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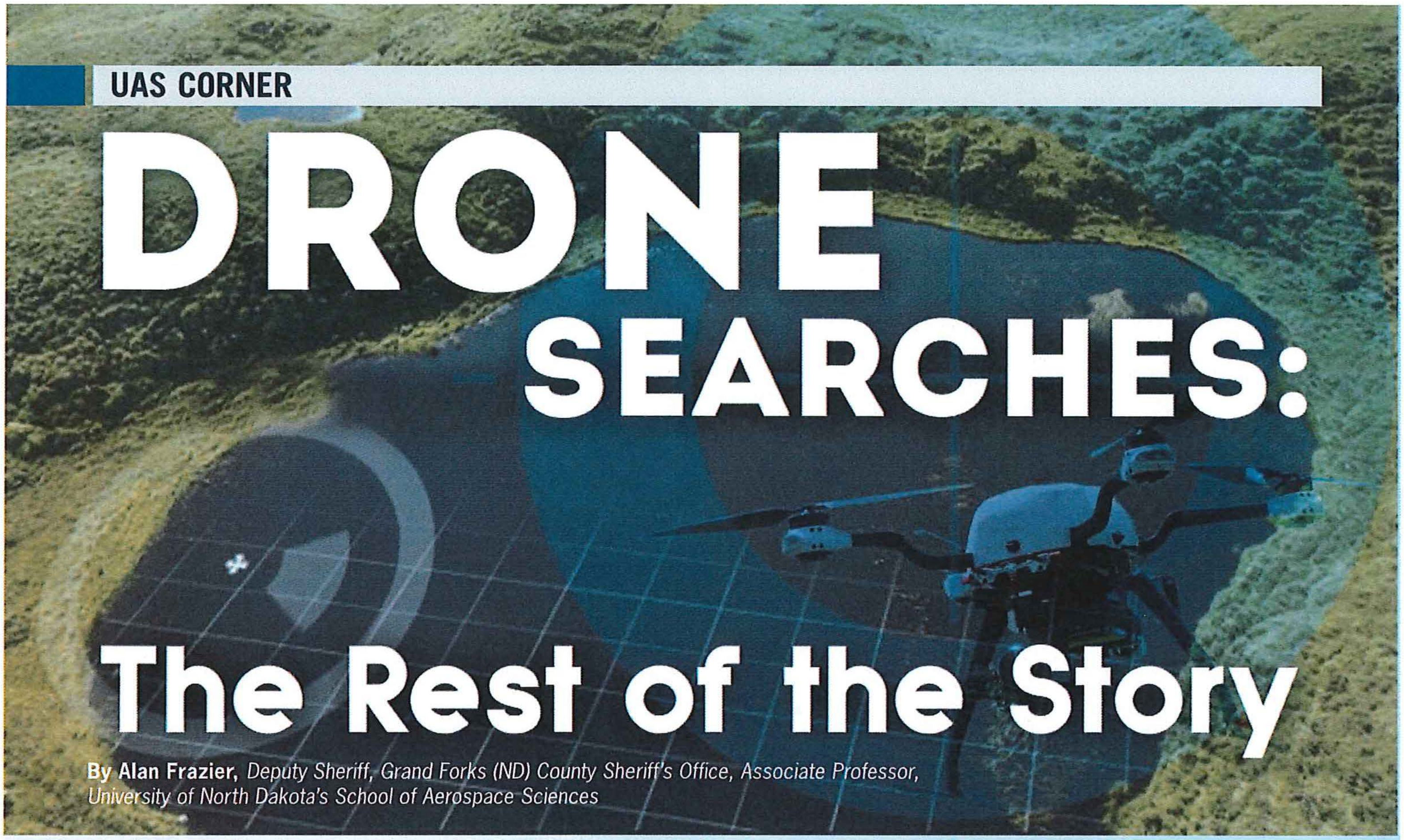

DRONE SEARCHES: The Rest of the Story

By Alan Frazier, *Deputy Sheriff, Grand Forks (ND) County Sheriff's Office, Associate Professor, University of North Dakota's School of Aerospace Sciences*

The press has covered the adoption of small unmanned aircraft systems by public safety agencies quite thoroughly. Most articles on police sUAS acquisition, as well as radio and television interviews, usually include a quote from an agency representative concerning intended sUAS uses. Invariably, the uses include "searches for missing persons."

While I am confident these statements are made in good faith, the reality is sUAS are only marginally effective in conducting wide area searches.

While agencies offer some success stories of finding people (good and bad) with sUAS, the instances are rare. This is due to a variety of factors. First, sUAS generally have flight times in the 15 to 40-minute range. This limits the size of the area that can be searched during a single flight.

Second, the Federal Aviation Administration and sound flight safety practices limit sUAS range to the pilot's line of sight. Experience shows "line of sight" range is approximately 0.5 statute miles (sm) during the day and 1 sm at night. (The longer range at night results from the bright LED lights on night flight-equipped sUAS.) The line-of-sight limitation requires careful planning to adequately search a wide area.

Third, sUAS sensor systems are significantly less capable than those carried aboard manned public safety aircraft. This is due to weight—most sUAS sensors must weigh less than several pounds due to limited payload capacity—and cost limitations—not too many agencies are willing to purchase a $50K sensor to be carried aboard a $5K sUAS.

Does this mean we should not use sUAS to assist in searches? No. What it does mean is we must have a realistic understanding of the limitations of sUAS tasked to searches and a good plan to mitigate them.

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WHERE TO START

The first consideration in conducting a search for a missing person is to identify the place last seen (PLS).

The PLS can be identified via an actual sighting of the victim, but it can also be a location identified by a ping from a cell phone, personal locator beacon (PLB) or aircraft 406-Mhz emergency locator transmitter (ELT). Pings from these devices can be geo-located in ways specific to the device (cell phone tower triangulation for cell phones; satellite reception for PLBs and ELTs).

A forensically discovered credit card transaction record, review of closed circuit television recordings, credible statement regarding a planned itinerary made by the missing person to a witness, or a trip itinerary left with a friend or government employee such as a park ranger can also be uses to determine the PLS.

Absent compelling evidence to the contrary, the PLS is usually the best place to begin a search. In the case of children missing from a home, church, daycare facility, etc., two different searchers must perform a systematic and thorough structure exploration prior to or when a wide area exterior search is initiated. This is because most missing children are found sleeping or hiding in or near the PLS.

CIRCLING OVERHEAD

Once the PLS has been identified and the decision made to begin a wide area search, a systematic search plan should be

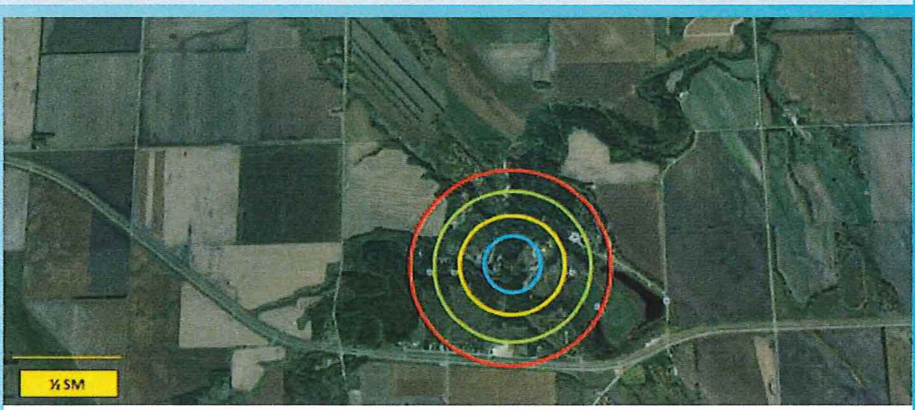

Fig. 1: *Shown here is an expanding orbit search pattern based on a maximum 0.5 sm radius from the sUAS pilot-in-command. Each search orbit is separated by 0.125 sm. Additional areas may be searched by relocating the PIC and creating another series of search orbits abutting the previous search orbit area. Flying such a pattern without an application guiding the sUAS requires well developed flying skills and practice.*

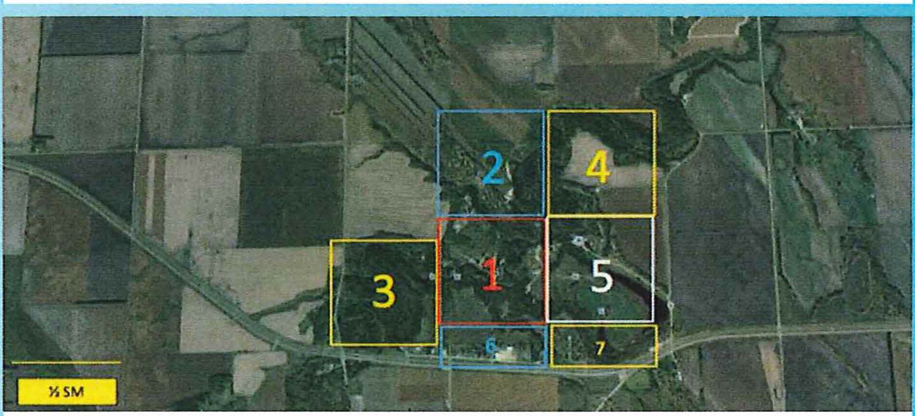

Fig. 2: *A series of grid search patterns may be developed and flown using proprietary software such as that used to operate the AeroVironment Qube Quadcopter or photometric applications such as Pix4D Capture or Drone Deploy. The example shown here utilizes a 0.5 sm square ensuring that the drone is never further than 0.5 sm from the PIC and usually within 0.25 sm. Search boxes are numbered in the order they will be searched based on a subjective evaluation (in descending order) of the likelihood that the missing person is in the search box.*

drafted. Too often, searchers launch an sUAS and begin randomly searching the area. While this is expeditious, it usually results in frustration and low assurance the area has been thoroughly searched.

Figs. 1 and 2 are examples of systematic sUAS aerial search plans that ensure the area is searched methodically and thoroughly. The plans are based on the idea the greatest line of sight range (PIC to sUAS) is 0.5 sm. In areas of dense foliage or during periods of reduced visibility, the dimensions of the search areas should be decreased to improve probability of detection.

The search plan can be formulated by using computer applications such as Google Earth or reverting to the old fashioned method of drawing lines and circles on a topographic map with a drafting compass and straightedge. The Google earth method allows instant availability of worldwide imagery and greater detail than a topographic map.

Fig. 1 illustrates a circular search pattern. Beginning at the PLS, the sUAS is launched, piloted to a safe altitude and, using GPS distance measurements displayed on the ground control station (GCS), flown outbound on a specific course for a distance of 0.125 sm. The aircraft is then pointed towards the pilot and commanded to climb to an altitude that provides a clear line of sight of the area between the sUAS and PIC. Using the GCS distance measurement and the PIC's visual estimate of distance to the sUAS, the aircraft is then flown in a 360-degree orbit at a 0.125 sm radius. Because the PIC will be busy with flight related tasks, one or more searchers can be used to monitor the downlinked video. The downlink can be accomplished by connecting the GCS to a large screen monitor via HDMI or RCA cables.

Upon seeing an object of interest, the searchers monitoring the video should coordinate with the PIC to further investigate. Frequent photographs should be taken to enable later analysis that may reveal objects not originally detected. The higher resolution of photographs versus video will support digital enlargement to provide greater detail.

Once the 0.125 sm radius, 360-degree orbit is completed, the sUAS camera should be placed in a downward looking orientation and a prominent landmark, such as a distinctive tree, cabin or clearing should be identified. The landmark serves as a reference point for the next step of the orbit search.

The sUAS should then be flown out to a 0.25 sm radius from the PIC on the same course as in the previous step. At that point, the sUAS and camera should be pointed toward the PIC. The previously identified prominent landmark should be visible halfway between the sUAS and PIC. Using the prominent landmark as a reference, the PIC should adjust the camera to focus on the 0.125 sm area between the sUAS and the prominent landmark. Note the 0.25 sm radius orbit is made from the PIC, not the prominent landmark. The landmark serves as a reference for aiming the camera at the unsearched area.

Using a visual estimate of distance to the sUAS, verified by the distance measurement displayed on the GCS, the pilot should complete another inward looking 360-degree orbit focusing on the area 0.125 to 0.25 sm from the PIC. Again, the use of additional searchers to monitor the downlinked video, close crew coordination and frequent photographs will add to the probability of success. The procedure should be repeated at radii of 0.375 and 0.5.

Upon completion of the 0.5 sm radius orbit, the sUAS should be returned home and landed. The sUAS battery should be exchanged with a fully charged unit and the camera SD card replaced. Using a search plan similar to the one shown in Fig. 1, the PIC and assisting searchers should relocate to the center of the next highest probability area to perform search orbits as previously described. One or more additional searchers should view the video and images captured on the SD card removed from the sUAS. The slower video and photo analysis allows the viewer to stop the video and view objects of interest, as well as the ability to digitally zoom in on photographs to further investigate. Anything significant could create the need to send in a ground team or bring the sUAS back for further investigation of the area.

ON THE GRID

Fig. 2 illustrates a parallel track, or grid, search plan.

Some sUAS, such as the AeroVironment Qube Quadcopter, have the ability to initiate GPS-guided grid searches of a specified area. Using a Panasonic Toughbook GCS running AeroVironment proprietary software, the PIC is able to define a square or rectangular search area by touching three points on the GCS moving map display. The PIC selects the desired camera overlap by percentage of viewing area and commands the sUAS to execute the search. The sUAS proceeds to the closest search area entry point and begins a GPS-guided series of parallel tracks. The program also provides a time estimate for the search. If an object of interest is observed, the PIC can command the sUAS to stop and maneuver it laterally and vertically to better view it. The PIC can then enter a resume search command, and the sUAS returns to the position and altitude from which it was diverted.

Several computer applications can be leveraged to auto-fly grid searches. Pix4D Capture and Drone Deploy were designed for tasks like creating orthomosaic images. They can be used to create a matrixed image of a large area that can then be further analyzed in an attempt to locate missing persons.

Drone SAR, a 2016 Irish startup company, has touted the imminent release of an application designed specifically to support DJI sUAS wide area searches. In December 2017, the Drone SAR co-founder said on Facebook the application was "just a couple of weeks from release" and would be initially only available as an iOS application. A May 9 search of the Apple Application Store failed to find the Drone SAR application.

Grid searches can be accomplished without GPS-guided search pattern programs, but they are difficult and can only be effectively accomplished over an area that is not homogenous in appearance. For instance, a pilot-flown search of a suburban city block would be feasible due to the many points of reference, such as streets, sidewalks, fences and houses. A pilot flown grid search of an agricultural field, wooded area or grassland would be difficult to perform methodically due to the lack of readily identifiable visual reference points.

Trails and river searches are best accomplished by "leapfrogging" along the trail or waterway. The sUAS is flown ahead of the searchers along the path; the searchers may use a variety of transportation methods, including hiking, horseback, all-terrain vehicles, mountain bikes or vessels. By searching ahead with the sUAS, the operator can explore a significant area to either side of the trail or waterway without the searchers departing the trail or waterway. This method of searching is more expeditious and potentially safer, as it avoids the need for searchers to stray into areas that may pose a higher level of risk due to steep terrain, swamps, animals and flora hazards such as poison oak.

Two types of sensor systems are widely used in sUAS operations: electro-optical cameras and infrared cameras. It is ideal to have both simultaneously aboard the sUAS during any systematic search. The ability to switch between EO and IR sensor systems adds effectiveness to day searches. Infrared cameras are essential for night searches.

RECORDKEEPING OF SEARCHES

Whichever search pattern is used, a record of the areas searched must be made to promote efficiency and help avoid duplication of efforts.

In addition to recording which areas have been searched, a subjective evaluation of the probability of detection should be recorded. The desire of the subject to be found versus hiding, as well as the topography and density of foliage, creates widely divergent probabilities of detection. Use a scale of 0-100 percent, where 0 equals no confidence the subject would have been detected and 100 equals absolute certainty of detection.

For instance, a sUAS search for an overdue hiker in an open grassland area using EO and IR sensors would likely result in a 90-100 percent probability of detection rating. In contrast, a search for an escaped convict in a heavily wooded area on a hot day with EO and IR sensors may result in a 10-15 percent rating due to the convict's attempts to hide, heavy foliage obscuring view and the high ambient air temperature rendering the IR sensor ineffective due to thermal crossover. Assignment of probability of detection ratings are useful in determining which areas should be more thoroughly searched by ground units and which may be bypassed.

sUAS are not the ideal tool for wide area searches, but if used in a methodical, pre-planned manner, their limitations can be partially mitigated. Do not fall victim to the "just get it in the air and start looking" mentality, as the approach will usually result in failure to find the victim and frustration for the sUAS crew.