THE FEASIBILITY OF USING SMALL UNMANNED AERIAL VEHICLES FOR WILDLIFE RESEARCH

By

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by

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Aerial surveys have developed into valuable tools for scientific research, especially wildlife management. However, problems with safety, cost, statistical integrity, and logistics plague aerial surveys taken from single-engine, manned aircraft. Small, unmanned aerial vehicles (UAVs) offer promise for addressing these problems and developing into a useful tool for many wildlife research applications. For this study, a 1.5-m-wingspan UAV equipped with autonomous control and sophisticated video equipment was purchased for US$35,000. This UAV was used to test the potential usefulness of such an aircraft for certain wildlife research applications in Florida. The UAV completed in excess of 30 missions over the course of two years before finally crashing into salt water due to engine failure. On these missions, the UAV captured high-quality, progressive-scan video of a number of habitat types and wildlife species (white ibis *Eudocimus albus*, other white wading birds, American alligator *Alligator mississippiensis*, and Florida manatee *Trichechus manatus latirostris*). The
autonomous control system worked satisfactorily, but the UAV system was unable to collect geo-referenced imagery and was extremely difficult to deploy in unimproved areas. The performance of the autonomous control system and the quality of the progressive scan imagery indicated strong promise for future UAVs as useful research tools. Different research applications will call for different UAV systems according to the sensors required (autonomous control, video, still photos, radio telemetry, etc.) and the distance required to reach/cover the area of interest. Larger UAVs can fly longer and carry more payload but are more expensive and difficult to operate. UAVs with a 1-2 m wingspan offer promise for a variety of wildlife research applications, having the ability to fly for 45-60 minutes and carry up to 3 kg of payload (sensors, autonomous control equipment, batteries). Recommendations for wildlife UAVs are that they be extremely durable (carbon fiber, Kevlar construction), modular (replaceable wing, tail, fuselage, engine, etc.), powered by an electric engine with lithium batteries, able to launch and land in vegetated areas (15 m by 50 m clearing), autonomously controlled, and operable by a minimally trained (two months) wildlife biologist.
INTRODUCTION

Aerial surveys have developed into valuable tools for wildlife management. Biologists have found aerial views to provide profound advantages in detecting animals that live in open areas. Aerial censuses, though normally designed to count individual animals, have also been used to census nests of raptors (Ewins and Miller 1995), rookeries of colonial water birds (Rodgers et al. 1995), food caches of beavers (Swenson et al. 1983), and to measure nesting attempts by sea turtles (Crouse 1984, Garmestani et al. 2001) and ecosystem health as indicated by populations of shorebirds (Kingsford 1999). Today, hundreds of aerial surveys are conducted annually on a wide variety of wildlife species. Since sound population information is fundamental to effective wildlife management, aerial surveys have greatly enhanced the success of management efforts.

However, four major problems are associated with aerial surveys. First, small aircraft crashes are the primary cause of work-related death for wildlife biologists. Since 1937, 93 wildlife biologists have died in the field, 62 (67%) of whom died from aviation accidents (Sasse In press). Most recently (January 26, 2003), three biologists and a pilot died in a crash into the Atlantic Ocean, eight miles off the coast of Florida, while conducting annual right whale surveys. Low-altitude operation of small airplanes and helicopters, usually the case for conducting surveys, provides a slim margin for pilot error with dire consequences. Second, aerial survey is costly. Agencies own and maintain planes and hire pilots or pilot-biologists. Most aerial surveys are conducted using commercial pilots and planes costing from $100/hr for some small fixed wings to
many multiples of that for larger fixed wings and rotor wing aircraft. The United States Fish and Wildlife Service recently spent over a million dollars on a new research airplane with sophisticated electronic sensing equipment (M. Koneff, United States Fish and Wildlife Service, personal communication). It is typical for a state agency to spend over $100,000 per year on these services (P. Zager, Idaho Fish and Wildlife Commission, personal communication).

Third, most wildlife count data are tainted with statistical errors. Anderson (2001) identified the serious sampling problems associated with wildlife count data as the practice of “convenience sampling” and the absence of detectability estimates. “Convenience sampling” is counts conducted along roads, trails, or natural features convenient to the surveyor but ignoring distribution of an animal population. Factors affecting detectability vary by species and location but include animal body size, movement behavior, coloration, group size, leaf cover, ground cover, water clarity, water depth, background of lake/ocean bottom, time of day, sun glare, shadows, aircraft altitude, aircraft speed, and observer ability (Bennetts et al. 1999, Caugley 1976, Garmestani 1997, Hilty and Lovell 1998, Holt and Cologne 1987, Lefebvre et al. 1996, Packard et al. 1985, Rice 1992).

Fourth, the usefulness of manned aircraft is totally dependent on weather and humans, usually obviating temporal and spatial considerations on population distributions.

Recently, there has been intense interest in the development of unmanned aerial vehicles (UAVs), especially for military interests. Small (< 3 m wingspan), autonomously controlled UAV’s have great potential as a safe, inexpensive, user-
friendly, and statistically robust option for a variety of wildlife survey applications. The safety advantages of a small, lightweight unmanned aircraft go beyond removing occupants to diminishing potential impact damage to objects or people on the ground in the event of a crash. UAV technology is developing rapidly, and as civilian markets are realized, cost should decrease dramatically. A UAV might be deployed under short notice at the site of interest, perform repeated flights in a short period of time, multiple UAVs could be deployed at the same time, and UAVs can often fly in weather that ground manned aircraft. Only one or two minimally trained operators are necessary, and there are few restrictions on the use of airspace by small UAVs.

UAV technology might be abused just as manned aircraft are in faulty statistical design of surveys. However, the UAV offers distinct advantages in sampling as well defined transects might be viewed in a single pass, multiple observer techniques are possible with videography (Anthony et al. 1995), and advances in automated counts using aerial videography are applicable to UAVs (Abd-Elrahman et al. 2001).

UAVs range in design from full size aircraft such as the military “Predator” that transmits images to ground stations via satellite from altitudes as high as 15 km, to the University of Florida’s micro aerial vehicles no larger than 10 cm with a very short range that might allow soldiers to quickly assess conditions over the next hill without exposing themselves (Hundley and Gritton 1992). Although one can envision biological applications of either extreme, our objectives were to 1) build a UAV system useful for wildlife research having the following attributes: portable, flight duration of 2 hours, easily flown under adverse conditions with limited take off and landing facilities, autonomously controlled with GPS, altitudinal and attitudinal control, durable and
incorporating geo-referenced videography capable of on-board data storage or live time
downlink capabilities; 2) field test UAV videography as a potential tool for assessing
wildlife populations and habitats.
METHODS

Initial Specifications

The Florida Cooperative Fish and Wildlife Research Unit’s initial specifications for a portable UAV for short-range surveillance and remote sensing were as follows:
- wingspan no greater than 2 m; gross weight not to exceed 3.6 kg; payload of 680 g;
- operating airspeed of 32 to 64 km/h; hand launchable; 2 hr flight duration; autonomous operation once launched, navigating a specified flight path using GPS waypoint navigation with altitude and airspeed specified for each course leg; automatic return-to-base with emergency parachute recovery; operating altitude up to 760 m; telemetry capability of 16 km radius; aircraft to be easily disassembled and together with all ground support equipment and supplies containerized into a minimal number of lockable, shockproof cases each capable of being checked onto a commercial aircraft; and engine to be easily replaceable from commercial sources and operate on standard gasoline and oil mixture with standard electric starting.

The MLB FoldBat UAV System

The MLB Company, a small independent aerospace engineering firm in southern California, was contracted to supply a UAV system meeting our specifications. The MLB FoldBat, a prototype aircraft, was a small UAV that had mission capabilities very similar to our specifications (Fig. 1). The FoldBat was a complete UAV system that could operate autonomously, deliver video imagery, and fit into two suitcase-sized cases by folding its wings. The aircraft was powered by a 0.32 cubic inch internal combustion...
engine (O.S. 0.32 SX-H) with a special muffler reducing noise level to nearly inaudible at 150 m altitude. The pusher engine was used to avoid propeller interference with forward-looking cameras and to avoid fouling the down looking cameras with unburned fuel. The cameras were mounted in removable pods on the wings. The FoldBat had flight duration of only 1 hour and telemetry range of approximately 3 km.

Figure 1. The MLB FoldBat. Equipped with foldable wings and tail, pusher engine, and GPS navigation. 1.5 m wingspan.

MLB developed a compact ground station for operating the FoldBat using a laptop PC as the primary control console. MLB also designed custom software for programming flight missions and monitoring the airplane while it was in flight (Fig. 2). The operating system provided a visual, moving map display showing the aircraft’s location, speed, heading, and altitude in real time. System-monitoring windows tracked performance and provided a live video capture window. Video was recorded on the ground using Sony Hi8 recorders. The flight path was specified as a series of mission legs (transects), each with its own altitude, speed, and waypoints. The plane could easily be programmed to fly multiple transect paths or to cover a polygon in a lawnmower pattern. The on-board flight computer could hold up to 15 GPS waypoints. The flight direction
could not be altered or updated in flight once the plane was aloft, although the revised edition of the FoldBat has this capability.

Figure 2. Windows screen produced by MLB groundstation computer software. The program allowed easy flight plan programming and displayed live flight information and tracking on a moving map display.

The FoldBat was hand-launchable and manually recoverable using traditional RC (remote control) landing procedures. An automatically deployed parachute could be utilized in emergency situations, but was not the primary recovery mechanism. MLB had flown the aircraft under 60 m cloud ceilings and in gusty winds exceeding 32 km/h--conditions under which UAVs had not normally been flown. The aircraft’s wing and tail surfaces folded, allowing it to be stored in a case 40 cm in diameter and 1.2 m long. The airframe was constructed of Kevlar, carbon fiber, balsa wood, and aluminum with Dacron wing skins. The FoldBat had a 1.5 m wingspan and a ready-to-fly weight of 4.3 kg.
Manual in-flight commands were by radio control 8 channel PCM uplink on 72 MHz uplink. 2.4 GHz downlink was used for video and 1200 band flight data.

The FoldBat was equipped with 3 CMOS analog video chip cameras with 330 lines of resolution (similar to the resolution displayed on standard cable TV). The plane was equipped with two video transmitters to relay the video to the groundstation where it could be recorded. One camera—a forward mounted, color chip camera—was for manual flight operation; the other two cameras (one color, one near infrared) were vertically mounted (down-looking). These collected imagery to be geo-referenced later using information from the on-board sensors (latitude, longitude, pitch, yaw, roll).

A Canon Elura 2 Progressive Scan digital video camera with 525 lines resolution was retrofitted into the belly of the FoldBat’s fuselage for comparative purposes. Loaded with a tape and battery, the Canon camera weighed 420 g. The progressive scan camera recorded data on board as opposed to transmitting it to the ground station. While the chip cameras were much lighter (less than 28 g), the progressive scan camera (420 g) produced higher quality imagery and allowed the user to capture still images from the video without compromising the image quality. The FoldBat’s chip cameras acquired interlaced images, where only half of a frame is collected at a time, with a 1/50 sec time gap between each half-frame. In a moving platform taking vertical images, every other line in the image will be shifted the distance the platform moved in 1/50 sec. For example, movement equals 14.9 cm at 140 km/h or 44.7 cm at 97 km/h. Progressive scan cameras take the full frame every 1/30 sec, which eliminates this problem. In simple terms, a progressive scan sensor allows for video to be paused and reviewed one frame at
a time without losing any image quality, whereas a paused interlaced video is consistently blurry.

Autonomous control means that a computer controls the flight of the plane rather than an on-the-ground pilot. The skill level required for operating such an aircraft is minimal but does not obviate some training (one or two months). More importantly, it enables the plane to fly a specific, repeatable programmed path. A custom autopilot system was developed by MLB consisting of groundstation software for programming flights and an on-board flight computer that allowed the aircraft to execute the flight plan by controlling heading, airspeed, altitude, pitch, roll, and yaw. The autopilot system integrated a global positioning system (GPS) receiver, an accelerometer/gyro system, and a pressure altimeter. The 3-axis solid-state accelerometer system estimated pitch, yaw, and roll angles in non-accelerating flight. This instrument was accurate to 2 degrees tilt, which produced a position error of less than 1 m at 90 m altitude. Altitude accuracy was estimated to be about 15 m with a pressure altimeter system. We therefore expected to know the location of the down-looking cameras’ aim point on the ground to within approximately 2 m plus any error in the aircraft’s absolute GPS measured position. The on-board GPS was sensitive to four decimal degrees (approx. 10 m), and reported position in latitude/longitude coordinates. Since GPS accuracy is sensitive to signal strength, this parameter could vary between 10 and 100 m.

**Missions**

We planned and completed a variety of missions to assess the performance and utility of the FoldBat UAV system and the visibility of certain wildlife species. These flights were conducted over agricultural lands (Archer, FL), a small Gulf Coast barrier island (Cedar Keys National Wildlife Refuge, FL), mangrove estuary (Pine Island, FL),
wetland impoundments (Goodwin Waterfowl Management Area, FL), a small lake (Lake Alice, Gainesville, FL), and a manatee wintering site (Apollo Beach, FL).
RESULTS

The FoldBat performed in excess of 30 successful missions in a variety of weather and landing surface conditions. Each of these preliminary missions uncovered valuable information about the strengths and weaknesses of the FoldBat system, the feasibility of using such a system for various wildlife research applications, and unforeseen specifications for future UAV systems intended for wildlife research.

Imagery and Geo-referencing

Our first flights at Goodwin Waterfowl Management Area (GWMA) near Melbourne, Florida, revealed that the CMOS chip cameras (330 lines, transmitted video) were not suitable for collecting images useful for most wildlife applications. Most flights were conducted at 100-150 m with the plane flying 48 km/h. A number of white wading birds (white ibis (Eudocimus albus), egret (Egretta sp.), wood stork (Mycteria americana)) were captured at GWMA with both the chip cameras and the progressive scan camera (525 lines, recorded on-board).

The chip cameras produced moderately blurred video, which was degraded further when paused since the video was interlaced. The chip cameras also struggled with adjusting to different light conditions. The birds appeared as white blobs with indistinct edges, and individuals often could not be distinguished from large groups. The transmitted video image suffered frequent dropouts, most of which lasted less than 2 seconds. The fact that the chip cameras had a fixed focal length (50 mm) caused the
width of the image footprint (zoom level) to be restricted by the altitude of the airplane (33 m minimum).

The GWMA flights also revealed that image geo-referencing was not possible with the chip cameras. The video was transmitted independently of the positional data, but it was thought that the video could later be matched with the positional data (latitude/longitude, altitude, pitch angle, yaw angle, roll angle) using known control points and time stamps. Once these points were located on both the video and the spreadsheet of positional data, the time stamps from the video recorder and positional data could be used to match the rest of the images. Unfortunately, there were varying time lags and sporadic dropouts in the transmission of the video and positional data, rendering this approach unfeasible. The time lags were probably the result of the varying distance of the plane from the groundstation and the slow speed of the groundstation modem used to convert the positional data from a transmitted audio signal to actual numbers.

The Canon progressive scan camera was very effective in capturing high quality images of a variety of wildlife and vegetation types. Most flights were conducted at 100-150 m with the plane flying 48 km/h. The progressive scan camera produced significantly higher quality images than the chip cameras, where species could sometimes be determined, and individuals could be isolated from large groups (Fig. 3). Since the progressive scan video was recorded on-board the aircraft, there were no video dropouts. The adjustable optics enhanced the variety of image footprints, and allowed for close up video (<10 m footprint) at safe altitudes (~100 m).
Figure 3. Aerial images of white wading birds at Goodwin Waterfowl Management Area. The image on the left was taken with a CMOS “chip” camera supplied by MLB (330 lines of resolution), and the image on the right was taken with a Canon Elura 2 progressive scan digital video camera (525 lines of resolution).

As the camera was zoomed (or flown at lower altitudes), the images had more detail but less ground coverage. After considerable experimentation, the camera was adjusted so that the altitude of the plane equaled the “footprint” of the image (i.e., if the plane flew at 100 m, the image would cover 100 m of horizontal ground space), simplifying geo-referencing calculations and providing adequate detail for sampling moderately sized animals in open areas at 100-150 m (wading birds, manatees, alligators, etc.).

Flights at Goodwin Waterfowl Management Area demonstrated that white wading birds were highly visible in the videography. These flights also captured a variety of wetland vegetation. Cattle were particularly visible, suggesting potential use in large mammal surveys. Flights over Lake Alice captured images of partially submerged alligator decoys (Fig. 4), white ibis and an alligator nest (*Alligator mississippiensis*), along with a variety of vegetation types. Flights over a manatee wintering site along Tampa Bay showed manatee adults and calves (*Trichechus manatus latirostris*), flute tags, and tethered radio tags to be easily visible by a minimally trained observer (Fig. 5).
As the video was viewed, individual manatees were observed surfacing and diving in and out of visual range. None of the targeted wildlife species displayed any disturbance as a result of the low-flying FoldBat airplane.

![Image of alligator decoys](image)

**Figure 4.** Image of alligator decoys. Captured with the Canon Elura 2 digital video camera at Lake Alice, FL. Four decoys are visible in the image. The FoldBat was flying at 90 m and no zoom was used on the camera.

Since there were no dropouts or delays in the video, the possibility of image geo-referencing remained intact with the Canon progressive scan camera. The time stamps associated with the recorded video (camera time) and positional data (GPS time) could be aligned, and the pitch, yaw, and roll angles used to calculate the position of the center of the image.

**Autopilot System**

The MLB autopilot system was consistently effective at guiding the plane on a variety of programmed missions. As the plane flew a straight transect, it maintained its heading within 3 degrees of the programmed values, relative to the baseline accuracy of the sensors (i.e., the plane did not have problems with over-steering). The plane held its altitude to within 1.37 m of the programmed values (75-215 m), and its airspeed to
within 1.6 km/h of the programmed value (48 km/h), relative to the baseline accuracy of the sensors (Fig. 6).

Figure 5. Wintering manatees (*Trichechus manatus latirostris*). Captured at Tampa Electric Company (TECO) canal, Tampa Bay, FL, with the Canon digital video camera. The MLB FoldBat was flying at 125 m with a zoom ratio of 3:2 (3 m altitude: 2 m image footprint).

The FoldBat never strayed off course when the operator loaded the flight plan properly. The groundstation computer software used transmitted positional data (latitude/longitude, pitch angle, yaw angle, roll angle, altitude, air speed, ground speed, battery voltage, heading, distance from home, etc.) once every one to two seconds (variable) to monitor the movement of the plane along a map and the status of the airplane on cockpit-like gauges. All of these parameters were recorded on the groundstation laptop on a spreadsheet. These features, along with live transmitted video from the CMOS cameras, allowed for effective monitoring of the plane when it was out of sight (>0.4 km from home).
Figure 6. A display of FoldBat flight data. Collected from a 15 minute autonomous flight. The airplane was programmed to fly a “lawnmower pattern” at 92 m traveling 48 km/h.

Attempts were made to cross-check the reported accuracy of the FoldBat’s positional sensors (GPS, 3-axis accelerometer) using known control points, but due to photogrammetric difficulties, the results have not been produced.

The groundstation software was exceptionally user-friendly. While other autopilot programs use a DOS-type interface and require the use of specific commands (e.g., Vesta Technologies MicroPilot 1000), the MLB system uses a “point and click” Windows-type program. It allowed for the user to plan an unlimited number of missions in the office, then easily recall and execute them in the field.

**Engine Performance**

Gas engines supply impressive amounts of power and are efficient enough to run for long periods of time. The OS SX-32 0.32 cubic inch nitromethane gas powered engine was mostly reliable, but had a few problems characteristic of small gas engines. On two occasions, the engine stopped running while in flight, but the plane was
recovered with minimal damage. This is something that is inevitable with small gas engines. However, while flying over the manatee wintering site, the engine failed while the airplane was on autopilot and the plane crashed into Tampa Bay, ruining the airplane and all of its internal parts.

On each flight, the fuel mixture had to be adjusted for maximum engine performance, since humidity and elevation alter the optimal fuel mixture. A pull start mechanism started the engine, which was reliable and durable. On one occasion, the engine froze after a rough landing, and it took about an hour to get it started again. The engine noise did not appear to disturb any of the targeted wildlife species, even when the plane flew below 100 m.

**Range and Time Aloft**

MLB claimed that the FoldBat could be safely flown 3.2 km away from the groundstation. On the mission to Pine Island, Florida, along the Indian River, these range limits were tested and the system performed adequately. However, the groundstation was situated in a forested area, which created data transmission problems when the plane was more than a mile away. Fortunately, the autonomous performance of the plane was controlled by the on-board flight computer and did not rely on data transmission, so the dropouts did not affect the path of the airplane. The positional data were more prone to dropouts than the video data.

Due to the limited range of the airplane and the importance of minimizing payload weight, the time aloft limits were not tested. With a full tank of gas, the FoldBat would be able to fly for about 2 hours. However, flight tests revealed that the FoldBat was too underpowered to fly in low winds with a full tank of gas. To minimize payload, the gas
tank was normally half filled, and the longest missions did not exceed 45 minutes (manatee flights).

**Flight Characteristics/Ease of Use**

It was hoped that a minimally trained wildlife biologist could operate the FoldBat. Unfortunately, launching and landing the airplane were more difficult than anticipated, and a considerable amount of skill, agility, and athleticism was necessary (Fig. 7).

![Figure 7. A failed FoldBat launch attempt at Pine Island, FL. Intended for use by a minimally trained biologist, it took an unexpected amount of remote control skill and athleticism to deploy the FoldBat in unimproved areas.](image)

The airplane was developed in coastal, southern California where steady 13-19 km/h winds were commonplace. Moderate winds like these create significant lift for both launching and landing the airplane, which was marginally powered for the plane’s weight. Flying the FoldBat in north-central Florida, proved to be difficult where maximum sustained winds did not exceed 8 km/h and were usually less than 2 km/h. A successful launch depended on a strong, precise throw and adequate space for the plane to build airspeed and lift (~50 m, depending on the height of the surrounding trees).
Landing the airplane, especially in tight spaces (landing strip less than 15 m wide),
required considerable piloting skill.

On the mission to Pine Island, the “docking area” was 46 m by 16 m with 5-7 m
trees around the perimeter. Only one of four launching attempts was successful. The
FoldBat was not useable in areas without a large, open area (90 m by 15 m) for launching
and landing. This amount of improved space is unavailable in most natural areas where
UAVs might be utilized.

Aerospace engineers at the University of Florida made slight modifications to
improve the launchability and landability of the FoldBat, but with marginal success. The
most significant improvement to the airplane was the removal of the large camera pods
suspended from the underside of each wing.

**Durability**

Although the airplane was constructed of high quality materials such as Kevlar
and carbon fiber, it did not hold up well under field conditions. When landing space was
limited and ungroomed, high speed landings (32-56 km/h) consistently caused damage to
the trailing (folding) edge of the foldable wings. Because of the unfavorable weight to
power ratio, the plane had to be landed at such high speeds, and especially with no head
winds. Field repairs to the wings were extremely difficult due to their intricate
construction, and spare wings were not provided. The belly-skid landing method obviated
landing gear and fouling of the gear in low vegetation, but the wings (elevated only 5 cm
from the base of the fuselage) consistently caught on vegetation >5 cm, causing the plane
to cartwheel. The rough landings usually resulted in wing damage, but the tail, fuselage,
engine, and internal parts suffered no damage from routine use.
Portability

The FoldBat system was purported to fit entirely into a hard-plastic golf bag case (5.5 kg), a 0.6 m by 0.75 m Pelican case (9 kg), and a leather laptop computer case (3.7 kg). In actuality, a number of additional items had to be included: a two-panel groundstation antenna with foldable tripod, one gallon of fuel with manual pump, extra batteries, a foldable table, and a large tool box for field repairs. Everything fit easily into the back of a small station wagon. The FoldBat could not be operated efficiently by a single person, but required at least two people to operate the system.

Approximately one hour was required to unload, prepare and launch the plane (two operators). The following tasks were performed before deploying the airplane: unload and set up equipment, assess area for optimal launching and landing spots/directions, start laptop and open autopilot software, plug groundstation antenna into receivers, attach groundstation antenna on tripod, turn on and connect video recorders, assemble FoldBat wings and tail, pump gas into FoldBat, plug all four batteries and insert progressive scan camera into FoldBat, test for video transmission and make adjustments, load pre-programmed flight plan onto FoldBat’s on-board flight computer, test for positional data transmission, start airplane, adjust engine for maximum performance, and launch airplane.

Once the plane was in flight, the FoldBat system required at least two operators—one to monitor the plane visually and watch the flight path on the laptop screen and the other to aim the groundstation antenna for data collection.
DISCUSSION

Although the FoldBat UAV system did not prove useful as an operational wildlife research tool, it possessed a number of respectable characteristics, and it illuminated system specifications that could only be discovered through experience with an experimental system. Due mostly to the inability to geo-reference the FoldBat’s imagery and its difficulty to launch and land in a small area with minimal R/C skill, the Florida and Idaho Cooperative Fish and Wildlife Research Units instigated a multi-disciplinary effort to create an improved UAV system scheduled for initial application research in January 2004.

A UAV useful to wildlife research is not “one size fits all”. It is important that wildlife researchers are careful in choosing applications appropriate to available UAV systems. A given UAV system can only accommodate a limited set of research applications, classified primarily by their range, time aloft, and image resolution requirements. The larger the range (and time aloft), the larger the UAV needs to be. As UAV systems increase in size and complexity, they become more expensive and difficult to operate. For many applications in Florida, a 2-m-wingspan UAV (considered a moderately sized UAV) seems most appropriate, offering a reasonable range, time aloft, and payload capacity. The second-generation generation system will be a 2 m size class UAV.
Imagery and Geo-referencing

The Canon progressive scan camera produced satisfactory images for wildlife research applications targeting species at least as conspicuous as waterfowl. However, the utility of the images is severely limited if they are not geo-referenced. The images and positional data must be simultaneously linked in the second-generation system. Equipment exists that can overlay positional data onto a videotape using the audio track. The UAV imaging system can be improved by incorporating an on-board positional data recording system with a progressive scan camera. On-board video and positional data recording will offer advantages in easily geo-referencing imagery and in greatly increasing the range of the airplane, relieving the plane from data transmission. However, if nothing is being transmitted from the airplane to the ground, it is impossible to track the airplane once it is out of sight (on a clear day, the plane is out of manually controllable range at 0.5 km). An improved system would include one small chip camera and video transmitter on the airplane for tracking purposes. This would represent only a very small cost in weight and dollars, and since the live transmitted video would only be used for monitoring, the quality of the video is unimportant and occasional dropouts would not impose a problem.

Since the FoldBat and Canon camera were purchased in the Spring of 2001, advancements have been made in camera and positional sensor technology. For example, the JVC digital video camera (GR-DVL9800u) captures twice the amount of pixels as the Canon. Also, new, miniaturized positional sensors for improved autonomous control and image geo-referencing are available. With these improvements, high quality, geo-referenced images will be available for a variety of wildlife research applications. The
word, “research”, is stressed here as these systems and statistical designs are not yet appropriate for operational monitoring.

While digital video cameras exist that capture high resolution video, software programs to review the video and extract individual frames tend to degrade the quality of the images, forcing them into a predetermined size instead of capturing them as they were originally recorded. Three different digital video software programs were tested—Dazzle MovieStar 4.2, Adobe Premier 6.5, and Final Cut Pro.

Another option is to use a digital still camera with the ability to take continuous pictures at a programmable rate (e.g., two frames per second). Still cameras capture much more resolution than video cameras, and generally weigh less. A new compact flash card (SanDisk) was released in March 2003 that holds 4 GB of information, enough to store 20-60 minutes of uncompressed images. However, a reliable time stamp would need to be affixed to each image; this may be difficult since digital still cameras are notorious for unpredictable lags in capturing images.

**Autopilot System**

Aside from including a link between the positional sensors and the imaging device, the MLB autopilot system had little room for improvement for initial application research. However, the updated version of the MLB autopilot system allows for the flight plan to be altered while the plane is in flight. This feature could be useful, but requires a reliable transmission link between the airplane and the ground, which imposes limits on flight range.

Recent advances in the miniaturization of positional sensors, computer processors, and GPS systems allows for an even smaller, more accurate autopilot system. While the MLB system weighed approximately 900 g (including batteries), UF aeronautical
engineers currently are working to create an autopilot system that weighs less than 250 g (P. Ifju, University of Florida, personal communication).

**Engine Performance**

The FoldBat’s RC-grade nitromethane-gas engine (also known as a glow engine) provided adequate endurance (2 hr max time aloft), but was not sufficiently reliable for an aircraft carrying thousands of dollars worth of equipment. As was mentioned, engine failure resulted in the airplane crashing into salt water, which ruined the airplane. Small gas engines can be reliable, but only when operated by an experienced person who is familiar with their idiosyncrasies. It is difficult for a minimally trained user to know if and when the engine is running properly, and how to adjust it accordingly. Even slight changes in temperature or humidity can alter the performance of a small gas engine.

Electric motor technology is developing rapidly, along with battery technology. Electric motors are incomparably reliable and require no maintenance or adjustments. They are also extremely quiet. A battery powered electric engine will likely power the second-generation airplane with enough power for easy launching and enough endurance to stay aloft for 45 minutes. Battery power to weight ratios are consistently improving, offering promise for longer flights.

For larger UAVs (>9 kg, >3 m wingspan) appropriate for larger scale sampling protocols (e.g., bighorn sheep surveys in Idaho), small diesel engines appear to hold promise. These engines, built for large RC airplanes, are significantly more reliable and user-friendly than the smaller, nitromethane glow engine used by the FoldBat. These engines are adequately powerful for consistent launches and efficient for long flights (5-6 hr aloft, 80-90 km range).
Range and Time Aloft

If all data are recorded on-board the aircraft, the UAV system is liberated from the tether of data transmission. A UAV useful for a variety of applications in Florida should be able to safely fly at least 6-8 km from home. This would allow access to a number of remote areas where a vehicle could not be driven (Everglades, islands, rugged terrain, etc.). A wider range also allows the researcher to be more selective (and safe) in choosing the “docking area”. The MLB system required that the groundstation be located within one mile of the area of interest, which severely limited its utility in monitoring wildlife populations. As range increases, so does the variety of potential applications. Battery technology will serve as the primary determinant of the range of an improved 2 m wing class UAV system, powered by an electric motor.

However, the FoldBat’s actual maximum time aloft (45 min) is thought to be adequate for many wildlife applications. Cruising at 48 km/h, the FoldBat could complete four transects (1 km long) up to 2 km from the groundstation in 45 min. It is known that this specification can be matched and potentially exceeded in the second-generation system.

Flight Characteristics/Ease of Use

A second-generation system must have modifications to improve the ease of launching and landing the airplane. The FoldBat system required a significantly experienced RC pilot who was proficient in hand launching, basic maneuvering, and landing in tight spaces (less than 10 m wide). If an airframe is used similar in size to the FoldBat (2 m wingspan), it should have more payload capacity, better aerodynamics, durable airframe, and a more powerful engine. This will allow the plane to build lift more quickly, thus requiring less space for launching. Another possible modification for
improved launching, aside from airframe design, is the incorporation of a catapult. It is recommended that the second-generation UAV be capable of performing an autonomously controlled deep stall landing, where the airplane approaches the landing area flying very slowly, but descending at a very steep angle with its nose tilted up.

If a smaller airframe were used (less than 1 m wingspan), it would naturally require a smaller space for launching and landing. A small airplane could be recovered using a mist nest or could be landed traditionally. The smaller, lighter, and more durable the construction of an airplane, the less affected it is by rough landings. As cameras, transmitters, batteries, sensors, and computers become smaller, UAVs should utilize smaller airframes.

**Durability**

The FoldBat was not durable enough to consistently survive our field tests. A UAV for wildlife research must be designed to accommodate rough, imprecise landings by minimally trained operators (or autonomous control systems). The folding wing of the FoldBat was its “Achilles heel”. The advantages that it provided in portability did not outweigh the sacrifice in durability. The second-generation system will utilize a non-folding, but removable wing, and modular construction. Armed with spare parts, little can prevent successful missions. The non-traditional, high strength materials (Kevlar, carbon fiber, aluminum) used to construct the FoldBat greatly enhanced its durability in comparison to a traditional wooden RC airplane, and these materials (or similar ones) must be employed in future designs.

Experience with the FoldBat illustrated the importance of waterproof UAVs in wildlife research. Water (especially saltwater) is notorious for ruining all sorts of electronic equipment. When such sizeable estimates of time and money are invested in a
UAV, it would be wise to attempt to waterproof it. If the FoldBat had been waterproof, it would have easily survived its crash into Tampa Bay, sustaining only minor structural damage from the impact. However, a waterproofing likely costs weights, so if the research applications do not require it, there is no need for waterproofing.

**Portability**

The FoldBat was neither as portable nor easy to use as was anticipated. Switching to an on-board data recording system could eliminate much of the groundstation equipment. Switching to an electric motor would greatly reduce the size of the tool kit and eliminate the need to carry fuel. The FoldBat system required at least two operators. If the groundstation were simplified by switching to on-board data collection, one person could easily set up the equipment and deploy the airplane.

**Liability issues**

Presently, there are minimal governmental restrictions on operating a UAV. However, the mission at Tampa Bay suggested that considerable caution should be taken when flying a UAV in populated areas. At Tampa Bay, the UAV was flying over civilians, traffic, homes, businesses, boats, and a large power plant. If the plane were to have collided with any of these, lawsuits could have resulted. Only thoroughly tested UAV systems with experienced operators should be deployed in populated areas. When flying in populated areas, more operators should be present to care for inquiring civilians and to manage other safety issues. The local police should also be notified, along with any other relevant organizations.

The Federal Aviation Administration (FAA) is currently working to include UAVs in its regulations. It is possible that deploying a UAV will not be as logistically easy as in five or ten years as it is today. A non-profit organization, the Association of
Unmanned Vehicle Systems International (AUVSI), is working to represent the UAV community in guiding the FAA’s future regulations.

The Federal Communications Commission (FCC) is also moving toward including UAVs in its regulations. Currently, if a UAV has a video transmitter whose power is equal to or greater than one Watt, the operator must have a technician’s license from the FCC. In order to get this license, one must pass a simple exam (example questions posted on the web) and pay a nominal fee.

**Conclusion**

Although new technical and operational challenges were discovered in our first attempt to create a UAV system useful for wildlife research, we are still confident that it is possible to develop this tool in the near future, and that it will have profound implications for aerial wildlife population and habitat assessment. The UAV has much promise as a scientific monitoring tool, but only when combined with appropriate sensors and with established sampling protocols and statistical analysis. The UAV offers enhanced capabilities in dealing with habitat/population relationships on small scales, since it has spatial/temporal capabilities that traditional aircraft and ground research simply does not. UAVs have the potential to remedy one of the largest causes of work-related mortality for wildlife biologists and to improve one of the major metrics of the profession, population estimation techniques.

Since the FoldBat arrived in July, 2001, UAVs have evolved from little more than a twinkle in an engineer’s eye, to a fully realized machine with a rapidly developing, and promising future. The advent of the “War on Terror” has catalyzed the UAV industry, and each month, more products become available on the consumer market at affordable prices. The potential applications of UAVs in the world are endless, but it is important
that the scientific community shows intense interest in utilizing these machines for specific applications, providing economic incentives for UAV manufacturers to design UAV systems appropriate for wildlife research (high resolution imagery, geo-referencing abilities, deployable in small, unimproved areas, etc.). Otherwise, it is doubtful that wildlife biologists will ever see a truly useful UAV system.
LIST OF REFERENCES


BIOGRAPHICAL SKETCH

George Pierce (PJ) Jones, IV was born on March 11, 1978, in Tampa, Florida. He moved with his family to Tallahassee as a child and grew up in a big house with a big yard with lots of big trees. Spending the summers building tree forts and vacationing at St. George Island and Cape San Blas, he enjoyed spending time outside much more than playing video games or watching television. Following the lead of the three previous G.P. Joneses, he aspired to go to college, join Sigma Chi fraternity, and become a doctor.

Graduating in the top ten of his high school class, he attended the University of Florida as an honors student on scholarship. Deciding to major in zoology, which would conveniently fulfill all of the pre-med requirements, he accidentally rediscovered the love for “nature” that he developed as a child. After tasting the stress of the life of a medical professional, he made a turn and decided to pursue a career involving the environment, with special interest in human interactions with the environment.

After graduating a semester early, he spent the next two years cultivating his interests, working at Twin Creeks Research Center at Great Smoky Mountains National Park, guiding educational backpacking trips in Western North Carolina, interning for two grassroots environmental organizations in Oregon and Washington, D.C., and working for the Florida Cooperative Fish and Wildlife Research Unit. In December 2001 he was married and started graduate school at UF the next month, continuing work on a project that he had begun with the Florida Coop Unit. He hoped his graduate experience would help mold him into an effective communicator between the scientific community and the
general public. Wanting to maintain a strong scientific background, he pursued a Master of Science through the Interdisciplinary Ecology program at the School of Natural Resources and Environment.

After enduring a challenging research project and experiencing a host of intriguing classes, he is ready to begin work as an environmental educator. Whether he is working for a park, an agency, a non-profit organization, or a grade school, his career goal is to participate in transforming citizens of the United States into more environmentally and socially responsible people. He looks forward to an exciting, low-budget life with his wife and family.