phases:
1 – Initial event
2 – Response/Life saving
3 – Damage assessment
4 – Mitigation
5 – Recovery
6 – Preventative planning

The most unusual aspect to this event evolved from a vacationing family that was swept away in a home during the initial flood of Saturday night. Other members of the family mustered an effort to launch a private search for their loved ones. While this sounds benign from an Incident Command standpoint, it had a tremendous effect on operations because of the sheer numbers of people, material, and assets that came to help them. On flood + day two, they had established a reception center at a local church and had already received 400 volunteers. Included with this was the arrival of up to six Robinson (not related to the author) R-44 helicopters, owned by private parties, intending to operate in the confines of the disaster zone. By flood +day six, this privately funded and managed search effort had more than 1,000 civilian volunteers, dog teams, and other specialists, while the number of private helicopters had risen to 14. This is an unprecedented and unexpected factor for any incident commander to contend with, especially when none of the private parties were familiar with National Incident Management System (NIMS) protocols or Incident Command procedures.

Airspace Activity – First on the Scene

As stated, the first aircraft request by Incident Command was for manned helicopters to assist in the extraction of people trapped on their rooftops by the rising floodwaters. Blackhawks are very capable, all-weather helicopters; two were made immediately available to the Wimberley Valley Incident Command. The weather conditions Sunday morning included rain bands, some wind, and cloud cover ceilings at or below 400' altitude above ground level (AGL). Each helicopter methodically searched up and down the river until they spotted flood victims needing to be extracted. While the two helicopters were very well coordinated by their respective pilots in command, there is no question that an unmanned aircraft could have been deployed faster even in this very early stage of the flood event. The most appropriate unmanned tool for use at this time would consist of several multi-rotor vertical takeoff and land (VTOL) aircraft. The range of this type of unmanned aircraft is rather short, but in a 15- minute deployment, they can scout out ahead of the manned aircraft. Upon locating flood victims, the coordinates could have been relayed to the manned assets, reducing the time required for the manned asset to visibly "search" for the next victims requiring assistance. It should be noted that there were no other aircraft, civilian or otherwise, in the immediate area because of weather conditions. This scenario would represent the fewest challenges for airspace de-confliction, as a trained unmanned aerial flight crew would not rely so much upon radio communications as they would their own hearing and visual observers to detect an approaching heavy helicopter. Unmanned aerial flight crew members utilize short-range, handheld radios to maintain communication during a mission. To enhance the safety of operating during this scenario, it is a recommendation that every unmanned aerial flight crew is equipped with a ground-to-air aviation radio and, if possible, tactical communications back to Incident Command and the Air Asset Manager.

Regulatory Considerations – Federal Aviation Administration (FAA)- Applying for the Emergency Certificate of Authorization (eCOA)

The current regulatory criteria for the use of unmanned aircraft requires any agency that wishes to utilize UA have a standing Certificate of Authorization (COA). A Certificate of Authorization is specific to the type of aircraft that may be utilized and the area in which it operates. Prior to this event occurring, the Wimberley Fire Department had a Certificate of Authorization (issued in December 2014) for the Spectra flying wing (a four-foot, five-pound fixed wing unmanned aerial vehicle), with an operational area of two nautical miles from the Winn Ranch Airport (closed) located in Wimberley. To operate outside these confines, the Wimberley Fire Department was required to submit an Emergency Certificate of Authorization (eCOA) application to the Federal Aviation Administration (FAA) for approval. The eCOA contains all the parameters approved by the FAA under the original application with the inclusion of additional areas of flight operations or conditions. This application is submitted in writing, along with a statement of need, to the Washington D.C. Office of the Air Traffic Control (ATC) for Risk Assessment. Changes may be made to the application by ATC prior to the application progressing to the local Flight Service District Office (FSDO) for coordination and final

approval. The initial challenges in this process is that 1) it began after-hours, 2) was on a holiday weekend and 3) communications were compromised by the flood to the point whereby only the occasional voice contact and text message could be made via cell phone. During this event, adhering to the formal FAA process was a technical impossibility without undue delays in the issuance of the eCOA. To their credit, the on-call individual at Air Traffic Control accepted the initial request by the Wimberley Fire Department's unmanned aerial team pilot using a simple text message and referencing the existing COA number. The Emergency Certificate of Authorization required minimal adjustments, again via text, and the FAA strongly recommended a TFR area be established to protect the airspace over the search area.

Control of Air Space - How to Manage a Temporary Flight Restriction (TFR) Area and Why

A TFR is used to protect a portion of the National Air Space (NAS) under circumstances that could endanger general aviation or the operations being conducted in a defined area.

Flood rescue operations performed by National Guard Blackhawks began early Sunday morning following the overnight flooding. These aircraft operated safely in the area. All resources were focused on locating and rescuing the individuals known to be, or presumed to be, in the water.

Texas Task Force 1 (TXTF1) arrived to begin search efforts in coordination with Incident Command. At the same time, the private search effort (see page 7) was started by an out-of-town family. At Incident Command, the Wimberley unmanned aerial flight crew was on site, but not deployed. A TFR was in place so that the Blackhawks could operate, but was cancelled at the time of their departure.

Additionally, Texas Search and Rescue (TEXSAR), an all-volunteer search organization, arrived to augment TXTF1. TEXSAR was soon deployed to Blanco to assist in the Blanco County search and rescue effort. During the next few days, the airspace became increasingly crowded as STAR Flight, Texas State Parks and Wildlife, Blackhawks, and other agency-manned assets entered the disaster zone.

On day two, the Wimberley Fire Department's unmanned aerial team could not deploy in the Wimberley area, despite requesting and receiving the approved eCOA, as the airspace was increasingly occupied by manned aircraft.

Communication was soon established between the Wimberley Fire Department and the Blanco County Incident Command. Blanco County requested assistance from the Wimberley Fire Department's unmanned aerial team, and they were subsequently deployed on day three. Wimberley Fire Department's unmanned aerial team determined that Blanco County would require a separate TFR area to protect all air operations taking place in that community. Blanco requested and received a TFR for the

Blanco River area. Geographically, Blanco County is located upstream and north of Wimberley, and had eight people confirmed missing. Primary search activities for those victims were shared among the Blanco Valley Fire Department/Emergency Management office, TEXSAR, and the Wimberley Fire Department's unmanned aviation unit.

Houston Center is the office of primary responsibility for the issuance of the TFRs and also issues Notice to Airmen (NOTAM), informing pilots of hazards. Terminal Radar Approach Control Facilities (TRACON) in Austin and San Antonio were notified of the operations for consideration of routing traffic around the area. With the Blanco Valley TFR area established, the Point of Contact (POC) for all manned and unmanned aircraft in this area was Gene Robinson of the Wimberley Fire Department's aviation unit. The initial unmanned flight crew was Gene Robinson (WFD) as PIC, Coitt Kessler (Austin FD RED Team) as VO, and Andrew Reyes (AFD RED TEAM) as PAC.

On flood + 5 day, the Wimberley Fire Department submitted the request for TFRs for an initial five-mile area. The FAA expanded that area to encompass a 13-mile area along the Blanco River in the Wimberley Valley. Gene Robinson was requested by the Incident Commander to assume the air operations position for the Wimberley restricted flight airspace. Air operations responsibilities included acting as the point of contact for all air-related operations and management of airspace de-confliction.

Communication of All Air Assets on Scene – De-conflicting Airspace

Throughout the flood response, the Wimberley Valley Incident Command benefited and operated out of a mobile incident command center; it provided a secure workspace with conferencing capabilities, and a full complement of computers and communication equipment. Initially, Air Operations unsuccessfully attempted to communicate ground-to-air using hand-held radios, but this failed due to low broadcasting power and the need for "line of sight." A stronger UHF base station was provided by the San Marcos Airport, although it had no antenna. The mobile incident command center had a mast with an antenna array that had the capability of transmitting on the aviation frequencies and was "patched in" to the communications array. While this was not the optimum configuration, it did provide incident command communications for the largest part of the Wimberley Valley area where the bulk of the aviation activity was occurring. Aircraft that entered the temporary flight restriction (TFR) area and were participating in the emergency response were advised to monitor the open frequency of 123.025mhz. Aircraft were instructed to "blind call" when entering the TFR zone and to also announce when within two miles of the search area on an inbound course. For the most part, the aircrews were responsible for traffic de-confliction much the same as operating around a municipal airport with no tower. The Incident Command Air Operations advised aircraft of other ongoing flight operations and advised when to steer clear of areas that had sensitive search operations underway. It should be noted that even with these efforts, state helicopters reported several instances where communications/contact could not be

made with Incident Command. There were four instances of non-cooperative aircraft during the flood response:

- R44 helicopter (# 1) flying low over an active canine search with the incident commander present;
- Unauthorized unmanned aircraft operating on behalf of volunteer group;
- State rotary aircraft entered into unmanned aircraft operational airspace unannounced; and
- R44 helicopter (# 2) flying low through unmanned aircraft operational airspace unannounced.

R44 helicopter (#1) and the unmanned aircrew lost privileges to operate within the TFR, and Air Operations asked both units to leave the area of operations. The state rotary aircraft was advised of infraction and was permitted to stay based on Air Operations judgment. The R44 helicopter (# 2) was unidentified and no further actions were able to be taken.

Recommendation:

- **A TFR and positive control of all air operations must be established at the outset of a disaster response. The Air Operations branch must be divided into both manned and unmanned groups. De-confliction of airspace can be accomplished by separations that include vertical distance, horizontal distance, or by timing of entering and exiting aircraft. All aircraft must be able to communicate with both ground-based air and air-to-air operations.**
- **Air Operations must be assigned at outset of response.**
- **All air assets must communicate with Incident Command's Air Operations; there can be no rogue units.**

Communications Between Air Assets, Incident Command and Volunteer Search Teams

The Wimberley flood response presented an extraordinary set of difficulties with two distinct bases of operations. While Incident Command was in charge of all authorized responders (sworn and unsworn), including TEXSAR and TXTF1, a volunteer civilian search effort was driven by a non-local, influential family who was unfamiliar with emergency operations or procedures in Hays County. The civilian volunteers were comprised of both air and ground resources. A liaison between the civilian volunteers and Wimberley Valley Incident Command was established but proved ineffective. Communications between the authorized responders and the volunteer effort were sporadic and remained poor throughout the event, despite repeated efforts from the IC.

At one point, volunteer air assets numbered as high as 16 full-scale, manned aircraft which were used for recon, search, and shuttling of personnel. The level of pilot qualifications varied from sport pilots that operate over game ranches to commercial flight instructors. The volunteer aircraft were solely dedicated to the volunteer search effort, and no volunteer aircraft were used by Wimberley Incident Command to perform searches, recon, and or any other task. All authorized air operations were provided either by the Wimberley unmanned Air Unit and/or State resources.

As TXTF1 concluded their operations, the temporary flight restriction issued for them was cancelled. While initially attempting to submit an application for a temporary flight restriction, the Wimberley Fire unmanned aviation unit was advised by the Emergency Operations Center in Hays County that an additional TFR would not be required. However, the number of aircraft flying without air control, in a small stretch of the Blanco River, was a concern to FAA staff in Washington, DC who were wary of the potential risk. The FAA worked through the night and into the next morning to assist and support the Wimberley Fire Department to secure a safe flying environment for all aircraft.

While operating in Wimberley, communications—both tactical and operational—were directed through Incident Command then relayed to authorized search personnel. However, in Blanco County the communications were limited, while performing primary searches. Poor cell coverage dictated that direct person-to-person communication between the unmanned aerial unit and ground search teams was required. When communication either by cell or radio was available, aerial search findings were communicated directly to Blanco County Incident Command.

Recommendation:

- **Incident Command must oversee the entire emergency response and if a separate volunteer work group is established, then a liaison between the two must be established immediately.**
- **Coordination of all resources and communication between the authorized responders and volunteer groups must exist and be documented.**

- **All air resources (manned and unmanned) must coordinate with Incident Command through the Air Operations branch.**

Transitioning Modes – Search, Recovery, and Mapping

The Wimberley unmanned aviation unit performed three different operations throughout the flood. The first involved performing a primary search in Blanco County; the second consisted of performing secondary searches in Wimberley; and the third was mapping a seven-mile stretch of the Wimberley Valley. All transitional operations were closely coordinated with Incident Command. The daily Incident Action Plan (IAP) briefing provided goals and direction for the unmanned unit.

All aerial photography taken in support of an emergency response should be accountable. It is important that sensitive imagery is not released or distributed without proper authority. Data gathered during both the search and recovery efforts required great attention to detail; personnel were required to review each image and identify points of interest (POI) that required further action. Throughout the event, the ground search teams found it impossible to keep pace with the unmanned unit. A list of geo-referenced points of interest was maintained and provided when requested. Once the search and recovery work was completed, Incident Command requested the mapping of the Blanco River to determine locations of debris. Unmanned aircraft were then assigned to begin mapping operations upstream of Wimberley for the damage assessment.

The unmanned aviation unit spent a total of four days mapping several areas of importance along the Blanco River. A seven- mile continuous length of Wimberley Valley took approximately two days. An additional day was required for a re-shoot of an area inadequately imaged. A total of 780 images were collected in the Wimberley area along with another 590 images taken in Blanco County. Images were processed to produce a large ortho-mosaic image with an effective ground resolution of 1.77”. The results can be viewed online at http://magic.csr.utexas.edu/public/views/ then select “To Imagery” then “UAV Blanco River.”

Recommendation:

- **Determine if the local authority has the capability to store data and if any policy is in place to ensure chain of custody.**
- **Personnel and equipment must be available to review imagery captured in the field. Once a quick field review has been completed and initial information has been provided, the search team then sends that data to a central location for a secondary, more thorough review.**

Communication Difficulties for Unmanned Aerial Teams

During the flood responses, unmanned aerial teams experienced difficulties with communications amongst themselves, incident command, search teams, air assets, and control organizations that included the FAA flight center and TRACON. Early in the event, all cellular and data service was lost due to both physical breakdown of the cellular networks and the overwhelming of the system. This fact made the filing of an eCOA very challenging and required all documentation to be sent through text messaging when service permitted. Once service was re-established, cell phones were a great tool but could not be depended upon due to poor cell coverage in the rural areas. Tactical radios belonging to local authorities were a great resource when available but could not be counted on due to short supply.

Recommendation:

- **At a minimum, all unmanned flight teams must possess a handheld transceiver. It is strongly recommended to use an aviation band, UHF base station.**
- **All air assets must have knowledge of radio frequencies being used in areas of operations.**
- **All members of the unmanned aerial team should have long-range, hands-free, two-way radio systems.**
- **Coordination of air assets should be made by air operations each day; no freelancing.**
- **Access to local authorities' tactical radio if possible.**
- **Distribute phone list each day during the briefing that includes radio frequencies.**
- **Improve eCOA procedure in case of extenuating circumstances.**

Fixed Wing vs. Rotary Wing

When operating an unmanned aircraft, best practices ideally include a three-person flight team comprised of PIC, VO, and PAC. There is a "First Protocol of Unmanned Aircraft Use" which dictates that unmanned aircraft will ALWAYS defer to the manned asset and give way, to the point of disposing of the unmanned aviation system in the most expeditious manner necessary to adhere to the Protocol.

The Wimberley aviation unit found fixed-wing unmanned aircraft launching, recovery, and visual observation somewhat difficult due to high tree lines, rocky river bottoms, steep cliffs, vegetative undergrowth, and at times, a densely residential population. However, the range flown and time involved dictated this choice. Typically, the Spectra fixed wing would have to take off from an area offset from the river and rely on its autopilot for way-point navigation. The Spectra has long flight endurance and using its autopilot provides precise imagery over large areas (1.77" or 4.5cm resolution at + or – 10 cm accuracy). While operating at 400 AGL, the aircraft and its autopilot communicate

through a ground station (laptop computer). With a flight plan loaded on the ground station the aircraft flies in a “mowing the lawn” grid pattern to obtain overlapping images. These images can then be processed afterwards, using various software packages, into large ortho-mosaic images for mapping purposes. When searching in larger areas, such as desert or open land, these fixed-wing aircraft images can also be reviewed to search for missing persons and other uses. The Spectra Fixed Wing is responsible for mapping the seven miles of the Blanco River. Lacking vertical takeoff and landing capabilities, a fixed-wing unmanned aircraft requires a certain amount of open space for launch and recovery. Small fixed-wing unmanned aircraft come in many different configurations weighing up to 55 pounds.

Multi-rotor aircraft was favored at times over the fixed wing for its vertical takeoff and landing (VTOL) capability. Early in the flood response, a DJI Inspire quad copter was used to collect imagery for the primary search. The ability to get on scene take high-resolution imagery, and then move to the next location in minimum time made the Inspire a great tool for low altitude information gathering (100’-200’ AGL). Multi-rotor platforms can provide a quick frame of reference and influence decision making that might normally place responders in areas of danger. It should be noted that the DJI Inspire was always under the operator’s control and did not use way point navigation to complete its mission.

Recommendation:

- **Provide Incident Command with both fixed-wing and multirotor capabilities.**
- **Never allow the failure of one system (single point of failure) to affect the mission. Always have another means to gather information.**

Coordination with Search Teams

The use of unmanned aerial systems to complete SAR is a new concept which must be introduced and developed. During the flood response, the UAS team worked hand-in-hand with the ground searchers by providing geo-referenced, high-resolution imagery. The process was simple, fast, and effective:

1. Collect imagery of either a pre-designated area or requested points of interest;
2. Review all imagery in the mobile command vehicle by laptop while looking for abnormalities that might include odd shapes or colors; and
3. Contact searchers, and provide details of location and physical description of identified points of interest..

Difficulties while coordinating the search included:

1. Communication with searchers when cell service was unavailable; and
2. Outpacing the searchers (providing imagery faster than they could respond).

Recommendation:

- **Ensure searchers and UAS teams have a direct radio channel to communicate.**
- **Provide the ability for searchers to see imagery and points of interest on a viewing device such as a tablet or laptop.**

Benefits of Working with Individuals Wearing a Badge

The tracking of resources and maintaining control of the disaster response scene is, at times, overwhelming and often made difficult by well-intentioned individuals and groups seeking to assist with mitigation. It is important to remember that the jurisdiction having authority and Incident Command maintain the final say in who operates within the emergency response area. During the flood events, many individuals challenged or neglected to announce themselves as they tried to participate in air operations. This dangerous behavior is unacceptable and should not be tolerated. By the order of Incident Command, a TFR was used to control access to air space; Wimberley Firefighter Gene Robinson was assigned to oversee all air operations, and coordinate the air space for both manned and unmanned resources. Gene was contacted directly by the FAA and made aware that outside entities were trying to gain access to the scene without receiving his permission, going so far as to claim authority under the Wimberley Fire Department's COA. It is very important that anyone wanting to assist with emergency response make their presence clear and work with authorized Incident Command designees.

Recommendation:

- **Always contact Incident Command and/or Air Operations' designees to determine if services are needed.**
- **Pre-plan future responses by creating a list of qualified responders that can be called upon for assistance.**
- **Recommend immediate establishment of TFR and assignment of Air Operations to control scene access.**
- **Inform local law enforcement of need to control air space and suggest enforcement against any unauthorized access.**

Pre-planning and Training for the Next Large Scale Event for Unmanned Resources

Unmanned aerial systems are not a replacement for manned air units but should be looked at as a force multiplier. The unmanned aerial system provides the Incident Commander another tool to gather information and assist with informed decision making. It is imperative that pre-planning and training takes place prior to the next emergency response in order for Incident Commanders to be made aware of, and understand, unmanned aerial capabilities.

Recommendation:

- **Joint training exercises should be created that involve manned air assets, unmanned aerial systems, and ground-based resources.**
- **All unmanned resources wishing to operate within the state should participate in regularly scheduled joint training exercises and become pre-approved to participate in real-world scenarios.**
- **A list of pre-approved, unmanned resources should be maintained and distributed for use by Incident Commanders.**

Getting on the Incident Commander's Radar

Unmanned aerial systems provide the Incident Commander with a new set of tools in order to make informed decisions. It is important that before an event ever takes place, Incident Commanders have been made aware of UASs' capabilities, best practices, and how to access them.

Recommendation:

- **Through the International Association of Fire Fighters (IAFF) and International Association of Fire Chiefs (IAFC), communicate capabilities and best practices for Incident Commanders.**
- **Use organizations within the state to provide a current listing of all pre-approved unmanned resources. Examples of who should receive such a list includes the Texas Forestry Service (TFS), State Fire Marshal's Office, Texas Division of Emergency Management, and the Texas Engineering and Extension Service (TEEX).**
- **Include unmanned aerial systems as a resource for the Texas Interstate Fire Mutual Aid System (TIFMAS).**

Communicating an Accurate After Action Report - Keeping the Message True and Consistent

In order to better understand the event and learn from our experiences, it's very important to provide accurate information when recounting the emergency response. Any effort to inaccurately promote oneself or group through the manipulation of details or events should be looked upon as an obstruction of facts. When made available, a Public Information Officer (PIO) should be consulted and a clear message presented on behalf of Incident Command. Remember that both internal and external messages are subject to public information requests and each can be shared across various mediums so to ensure consistency and accuracy, all messages should be routed through the PIO prior to distribution.

Recommendation:

- **Communicate all messages regarding emergency response through Incident Command and/or designee (PIO).**

GIS Support

Geographical Information Systems (GIS) are used to capture, store, manipulate, analyze, manage, and present all types of spatial and/or geographical data. GIS-based maps and visualizations greatly assist in understanding situations and making informed decisions. The best thing that an Incident Commander can do is identify local partners who can assist with mapping and analysis needs. It was recognized early in the event that having an assigned GIS representative at both the Command Post and assigned to the unmanned aerial team would have improved the emergency response effort.

Recommendation:

- **Enlist GIS assistance from the outset of the event.**
- **Coordinate with GIS to make best uses of UAS imagery.**
- **Once the event has concluded, use GIS to assist in post-incident review.**
- **Train with GIS representatives in order to identify gaps and needs that may occur during an event.**

Logistics for Unmanned Systems and Their Teams

The Wimberley unmanned aviation unit required the following logistical support for operations:

- Food and drink;
- Laptop computer for review of images;
- Fuel for the mobile command vehicle's generator;
- Access to ATV for VO;
- Batteries for radios;
- Batteries for UAS platforms;
- Field repair kit; and
- Cell phone.

Aside from the regulatory requirements currently necessary to be cleared before operations, the most formidable challenge to the unmanned aerial team on the ground is communications. Not only do the teams need to be able to communicate with Incident Command but also with the necessary aircraft and control organizations (Flight Center, TRACON, etc.). The obstacle lies in the various radio frequencies being utilized by agencies and where they are being used. It was discovered very early on that communications among the unmanned aerial flight crew and other aircraft and agencies via a handheld radio is ineffective unless within a very short range. Those frequencies do best when the transmitter and receiver are at altitude, so this was not unexpected. The use of an aviation band UHF base station with an elevated antenna was certainly the biggest benefit during this incident. Tactical radios used by Fire and Law Enforcement are bound by some of the same limitations, but repeaters can be deployed to rectify the range situation and allow for effective communications. Finally, as it became available, cell phone communication played a large role in the operation and coordination of assets. Technology today allows for the aggregation of all these communication methods in a single "box" that should be deployed on an incident of sufficient magnitude.

Unmanned aerial flight crews also had to contend with ground transportation issues that precluded them from reaching an area directly. An ATV was made available to the flight crew, allowing a visual observer a position up or down river from the pilot in command for better visual awareness in case of temporary flight restriction area infractions.

Recommendation:

- **UAS team should remain self-sufficient for daily assignments.**

Conclusion

Unmanned aerial operations are required to better improve the outcome of future emergency response. In order for Incident Commanders to understand and want to use Unmanned Aerial Systems (UASs) technology, we must first accomplish the following:

1. Create a policy and procedure that helps steer future UAS response.
2. Develop positive public perception for the use of UAS technology.
3. Create a group that represents all UAS assets that might participate in future events. Those assets must communicate and train together throughout the year while remaining easily accessible by command. Any participating member should be credentialed and trained up to a standard that would allow for ease of integration into the emergency response.
4. Participation of UAS units in local, state, and Federal training exercises.
5. Divide the aviation branch of the Incident Command System into both manned and unmanned groups.
6. Work hand-in-hand with leaders in research and industry to create UAS technology specific to emergency response.
7. Become a recognized tool that local, regional, state, and Federal assets can call upon.
8. Provide education on UAS response and a list of resources to emergency managers, first responders, and state and local officials.

The implementation of UAS into emergency response requires support from local, regional, state, and Federal leadership. It will not be long before first responders wonder how they ever operated without the use of unmanned aerial systems.

During the days spent in the field following the flooding, the authors met with a number of private property owners to ask permission to position a mobile command unit on their land and operate UAS over their property. As Austin Fire Department Firefighter Coitt Kessler introduced himself to these individuals, who had just seen the river rise to their doorsteps and beyond, he was greeted graciously and even offered refreshments. Privacy issues were not voiced as a concern during these operations. In fact, some property owners asked for copies of the images. Therefore, in disaster situations, the authors' experiences are that privacy issues take a back seat to rescue, recovery, and rebuilding. That being said, the flight crew continues the practice of not disseminating images to the public.

Appendix A -- Acronyms

AFD	Austin Fire Department
AGL	Above Ground Level
ATC	Air Traffic Control
ATV	All Terrain Vehicle
COA	Certification of Authorization
eCOA	Emergency Certification of Waiver or Authorization
FAA	Federal Aviation Administration
FSDO	Flight Service District Office
GIS	Global Information System
IAP	Incident Action Plan
IC	Incident Command
NAS	National Airspace
NIMS	National Incident Management System
PAC	Pilot at Controls
PIC	Pilot in Command
PIO	Public Information Officer
POC	Point of Contact
POI	Point of Interest
RED	Robotic Emergency Deployment
SAR	Search and Rescue
TEEX	Texas Engineering and Extension Service
TIFMAS	Texas Interstate Mutual Aid System
TFR	Temporary Flight Restriction
TFS	Texas Forestry Service
TRACON	Terminal Radar Approach Control facility
UA	Unmanned Aircraft
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
VO	Visual Observer
VTOL	Vertical Takeoff and Landing
WFD	Wimberley Fire Department

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