Annex 5 – Final Progress Report

1. **Identification:**

Partners Name: Duke University
Budget line: BAC: not known
POW 2014-2015 Sub-programme: not known
Expected Accomplishment(s): Improved monitoring system for tracking of the African forest elephant that accurately estimates populations.
Output(s): Reports
Title of the approved PRC project: Developing A Quadcopter And Infrared Camera System To Monitor And Track The African Forest Elephant (Loxodonta Cyclotis)
SSFA starting date: 03/01/2016
Completion date: 15/04/2017

2. **Summary of Status:**

In an effort to help combat the alarming decline of African forest elephants, the Duke University and the Humans and Autonomy Laboratory partnered with the Nicholas School of the Environment, and the Agence Nationale des Parc Nationaux in Gabon to design and develop a low-cost, mobile airborne elephant monitoring and tracking system. Current state-of-the-art methods of estimating elephant populations rely on counting dung piles; however, these methods are known to be imprecise and labor-intensive. Our system, which uses a quadcopter, custom infrared camera, and tablet-based ground control station, will give conservationists a direct method of counting elephants, as well as monitoring their behavior non-invasively.

The initial design of the system was one that leverage an off-the-shelf, relatively inexpensive drone, and both a day and night (i.e., infrared) cameras were added. In addition to the on-board hardware, the system included a user interface design component for developing an easy-to-use ground control station displayed on a tablet, making the system light and portable, as well as accessible to a wide population of users. The interface was designed such that users with little technical experience can designate waypoints for the quadcopter to circle, capture video, and return to the pre-designated home location. By arming local conservationists with this new technology, the goal was for local conservationists to be able to more directly monitor the behavior of forest elephants and more accurately estimate population numbers. The system could also assist in anti-poaching efforts during the night hours when poachers are difficult to locate.

A field excursion occurred in January 2016 to Rèserve Prèsidentielle de Wonga Wonguè, with the inexpensive (~$1,500) quadcopter and daytime/nighttime video camera. This trip provided insight into how this system would assist the ecoguards, and provided a testing environment that led to many lessons learned that would be difficult to predict in the United States. While we were unable to test the system at night with the infrared camera due to problems with the drones (outlined below), we were able to gather daytime footage of both forest elephants and buffalo. The noise from the drone caused many elephants and buffalo to retreat into the forest, possibly due to the noise being similar to that of a swarm of bees, therefore, further research is needed to determine what frequencies disturb elephants

and buffalo. We also received very insightful feedback from the head of the ecoguards as to what applications he would find this system useful for. In addition to the monitoring of the forest elephant, he stated that the system could be used to patrol the coast of Wonga Wonguè to determine if any illegal fishing is occurring offshore. The boats that illegal fishermen use are difficult to spot at night, but with the use of the infrared camera, locating them would be simple.

Lessons that were learned from our trip to Rèserve Prèsidentielle de Wonga Wonguè, Gabon included:

1. The infrared camera sensor components should be housed to reduce the complexity of the connecting the wires.
2. The communication reliability for the infrared camera should be addressed as it can be unpredictable at times
3. There should be a method for storing infrared footage onboard the drone on a micro-SD card in the same method as the GoPro Hero 4.
4. The drone should be exposed to hot (>85 degrees F) and humid (>70%) environments for an extended period of time (>5 days) without any time in the air conditioning.
5. The system can be used for more than just wildlife monitoring. There was high interest in using the system to monitor the coastline for illegal fishing.

This trip then provided the motivation for two follow on projects. The first derivative project is looking at the noise issues uncovered during the trip. As noted above, one problem with using drones to monitor elephants is the noise, which appears to irritate some, but not all, elephants. One theory is that drones sound much like bees to elephants, which are a known irritant. This finding from the trip was noted in on online article for The Atlantic, http://www.theatlantic.com/technology/archive/2016/05/elephant-vs-drone/481701/. Given this issue, research is currently underway to test a myriad of drones to determine what their operating frequencies and how similar they are to those of bees. This research is the subject of a student undergraduate thesis and will be available to the public in May of 2017.

The second derivative project is the use of GPS collar tracking data to develop models of African elephant behavior using machine learning and data mining techniques. While in Gabon, we worked with other Duke University researchers who were gathering GPS data f rom collared elephants. Given other efforts in the laboratory to develop predictions based on such data, one student began determining whether such data could be used to predict where unknown watering holes were for the group of elephants in the Rèserve Prèsidentielle de Wonga Wonguè. Initial results look promising but the work is still underway.

3. Activity delivery status

Activity	Description of work undertaken during reporting period	Deliverables	Delivery date	Status of Activity (completed or not completed	If activity not completed, please describe the reason why and indicate mitigation actions that were taken.
Activity 1	Trip to Gabon Africa for field testing	Technical report		completed	
Activity 2: add	Small UAV Noise Analysis	Technical report	15/03/2017	Not	Derivative follow on work, not part of

on				completed	original effort
Activity 3: add on	The Development of Machine Learning Algorithms to Track the African Forest Elephant (Loxodonta Cyclotis)	Technical report	ongoing	Not completed	Derivative follow on work, not part of original effort

4. List of attached documents

- Gabon Trip Technical report
- The Development of Machine Learning Algorithms to Track the African Forest Elephant (Loxodonta Cyclotis)
- Small UAV Noise Analysis Design of Experiment report

Signature: 

Date: 12/01/2017

Name and title of signing officer: Dr. Mary L. Cummings, Professor Duke University