DDF Annual Report

**Title of Investigation:**

**Interferometric Geolocation Communication Sensor—Towards a Bird Sensor Web**
**(Original Title: Tracking Global Song Bird Migration from Space)**

**Principal Investigator:**

**Dr. James A. Smith (Code 920)**

**Other External Collaborators:**

**Dr. Martin Wikelski (Princeton University) and Dr. George Swenson (University of Illinois at Urbana-Champaign)**

**Initiation Year:**

**FY 2004**

**Aggregate Amount of Funding Authorized in FY 2003 and Earlier Years:**

**$0**

**FY 2004 Authorized Funding:**

**$40,000**

**Actual or Expected Expenditure of FY 2004 Funding: In-house:**

**$40,000**

**Status of Investigation at End of FY 2004:**

**To be continued in FY 2005 with 0.3 full-time equivalent (FTE) from FY 2005 Director's Discretionary Fund (DDF) to be allocated to the Integrated Mission Design Center (IMDC)**

**Expected Completion Date:**

**May 2005**

**Purpose of Investigation:**

The study of bird migration on a global scale is one of the unsolved problems of modern biology. It has major implications for human health and conservation biology, and could affect international agreements and treaties. Together with colleagues from Princeton University and the University of Illinois, we have developed a concept for using interferometric-geolocation communication sensors to track small animals from near-Earth orbit. The concept is called the International Collaboration for Animal Research Using Space (ICARUS).

The basic principle is to estimate the geolocation of a migrating bird by detecting emitted electromagnetic pulses transmitted by a small antenna payload placed on the bird. Once this radio signal is detected from an orbiting platform, the orbital motion of the spacecraft determines the bird's location along one coordinate axis by the Doppler shift of the pulse's frequency, much as

one can determine whether a train is moving toward or away from by listening to the changing frequency of its train whistle.

The principle of interferometry is used to locate the bird along a second coordinate. Here, the change in phase of the traveling electromagnetic pulse as it reaches two or more receiving antennas on the spacecraft can be related to location in the cross-track direction of the orbiting platform.

We propose to use the Integrated Mission Design Center (IMDC) at the Goddard Space Flight Center to refine our concept and scope out possible packaging for future funding opportunities, including flights on Unmanned Aerial Vehicles (UAV) and the International Space Station, or piggybacking on separate low-Earth orbit launch opportunities. Several technical issues could affect architecture choices and signal-processing demands. One such technical issue, for example, is developing the ability to detect 1-mW signals from space and the need to provide a quiet environment on the platform. We anticipate that the results of our IMDC run will allow us to develop an implementation strategy. This would include prototyping a UAV system and refining a path for a space-based mission managed at the Goddard Space Flight Center.

**Accomplishments to Date:**

Our team has met three times to develop a traceability matrix of requirements and tradeoffs for estimating the accuracy and coverage required for pinpointing migrating birds in preparation for an IMDC run. We discussed the signal strength requirements for detection of a single, short pulse from a low-orbit satellite with communication engineers at Goddard and presented our initial concepts. However, we were not able to schedule an IMDC run because of the demand and priorities for its use in FY 2004. It is now scheduled for FY 2005.

*Figure 1. Catharus ustulatus is an example of a neotropical migrant. The bird weighs about 30 grams. It winters in South America and breeds in Canada.*

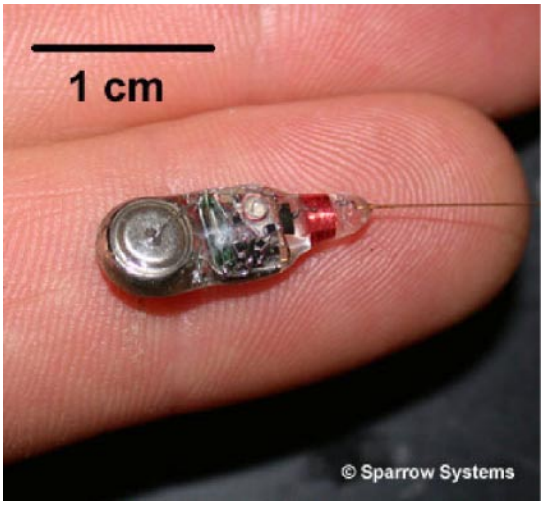


*Figure 2. Example of a transmitter that currently is used in bird research. It could be tracked from a low-orbit satellite*

Using the characteristics of a typical transmitter that currently is used in bird-migration studies (see Figure 2), we estimated what an Earth transmitter would have to generate to be detected with a conservative signal-to-noise ratio by a satellite receiver. Using a carrier frequency of 150Mhz, a wavelength of 2.0 m, a receiver system noise temperature of 50 Kelvin (K), a satellite height of 400 km, assuming the Earth is a black body at 300 K, completely occulted by the antenna beam, a receiver bandwidth of 10 Khz with a satellite receiving antenna gain of 15 dB and signal-to-noise power ratio at the detector of 10 dB, we arrived at the 1 mW requirement for the transmitting antenna on the organism.

Figure 3 shows an example antenna layout that would determine the position of the migrating birds. The along-track position is obtained using the Doppler frequency shift of the aerial or space platform and the cross-track position from phase comparisons of the interferometer. Higher-order

systems with multiple antennas also are possible. A five-antenna array could be spaced within a 2.3 by 2.3 wavelength configuration. How much real estate would be required on a satellite, how such a system could be packaged for launching, and how it would be erected in orbit are some of the questions to be addressed during an IMDC run.

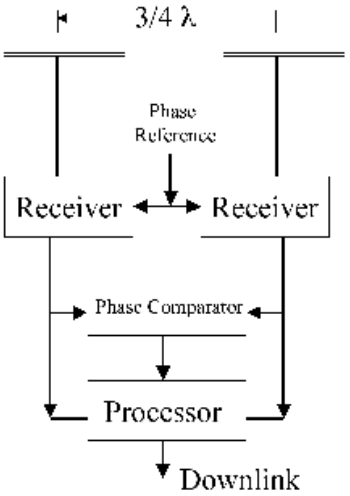


*Figure 3. Outline schematic of one potential solution using two receiving antennas, with dual polarization and four receivers in phase-matched pairs*

**Publications and Conference Presentations:**

We presented and published our work in the following venues:

- We presented our concept at the IEEE International Geosciences and Remote Sensing Symposium, IGARSS 2004.
- George W. Swenson, Jr., Martin Wikelski, and James A. Smith, Tracking Very-Low Power Ground Transmitters from Near Earth Orbit. Proc. IEEE Int'l Geosci. And Rem. Sens. Symposium. Anchorage, Alaska, 19-24, September 2004.
- We also have informally presented our ideas and are soliciting feedback at Princeton University, the USGS Biological Research Division Mid-Continent Research Center, the USGS Biological Research Division Alaska Science Center, and at Goddard Space Flight Center.

**Planned Future Work:**

Because of the intense demand for its services, we were not able to schedule the IMDC for our project in FY 2004. For FY 2005, we were awarded a no-cost extension to our Director's Discretionary funding award, plus the 0.3 FTE that is required for the IMDC. Our design run is scheduled for the week of February 28–March 7.

**Summary:**

Developing a space-based global monitoring and tracking capability would be revolutionary. Basically, we are proposing a new type of what could be called a geodoscope to study the environment. We also are looking at the cooperative use of multiple sensors, including lasers and passive sensors, to sample migrating organisms and their surrounding environment. As proposed, a communication sensor would directly support key objectives outlined in the Earth Science strategic plans. The proposed system also would help develop a framework for understanding the impact of avian movements as important disease carriers or as agricultural pests.

This is a feasibility study to determine the characteristics and potential for tracking long-distance (cross-continental) migration of small propagule, a bud or spore that becomes detached from the rest of the plant or fungus and forms a new organism. Depending on the outcome of additional studies, the technology could lead to future Goddard missions aboard a UAV, the International Space Station, or as an add-on, low-cost instrument for other free-flying missions.

Existing systems for tracking migrating organisms require large, bulky transmitters that are affixed to the species. Consequently, the technology is inappropriate for the species we are studying. Currently, transmitter modules are available that weigh one gram or less, including antenna and battery, and are able to deliver peak pulse power of one mW. However, one technical risk is whether this signal strength is sufficient given the considerable environmental and satellite noise factors. Packaging for space platforms also could be an issue. The major non-technical issue is the availability of the IMDC and technical experts for our study.