# A Penguin Population Polar Express

## NOAA's Quest to Count Penguin Breeds Speeds Up With a VTOL UAS

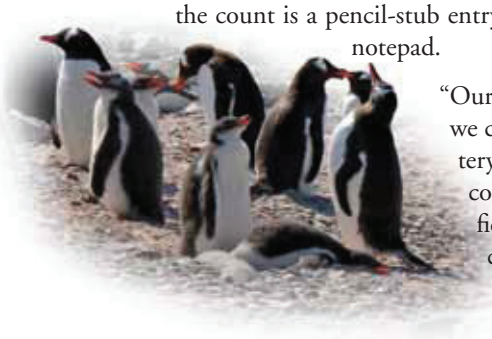
By Steve Gardner, Don Leroi and Wayne Perryman

Each austral summer for the past 25 years, the National Oceanic and Atmospheric Administration's Antarctic Marine Living Resources program has performed an extensive survey of marine wildlife populations in the vicinity of the South Shetland Islands, an island group about 75 miles north of the Antarctic Peninsula, examining creatures from the smallest zooplankton to large predators.

Part of this survey includes monitoring colonies of penguins at Admiralty Bay at King George Island and at Cape Shirreff on Livingston Island. By creating a long historical record of populations, the project is able to recognize the impact and pace of ecosystem changes resulting from climate variation, fishing or other factors.

With support from the NOAA Unmanned Aircraft Systems Program Office and the Southwest Fisheries Science Center, a team of scientists and engineers joined the researchers at Cape Shirreff this past January to determine whether a small unmanned aerial vehicle could be used to facilitate counting and identifying animals on land. It's a demanding problem, since the conditions are difficult, with strong winds, cold temperatures and rugged terrain, and the quality of the imagery has to be superb for differentiation between chicks and adults and also between different species of penguins that have only minor differences in markings.

Despite the harsh environment, summer in this region brings on a riot of new life as penguin colonies and fur seal breeding sites abound with chicks and pups. Obtaining accurate counts of these animals is challenging work since the aggregations are large and the animals are quite mobile, and multiple species are mixed in the same area. Counting has traditionally been performed by walking through the colonies using a hand-held tally counter. Even with modest-sized colonies, counts taken in this way are subject to substantial inaccuracy, while in areas with populations of tens of thousands of animals the task is nearly impossible. And in the end, the only record of the count is a pencil-stub entry in a weathered field notepad.



"Our goal was to show that we could use a small, battery powered aircraft to collect imagery of sufficient quality that we could perform counts from the images and that we could collect the images with sufficient rapidity [so] that movement of the animals during the flyover would be insignificant," says Wayne Perryman, the principle investigator for the project. "And we wanted to do it in a way that didn't disturb the animals."

### The Aircraft

Cape Shirreff is a rugged, rocky and windswept peninsula that juts northward out of the ice-capped mass of Livingston Island into the Drake Passage. NOAA operates a summer field camp made up of three small cabins to house the research team but otherwise has no means of providing logistical support to an unmanned aircraft of any size. A small vertical takeoff and landing design seemed the most appropriate to the task, since it has no runway requirements and can hover over aggregations of animals. To get the best match of capabilities, the team decided to specify their own design, which was then built by Aerial Imaging Solutions of Old Lyme, Conn.

The hexacopter is electric powered and uses six counter-rotating blades to fly for up to 20 minutes on a battery pack, yet a single field scientist can carry the aircraft and ground station for many miles without difficulty.

### Image Requirements

Most UAS for intelligence, surveillance and reconnaissance applications use video for imagery, and the state of the art in most video systems is 1080p high definition. But individual frames of HD video are comprised of only 2 megapixels, which is inadequate for this application. Instead, the UAS was designed to carry an Olympus E-P1 digital camera with a 17-millimeter F2.8 lens. This 12.3-megapixel camera uses a mirrorless single lens reflex design that provides quality high-end still image cameras while keeping weight to an absolute minimum — critical for use with an aircraft that weighs only a few pounds itself. The camera was configured to capture an image every two seconds, and the crew retrieved images by removing the camera's memory card at the conclusion of the flight.

With a fast lens and a very sensitive sensor, the E-P1 allows shooting with a very high shutter speed, eliminating the effect of low-frequency vibration. With simple mechanical damping, it also removes high-frequency vibration. Thus there is no need for image stabilization.

Flying at a height of 100 to 150 feet, an image spans about 50 feet of ground on its long dimension, so that the camera provides about 12 pixels for each inch (compared to 3 pixels per inch for HD video and about 1 pixel per inch for standard definition video). This outstanding resolution makes it possible to clearly see the eyeballs of individual penguin chicks.

## Flying Conditions

Despite having outstanding stability for such a small aircraft, the hexacopter becomes hard to control at wind speeds more than 20 knots. In addition, to hover in wind requires that the aircraft fly with a tilt, which makes the images more difficult to stitch together unless a tilting camera mount is used. The team was especially conservative in choosing flight conditions, given that this was a first trial of the system. Of the 21 days on Cape Shirreff, only about half met the wind speed requirements and usually only for part of the day.

## Method of Operation

The team found that penguins reacted to the aircraft at lower altitudes, but at 100 feet or more they appeared completely unaware of its presence. To provide space for gaining altitude, the hexacopter was usually launched from a point 150 feet or so away from the population to be surveyed and upon takeoff climbed immediately to its steady state height before flying over the colony.

Although eventually the plan is to automate flying using waypoints, flights on this trial were all under full manual control. Because it is difficult for the pilot to judge depth, three people were needed to conduct the flight, with one team member at each end of a colony to guide the pilot. The first guide directs the pilot to fly the UAS to a point right overhead, and then the second guide directs the flight until the UAS is over his head. The first guide then moves to the next end point and directs the flight back toward him, with the process repeating until the entire colony has been passed over. Using this method, collecting images for a colony of 1,000 penguins can easily be completed in a flight of just a couple of minutes.

## Results

Upon returning to the cabin and a warm cup of coffee, the team offloads the images to a computer and stitches them together to form a mosaic of the entire penguin colony. Commercial image processing software includes tools for tagging multiple kinds of objects in an image — in this case gentoo and chinstrap penguin adults and each

Flying the hexacopter UAS. The penguins didn't like it when it flew low but ignored it once it reached 100 feet or more in altitude. All photos by Steve Gardner.

breed's chicks chicks. The tagging is a manual process, but the counting is instantaneous once the tagging is complete.

By comparison with traditional manual counting, the UAS approach seems luxurious. Time spent outdoors in the cold is substantially reduced, and instead of a smudged pencil entry, the record of the survey is an image showing every bird in the colony that can be checked and rechecked for veracity years from now. The counts made in the flights matched manual counts previously taken to within statistical significance.

"Gentoo adults differ from chinstraps by the distinctive white band that connects their eyes across the top of their head," says Perryman. "The band is clearly visible in overhead images. And the gentoo chicks have a stripe of white along their wings. In our images, we can easily distinguish gentoos from chinstraps and chicks from adults, so we are very happy with the result."

While the team's focus was on penguin colonies, some flights were also conducted over fur seal aggregations. A useful outcome of these abbreviated flights was the recognition that the aerial images allow identification of animals in the clear shallows where large numbers of seal pups are commonly playing — a part of the habitat that can't be surveyed on foot.

## Next Steps

Beyond a trial, a fully operational system should be designed to allow operation by a single field scientist. The hexacopter can easily be made to record waypoints, so that the field scientist can simply walk to the various waypoints and push a button to log each, and then let the aircraft fly itself. Once the waypoints have been entered, the hexacopter can record them in non-volatile memory so that on repeat visits to the colony the field scientist can just select a colony identifier and launch the aircraft.

The most difficult part of the flight is landing, since the backwash of the propeller blades and frequent gusts of wind can result in the UAS flipping over on touchdown, which could damage its blades and motors.

Another important mission is ship-to-shore operations, allowing survey of populations on islands and land masses that are not safely approached by humans.

There is much to do, but as a first step, the NOAA team viewed this project as a resounding success in demonstrating the utility of small UAS in support of field work in demanding environments.

A chinstrap penguin mother and her chicks.

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Penguins move around a lot and multiple types group together, making identification sometimes difficult.