Unmanned Aerial Vehicle Use in Search and Rescue Operations

An Assessment of Current Technology, its Applications to Search and Rescue, and a Roadmap for Future Development.

Authors: Ben McCandless, MSME, Allegheny Mountain Rescue Group, Pittsburgh, PA
Bill Rose, MD, MSEE, Mountaineer Area Rescue Group, Morgantown, WV
Paula Repka, BA, Mountaineer Area Rescue Group, Terra Alta, WV
Michael Hansen, CHMM, Delmarva Search and Rescue Group, Baltimore, MD

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Abstract

The ASRC is a membership organization of professionally-trained volunteer search and rescue (SAR) teams that provide incident management and field resources for SAR operations in the Mid-Atlantic region, with teams in Ohio, Virginia, West Virginia, Maryland, and Pennsylvania. . The purpose of this paper is to present an overview of the current technology of unmanned aerial vehicles (UAVs) and present the opportunities and challenges associated with integrating UAVs into search and rescue (SAR) operations. This paper provides an overview of the current state-of-the art in UAV technologies and an examination of how those technologies may be integrated into SAR operations. In addition, the paper lays out three efforts that should be undertaken to maximize the benefits of UAVs in SAR:

1. Advocacy to increase acceptance of UAVs among the wider community and forestall excessive restrictions on UAV use
2. Research to quantify UAV performance in SAR
3. Building of UAV capabilities within ASRC teams

The capabilities offered by UAVs at this time are extremely compelling, and the ASRC should recognize that it has an opportunity to become a leader in the integration of UAVs into search and rescue operations.

1 Introduction

Unmanned aerial vehicles (UAVs) have sprung into the public consciousness recently. They are frequently discussed on the news, photographers and dare-devils are using them to capture imagery from perspectives that were too expensive or unwise in the past. The hobbyists who first built the designs that are becoming common today are still refining and improving them, but there is still only a tentative acceptance of UAVs by the public at large. While only a few years ago, affordable UAVs were strictly experimental aircraft, they are now starting to evolve to fill the many needs of various individuals, as well as public and private organizations. This paper is focused on the application of UAV technology to SAR. It examines the current state of UAV technology, provides a brief discussion UAV history, and examines a number of UAV systems that are currently on the market. Later sections discuss how UAVs are currently being implemented in SAR and opportunities for improvement. Finally this paper presents a set of recommend specific actions that the ASRC should act to assist its member teams in integrating UAVs into their own operations.

1.1 Terms of Reference

The term UAV is an abbreviation of Unmanned Aerial Vehicle, meaning aerial vehicles which operate without a human pilot. Several other commonly used terms are listed here:

- Dynamic remotely operated navigation equipment (Drone)
- Remotely Piloted Aircraft (RPA), used by the International Civil Aviation Organization (ICAO)
- Unmanned aircraft systems (UAS)
- Unmanned Aerial Platform (UAP)

The acronym UAV has been expanded in some cases to UAVS (Unmanned Aircraft Vehicle System). The FAA has adopted the acronym UAS (Unmanned Aircraft System) to reflect the fact that these complex systems include ground stations and other elements besides the actual air vehicles. These are all acceptable terminology, but for the purposes of this paper, the term “UAV” is used.

1.2 Current Uses for UAVs

The global small UAV market is estimated to be $218.10 million in 2014 and is expected to be $582.20 million by 2019[1]. As the capabilities of UAVs are progressively increasing and are demonstrating their potential as an effective, low-cost alternative to manned aircraft, demand for UAV technology will be increasing in the marketplace. UAVs have many applications in law enforcement, military, emergency response, business, civic, and personal applications. Several Major uses of UAVs are discussed below.

- Aerial Reconnaissance and Mapping – UAVs are often used to obtain aerial imagery and video of remote locations, especially where there would be unacceptable risk to the pilot of a manned aircraft. UAVs can be equipped with high resolution still, video, and infrared

[1] “Research and Markets: Small UAV Market by Trends, Propulsion, Payload, Application & Region - Global Forecast to 2014 – 2019.” Research and Markets. February 2014. Retrieved October 4, 2014. http://www.researchandmarkets.com/research/fhlr26/small_uav_market

cameras. Imagery and other sensor data obtained by the UAV can be streamed back to the operator at the control center in real time.

- Scientific Research – In many cases, scientific research necessitates obtaining data from hazardous or remote location, or has other requirements that are cannot be met by manned aircraft. For example, (i) UAVs can be used to investigate environmental conditions areas where manned aircraft simply can't fit; (ii) can be operated in remote locations where there is no infrastructure to support larger aircraft; and (iii) do not put the operator at risk when being flown in hazardous conditions.
- Logistics and Transportation – UAVs can be used to carry and deliver a variety of payloads. Helicopter type UAVs are well suited to this purpose, because payloads can be suspended from the bottom of the airframe, without dramatic effects on the unit's stability during flight. A number of companies have expressed interest in using UAVs for deliveries of packages and parcels. Recently, Deutsche Post DHL AG announced on 25 September, 2014 that it will use UAVs to deliver medication to a German island in the North Sea, marking the first routine use of UAV technology to deliver parcels to customers.[2]

1.3 A Brief History of UAVs

The earliest recorded use of an unmanned aerial vehicle for warfighting occurred on August, 1849, when the Austrians attacked the Italian city of Venice with unmanned balloons loaded with explosives. The first pilotless aircraft were built during and shortly after World War I. After World War I, three Standard E-1s were converted as drones. The Larynx was an early cruise missile in the form of a small monoplane aircraft that could be launched from a warship and flown under autopilot; it was tested between 1927 and 1929 by the Royal British Navy. The early successes of pilotless aircraft led to the development of radio controlled pilotless target aircraft in Britain and the US in the 1930s. In the 1930s the US Navy and US Army Air Forces began experimenting with unmanned aircraft. The Naval Aircraft Factory assault drone "Project Fox" installed a television camera in the drone and a television screen in the control aircraft in 1941. These aerial torpedoes and assault drones were successful through the post-WWII era leading to the use of attack drones during the Cold War era. From their early use as target drones and remotely piloted combat vehicles, UAVs progressively took on new roles, an example being stealth surveillance during the Vietnam War.

In 1978, Israel Aircraft Industries (IAI) built Scout, a piston-engine aircraft with a 13-foot wingspan made of fiberglass. Scout's fiberglass frame emitted an extremely low radar signature, which, coupled with the UAV's small size, made it almost impossible to shoot down. The inexpensive Scout UAV could transmit real-time, 360-degree surveillance data via a television camera in its central turret. Any questions about the appropriateness of UAVs for military use were laid to rest dramatically with the Israeli Air Force's victory over the Syrian Air Force in 1982. During the Bekaa Valley conflict between Israel, Lebanon, and Syria, Israel famously used a fleet of Scouts to search out Syrian missile sites and entice the Syrians to activate their

[2] Nicas, Jack. "Deutsche Post DHL to Deliver Medicine via Drone." Wall Street Journal. September 25, 2014. Accessed October 1, 2014. http://online.wsj.com/articles/deutsche-post-dhl-to-deliver-medicine-via-drone-1411576151rone-1411576151

radars. These allowed Israeli bombers to swoop in and destroy all but two Syrian missile sites (17 in all), allowing them to fly unchallenged in the skies. Israel built the “Pioneer” UAV in the late 1980s. After witnessing Israel's success with light UAVs, the U.S. Navy, Marines, and Army immediately acquired more than 20 of the new Pioneers, which became the first small, inexpensive UAVs in the modern American military forces. UAVs command a permanent and critical position in high-tech military arsenals today, from the U.S. and Europe to Asia and the Middle East. They also found a role in peacetime as monitors of the Earth's environment.[3]

1.4 UAV Platforms Currently available on the Market

Until very recently, civilian UAVs were model aircraft, flown for pleasure. The transition from remotely controlled (R/C) model aircraft to the UAVs of today is due to the confluence technological evolution in three areas. These trends are described below:

- The first was the development of high power-to-weight ratio lithium polymer (LiPo) batteries, which combined with electric motors to replace nitromethane/methanol combustion engines.
- The second was the development and wide acceptance of personal microelectronics. Once the tools and resources were available for hobbyists to design and build their own electronic systems, they were quick to incorporate them into their airplanes.
- The third important development was the advent of affordable miniaturized sensors. Combined with the processing power now available in modern electronics, information about flight parameters could be fed directly from sensors back to an onboard computer, which could adjust the controls appropriately – without requiring the operator’s attention and allowing a single person to easily manage what would otherwise be a very complex flight system.

The convergence of these three trends resulted in an explosion of model aircraft development, and the selection of UAVs available today. The reminder of this section will describe some of the types UAVs that are currently available in the marketplace.

1.4.1 Fixed-Wing

Initial efforts to convert model aircraft with traditional airframes into rugged, load carrying UAVs met with problems: these airframes require many control surfaces and tend to be highly susceptible to damage. While they can be made to work, consensus is building that a simplified "flying wing" design is more suitable for systems that are subject to more robust use. Flying wings can be difficult for an operator to control, but modern onboard computers significantly decreases the required skill to operate them.

An example of a flying wing developed by Gene Robinson of RP Flight Systems has been used for SAR work by his nonprofit company (RP Search Services) and by Texas EquuSearch for at least five years. The Spectra Flying Wing has a 56" wingspan, is hand launched, has a 45

Figure 1: Spectra Flying Wing. Photo courtesy of RP Flight Systems.

[3] Krock, Lexi. “Timeline of UAVs.” PBS. Accessed October 1, 2014. http://www.pbs.org/wgbh/nova/spiesfly/uavs.html

minute flight time, and can carry a 2 to 4 pound payload. This unit records high resolution geo-referenced digital imagery for playback on a laptop. Advantages of such a fixed wing system include extended flight time and a relatively heavier payload capability. A distinct disadvantage of any fixed-wing unit is that they need a large open area in which to land—which is not a problem in Texas but may be a problem in heavily wooded search areas like those found through much of the ASRC's response area. The Spectra is a proven design worth careful consideration but its high cost ($25K) puts it out of reach by most volunteer SAR groups.

1.4.2 Multi-rotor (MR)

Single-rotor R/C model helicopters have also been available for decades and significant early attempts were made to utilize them as aerial camera platforms. However, the steep learning curve required to fly these single-rotor model helicopters, their inherent unstable flight characteristics, and high vibration of the frame made their use as a camera platform extremely limited.

With the more recent development of MR units (using three to eight rotors on a single airframe) the disadvantages present in single rotor units are reduced. Contrary to model helicopters, these multi-rotor units are very stable and motorized gimbals and anti-vibration platforms make them superior aerial camera platforms. Most photographers and videographers engaging in aerial photography are making use of this category of UAV. The most common designs used in for SAR are commonly referred to as quadcopters (4 rotors) and hexacopters (6 rotors). Quadcopters tend to be smaller, more agile platforms whereas the hexacopters tend to be larger, more expensive, able to carry larger payloads, and slightly more stable in flight.

There are multiple models of UAVs from numerous manufacturers, each with their own capabilities and options. When the FAA guidelines are finally clarified and more large-scale production occurs, it is likely that more options will be available and there is a potential for unit costs to decrease with economies of scale. For illustrative purposes, the following are just a few examples of currently available MR UAVs and their capabilities. Approximate prices are current as of October, 2014.

DJI "Phantom 2 Vision+" (P2V+) by DJI Innovations

This quadcopter is a *small* (35cm diagonal motor-to-motor) UAV marketed for general hobbyist use as well as professional aerial photography and aerial cinematography. Although not actually designed for SAR use, large numbers of these units are being used worldwide for SAR due to their vast popularity and relatively low price.

Features:

- Flight time ~ 20 minutes
- Range: 700-800m
- Minimal learning curve for operators with no previous R/C experience
- 3 axis motorized gimbal for vibration free photography and video
- Built-in 14 MP camera for digital photos and 1080p HD video

Figure 2: Phantom 2 Vision+. Photo courtesy of DJI Innovations.

- Ground station: A mobile device application on the video monitor (iOS device, Android device, or a laptop computer) allows preset waypoints superimposed onto aerial imagery of the local area, allowing the user to define a preset autonomous flight path (search grid) over a set terrain.
- Relatively low cost (~$1200--excluding cost of the video monitoring device)

Disadvantages:

- GPS coordinates are not displayed on the monitor, nor are they geo-coded to the video (only to the digital photos); however, some add-on equipment allows this option.
- Camera/gimbal system is very fragile, easily damaged during a crash, and not field repairable.
- Minimal payload capacity

Because the DJI Phantom 2 Vision+ is so popular and is the UAV being experimented with by two of the authors for future SAR use, detailed features of this unit are included for reference in Appendix D.

"Iris" by 3D Robotics (3DR)

This is another small quadcopter with many of the features of the P2V+ above but uses a GoPro Hero3 camera as its recording device. Some of these are used by the SAR community due to their low cost and availability.

Features:

- Larger payload capacity 425g (0.9 lbs) but this doesn't include the GoPro camera which weighs 74g
- Low cost (<$2K, including gimbal and GoPro camera)

Figure 3: Iris. Photo courtesy of 3D Robotics.

Disadvantages:

- Limited flight time ~ 10-15 minutes
- Appears to have a steeper learning curve to fly than P2V+
- Limited features compared to P2V+

"S800 Evo" by DJI Innovations

This a *large* (88cm diagonal motor-to-motor) hexacopter designed for high-end professional cinematography because of its superior stability but used by some for SAR due to its worldwide availability.

Features:

- Superior camera stability
- Retractable landing gear--keeps skids out of camera's field of view

Figure 4: S800 Evo. Photo courtesy of DJI Innovations.

Disadvantages:

- Large size (has to be folded up to fit inside most vehicles)
- High cost (~$8K, including gimbal and camera)

"Guardian" by Draganfly Innovations

An advanced *small* UAV quadcopter built specifically for commercial applications including SAR, fire, law enforcement, this unit by a Canadian company is "specifically designed for first responders on a budget." The quadcopter includes a Sony QX100 video camera and a 2 axis gimbal. Technical specs are not publicly available but many options are available including infra-red (IR) sensors. This UAV should be given consideration for SAR use based upon it being specifically designed for commercial field use.

Figure 5: Guardian. Photo courtesy of Draganfly Innovations.

Disadvantage:

- High cost (~$8.5K)

"X4-ES" by Draganfly Innovations

Another small UAV quadcopter built specifically for commercial Emergency Services applications and first responders, this is the UAV used by the Royal Canadian Mounted Police in their highly publicized SAR mission in May, 2013. This unit includes a handheld ground station, charging system, transport case, high res camera, and optional FLIR camera. This is probably the ultimate UAV for SAR use, but its price ($25K-$30K) puts it out of reach of most volunteer organizations.

Figure 6: X4-ES. Photo courtesy of Draganfly Innovations.

"Qube" by AeroVironment

This quadcopter is another advanced, *large* (90 cm) UAV built for commercial SAR, fire, and law enforcement applications. It is designed specifically as a compact, rugged, professional-grade system for use in harsh field environments. AeroVironment has 25 years of experience in UAS for the US military.

Features:

- 40 minute flight time
- High resolution images and video include zoom capability
- Dual onboard color and thermal (IR) video cameras, selectable by the operator
- Video recordings and images include time-stamped, geocoded data
- Range: 1000m

Figure 7: Qube. Photo courtesy of AeroVironment.

Disadvantages:

- Is currently sold only to government agencies
- Extremely high cost ($50K)

The selected UAVs described above are off-the-shelf models, and if an organization has a special need, there are several companies available that will customize an off-the-shelf model to meet that organization's exact requirements.[4] This may involve modifications of any sort, but commonly changes are made to extend the range, payload, or other operating parameters of the UAV or base equipment.

1.4.3 Lighter than Air (LTA)

Figure 8: LTA 75. Photo courtesy of Aerial Products.

The oldest technology used to "look down from above" consists of a tethered helium filled balloon fitted with a camera. Although mostly out of favor now, some units such as the LTAS 75 Balloon System by Aerial Products are available. This system comes on a single-axis trailer with six helium tanks, generator, cable/winch system for tethering, gyro-stabilized camera gimbal, and video downlink to a mobile viewing station but with a price tag of $85K-$120K depending on options. The major disadvantages of these systems in addition to their high price include their slow deployment and inability to relocate from their tethered position. Thus, these balloon systems appear to be used mostly for fixed area surveillance zones like border crossings, military applications, and large scale disasters.

Other LTA systems include blimps, which have gained popularity due to their neutral buoyancy which equates to minimal power needed to keep them airborne for hours. The most obvious drawback of these units is the large size needed to achieve adequate buoyancy to loft a payload and maintain flight. Their large size makes for slow deployment time as well as significant control issues during windy conditions.

1.5 Costs of Maintaining UAV Platforms

The costs fielding a UAV are not limited to the initial purchase price. Transport cases are recommended for SAR use to protect equipment while in transit to and from a task location. Propellers are likely to be damaged and need replacement and batteries will need replacement after a finite number of charge/discharge cycles. Additional costs may include liability insurance and coverage for potential loss of the equipment. Potential future costs may include obtaining 3rd-party certifications or registration of UAVs with the FAA. While these are not required at this time, it is possible that they will be implemented in the future.

1.6 Payloads

The selection of UAV payloads currently available to volunteer search and rescue teams with limited budgets are currently fairly limited. Payloads that are directly applicable to SAR are described in the remainder of this section.

1.6.1 Sensors for SAR

A variety of sensing technologies are appropriate for use with UAVs, but most of them are not commercially available at this time, are currently extremely expensive, require more equipment than most small UAVs are able to carry, or some combination of these. However, it is important to continue to monitor their status, as technological improvements may quickly eliminate these

[4] Examples include DSLR Pros of Oakland Park, FL and Drone Assets of Orlando, FL

restrictions. At present, the vast majority of sensing technologies available for UAVs are cameras, but a number of other interesting technologies worth watching are on the horizon.

Cameras

Cameras are by far the most common sensing technology used on UAVs. The most basic approach to using a camera onboard a UAV is to have a camera system which automatically takes pictures or video and stores the photograph locally until the UAV is retrieved by the operator and the data can be analyzed. More advanced UAVs incorporate a telemetry package that allows the operator to receive a live feed from the camera, allowing more accurate photograph composition, extended operations, or real-time search using live video.

- Digital camera - These can be used to generate the high resolution images that are common in aerial photography. Smaller UAVs often carry a small point-and-shoot camera ($90 - $500), while larger units can carry a professional grade camera ($1500 and up).
- Video Camera - These units allow video to be recorded. Video cameras typically record at a lower resolution than still cameras, but when combined with a telemetry package, allow the operator to have a much better idea of the current state and orientation of the UAV. In addition, they usually allow the operator to capture video of any particular area of interest. While some UAVs come with integrated video cameras, others provide the mounting bracket or gimbal for third-party cameras such as the GoPro Hero series ($300 - $500).
- Forward Looking Infrared (FLIR) Camera - These units are used to identify objects that are a different temperature than their surroundings. They offer many advantages for lost person search in that they are able to penetrate some foliage and can locate people and animals that are of similar color to their surroundings. The principal disadvantage of these units is their cost, which begins at approximately $2,000 and increases rapidly with the higher resolution units.

Speakers and Microphones

Just as video can be relayed from a UAV to its operator, it is possible to create a two way audio link. Currently, this capability is not available in off-the-shelf units, as UAV operation is usually loud enough to drown out surrounding sounds, but if a UAV were to locate a person on the ground, judicious use of an audio relay would allow communication with the operator. This would be more straightforward for multi-rotor units, which could land near the person of interest and shut off the motors, removing interference from flight noise. In addition, a UAV equipped with a public address system could be used for attraction or addressing other people on the ground in the vicinity.

Synthetic Aperture Radar

Microwave radiation can be used to image objects and landscapes, but the resolution of the image generally increases with antenna (or “aperture”) size. It is impractical for small aircraft or UAVs to carry antennas large enough to develop the resolution that would be useful for any sort of aerial imaging. These limitations can be overcome by analyzing radar data from several points along the aircraft trajectory, effectively creating a larger “synthetic” aperture and increasing image resolution substantially. Currently there are no non-military products using this technology available for use on UAVs, but it is likely that experimental systems built by hobbyists will be flown within 2-5 years.

LIDAR

This technology uses a sophisticated rangefinder to sweep a laser beam over the surrounding environment to create a set of georeferenced elevation data. These units are frequently used on autonomous robots, space exploration and the earth sciences. In general, the unit cost is strongly linked to its angular resolution – the angular increment at which it takes a distance measurement around the unit. The standard resolution available on the market is 0.5 degrees, which is not yet sufficient for SAR work. Units with higher resolution are not widely available due to their expense. These units are not currently being integrated into small UAVs due to size, weight, and power constraints, but future improvements to the technology may make them more suitable for UAV use.[5]

1.6.2 Actuators

Actuators allow the UAV to move objects. Most currently available actuators fall into one of two categories:

- Gimbal - Allows a camera carried by the UAV to be repositioned while in flight. Typically these are of the "Pan-Tilt" type, allowing the camera to be rotated in all directions. Some units incorporate image stabilization which use additional servos to mitigate the vibration of the UAV during flight.
- Remote Release - Allow the operator to release an object from the UAV. This could be used to drop a communication device or other essential supplies to a person on the ground (likely items include, cell phones, radios, medications, food, water, or emergency shelter materials). Some advanced units, like those demonstrated by Google's Project Wing can retrieve objects as well.

As of October 2014, there seems to be little interest or recognized potential for development of other actuator capabilities.

1.7 Currently Identifiable Deficiencies in UAV Platforms

Deficiencies in currently available UAV platforms do exist. All of the multi-rotor UAVs are electrically driven using LiPo batteries. Although these Li-Po batteries have made the currently available UAVs possible by their superior current output to weight ratio, they limit flight times to 10 to 30 minutes and take 1 to 2 hours to recharge. Adding batteries onboard forces reductions in the normal sensor payload, which is already usually limited to a camera. However, flying at a speed of 4 meters per second, at 30 meters above ground level, a UAV could theoretically fly over and photograph 40,000 square meter area (4 hectares or 10 acres) in 3 to 5 minutes.

[5] "New Camera System creates high-Resolution 3-D Images." Heriot Watt University. April 2, 2013, Accessed October 1, 2014. http://www.hw.ac.uk/news-events/news/new-camera-system-creates-high-resolution-3-d-11809.htm

Sensor Limitations

Recent developments in digital camera sensor technology have resulted in dramatic increases in the quality of video and still images available. However, attempting to capture clear images and videos from UAVs can be difficult without the use of a camera gimbal. Gimbals tend to be very fragile and can result in a costly repair bill if the UAV crashes. Lack of optical zoom capability (except on the very high end units) is another limiting factor, but a closer image of most areas can be acquired by reducing the UAV's altitude. Recently, small thermal cameras that produce images using the infra-red (IR) portion of the spectrum have been developed that are compatible with small UAVs, but they remain quite expensive. A typical commercial IR camera may cost $6,500, which could be significantly more than the cost of the platform carrying it. Even at this price, current IR sensors give grainy images far below the quality of a normal optical sensor, and have difficulty in distinguishing between a human search subject and other heat sources, such as local wildlife. Ideally the UAV should carry both cameras and have both images transmitted back to the operator.

Physical Risk

Most UAVs currently available rely on high speed electrical motors to drive a rotor, which can pose some risk to other searchers, bystanders, SAR canines, the aeronautical community, and the missing person. Most of the time, a UAV involved in a SAR mission is flying over rural, minimally populated areas, which reduces the risk of accidental harm. These risks are generally considered to be small when the UAV is operated according to standards developed by organizations within the R/C model aviation industry such as the Academy of Model Aeronautics and appropriate FAA advisories.

Due to the limited use of UAVs except by larger SAR units and non-SAR trained hobbyists, lack of written SOPs regarding when to deploy, how high to fly, what speed to fly, whether to use video or still images, and when to not to deploy are all questions that appear to remain unanswered. This would suggest that any organizations (such as the ASRC) getting involved now with UAVs for SAR would be the groups to help develop such SOPs.

2 UAVs in SAR

While hobbyists and photographers have bought into UAV technologies and promoted its uses with great fervor, there has been very little promotion and implementation of UAVs in SAR. A few organizations like RP Flight Systems have been investigating the use of these technologies in SAR, but the pace of implementation has been slow. While it is important to recognize current uses of UAVs in SAR, this paper also attempts to take a wider view and determine aspects of the SAR where there are previously unobserved opportunities for this technology to integrate with and improve existing capabilities, or to develop entirely new ones.

2.1 Current Use of UAVs in SAR

With the rapidly expanding affordability of UAVs, there is much interest in applying this technology to other areas. One of the first to investigate using UAVs for SAR was Gene Robinson of RP Flight Systems. Mr. Robinson has put much research effort into this emerging technology through development of the Spectra flying wing design and its application to SAR operations. His efforts are discussed in his recent publication First to Deploy[6], is recommended reading for anyone considering UAVs for SAR, although most of the book discusses use of the flying wing rather than multi-rotor units.

Texas EquuSearch is a SAR group based in Dickinson, TX. This organization has been deploying UAVs (RP Flight Systems) since 2006 and has located search subjects using this technology. In February, 2014, the FAA contacted the group and ordered it to cease UAV operations, which the agency considered to be in violation of regulations. Texas EquuSearch then sued the FAA stating that there is no basis in law to prohibit operation of model aircraft for humanitarian search and rescue activities and that their use of UAVs falls outside FAA restrictions. In July, 2014, this suit was dismissed by a panel with the US Court of Appeals after the FAA filed a brief stating that they had not officially issued a Cease and Desist Order. Texas EquuSearch has since resumed their use of UAVs.[7]

Jim Bowers started an international listing of UAV hobbyists who have agreed to do volunteer SAR work with their devices if needed. This group called Search with Aerial RC Multi-rotor (S.W.A.R.M.) is a web based listing of over 1,500 UAV operators in 38 U.S. states and 31 countries.[8] Members of S.W.A.R.M. are currently activated by family request only so that the UAV operator is not responding as a member of an official SAR group which could potentially be labelled "commercial use" which is currently banned by the FAA. The SWARM Standard Operating Procedure is included for reference in Appendix C.

A Mountain Rescue Association (MRA) webinar titled "Unmanned Aerial Drone Rescue: An Overview of UAV Utility, Tech Specs, and Legal Threats" was presented in August, 2014, by Ron Zeeman of the Utah County Sheriff's SAR group. He uses various UAVs, including multi-rotor units because of the ability to hover and potentially deliver supplies to people on the ground.

The Royal Canadian Mounted Police of the Saskatchewan Province used their FLIR equipped Draganfly X4-ES quadcopter for the successful find at night and in freezing temperatures that has been widely publicized. This rescue is reviewed on their website.[9]

On October 1, 2014, the FAA granted emergency permission for UAVs from Virginia Tech to participate in the search for missing University of Virginia student Hannah Graham at the request of local law enforcement. “Police had reached out to Tech’s drone experts . . . for help as they try to comb through some tough terrain” stated Tech’s Aviation Partnership Director Rose Mooney.[10]

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[6] Available for purchase on the web at www.suasnews.com

[7] Roberts, Jeff John. “Search-and-Rescue Drones Fly Again After Court Throws Out FAA Case.” Gigaom. July 24, 2014. Accessed October 1, 2014. https://gigaom.com/2014/07/21/search-and-rescue-drones-fly-again-after-court-throws-out-faa-case/

[8] S.W.A.R.M.’s website can be found at: www.SARdrones.org

[9] “Single Vehicle Rollover – Saskatoon RCMP Search for Injured Driver with Unmanned Aerial Vehicle.” Royal Canadian Mounted Police. May 9, 2013. Accessed October 1, 2014. http://www.rcmp-grc.gc.ca/sk/news-nouvelle/video-gallery/video-pages/search-rescue-eng.htm

[10] Demmitt, Jacob. “Virginia Tech lends drones to search for Hannah Graham.” The Roanoke Times. October 1, 2014. Retrieved October 3, 2014. http://m.roanoke.com/news/local/blacksburg/virginia-tech-

Several attempts were made to solicit various teams' Standard Operating Procedures (SOPs) through various UAV SAR forums. Only S.W.A.R.M. was willing to provide or describe the content of its SOPs (See Appendix C). Plausible explanations for this dearth of responses are a) that most teams do not have SOPs yet, and b) there is significant regulatory uncertainty in the US and some other countries, and groups that may have or being developing protocols do not wish to draw the attention (and regulatory scrutiny) of the FAA (or their country's equivalent). Two examples that illustrate this second point are listed below.

1. A UAV operator[11] for a SAR group in Saskatchewan Province, Canada flies a DJI Phantom. He states that when activated, his team goes to the muster station, gets the initial briefing, then proceeds immediately to the on-scene command post where they fly an overview flight of usually 150-200 feet to identify any deviations in terrain, obvious hazards, etc. They then make multiple passes through the search area, covering and recovering 8-10 acres in about 30 minutes. The photos are then transferred to a computer for review by other personnel.
2. Another Canadian UAV operator stated that "as it stands now, if I were to join a team and fly UAV it could be considered commercial. That would mean that I would have to apply to Transport Canada for a Special Flight Operation Certificate (SFOC) which takes at least 20 days to be approved . . . not effective for SAR." So, he responds unofficially as a hobbyist. He states that "the majority of time UAVs are used in a support role, scouting, recon, mapping and the like." He uses a quadcopter and generally flies at 200 feet and below. He takes video for 15 minutes, reviews this for 15 minutes, flies for 15 minutes, etc.[12]

2.2 Potential Applications of UAVs in SAR

The addition of UAV technology to a SAR group's resources adds significantly its mission capabilities and allows it to offer other services to larger public safety community. A number of potential applications are discussed in this section.

2.2.1 Situational Awareness and Planning

UAVs have potential to substantially increase the ability of search management to gather information about the condition of the search area. There are a variety of specific applications for which UAVs are well suited that will complement, not replace, the existing capabilities of SAR teams. Generally these capabilities fall into two categories: *situational awareness*, the "big-picture" of what the search area looks like today, and *studying points of interest*.

UAVs have already proven useful in large scale disaster situations (tornadoes, hurricanes, floods, landslides, explosions) where part of the initial issue is just getting an idea of the scope of the overall problem. A view from above can direct critical resources to the worst hit areas quickly as well as help search for survivors.

lends-drones-to-search-for-hannah-graham/article_bb940777-87fc-55cb-8435-21a0a3693c67.html?mode=jqm

[11] Personal communications with Bill Rose. June, 2014. This individual requested anonymity.

[12] Personal communications with Bill Rose. August, 2014.

Situational awareness is crucial to a search mission, as it determines the strategies by which the search will proceed. A common problem in search and rescue is that the information available to search managers and the planning staff, which is necessary to create tasks for field teams is outdated or missing entirely. The commonly used USGS maps of the area may be at least fifteen years old, and in that time a variety of changes may have occurred that will directly impact a ground unit's ability to search the area. For example: A new housing development may have been built, a new strip mining operation may have begun, or a new trail system may have been cut in what was once dense forest. While these are both examples of increasing development, the reverse is also possible: What was once an open field may now be a large rhododendron thicket, and what was once a wide gravel road may now barely qualify as a Jeep track. These differences have practical implications for the unit's ability to search the area or may interfere with other search functions, such as transporting of resources. For these reasons, many UAV teams do an early flyover of the search area for direct input to the planning section. Currently, Geographical Information Systems (GIS) are being incorporated into search, but their ability to sort and manage information is limited by the data that is available to them.

2.2.2 Search

Searching with UAV use can be broken down into several categories including active searching, passive searching, logistical or rescue support to the searchers or the subject, training, and special operations. Each of these will be discussed in detail:

Active Search

UAVs are not, and likely will never be suitable for replacing ground searchers. Flying from 50 to 150 feet above local terrain, UAVs are currently not capable of detecting spot clues with the same probability of detection (POD) that a team of ground searchers can. Nor will they be able to eliminate areas with a high POD by themselves. In the right scenarios, though, a UAV may be able to search areas to a useful POD much faster than a ground team, i.e. areas that are challenging for ground searchers to traverse but does not have significant vegetation to obstruct imaging from above. Such areas would include large fields with tall grasses, agricultural fields, rocky river banks, shallow lakes/ponds, marshes, cliffs, and even forested areas when the canopy is defoliated (~7 months out of the year). In many ways, the use of a UAV for these areas may be analogous to running a reflex task - even if the UAV does not generate PODs as high as a ground team, the time required for an aerial search is very short. In the event that a UAV unit can locate the subject of the search rapidly, then the search becomes a directed rescue mission.

A UAV with a high resolution digital camera, a high resolution video camera, (or both) would be appropriate for search. The video images recorded by the onboard camera are relayed back to the operator and can be analyzed in real time for clues or the missing person. If something of interest is spotted, a multi-rotor UAV can stop and hover over the area and even descend for a clearer look. While this live video feed is typically of lower quality than the video stored on the onboard memory card, the SD card can be brought back to base and analyzed in more detail on a delayed basis using a laptop computer. Some UAV operators feel the video is the best method for finding subjects since movement by the subject will be viewable in real time on the monitor.

Other UAV operators believe use of the digital still images are better since they can be "zoomed in" for closer analysis. These still images can be automatically taken by the onboard camera at preprogrammed intervals based upon altitude and speed. However, this eliminates an advantage of live search – the human eye's ability to detect subject movement. Once the images are brought back to base, it is possible that images could be uploaded for viewing remotely by team members that cannot be present at the search location.[13] Whether to use video on still imagery is an area that remains open for investigation, with image resolution and sweep width measurements having a major impact on the final decision.

Some search teams have also equipped their UAVs with IR sensors, in place of, or in addition to a standard camera able to image the visible spectrum. These IR sensors seem to be very effective for picking up subjects where their body temperature is markedly different from the surrounding environment and they have been used effectively in both daylight and dark operations. The drawback to this is that the IR sensors are very expensive ($2500 to $7500) and currently available equipment produces images that have a much lower resolution than those produced by normal cameras.

Active searching can be done either by direct piloting of the UAV using direct visual line-of-sight (or via First Person View using the video monitor or FPV goggles) or by setting up various waypoints using ground station software. Using a predefined series of waypoints allows for a particularly methodical and largely automated search, but requires that the appropriate resources are available before the UAV is launched.

Passive Search

UAV motor/rotor noise is very distinctive and can be audible from some distance. As such, a UAV may serve as an attractive signaling device itself, but sirens, strobes, loudspeakers, or others devices could be attached to UAVs as well, creating a widely visible or audible signaling platform. Periodic monitoring of a perimeter area may also be performed by a UAV. It is plausible that a UAV could serve as a listening device by adding an onboard microphone; however, this may be impractical due to the rotor noise while the UAV is in flight.

2.2.3 Logistical or Rescue Support

Larger UAVs with more payload capability and endurance may eventually be able to serve as communications platforms for VHF repeaters - allowing communication between field teams and search management in areas inaccessible to normal radio communication. Likewise, UAVs may serve as platforms for internet access Wi-Fi hotspots in areas where cellular service is limited. This could enhance the downloading of maps, weather information, and even the uploading of images or clue information. Search teams could potentially get a new supply of batteries for their radios or headlamps delivered by a UAV without having to return all the way to base.

Once the subject is located and the search has become a rescue operation, UAVs offer a mechanism to provide small items to the subject, such as a cell phone, space blanket, food, and/or water, until rescuers arrive. If the subject is injured or ill, a person with suitable medical

[13] Similar crowd sourcing was used in the search for Malaysia Flight 370.
http://www.digitalglobeblog.com/2014/03/10/missingmalayairjet/

training could monitor their status, brief the evacuation team on what to expect, and possibly even instruct the subject on how best to help themselves until ground units arrive on scene. Information about the subject's environment can provided to rescue teams that are en route to the subject, ensuring that they are aware of any hazards in the area. In preparation for evacuation, an UAV team could scout egress routes and offer advice on obstacle avoidance to the evacuation team, as well as allowing command to monitor the status of the evacuation. Likewise, visual monitoring of the subject by higher trained medical personnel not on scene could prove valuable.

2.2.4 Training

The incorporation of UAVs into routine training would have several advantages. Instructors may observe their field teams in action and make suggestions in real time. Further, team members could review their own performance by seeing their route, areas covered, search grid formation, etc. after returning to base. Equestrians could watch their formations in a field, how they search trails, riding techniques, and troubleshooting. Canine handlers could review search patterns and performance measures of their dogs.

2.3 Non-SAR Applications

Teams possessing trained UAV personnel may be called in by a responsible authority (RA) to help in other areas not previously recognized. Fire Departments occasionally need help with hazmat incidents and major chemical spills. The ability to fly over the incident before sending personnel into hazardous situations could prove very useful. Likewise, the ability to position a camera over a burning warehouse or high-rise structure and locate hotspots that are not visible from the ground would be invaluable.

Law enforcement personnel frequently find themselves in real life-threat crises and using a UAV from a distance could be invaluable to them. UAVs may also be useful for a law enforcement agency's collecting of evidence at a major crimes scene. After a demonstration of UAV capabilities, the Monongalia County Sheriff's Department (Morgantown, WV) has already expressed interest in a UAV assisting his department in the future. Teams would have to decide whether they wished to help with these types of missions or not before the situations arise, but this could be a new service for ASRC to offer nearby public safety agencies. SAR teams with UAVs could also serve as a resource for helping these other departments procure their own UAV, thus fostering further interagency cooperation.

3 Challenges to UAV Adoption:

While the authors see numerous advantages to UAVs, they are not being deployed effectively for SAR. In general, organizations that might make use of UAVs are attempting to maintain a low profile in hopes that regulators will not notice them. To do this, UAVs are frequently operated in SAR organizations by a person who is nominally independent of the group. While this gives the organization some plausible deniability, it denies it the ability to establish effective policies, procedures, and training programs. *More importantly, it denies organizations expert authority in the public discourse about the benefits and limitations of including UAVs in SAR operations*, which will be critical if the organization wishes to influence the discussion. A better approach would be for a well-known and respected organization to be very open about its desire to integrate UAVs into its operations and demonstrate how it is taking a careful, measured approach to this effort. Several more specific challenges are discussed below:

3.1 Cost

Most SAR groups in the United States are volunteer based non-profit organizations (i.e. Internal Revenue Service registered 501©3), and may not have significant financial resources available. The cost of procuring, maintaining, and operating a UAV is likely the largest barrier to applying the technology to SAR missions. Several examples of costs that may be incurred by and organization fielding UAVs are listed below:

- A simple UAV capable of transmitting high-quality live video to the operator typically costs $1,000 or more. The most advanced UAVs can cost in excess of $25,000. While the purchase and operational costs of UAVs are orders of magnitude cheaper than many other aircraft used for SAR, most SAR teams are all-volunteer organizations, and the procurement of even a low priced UAV could represent a significant expenditure for a non-profit SAR team.
- UAVs may be expensive to insure against damage and loss of equipment, which could have an adverse effect on organizations with limited budgets, like most volunteer SAR groups.
- Liability insurance for UAV operations may have an added cost.
- Training and, if necessary, certifying an operator may be significant investment of time and resources. Teams will need to determine if the resources required are worth the benefits provided.

3.2 Regulation

A number of governmental bodies have the ability to regulate the use of UAVs. At the Federal level, the Federal Aviation Administration (FAA) has the primary responsibility for regulation of aircraft, but a number of other agencies have taken action to restrict UAV use as it pertains to their individual areas of authority.

3.2.1 Federal Aviation Administration (FAA)

The FAA is the only agency permitted to regulate US airspace and aircraft operation. Until recently, the FAA had not released proposals for rules governing the use of UAVs. The FAA Modernization and Reform Act of 2012 sets a deadline of 30 September 2015, for the agency to establish regulations to allow the use of commercial UAVs.

- Current FAA rules require that all UAVs be flown within visual line of sight of the operator. The use of First-Person View (FPV) goggles by operators has been explicitly forbidden by the FAA. Numerous groups are appealing this ruling as FPV operations allow a operator to guide the UAV much more effectively and substantially extend the range of the aircraft.

- The FAA has attempted to disallow commercial use of UAVs[14], and has in at least one case, considered the use of UAVs in SAR operations to be commercial.[15]
- In August, 2014, multiple lawsuits[16] were brought against the FAA in an effort to challenge the FAA's stand against the commercial use of UAVs and for the FAA's issuance of new rules limiting the use of model aircraft.[17]
- These legal issues are all relating to policy documents and proposed rules. The current legal landscape regarding UAVs and the FAA have been summarized by Peter Sachs, Esq. on the Drone Law Journal website, where he states that, currently "there really are no federal statutes, regulations or case law that applies to [remote controlled model aircraft]."[18]

As is apparent from the details above, the FAA's proposed rules and regulations are proving to be highly controversial, and there is little certainty in what the final regulations will be at this time. Any organizations who are interested in influencing the final Federal regulations should be certain to act in the near future.

3.2.2 Bureau of Land Management (BLM)

A number of recreational areas have restricted the use of UAVs, due to visitor complaints and UAV operators intentionally disturbing wildlife.

3.2.3 National Park Service (NPS)

On June 20, 2014 the NPS Director instructed park supervisors to prohibit the launching, landing, or operation of UAVs on NPS property. Some exceptions are permitted, and it is possible to apply for permits for commercial photography and a few administrative purposes. This appears to be a temporary measure until a permanent regulation covering UAV use is put in place.

3.2.4 State Legislation

Many states legislative bodies considered legislation restricting the use of UAVs during the 2013 to 2014 legislative session. A selection of proposals from the most recent legislative session in states with ASRC teams at the time of writing are listed below.[19] Much of the recent activity relates to restricting the ability of Law Enforcement agencies to use a UAV without a court issued warrant. In the states where ASRC teams operate, SAR is considered to be a Law

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[14] The FAA imposed a $10,000 fine on a commercial photographer who was using a UAV to take pictures of the University of Virginia Campus. This fine was overturned by an administrative law judge (*Pirker v. Huerta)*, who ruled that the FAA had not issued regulations prohibiting the action in question.

[15] Texas EquuSearch is a non-profit search and rescue organization that has been subject to the threat of regulatory action by the FAA. A subsequent lawsuit *(Texas EquuSearch v. FAA*) was resolved in favor of Texas EquuSearch.

[16] *Academy of Model Aeronautics v. FAA*; *UAS America,Skypan,Drone Pilots Association, FPV Manuals v. FAA*; *Council on Government Relations v. FAA*

[17] FAA 14 CFR Part 91. Docket No. FAA-2014-0396. Interpretation of the Special Rule of Model Aircraft.

[18]Used with permission. Peters Sachs, Esq. http://dronelawjournal.com/

[19] These bills were found on the respective state websites by searching for the following keywords: Drone, UAV, unmanned, and then manually sorting through the results.

Enforcement function, so overly-broad restrictions may limit the abilities to field UAV teams in searches operated by Lead Enforcement agencies.

Delaware

- No current law explicitly restricting UAV use.
- No bills restricting UAV use are currently active in the legislature

Maryland

- No current law explicitly restricting UAV use.
- House Bill (HB) 847 - Would forbid the use of UAVs by law enforcement except with a warrant. Does not list any explicit exceptions for search and rescue, but does mention that SAR is a promising use for UAVs.

Ohio

- No current law explicitly restricting UAV use.
- HB 207 - Defines “Drone”. Requires that law enforcement agencies procure a warrant for use of a drone in any circumstance, unless authorized by the US Secretary of Homeland Security, or there is a reasonable suspicion that “that swift action is needed to prevent imminent harm to life or serious damage to property, or to forestall the imminent escape of a suspect or the destruction of evidence”. It may be possible to interpret this passage as permitting the use of drones for SAR. No specific SAR exemption is listed.

Pennsylvania

- No current law explicitly restricting UAV use.
- HB 452 - Would add “Criminal Surveillance” to the PA code and contains an exception for Law enforcement, but not Search and rescue.
- HB 961 - Would allow the Attorney general, district attorney, or their deputies to apply for a warrant to use a UAV for surveillance purposes.
- Senate Bill (SB) 1332 - This bill would define UAV, and makes it unlawful to use one to disturb wildlife except as part of lawful activities defined in Title 34, or to interfering with a person who is lawfully taking game or wildlife. Contains exceptions for Law Enforcement, but not Search and Rescue.
- SB 1332 - This bill would define UAV, and makes it unlawful to use one to disturb fish except as part of lawful activities defined in Title 30, or to interfering with a person who is lawfully taking game or wildlife. Contains exceptions for Law Enforcement, but not Search and Rescue.
- HB 2084 - Same intent as SB 1332 and SB 1334. No exceptions for Search and Rescue
- HB 2158 - Would amend Title 18 to define “Drone” and prohibit their use by law enforcement except with a warrant. All government agencies using Drones would be required to file an annual report on drones to the Pennsylvania State Police. This Bill explicitly permits “drone” use for Search and Rescue.

Virginia

- Current law restricts the use of UAVs by law enforcement. A state wide moratorium on UAV use by Law Enforcement is in effect until July 1, 2015, though exceptions may be granted in emergency situations and for training. A warrant shall be required for non-emergency use.

- No bills restricting UAV use are currently active in the legislature

West Virginia

- No current law explicitly restricting UAV use.
- HB 2997 - Would require that law enforcement secure a warrant before using a UAV to collect evidence, except in exigent circumstances, and in cases of “public safety” or emergency declarations, and requires that all use of UAVs by law enforcement be documented.

3.2.5 Community Concerns

Public Misperceptions among SAR and Related Agencies

As with other new technologies, there is a risk of developing a perception that UAVs have no utility in SAR, which may result in UAV deployment being delayed or avoided altogether. A clear parallel may be drawn to the use of canine resources: While many incident commanders have a good idea of the uses and limitations of canine units, some will rely exclusively on canines to the exclusion of other resources. Other incident commanders will not make any use of canines, even when they are available and appropriate for the task at hand. To prevent this, a concerted effort will be needed to educate all personnel who will be calling for resources or consulted on operational decisions.

Privacy Concerns

Many individuals are aware that UAVs are able to carry cameras and some are concerned that such aircraft may violate their privacy. Responsible authorities and Search and Rescue units should have policies and procedures in place to ensure that:

- SAR UAVs are only being used for legitimate emergencies under the supervision of a responsible authority, and for training.
- SAR UAVs are being operated by well-trained and competent individuals
- Maintaining the privacy of individuals is vital to maintaining community goodwill and procedures and training should reflect this.
- Any potentially private information that is collected will be appropriately dealt with.

The best practice for all organizations using UAVs is complete transparency about training and operational practices.

4 The Future of UAVs in SAR

If the ASRC desires to influence the adoption of UAVs in search and rescue, a combined approach of several efforts should be mounted. First, there is a public relations aspect; the Conference should work to increase awareness and promote interest among the wider community. Next, the Conference should begin a research program, to better understand more precisely what the capabilities and limitations of the available technologies are. Finally, the Conference should work to incorporate UAVs into the training, simulation, and eventually, mission activities of its constituent teams. The remainder of this section presents additional detail on each of these efforts.

4.1 Strategies for Increasing Interest in UAVs for SAR

Even if UAVs dramatically outperform all expectations for their performance in SAR, public opinion will have a substantial effect on the ability of organizations like the ASRC to field them. There is currently a nationwide debate about the limitations that should be imposed on UAV use. The ASRC should be a part of that discussion and should work to show that it has a vision for UAV use that satisfies those who are concerned about misuse of this technologies, while still forwarding the Conference's mission. To do this, the Conference should identify the groups who have a substantial impact on these future uses and encourage them to support the Conference's vision for the future.

Legislative Bodies

Based upon privacy concerns and media sensationalism, many states are proposing laws to govern the use of UAVs. A clear and concise presentation on the technology and a demonstration to a state senator or legislator is encouraged to help ensure that any future laws passed do not hinder use of UAVs for SAR and may even gain your agency grant money for the initial purchase.

Partner Agencies

Several large police agencies with substantial budgets are already early adopters of UAV technology but agencies with more modest budgets frequently have limited opportunities to access this technology's potential. Some states are passing laws to limit surveillance via UAV by law enforcement agencies unless a warrant is obtained. Meeting with these local agencies can do three things:

1. Make them aware of what the UAVs are being used for locally in order to head off any possible complaints from anxious citizens.
2. Develop agreements to allow agencies access to UAV teams and equipment in the event of non-SAR emergency situations such as large multiple-casualty or hazmat incident, if needed, or
3. Offer assistance in the event that an agency wishes to purchase their own UAV and start a training program.

SAR Community

Adoption of new technologies within SAR can be a contentious process, and is rarely fast, as is demonstrated by the gradual acceptance of GPS and GIS technology. UAV adoption will take time and will be accomplished by allowing input from the general membership into how to best use this technology for the advancement of the our missions. Incorporation of UAVs into regular training sessions will gradually allow the members to see where this fits into their skill set as a team. Larry Bulanda has written a series of three articles on Robotic Systems in Search and

Rescue[20] that explains canine handler considerations and how a well-trained search dog should be familiar and comfortable with many kinds of environmental distractions, of which a UAV is just another distraction to which the dog will need to be acclimated. Just as canine should be familiarized with UAVs, other types of SAR units will need to be trained so that they can safely interact with a UAV in the field.

Community At-Large

In an effort to generate community interest and to counter privacy concerns, SAR teams must educate their communities with the positive idea that we are exploring ideas for the safe use of UAVs as another tool in our mission of finding missing persons. Often, just an explanation to people in the area about what we are doing and why has resulted in immediate support. However, agencies may find that a local newspaper or TV news spot will give them stronger community buy-in. Holding open training sessions run by experienced UAV operators and inviting the media for demonstrations of this technology is suggested. Having members of the SAR agency become the guest speakers at local civic organization meetings to discuss "what new things we are doing within the search and rescue community" also gets the word out quickly and may result in offers of financial support.

4.2 Proposed Research Activities:

Today, many Search and Rescue organizations like the ASRC have been working to quantify and improve their performance by making use of advances in Search Theory, Geographic Information Systems, and quantification of searcher performance via sweep width measurements.

In order to make most efficient use of UAVs, it is necessary to quantify their performance with testing. For example, research on Sweep Width determinations remains to be done to actually compare that of the UAV with human searchers, but if the Sweep Width of the UAV is even half that of a helicopter then deploying a small UAV (with a small team trained to use it) may be more worthwhile for the overall mission than that assigning those same individuals to ground search tasks. The purpose of this section is to lay out a few of the applicable questions and suggest a set of experiments.

Currently, there is no publicly available sweep width data for use of UAVs on searches, and certainly no data describing their performance in any of the various types of wilderness that are present in the ASRC's response area. Helicopters are the closest analog for which data is readily available. According to the United States National Search and Rescue Supplement to the International Aeronautical and Maritime Search and Rescue Manual[21], the sweep width for a helicopter behaving most like a UAV (flying slowly, at low altitudes, looking for a single person) ranges from roughly 100 meters to over 800 meters, depending on terrain and vegetation. It seems reasonable to assume that a UAV's sweep width is more similar to a helicopter's than to

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[20] Bulanda, L.: Robotic Systems in Search and Rescue in NSDA's SAR Dog News, Vol. 8, No. 6-8. 2014.

[21] National Search and Rescue Committee. "United States National Search and Rescue Supplement to the International Aeronautical and Maritime Search and Rescue Manual." Appendix G. May 2000.

a ground searchers, but the specifics are currently unknown. To correct this, it is necessary to find answers to several questions:

- How do the following variables affect sweep width?
  - Altitude
  - Atmospheric Visibility
  - Vegetation and terrain
  - Camera resolution
- It is possible to search both by live video and by stored digital photographs. How does the method of search affect Probability of Detection?
- How much search effort can a UAV exert in a single task before needing to return to the operator?

While suggesting experimental protocols is outside the scope of this paper, the ASRC should encourage those who are interested in performing experiments to explore these questions.

4.3 Recommendations for Integrating UAVs into ASRC Operations

Member teams of the ASRC have an opportunity to influence the adoption of UAVs for SAR at both the local and regional level, Provided below are several specific recommendations for the ASRC to consider as its member teams continue to explore this promising technology:

1. The ASRC should appoint an individual to act as the Conference's chief point of contact for UAV related matters and act as a community facilitator. This individual will be expected to identify stakeholders both within and without the organization (including both UAV operators and individuals who are engaged in activities where incorporation of UAVs may be productive), develop a plan for, and work to achieve the ASRC's goals related to UAVs. This individual should also support the development of UAV resources among ASRC teams.
2. The ASRC should monitor the regulatory environment, and work to ensure that any policies and standards comply with the evolving regulatory landscape.
3. The ASRC should compile a list of associated people and organizations that own UAVs and may be interested in developing or participating in experiments and the development of ASRC resources. This pool of people may be able to provide the manpower and equipment needed to perform testing, and if large enough, may be able to sustain a community of UAV operators that could become the base for an ASRC UAV testing and training corps.
4. The ASRC should encourage the inclusion of UAV testing on any search experiments i.e. sweep width. Individuals who are developing experiments should consider the use of UAVs when designing protocols, running experiments, and reporting results.
5. The ASRC should develop and refine protocols for the use of UAVs in searches, and for search personnel who may interact with UAVs, by encouraging the participation of UAV operators in mock searches. Practical, on-the-ground experience in a simulation will allow UAV operators to test various search strategies, identify opportunities for improvement, and hone their piloting skills.
6. As soon as is practical, the ASRC should develop a short list of guidelines for incorporating UAVs into searches, and should disseminate guidance and train search

managers how to safely incorporate UAVs into a search effort. This guidance and training should be reviewed and updated periodically to reflect the results of ongoing experiments and improving capabilities.

7. If resources are available, specific experiments to characterize UAV performance as described above should be developed and run by the Conference.

5 Conclusions

UAVs currently offer a large number of compelling reasons for incorporating them into search operations, and their capabilities are improving at a rapid pace. However few organizations have taken the time to seriously investigate the use of UAVs in search and rescue, and those that have are still early in the process. This, combined with the fact that their use is not yet highly regulated, presents the Appalachian Search and Rescue Conference with an opportunity to shape the field, and solidify its position as a leader in the incorporation of new technologies in SAR.

To do this, the ASRC needs to take action quickly, engaging UAV operators, member teams, community leaders, and regulators, winning them over to the ASRC vision of how UAVs can be efficiently, safely, and quickly incorporated into search and rescue. This paper posits that there are three fronts where there is an opportunity to directly shape the future of UAVs in SAR.

1. Research - The ASRC should work to quantify the performance of UAVs and determine how best to apply them in a search effort. Given that the Conference has a history of research and has devoted much effort to measure and improve search efficacy, it is likely that the ASRC is one of the best organizations in the nation for performing for this task. However, the Conference should be ready and willing to collaborate with other interested organizations.
2. Outreach to the community and regulators - UAVs are still something of a novelty and many people, including regulators, lack a true understanding of the potential of UAVs in SAR. Given the current level of scrutiny in the media, there is a real risk of community backlash and over-regulation due to the actions of a troublesome or blithely ignorant minority. The ASRC should act as a voice of reason, and work with communities and regulators to ensure that our mission, finding lost people, is not compromised.
3. Asset Development - The ASRC should encourage and support its member teams in developing the technical and organizational capabilities needed to field and effectively use UAVs for search, as well as promoting these capabilities to the wider SAR community.

In closing, the ASRC should act promptly - we are currently at a key point in the adoption of UAVs. First, opinion and regulation about the use of UAVs in public are still developing and few SAR organizations have been actively advocating for, or demonstrating their use. The sooner that the use of UAVs in SAR is placed into the public consciousness, the more likely that regulation and public opinion will be favorable. Second, few organizations are currently generating technical guidance on the use of UAVs in SAR. If the ASRC is able develop their capabilities to offer that, and operational experience, it will position the Conference as a technological leader in global SAR community. We, the authors, are excited by this opportunity, and urge the ASRC to embrace it.

Thanks

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Appendix A: National Testing Sites

After a rigorous 10-month selection process involving 25 proposals from 24 states, the Federal Aviation Administration has chosen six unmanned aircraft systems (UAS) research and test site operators across the country.[22] In selecting the six test site operators, the FAA considered geography, climate, location of ground infrastructure, research needs, airspace use, safety, aviation experience and risk. In totality, these six test applications achieve cross-country geographic and climatic diversity and help the FAA meet its UAS research needs.

A brief description of the six test site operators and the research they will conduct into future UAS use are below:

- **University of Alaska.** The University of Alaska proposal contained a diverse set of test site range locations in seven climatic zones as well as geographic diversity with test site range locations in Hawaii and Oregon. The research plan includes the development of a set of standards for unmanned aircraft categories, state monitoring and navigation. Alaska also plans to work on safety standards for UAS operations.
- **State of Nevada.** Nevada's project objectives concentrate on UAS standards and operations as well as operator standards and certification requirements. The applicant's research will also include a concentrated look at how air traffic control procedures will evolve with the introduction of UAS into the civil environment and how these aircraft will be integrated with NextGen. Nevada's selection contributes to geographic and climatic diversity.
- **New York's Griffiss International Airport.** Griffiss International plans to work on developing test and evaluation as well as verification and validation processes under FAA safety oversight. The applicant also plans to focus its research on sense and avoid capabilities for UAS and its sites will aid in researching the complexities of integrating UAS into the congested, northeast airspace.
- **North Dakota Department of Commerce.** North Dakota plans to develop UAS airworthiness essential data and validate high reliability link technology. This applicant will also conduct human factors research. North Dakota's application was the only one to offer a test range in the Temperate (continental) climate zone and included a variety of different airspace which will benefit multiple users.
- **Texas A&M University – Corpus Christi.** Texas A&M plans to develop system safety requirements for UAS vehicles and operations with a goal of protocols and procedures for airworthiness testing. The selection of Texas A&M contributes to geographic and climatic diversity.
- **Virginia Polytechnic Institute and State University (Virginia Tech).** Virginia Tech plans to conduct UAS failure mode testing and identify and evaluate operational and technical risks areas. This proposal includes test site range locations in both Virginia and New Jersey.

[22] http://www.faa.gov/news/updates/?newsId=75399

Appendix B: Sample UAV Imaging Capabilities

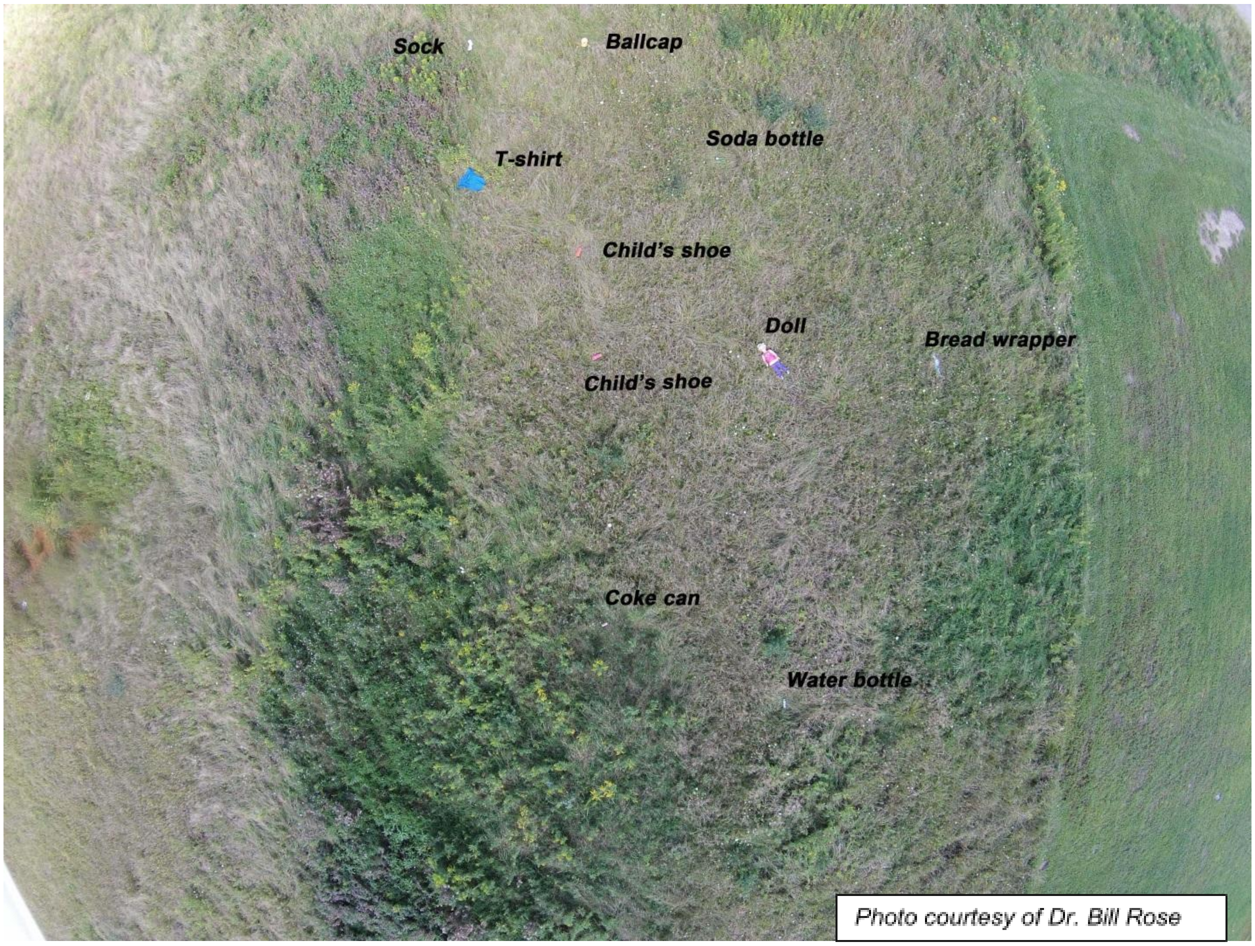
Experimentation with the Current Technology Focusing on Search and Rescue

Minimal work has been reported in the literature regarding search technique using UAVs. Bill Rose of Mountaineer Area Rescue Group has done some brief experimentation by taking digital photographs of a 35 inches tall doll (the size of a two year old) and various personal items at incremental altitudes above ground level (AGL) in order to illustrate what a "squint" (person analyzing the photos) should be looking for. The following photos show these items which were placed in a field with waist deep vegetation.

Photo 1 at Ground Level:

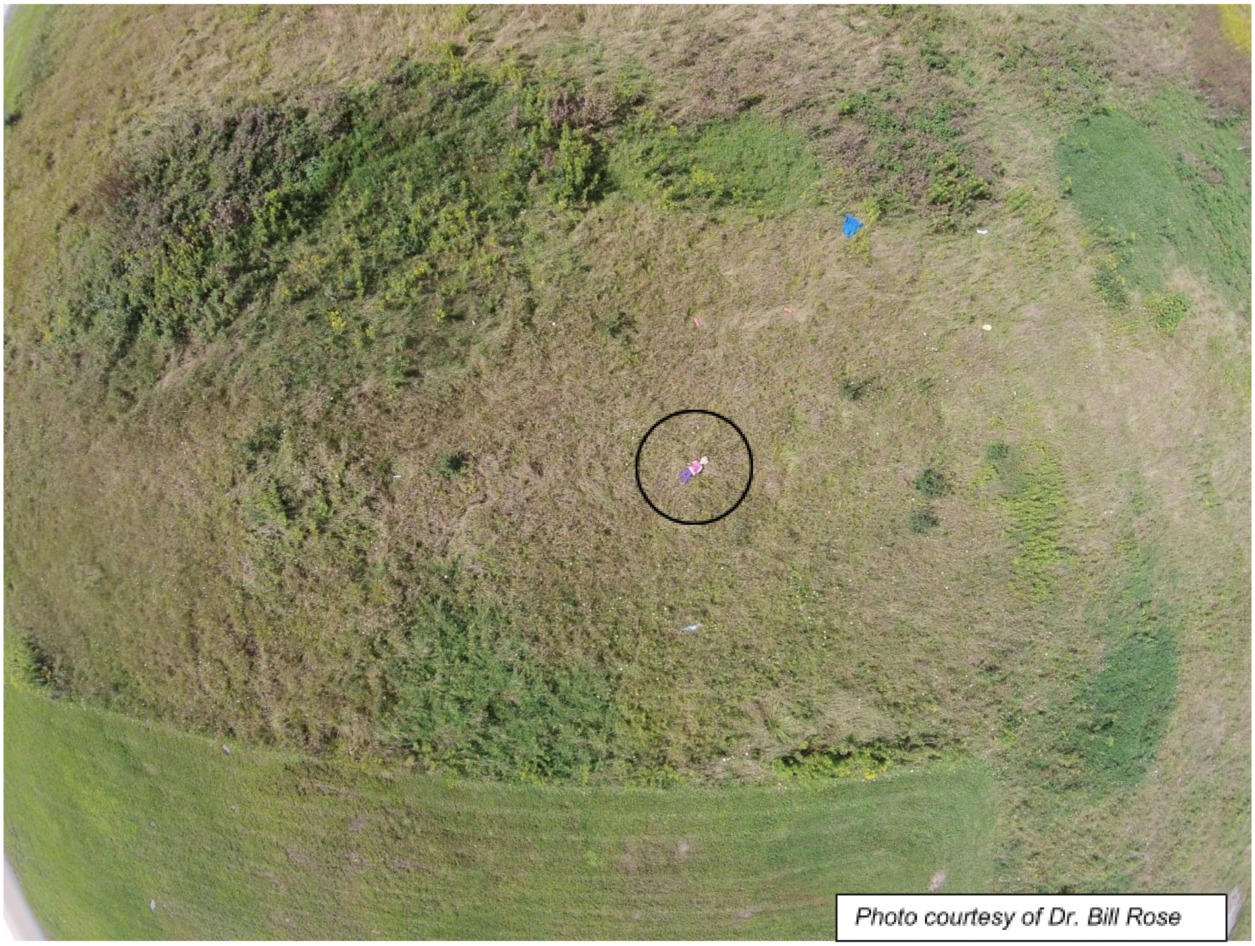
Photo courtesy of Dr. Bill Rose

Photo 2 at 50 feet AGL:



The clue items (child's shoes, sock, ball cap, soda bottle etc.) are very small in this photo but the child-sized doll is clearly seen and the actual images are much more revealing when one "zooms in" and uses a full size video monitor.

Photo 3 at 75 feet AGL (Note photo is rotated 90 degrees clockwise from Photo 1):



At this 75' AGL the child-sized doll can be clearly seen in the center of the photo and the other clues are visible enough to attract one's attention.

Photo 4 at 100 feet AGL:

Even at 100' AGL, the doll is visible; however, using the original image, a "zoomed in" look using this same photo reveals the following.

Photo 5 (Same photo as #4 above but "zoomed in"):

Photo courtesy of Dr. Bill Rose

As you can see, the doll, the shoes, T-shirt, sock, ball cap are all still visible. However, for the smaller sized clues this altitude is bordering on the upper limit of usefulness—at least with this DJI FC200 camera and this resolution.

Developing the best search technique for UAV searching will require further experimentation. Whether the best technique is to have the UAV actually fly the device visually, or using First Person View, or by use of a software program using waypoints placed in a grid pattern using a ground station will have to be determined, along with Sweep Width calculations.

Gene Robinson gave some insight into how he does this: "The pattern we attempt to fly is very little different than that of mowing your lawn. The aircraft is taken to the edge of vision with the naked eye and then returned with the path offset enough to photograph new area with approximately 20% overlap on the previous pass. This does two things for us. First we can be assured that we have covered 100% of the area in question, and second, it sometimes gives us a different angle on images taken in the first pass. The second reason can be very important in confirming whether a "target" is something that is valid and if manpower should be expended to investigate further."[23]

[23] First to Deploy. Gene Robinson. 2014. eBook.

Appendix C: SOP of SWARM[24]

Standard Operating Procedures

SWARM is an organization that offers aerial search services to SAR organizations and the families of missing persons. Under no circumstances should any SWARM network member require compensation or any fee for their services. Only under special circumstances and arrangements made PRIOR to services rendered can the "pilot" be reimbursed (at the discretion of the SAR Unit in charge or family), for additional equipment or gear needed to execute the search. For example, the SAR unit might authorize the purchase of several batteries in order for you to conduct a longer search. This is permissible as long as it doesn't come in the form of "compensation" for services.

SWARM is a worldwide volunteer network. Volunteers will not receive compensation for their services. This includes any damages or repairs incurred while on SAR missions.

SWARM members flying UAV's, should be equipped with a minimum of FPV (first person view) capability. In addition, it is highly recommended and useful to have OSD (On Screen Display Information) and 5-6 spare LiPo batteries as your secondary tools.

Other useful (but not mandatory) tools include:
A) Video Record Capability.
B) UHF TX/RX (Long Range reception)
C) Tilt Camera Gimbal.
D) "Low Light" Camera up to FLIR or Infrared Technology.
E) Autonomous Ability for autopilot "Waypoint" search missions.
F) First Aid Kit
G) Ground Station Monitor (for spotter)
H) 2nd pair of Goggles (for "ride along" spotters)
I) 2nd person to act as "ground spotter" for your aircraft
J) Head Tracker (fixed wing)
K) GPS Tracker (to recover lost aircraft)
L) Low Battery Warning Alarm/Beeper

• Drone Pilots should contact and join their own local SAR unit in their respective Country/State/County. Becoming a "certified SAR volunteer" will aid you when a SAR happens in your area that needs aerial search capabilities.
• Pilots should acquire an FAA Sectional Aeronautical Chart (WAC) from their local FAA field office. This chart gives information about airports in your area and the no-fly zones around them. Contact your local FAA with your intentions to fly where and when necessary.
• All equipment should be maintained, pre and post flight inspected and in good working order at all times. (If you are not sure, don't fly).

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[24] Reproduced with permission. Jim Bowers, SWARM founder.

• It is highly recommended that all pilots carry a basic first aid kit with them plus rations for the day. Food / Water and First Aid could be beneficial for the victim and/or you.
• Pilots are RESTRICTED from flying above 400′ AGL (Above Ground Level). In most situations, 200-300′ AGL is optimum for scanning urban terrain, dense foliage and wooded areas. Check with local law enforcement and/or the FAA or local SAR unit for any variances on this matter.
• We will ALWAYS conduct ourselves in a professional and courteous manner at all times. Remember what we're there for. To provide help and potentially closure to a worried or grieving family.
• Flying close, in or around groups of people is prohibited. Always take off and land at least 25′ away from people that are unfamiliar with the operation of your aircraft.
• Check with the SAR unit in charge before speaking to the media about Drone operations or the missing person case at hand. In many situations, contact with the media is frowned upon. In the event that you DO speak with the media, keep it professional and represent our SWARM network with the utmost in professionalism. Only talk about what you KNOW to be the facts. Keep personal opinions and conjecture out.
• Always check-in with ground personnel or officer/s in charge at the scene. NEVER fly without the necessary permission to do so. Flying without permission puts your credibility and our reputation and professionalism at risk.
• Extreme care and planning should be taken when there are more than one aircraft in the SAR area (especially conventional aircraft, helicopters etc.). Coordinate closely with the on-scene officer/s, and create a working plan to avoid any potential midair incidents. In the event that you are flying with more than one UAV pilot, perform a pre-flight meeting to discuss any conflicts between your broadcast frequencies etc. Do NOT turn on your radio or video transmitter BEFORE checking with officials and other UAV pilots on scene.
• Whenever flying in a SAR operation, keep a written flight log of the time and location/area that you flew. This information may be required of you later by authorities.
• Maintain your equipment! It is crucial to perform a pre-flight check before EVERY take-off – it is recommended that you carry a check-list with you;

- A) Check all of your aircraft batteries with a voltage checker. Check camera Battery. Check GPS tracker Battery. Check ground station Battery. Check goggles Battery.
- B) Know what your "course" or survey area will be. There's no point in searching an area that has already been thoroughly searched.
- C) Perform a Compass Calibration (remember – you are in an entirely new area with potentially new compass parameters) Better to be safe than sorry.
- D) Check ALL Transmitter Radio Switches and Toggles to ensure they are in the correct position before take-off. Never take-Off in Manual Mode unless you are an expert pilot and have good reason to do so.
- E) Wait for GPS lock on the ground. Allowing the aircraft to "lock" in the air does NOT guarantee it will "return to home" safely.
- F) Check your prop adapters for adequate tightness.
- G) Take off from an "OPEN" area whenever possible. Taking off in dense trees does not guarantee that it can return to home accurately through tree limbs or obstacles.
- H) Whenever switching out your battery for fresh one, be sure to turn your radio TX OFF and back on again BEFORE you plug in your fresh battery.

- I) If you are not using OSD information, it is advisable to install a battery beeper alarm on your aircraft to alert you when the battery drops below the preset voltage parameters.
- J) If you ARE utilizing OSD info, again, wait for full GPS satellite lock BEFORE lifting off.
- K) If you are flying in an unfamiliar area, look for large “stand out” landmarks around you in order to “find your way” home again.
- L) Whenever possible, bring a “spotter” with you. That person can assist with your course travel plus help search using a ground station monitor or “ride along” goggles. A second support person can be invaluable!
- M) It is advisable to fly in GPS mode whenever possible. This ensures that the aircraft will be stable in the air if/when you are distracted on the ground. (Flying in ATTI or full Manual Mode allows the aircraft to “drift” potentially into a dangerous situation).
- N) Any and all aerial footage captured with your aircraft is the “property” of the SAR unit and/or family. Copies of that footage should be made available to them as soon as possible.
- O) Recorded Aerial Video should be inspected for potential “targets” either on-scene or same day ASAP.
- P) Post flight aircraft inspection – ensure that motors, batteries and esc’s are within normal temperature parameters. Inspect aircraft for any damage to components.

DISCLAIMER

Members of the SWARM network must be 18 years or older (15 years old to act as “SPOTTER” with a guardian) and are solely responsible for any and all actions in the field. Members are advised to carry their own insurance, AMA membership/insurance etc. SWARM and or its officers will not be responsible for any accident, injury or incident in the operation of your aircraft or your participation in any and all SAR operations. We are ONLY an online resource for available SAR volunteers. SARdrones.org and on Facebook.com exists ONLY to provide an online resource of available SAR volunteers around the world. We are not a sanctioned organization or an official non-profit entity. While a majority of our pilots have sufficient multi rotor and RC experience or carry credentials in SAR application, we cannot guarantee the performance of any pilot or equipment. It is solely at the discretion of the official on-scene SAR unit to qualify any and all volunteers from this network prior to their volunteer services.

Appendix D: Example of UAV Specifications

DJI "Phantom 2 Vision+" (P2V+) by DJI Innovations - Expanded Features List:

- Flight time ~ 20 minutes using rechargeable LiPo batteries
- Minimal learning curve for pilots with no previous R/C experience
- GPS stabilized flight control system allows continuous hover in a fixed position or stable drift-free flight over an area
- 3 axis motorized gimbal for vibration free photography and video
- Built-in 14 MP camera for photos and 1080p HD video
- FPV video is relayed back via telemetry to an iPad, iPhone, or Android-based device mounted on the handheld remote controller (transmitter).
- Digital imagery and HD video is recorded on an onboard micro-SD card for later playback/analysis on a computer. Digital images are coded with GPS coordinates while the HD video is not.
- Yaw control of the UAV allows rotational scanning of the area.
- Remote camera tilt control allows zero degrees (horizon view) to -90 degrees (straight down) observations.
- Ground station: A mobile device application on monitor allows preset waypoints superimposed onto aerial imagery of the local area. This allows the user to define a preset autonomous flight path (search grid) over a set terrain.
- Range: 700-800m. Direct line-of-sight (LOS)
- Failsafe: The unit's Home Point is marked by GPS prior to takeoff. If the unit loses its control signal (or if the pilot loses visual orientation and manually triggers "Failsafe" mode) the UAV ascends to 20m, hovers, flies back to its Home Point, hovers, and then lands—assuming the pilot doesn't take back control.
- Radar feature (not actually radar): If the pilot loses visual orientation he/she can look at an icon on the monitor and determine the UAV's heading
- Low Battery Warning: If the onboard battery charge reaches a preset *low* value (typically 20-30%) both a visual and audible alarm is triggered on the monitor. If the battery charge reaches a *critically low* level, the UAV descends and lands.
- Information superimposed on the video display shows flight parameters including range, altitude, speed, number of GPS satellites being received, onboard battery status, onboard SD card status, Wi-Fi signal strength, etc.
- Complete UAV, remote controller, video monitor, extra batteries, and other accessories fit nicely inside a Pelican 1560 case for easy transport.