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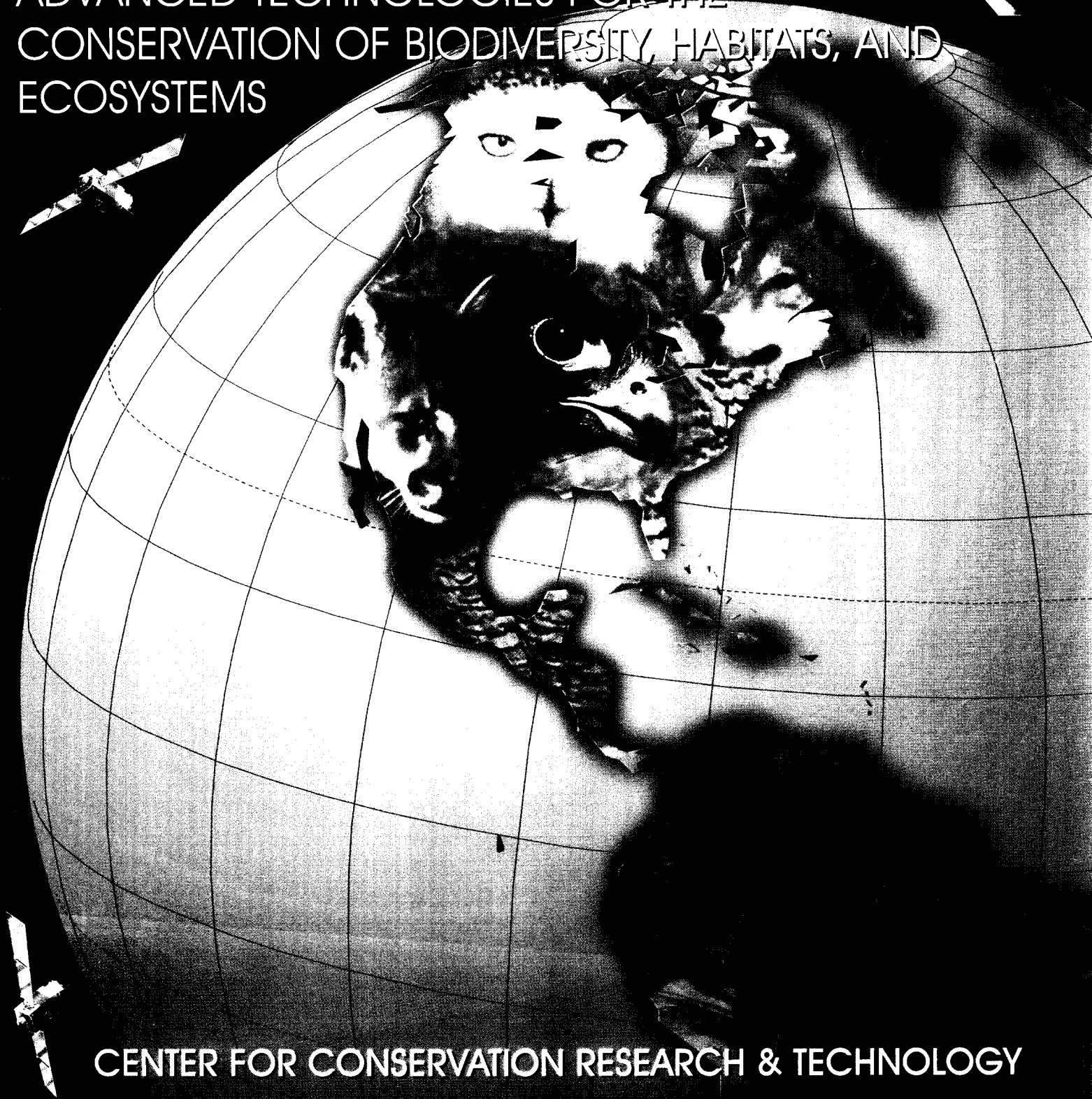
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RESOURCE MANAGERS' TECHNICAL REVIEW

ADVANCED TECHNOLOGIES FOR THE
CONSERVATION OF BIODIVERSITY, HABITATS, AND
ECOSYSTEMS



CENTER FOR CONSERVATION RESEARCH & TECHNOLOGY



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Conservation is the state of harmony between men and land. By land is meant all of the things on, over, or in the earth. Harmony with land is like harmony with a friend; you cannot cherish his right hand and chop off his left.... The outstanding scientific discovery of the twentieth century is not television, or radio, but rather the complexity of the land organism. Only those who know the most about it can appreciate how little we know about it. The last word in ignorance is the man who says of an animal or plant: "What good is it?" If the land mechanism as a whole is good, then every part is good, whether we understand it or not. If the biota, in the course of eons, has built something we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering.

—Aldo Leopold, *A Sand County Almanac*

The Center for Conservation Research & Technology (CCRT) is a private/university/government partnership dedicated to the continued development and application of advanced technologies for the conservation and management of wildlife species, habitats, and ecosystems. CCRT has offices in Baltimore, MD and Boise, ID. CCRT is headquartered at the University of Maryland Baltimore County. For additional information, please contact Dr. William S. Seegar at (410) 436-2586, e-mail: WSSEEGAR@aol.com or Mr. Blake Henke, e-mail: blakehenke@msn.com

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PREFACE

RESOURCE MANAGERS' TECHNICAL REVIEW

Advanced Technologies for the Conservation of Biodiversity, Habitats, and Ecosystems

In 1981, the U.S. Army initiated a program with the Johns Hopkins University Applied Physics Laboratory (JHUAPL) to investigate the potential of developing small platform transmitter terminals (PTTs) to be mounted on animals and tracked by the French-U.S., Argos satellite system. The program was designed to provide a capability that could track migratory birds and other widely ranging species anywhere on Earth. Since the inception of the program, miniaturization has led to the commercialization and fielding of PTTs that weigh less than 20gm and can interface with an array of sensors.

Beginning in FY94, the Department of Defense's Legacy Resource Management Program (Legacy) and Strategic Environmental Research and Development Program (SERDP) funded related projects to develop, demonstrate, promote, and improve satellite tracking and monitoring systems for resource management and conservation on military lands. These

projects were planned and executed in parallel. Legacy provided support for field demonstrations and applications of existing technologies, while SERDP provided support for basic and exploratory (6.1 and 6.2) research, as well as advanced development (6.3), of new capabilities.

This Resource Managers' Technical Review summarizes:

- The Legacy/SERDP projects;
- The current state of these capabilities;
- Illustrations of how these systems and capabilities have been effectively used on a global scale;
- Current and planned innovative applications of these technologies for resource management on federal and private lands;
- Future development opportunities.



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ACKNOWLEDGMENTS

We would like to acknowledge and thank the Deputy Under Secretary of Defense (Environmental Security), Ms. Sherri W. Goodman, for support through the Legacy Resource Management Program. We would also like to thank the Strategic Environmental Research and Development Program (SERDP) for support and guidance. We have many collaborators to thank, including The Raptor Research Center at Boise State University, the University of Maryland Baltimore County, the Edgewood Research Development and Engineering Center of the U.S. Army Chemical and Biological Defense Command, the U.S. Geological Survey of the Department of Interior, Johns Hopkins University Applied Physics Laboratory, Pennsylvania State University, Utah State University, Bristol University (UK), and Partners in Flight. The contributions and kind cooperation of natural resource personnel from cooperating installations nationwide are also gratefully acknowledged.

We are especially grateful to the following individuals for their support and guidance throughout these projects: Mr. Peter Boice (Legacy), Ms. Jackie Howard (Legacy), Col. (Ret.) Robert McGuire (Legacy), Dr. Femi Ayorinde (SERDP), Dr. John Harrison (SERDP), Mr. Brad Smith (SERDP), and Mr. Gordon Wood (SERDP, Ret.). Others deserving special thanks include Mr. Joseph Verrier, Dr. F. Prescott Ward, Mr. Paul Dunaway, Dr. William Mattox, Gen. John Kane, Ms. Marjorie McHenry, and Dr. Paul Howey. The following people generously contributed photographs and/or graphics to this brochure: Mr. Michael Colopy, Mr. William S. Clark, and Mr. Judd Rizzo. Ms. Janet Harvey and Ms. Stella Matalas provided the design and layout. Reviewers included Dr. Steve Garber, Ms. Jackie Howard, Mr. Brad Smith, Mr. Joe Wall, and Mr. Gordon Wood.

ATIVE SUMMARY

ADVANCED TECHNOLOGIES FOR THE CONSERVATION OF BIODIVERSITY, HABITATS, AND ECOSYSTEMS

Since the early 1980s, the technology available for wildlife research and management has improved dramatically, and the founders of the Center for Conservation Research & Technology (CCRT) have been heavily involved in exploring new technologies and developing new approaches. This Resource Managers' Technical Review summarizes nearly 20 years of wildlife research, technology development, and field application of innovative tools and methods on military lands and throughout the world. In 1984, we placed the first experimental satellite received, platform transmitter terminal (PTT) on a Bald Eagle at Aberdeen Proving Ground, Maryland and tracked it for 270 days between Maryland and Florida.

Since then, miniaturization has led to the commercialization and fielding of PTTs that weigh less than 20gm and can interface with an array of sensors. These space-based technology tools are particularly applicable for studies of free-ranging animals that (1) travel long distances over extended periods, (2) frequent rugged, inaccessible habitat, or (3) occupy secure areas (such as military installations). Today, advanced biotelemetry capabilities that incorporate the latest innovations in microelectronics, geographic information systems (GIS), remote sensing, and computer modeling offer great promise in helping to define and characterize human effects on species and ecological communities and to identify strategies to ensure their sustainability in the face of expanding human enterprise.

Beginning in FY94, the Defense Department's Legacy Resource Management Program (Legacy) and Strategic Environmental Research and Development Program (SERDP) funded related CCRT projects to demonstrate satellite-based biotelemetry technologies on military bases, and to develop new capabilities to enhance existing systems. These projects were planned and executed in parallel.

Through support from Legacy, CCRT demonstrated commercially available PTTs on five military bases in the western U.S.:

Dugway Proving Ground, Utah (Pronghorn, wild Horses, Ferruginous and Swainson's Hawks);

Hill Air Force Base, Utah (Ferruginous Hawks);

Idaho Army National Guard Orchard Training Area, Idaho (Golden Eagles, Ferruginous and Swainson's Hawks);

Naval Air Station Fallon, Nevada (White Pelicans and White-faced Ibis); and White Sands Missile Range, New Mexico (Oryx).

These Legacy field demonstrations have produced comprehensive tracking and monitoring databases for the target animals. CCRT analyzes this tracking and monitoring information with GIS to map animal movements in relation to habitat types, geo-political boundaries, vegetation cover, geomorphology, water resources, military land use activities, and many other geographically discrete data sets. In this way, we are providing valuable (and often previously unattainable) resource management information to military land managers.

We also applied numerous PTTs to selected migratory bird species throughout North America as part of larger, transcontinental migration studies in conjunction with Partners in Flight. In fact, we pioneered the application of space-based technology for the study of neotropical migratory birds. We successfully developed a methodology and study protocol for application of satellite tracking to Tundra Peregrine Falcons (*Falco peregrinus tundrius*) and Swainson's Hawks (*Buteo swainsoni*) using the smallest available PTTs. In only a few years, these transmitters have provided more data of Peregrine Falcon migratory patterns than the past 25 years of conventional field studies and leg band returns. Scientists are now learning exactly where these birds travel, where they stop along their trek, and what threats may exist to their survival along the way. And our work with the Swainson's Hawk — i.e., tracking individuals from throughout their breeding range to wintering areas in the pampas of Argentina — revealed the cause (massive mortality from chemical pesticide applications in Argentina) of a potentially catastrophic population decline that could have affected 90% of the North American population. In fact, this study (conducted with many collaborators) may have prevented listing of the Swainson's Hawk on the threatened and endangered species list.

Our contribution to the development of satellite telemetry stemmed from our endangered species program initiated in 1970. During the past three decades, we have conducted a comprehensive study of the Tundra Peregrine Falcon and other sub-species throughout their breeding, migratory, and wintering ranges. With new technologies and evolving field methods, we are now better able to understand and fully describe the intricate relationships which exist among key organisms — such as the Tundra Peregrine Falcon — their critical habitats, and their broad but declining avian prey base in the Americas.

Through support from SERDP, we have fielded a Global Positioning System (GPS) PTT, new meteorological sensors, as well as an acoustic sensor that will be small enough to be integrated into a PTT to perform a variety of functions. As a

result, a new, more capable generation of satellite tracked PTTs will soon be available for deployment. The new GPS PTTs will provide location estimates to within ± 100 m, which represents a quantum leap forward in the application of radio telemetry to wildlife science. GPS readings can be collected according to a pre-programmed schedule to dramatically increase the number of positions that are possible (via satellite) and to enhance our ability to derive important facts regarding species range and habitat use. The acoustic sensor is designed to recognize animal vocalizations, thus allowing more thorough, remote study of animal behavior, species interrelationships, and microhabitat components of an animal's range.

From a practical standpoint, the use of advanced, satellite-based tracking and monitoring technologies to acquire the natural history information necessary for effective management and conservation of widely ranging animals could save roughly 10–30% over currently available best methods (i.e., conventional, ground-based radio telemetry). These cost savings accrue in a variety of ways: through reduced direct costs for personnel, equipment, and field time; through enhanced speed of collection and accuracy of the data; and through avoiding conflicts with military training and testing operations and other land use activities. Equally important, these technologies provide methods to acquire otherwise unattainable natural history information for wildlife species of interest. These technology-based systems are poised to foster the early integration of military mission planning activities with critical natural resource information. And CCRT stands ready to employ these tools to enable planners and managers to meet military and environmental requirements quickly, cost effectively, with accurate information, and with minimal interruption to regular base activities.

The SERDP Program has supported the fielding of advanced satellite telemetry hardware and sensors, while the Legacy Program has supported the demonstration and implementation of existing technologies on pilot military bases. Through support from these programs, CCRT is defining the cutting edge of remote tracking and monitoring capabilities. And most importantly, we are using these advanced systems and the resulting data to provide comprehensive analyses and new approaches to pressing wildlife management concerns, nationally and globally, as well as to applied operational and safety issues such as aircraft bird strike avoidance.

CCRT is developing a Bird Flight Forecast and Information System to reduce the risk of bird/aircraft collisions. Minimizing this bird strike danger without compromising the military mission requires forecasts of bird activity with lead times compatible with operational planning. The daily cycle of soaring bird activity varies substantially in response to the changing weather. Therefore, reliance on statistical averages of bird behavior incurs both excessive risks and undue mission interference. Daily soaring bird forecasts with adequate lead times are therefore essential to meet mission requirements of military aviation units. Our studies of soaring bird flight suggest

that such forecasts are possible and can be provided in much the same way that weather forecasts are made available to mission planners. By combining satellite and conventional, radio telemetry tracking technology with meteorological observations and models, CCRT is developing a bird flight forecast and information system to predict potentially hazardous bird strike conditions hours and days in advance. Once completed, this avian flight model will be applicable virtually worldwide for a variety of avian species.

In another initiative, CCRT has begun a satellite tracking study of White-faced Ibis near Naval Air Station Fallon and Hawthorne Army Depot in Nevada in order to determine the source(s) of chemical contamination affecting a portion of the population. These long-legged wading birds feed primarily on invertebrates in the wetlands and irrigated croplands in and adjacent to military use areas. Ten years ago, this population of Ibis was found to be burdened with high levels of DDE, the principal metabolite of DDT. The results were egg shells 18% thinner than normal and a 20% decrease in breeding production. This situation has **not** changed, and it has been determined that these contaminants are **not** being acquired in western Nevada. Just where and how these birds are being contaminated with DDT remains a mystery. We are employing satellite tracking and monitoring technology to investigate White-faced Ibis migration routes and habitat use to pinpoint the source(s) of contamination affecting this troubled population.

In 1998, CCRT initiated a telemetry study (via satellite) of Common Loons in the Great Basin of Nevada using implantable PTTs to investigate their breeding areas and migration routes. Future efforts include a planned satellite telemetry study of Hudsonian Godwits from northern Canada to discover wintering areas and migration routes.

In addition to the Legacy and SERDP supported efforts, CCRT has collaborated with the Departments of Defense and Interior to provide support to the Russian Federation in the area of sensitive, threatened, and endangered species research and conservation. During the summer of 1994, Peregrine Falcons were blood sampled and tracked via satellite from their breeding grounds on the Kola Peninsula to wintering areas in Western Europe. These international efforts have continued with other species, including Steller's Sea Eagles (SSE) in Russia. Recently, CCRT participated in studies of SSE migration and wintering behavior, and their distribution and breeding dynamics. During the spring of 1997, we outfitted SSEs with satellite PTTs in the Magadan region of Russia, in Kamchatka, and in the Amur region. The use of radio tracking via satellites is particularly appropriate given the remoteness of areas in which this bird lives.

All of this research, development, and technology transfer has culminated in the formation of CCRT. The systems we have developed continue to be defined and advanced, and the potential applications are practically limitless.

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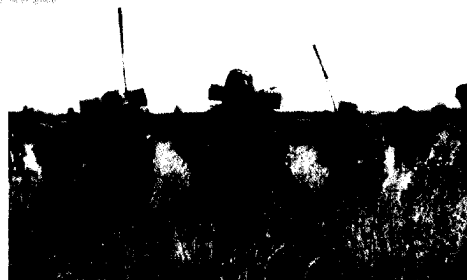
DoD STEWARDSHIP MISSION

The Defense Department's stewardship goals are to conserve, protect, enhance, and manage the natural resources under its control in a manner consistent with its military mission, while simultaneously complying with all laws and regulations and providing optimal use of these resources. An important part of achieving these goals is the knowledgeable, proactive management of the natural resources that provide the realistic training environment in which exercising and testing the capabilities of military forces is most effective. Various national (see inset box on next page) and state statutes, regulations, and requirements provide specific direction for maintaining military training and testing lands. However, these requirements generally relate to land use planning and management. Therefore they assume or require previous acquisition of extensive information on which to base and implement planning and management regimes. CCRT's mission is to provide such information relative to wildlife conservation.

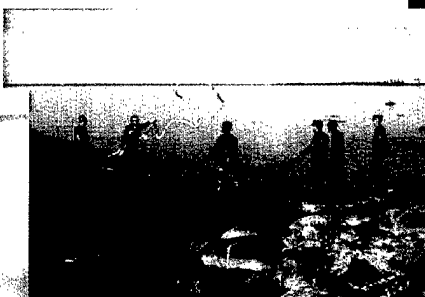
The Department of Defense (DoD) is the third largest public land-holder in the United States (on a department level) and manages more than 900 installations that collectively comprise more than 25 million acres. The DoD uses this land for training (infantry, armor, artillery, and aircraft) and material testing and evaluation. DoD installations range in size from more than 3 million acres to less than 10 acres. Access to military installations is often restricted, and environmentally sensitive areas are usually further restricted. With broad geographic distribution, DoD lands represent a remarkably diverse collection of ecosystems and habitat types containing globally significant species and natural communities that are shielded from the development pressures existing beyond military boundaries. DoD lands also provide refuge for a broad spectrum of rare and endangered plants and animals. The public entrusts the DoD to act as a good steward of the Nation's air, land, and water resources. ■



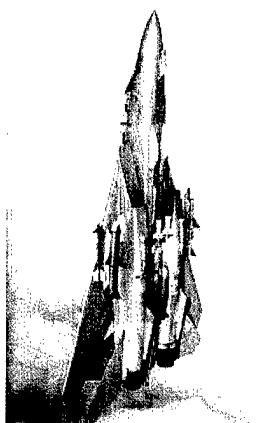
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KEY FEDERAL LAWS AND PROVISIONS DIRECTING DoD'S WILDLIFE MANAGEMENT AND STEWARDSHIP MISSION

The Migratory Bird Treaty Act of 1918 requires federal protection of certain migratory birds, their eggs, nests, or young.

The Fish and Wildlife Conservation Act of 1956 provides for conservation, protection, restoration, and propagation of certain species, including those migratory birds threatened with extinction.

The Sikes Act of 1960 promotes effective planning, development, maintenance, and coordination of wildlife, fish, and game species conservation on military lands. It requires integrated natural resource management planning and promotes coordination among DoD, the U.S. Fish and Wildlife Service, and state fish and game agencies.

The National Environmental Policy Act of 1969 requires that major federal projects be evaluated for their impact on the environment. It is the key environmental planning law that calls for all information to be provided to decision-makers and the public before actions are taken.

The Endangered Species Act of 1973 (as amended in 1978) requires special protection for endangered and threatened species and the habitat necessary for their continued existence. The act directs federal agencies to enhance the prospects for survival of threatened and endangered species by working cooperatively on conservation and recovery efforts aimed at maintaining viable populations of listed species.



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NATURAL RESOURCE MANAGEMENT PROCEDURES



Michael Colopy

The process of natural resource management and planning begins with a thorough inventory and description of a natural system's flora and fauna. This information is critical for the development and implementation of effective integrated natural resource management plans. Such plans, in turn, allow land managers—such as the U.S. Department of Defense (DoD), Forest Service, and the Bureau of Land Management—to maintain biodiversity, conserve natural resources, and comply with applicable environmental laws and regulations. A central component of effective planning and management is the acquisition of comprehensive scientific information on: (1) highly mobile species (such as migratory birds or other widely ranging animals); (2) rare, elusive, sensitive, threatened, or endangered species (as well as candidate species); (3) species of concern or otherwise special management species, such as exotics or big game species; and (4) animals that frequent inaccessible habitats or extremely rugged terrain. This process can be difficult and expensive.

This is especially true for migratory birds that cross geo-political boundaries seasonally and must be managed (by law in the U.S. under the Migratory Bird Treaty Act of 1918) at both ends of their migrations and all important points along migration routes. Each year millions of birds

representing hundreds of species cross dozens of geo-political boundaries during their migration from their North American breeding grounds to milder climates in Central and South America and the Caribbean. During migration, these birds stop to rest and feed in areas that provide resources to shelter them and to fuel their flight. These "stopover" areas constitute critical habitat for many species. Without continual management of these habitats, substantial loss of avifauna could result. In fact, many of these species are declining in numbers annually. Threats to migratory species can occur anywhere along migration routes. Pinpointing problems or reasons for a species' decline is often extremely difficult as a result.

Species inventory and monitoring is a difficult and time consuming effort. Gathering substantial management information—such as habitat delineations, range analyses, key species interactions, and impact assessments—often requires intensive study over many years at a level of effort that may not be feasible with conventional, low technology approaches.

Complicating matters on military lands, field data gathering efforts often interrupt or conflict with ongoing land use activities, such as military, mission-related material test/evaluation, troop training, intensive agricultural enterprise, and logging. Advanced information gathering technologies—such as wildlife radio tracking via satellites—provide sophisticated, state-of-the-art, methods to acquire otherwise laborious, expensive, or unattainable data while creating little or no interference to ongoing land use activities. ■



A radio-tagged Golden Eagle is marked with red dye so it can be easily recognized to avoid recapturing the same individual.



DoD UNIQUE NATURAL RESOURCE MANAGEMENT ISSUES

The DoD's primary mission of maintaining combat troops in a state of readiness requires a variety of unique and intensive air and land use activities, such as troop training, artillery range maneuvers, joint AirLand exercises, bombing runs, aircraft pilot training, amphibious assault training, smoke and obscurant exercises, and many others. At the same time, the DoD strives to preserve the Nation's natural resources under its control.

Outside military land boundaries, the conversion of land for residential, industrial, and transportation uses continually modifies many of the remaining natural communities. These modifications can accelerate endangerment of particular species and native communities. Many military installations have therefore become natural habitat "islands" in urban and agricultural "seas." This situation has positive and negative implications.

Biodiversity often has been sheltered on military lands, at least temporarily; but because extant rare species populations on military lands have become increasingly isolated from regional populations, they are subject to increased probability of local extinction. Furthermore, because military lands are viewed by many of the surrounding communities as permanent refuges for threatened and endangered species, the military has, in some cases, become the sole organization responsible for the continued existence of some species or populations. All of these factors make the job of species conservation on military lands complex and difficult.

DoD officials estimate that more than 220 federally listed

threatened or endangered species occur on military installations. In addition, nearly 200 candidate species are known or expected to occur on Army lands alone. These values are roughly comparable to the total number of listed species reported for other major federal land management agencies/services combined, including the Bureau of Land Management, the National Park Service, and the Fish and Wildlife Service, and the U.S. Forest Service. The DoD, however, owns the fewest number of hectares of all major federal landowners. Thus, when expressed in terms of density, the number of federally listed species per unit of land is substantially higher for DoD lands than for lands held by other federal landowners—9.4 species/million hectares for DoD lands compared to 1.0 to 3.2 species/million hectares for other federal landowners.

Migratory birds frequent military bases during their annual migration between North American breeding grounds and wintering grounds in Central and South America. Many of these migrants proceed step by step, feeding and resting along the way. These "stopover" areas constitute critical habitat for many species, and DoD lands are central to this annual cycle.

Changes in military training, including the need for more combined force training that require use of additional land and airspace, can place additional pressures on the Services and on the natural environment. Through understanding and use of advanced technologies for environmental change detection and tracking of mobile animals, mission readiness and natural resource management can occur with little or no conflict.



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TECHNOLOGY



One of the first prototype satellite PTIs, developed in 1984, shown here on a Golden Eagle.

BIOTELEMETRY BACKGROUND

Methods to acquire scientific information on free-ranging and elusive animals have improved over the years. Conventional biotelemetry systems, developed in the 1950s and 1960s, use directional receiving antennas to locate radio transmitters. Such systems have enabled biologists to relocate previously captured and radio-tagged animals and to collect information on their location and behavior.

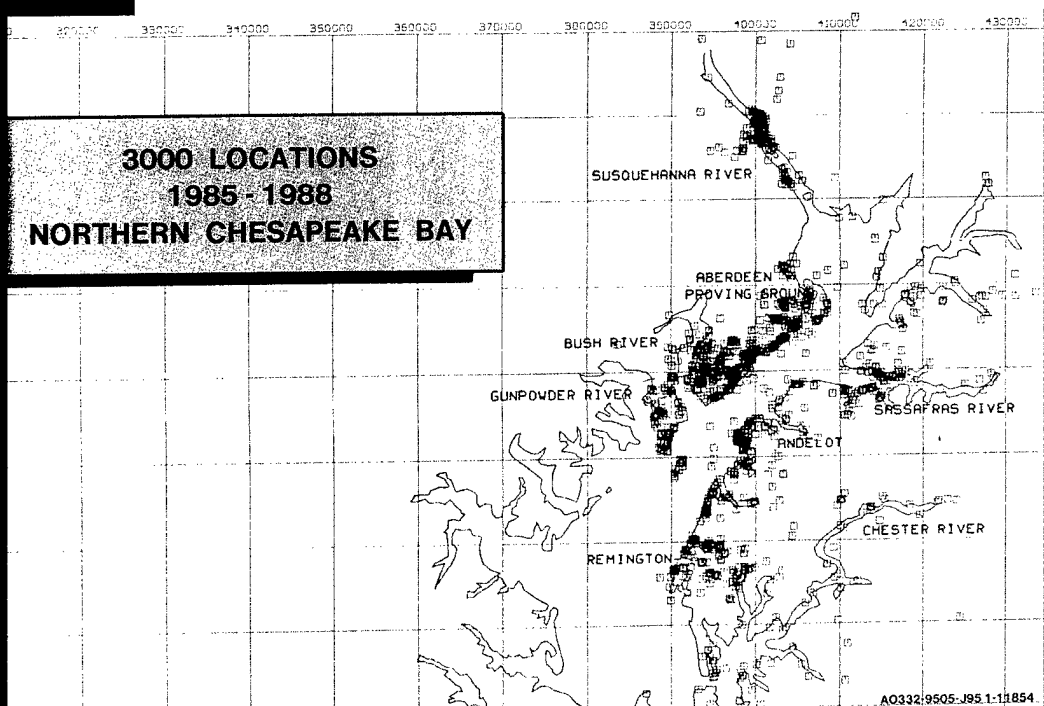
Biotelemetry also can be used to collect information from the environment surrounding the radio-tagged animal (e.g., temperature, altitude), as well as behavioral and physiological parameters (e.g., motion, core temperature, and heart rate).

Until biotelemetry became available, information on free-ranging animals was difficult to

obtain, and for many secretive animals this information could only be inferred from meticulous, indirect sampling methodologies. Conventional biotelemetry systems, while a significant improvement over many previous data gathering methods, are typically restricted to small geographic areas accessed on foot, from automobiles, or by aircraft.

For studies of free-ranging animals that (1) travel long distances over extended periods, (2) frequent rugged, inaccessible habitat, or (3) occupy secure areas (such as military installations), space-based tracking and monitoring systems are advantageous.

Since the late 1960s, the technology available for wildlife research and management has improved dramatically, and CCRT has been heavily involved in exploring new technologies and developing new approaches.



The results of a conventional, radio telemetry study of 70 Bald Eagles captured near Aberdeen Proving Ground, MD. Each of these location estimates (in blue) was obtained by field teams triangulating radio signals; the effort was extremely labor intensive.

Bald Eagles frequent the Aberdeen Peninsula, the Susquehanna River drainage, and the Eastern shore of Maryland but do not use the Baltimore-Washington corridor.



A Pronghorn
outfitted with a
satellite PTT
near Dugway
Proving Ground,
UT.

SATELLITE-BASED BIOTELEMETRY

Miniature, satellite-received transmitters (i.e., platform transmitter terminals, or PTTs) light enough to be carried on the backs of birds were first developed by CCRT in the 1980s. In 1984, we placed the first experimental PTT on a Bald Eagle at Aberdeen Proving Ground, Maryland and tracked it for 270 days between Maryland and Florida.

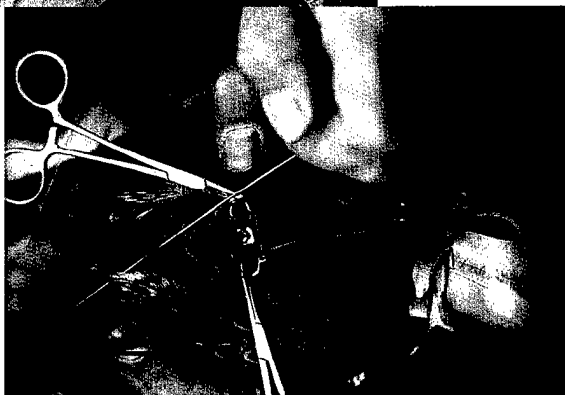
PTTs are now widely used. They employ the Argos satellite system and allow the remote location and tracking of the target organisms to which they are attached. The current system is

capable of tracking mobile organisms anywhere on the face of the Earth to within $\pm 3\text{km}$, depending on the geometry of the satellite pass and the quality and strength of the PTT transmission. While the extremely low power transmissions from a miniature PTT result in relatively few locations, results are sufficient for most biological applications. PTTs can weigh less than 20 grams—3.5 grams of electronics, an 8 gram battery, and the remainder in the container—and are now produced commercially by Microwave Telemetry, Inc. and several other manufacturers. Recent advances integrating the Argos PTT with Global Positioning System (GPS) receivers are bringing on line new and more powerful tracking tools for the location and monitoring of free-ranging animals (see pp. 42–45 for details).

From the beginning, our use of radio tagging always has been based on careful consideration of the effects of the transmitters on the animal, especially concerning bird behavior and flight. Since the early 1990s, CCRT and others have successfully applied over 1,000 PTTs to more than 20 avian species and many terrestrial and marine species on a global scale. ■



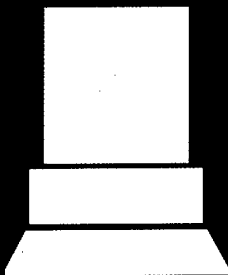
The application of
satellite PTTs is a
meticulous process
that takes less than
an hour for proper
sizing.



Ferruginous
Hawk
outfitted
with a
satellite PTT.

©Michael Colopy

COMPU



The utility of remote tracking and monitoring technology, such as transmitter and sensor hardware, is greatly enhanced when combined with the latest computer processing capabilities.

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

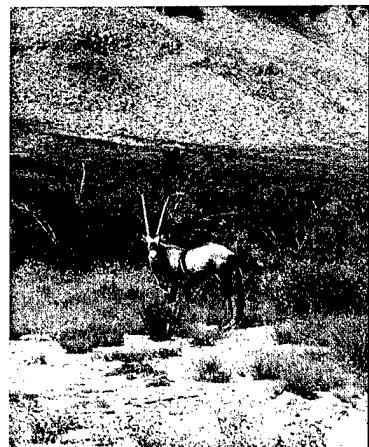
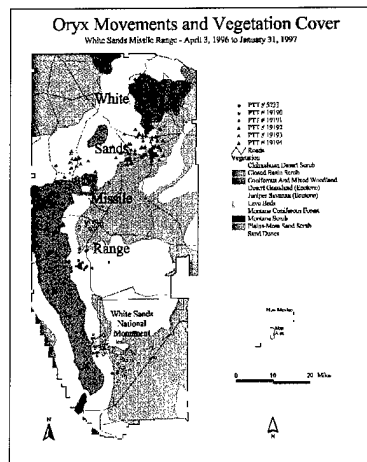
In the broadest context, a geographic information system (GIS) is a computer-based system used for the storage and analysis of geographically referenced (or "spatial") data. In our case, GIS serves as an integrating analytical tool that enables us to relate animal movements and behavior patterns to habitat, water resources, land ownership, geo-political boundaries, land use activities, geomorphology, vegetation cover, weather, and virtually any geographically discrete data base or variable that might affect the survival or health of particular species or ecosystems.

GIS data are usually stored within separate files as "layers," with each layer containing one type of feature, such as vegetation types or transportation routes. These data can exist in a number of spatial data formats, the two most common being vector and raster. Vector GIS data layers consist of points, lines, and polygons (such as roads and lakes), while raster GIS data layers consist of an array of grid cells such as from remotely sensed images or aerial photographs. The unifying feature of GIS is that each data layer

contains references that locate or relate that information to exact points on the surface of the Earth.

Some users employ GIS for true spatial analysis. In these cases, complex algorithms are used to help answer difficult spatial analysis questions and to create answers to hypothetical scenarios. The majority of GIS applications, however, rely heavily on storage of data (i.e., "inventory") rather than actual analysis (although the two are not mutually exclusive). The convenience of storing separate data layers facilitates cartographic production, as well as relational analysis, by allowing the GIS user to isolate certain data layers and to plot them against other layers at the touch of a button.

CCRT applied this "inventory" style GIS in the Legacy/SERDP programs, although we are also pursuing various spatial analysis applications, such as analyzing species home and wintering ranges, and forecasting bird migration routes. Primarily, our GIS stores geographical or spatial data associated with the military installations under study (such as vegetation cover and land use information), along with the animal location data obtained from the telemetry devices. We can easily plot the animal telemetry data in conjunction with the base GIS data to examine patterns and to identify cause and effect relationships.



The movements of animals tracked via satellite—such as this Oryx on White Sands Missile Range, NM—can be gathered remotely via Service Argos and imported into a GIS for spatial analysis and management planning.

ArcView and ARC/INFO

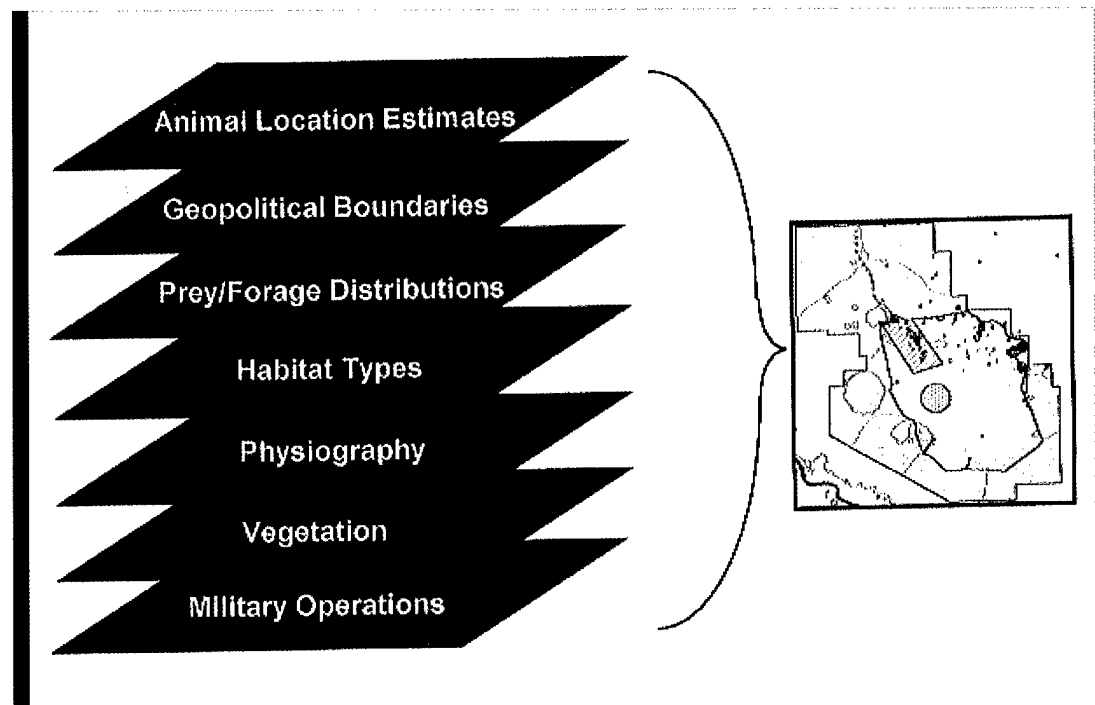
The two GIS software packages used for the Legacy/SERDP programs are ArcView and ARC/INFO, both produced by the Environmental Systems Research Institute (ESRI) of Redlands, California. ArcView is a "desktop," windows-based GIS package that uses a graphical user interface (GUI) to allow users to assemble geographic data layers for simple analysis and to construct cartographic products using the point-and-click approach. ARC/INFO is a much larger and more complex GIS and contains superior analysis capabilities. Unlike ArcView, ARC/INFO does not use a GUI and requires extensive training to operate effectively.

In the Legacy/SERDP programs, we have used ArcView for combining data layers, visual analysis, layer creation, and map production; and we have used ARC/INFO for technical data management, such as accurate conversions between map projections.

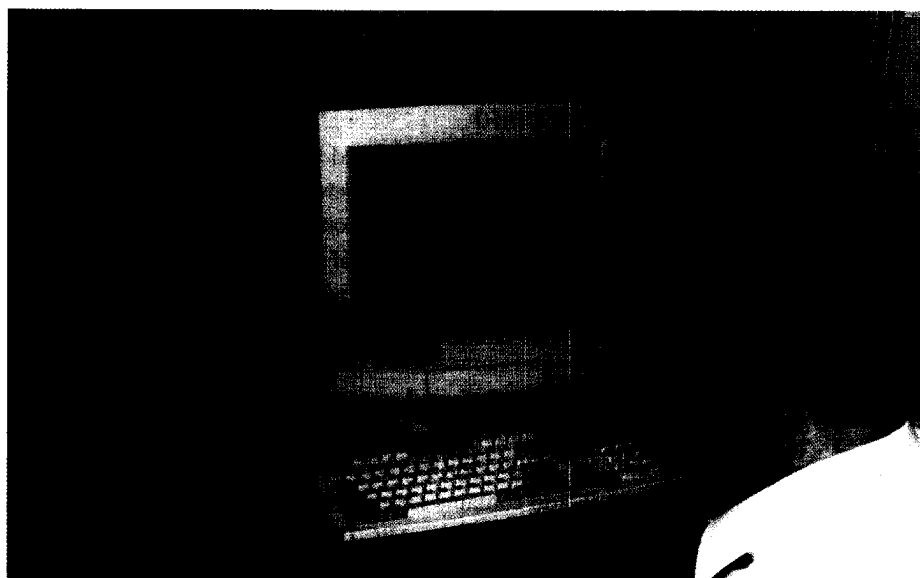
Graphical User Interface (GUI)

Like most applications, GIS software packages offer a select suite of functions necessary for the most common tasks. No software package considers all possible problems for all potential users. For this reason, many packages (including ArcView and ARC/INFO) are designed to interact with standard programming languages so the user can customize the software and create new functions for task-specific needs. For the Legacy/SERDP programs, we created an advanced suite of GIS functions—accessed through pull-down menus, buttons, or interface tools—to accommodate our specific display and analysis needs. This has been a significant improvement to the functionality of the Argos system for natural resource management. In ArcView, such a collection of functions can be made into an "extension." CCRT's ArcView GUI extension for incorporating satellite-derived Argos locations from radio-tagged animals into GIS analytical systems is available upon request.

Geographically discrete databases describing various types of land use/land cover information can be stored in a GIS and overlaid to allow relational analysis. Animal location estimates from satellite transmitters constitute one data layer.



GIS is used to relate animal movements to geographically linked information and land use activities. Remote sensing data is easily imported into GIS.



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REMOTE SENSING

Along with GIS, remote sensing has revolutionized the way scientists handle and analyze geographic data. Remote sensing refers to the acquisition of geographic data without making physical contact with the area of study. Today, remote sensing generally pertains to satellite images and aerial photography/imaging, both of which are sensitive to portions of the electromagnetic spectrum not visible to the human eye or most cameras (e.g., infrared, microwave). The ability to measure invisible energy and to record vast amounts of high resolution data from great distances is a very powerful tool.

A number of government agencies and private companies now distribute satellite imagery acquired from several satellite systems. The two most common satellite systems in operation are Landsat and SPOT. The Landsat satellite program was first implemented by the federal government in the late 1970s, but control over the imagery has now transitioned to other branches of the government and to private companies. SPOT (Satellite Pour l'Observation de La Terre) data are of French origin but are available domestically via an American branch office. Both systems provide powerful, high resolution imagery covering virtually the entire surface of the Earth.

Remotely sensed images are recorded as raster data and stored in grid cells. Each cell is coded

with an integer value associated with the phenomenon being measured. For example, in an image showing infrared energy, each cell is coded with an integer value directly correlated with the amount of infrared energy detected in that cell. These cell values then can be classified according to how the reflected value is associated with a terrain feature, such as land cover or vegetation. The surface area covered by each grid cell is directly related to the spatial resolution of the sensor from which the imagery was obtained; the higher a sensor's spatial resolution, the smaller the area covered by each grid cell. The Landsat sensor system provides data at a spatial resolution of 30 meters. The SPOT sensor system provides data at 20 meters but also provides panchromatic data at 10 meter resolution. Panchromatic data include many wavelengths of the electromagnetic spectrum grouped together for increased spatial resolution.

Remote sensing technology can be used to obtain data for Legacy/SERDP study areas. Since remotely sensed data offers virtually worldwide coverage, we can obtain data for remote areas of the Earth, even where no previous data has ever been mapped. By plotting telemetry locations on satellite images, we can correlate animal movements with up to date ground cover, water resources, human activity, and other geographically-linked variables.

Geese on migration.



©Michael Colopy

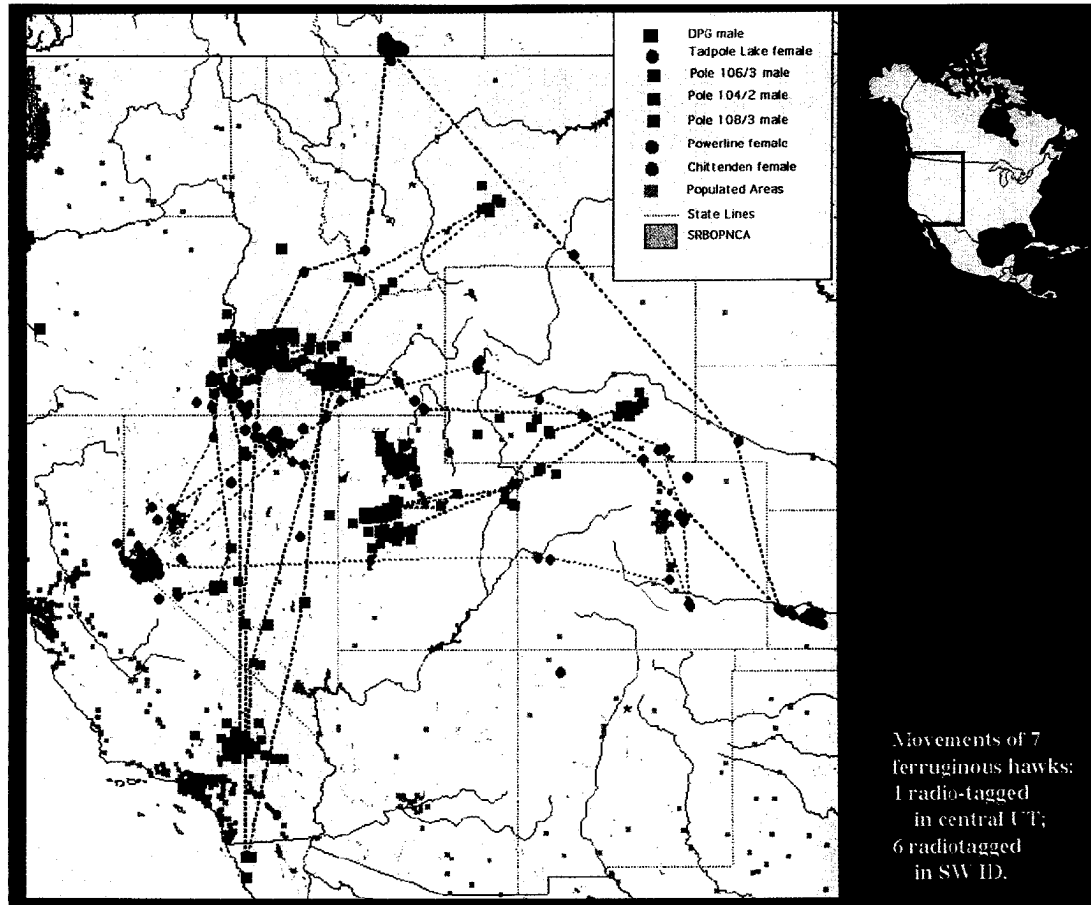
COMPUTER MODELING

Computer models have been used in recent decades to study a wide range of dissimilar processes such as the airflow over a high performance race car or the probable trajectory of a missile launched from a destroyer. Although each model may differ significantly in structure and complexity, the ultimate objective is the same: to simulate or forecast the evolution of one or more processes. The cornerstone of each computer model is a set of mathematical equations that describe the processes of interest. Using observational or experimental data to initialize the model, the computer solves these equations, thereby providing information on how these processes unfold, either now or in the future. Arguably the most well known computer models are those used by meteorologists. These models combine equations describing atmospheric motion with observational data to forecast changes in the weather. The concepts involved in the development of weather forecast models can easily be applied to other disciplines, resulting in a forecasting capability that previously did not exist.

Satellite-based biotelemetry data displayed on a GIS constitute a powerful tool for tracking and monitoring individual wild biota. Combined, these technologies have already proven valuable in developing wildlife management plans for military installations. For example, such data have been used to diagnose seasonal variations in the density and distribution of birds on and immediately adjacent to military installations. These analyses have been beneficial in reducing the bird strike hazard to aircraft. They illustrate how the abundance and distribution of birds vary on seasonal time scales, allowing military personnel to adjust flight paths and schedules to avoid typical high density bird areas during different times of the year. Unfortunately, due to local weather or other abiotic events, shorter term behavioral patterns of animals (and birds) often deviate dramatically from average observed patterns, enough so that the diagnostic nature of these technologies limits inferences of future animal movements and locations. Averages derived from observations, themselves, cannot represent the whole realm of possible or even likely outcomes. Therefore diagnostic biotelemetry data alone (i.e., simply extrapolating past observations to predict future animal movements) is not sufficient to forecast animal movements or patterns. Overcoming this obstacle requires the development of forecast models that predict animal movements based upon the dynamics that influence movements of individuals and/or groups.

Research has shown that animal movements are often intimately related to changes in the environment, seasons, and weather. Therefore, forecasting changes in those parameters that influence animal movement provides more accurate forecasts of future animal locations. For example, it is easy to predict that as autumn approaches migratory birds in the Northern Hemisphere will begin to fly south in response to seasonal changes in the weather. Although this simple "forecast" provides a general idea of how bird populations move on average, it cannot resolve how the abundance and distribution of birds will vary on much smaller temporal and spatial scales. Because exactly when, where, and at what altitudes different species fly can vary

Satellite derived movements of 7 Ferruginous Hawks from two military training areas in the Western U.S., Dugway Proving Ground, UT and Hill Air Force Base, UT.



according to such factors as the geography and time of day, it is important to predict those parameters on appropriate temporal and spatial scales to provide the best possible forecasts. In an effort to test this capability, we are currently developing a forecast model that predicts avian soaring flight based upon hourly and daily changes in the weather. (See pp. 33–35 for more information about CCRT's bird flight modeling and prediction efforts).

Although the system we are currently developing focuses exclusively on bird flight forecasting, it is likely that computer forecast models can be applied to a whole range of wild biota to predict

their movements. The theories underlying each model are typically simple conceptual models that describe one or more processes or relationships. Recent advances in computer technology have made it possible to operate such models on desktop personal computers, as opposed to the bulky super computers that earlier models required for compilation. Given these advances, it is likely that future forecast models will provide highly detailed and accurate information of animal movements on a very timely basis. This information will be invaluable to military personnel when planning movements of their own. ■

HOW DOES SATELLITE

WORK?

THE ARGOS SYSTEM

Service Argos is a satellite-based system which collects environmental data from autonomous platforms and delivers it to users worldwide. Argos has *truly* global service and is fully integrated, providing data from the source to the user's desktop.

The Argos system involves three interactive subsystems:

- Platform Transmitter Terminals (PTTs),
- The Space Segment,
- The Ground Segment.

Platform Transmitter Terminals (PTTs)

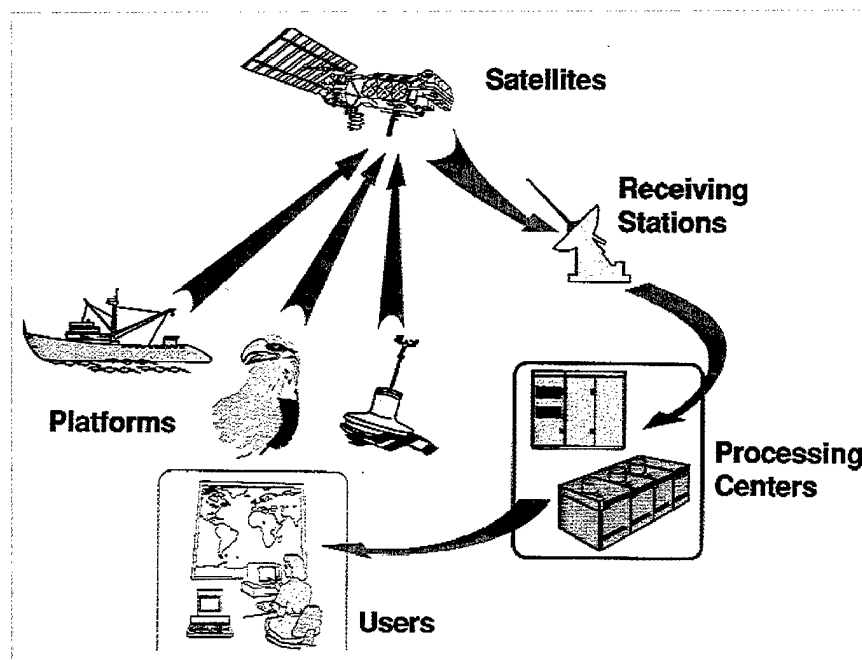
Argos operation begins with transmissions from PTTs attached to sensor equipment and the platform (bird or animal) from which data are collected. Typically, PTTs are built to withstand punishment and the environment. PTTs are interfaced with sensors and microprocessors; and they are configured by size, weight, power

consumption, and housing according to application requirements. Power consumption on PTTs is low due to the satellites' low-earth orbit and highly sensitive receiver equipment. This enables extended operation—a year or more—on battery power alone.

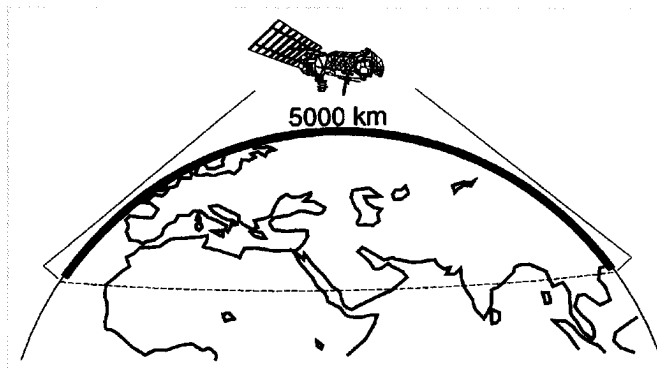
PTTs uplink (transmit) their message at preset intervals without cueing by the satellite. Each message may contain up to 256 bits of sensor data. A full message uplink takes as long as 960 milliseconds. The uplink "time-out," or repetition period, is normally set between 50 and 200 seconds, depending on the application. Although all PTTs transmit nominally at 401.65 MHz, different frequencies are received by the satellite receivers due to Doppler shift principles.

The Space Segment

Argos instruments are flown on board the National Oceanic and Atmospheric Administration (NOAA) Polar Orbiting Environmental Satellites (POES). The satellites receive Argos



The Argos Data
Collection and
Location System



The "footprint," or visibility circle of an Argos satellite pass. (not drawn to scale).

messages from PTTs and relay them to the ground. They also store them on tape recorders and read out the messages to one of three main system ground stations:

- Wallops Island, Virginia, USA,
- Fairbanks, Alaska, USA,
- Lannion, France.

Visibility Area

At any given time, each satellite simultaneously "sees" all PTTs within an approximate 5,000-kilometer-diameter "footprint", or visibility circle (see figure above). As the satellite proceeds in orbit, the visibility circle sweeps a 5,000 kilometer swath around the Earth, covering both poles. Due to the Earth's rotation, the swath shifts about the polar axis on each revolution.

Because of the Argos system's near-polar orbit, the number of daily satellite passes over a PTT increases with latitude. At the poles, each satellite passes approximately 14 times a day for a total of 28 (two satellites) passes. At the equator there are 6 to 7 passes total (see figure below). The number of satellite passes over a given PTT equates to the number of PTT

uplink opportunities.

The duration of PTT visibility to the satellite (pass duration over the transmitter) is the "window" during which the satellite can receive messages from a PTT. It lasts between 8 and 15 minutes (10 minutes on average).

The Ground Segment

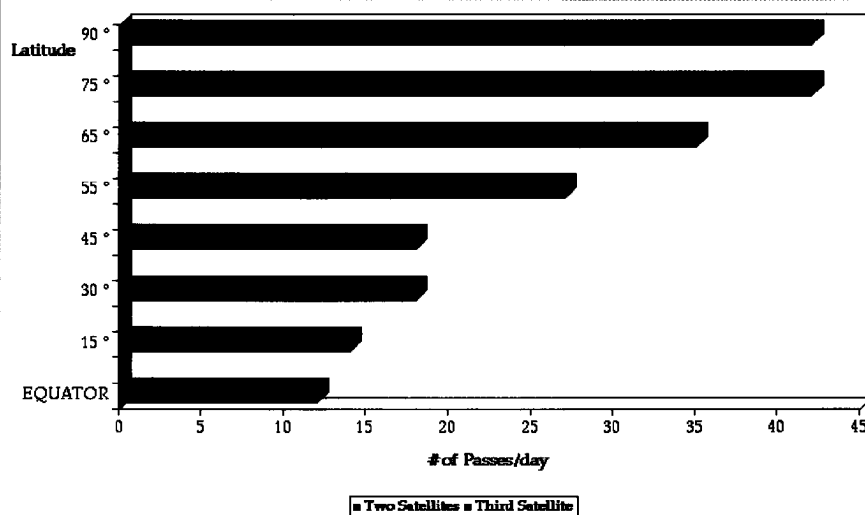
The current ground segment includes fully redundant receiving and processing equipment. All messages recorded by the satellite during an orbital revolution will be received by at least one of the three main ground stations, providing complete global coverage.

Regional receiving stations receive PTT data from the satellites in real-time whenever a satellite is within station visibility. The main ground stations also act as regional receiving stations.

The Global Processing Centers (GPCs) near Washington, D.C. and Toulouse, France process all data received from the receiving stations. They archive the results and make them available to users on line, via the Internet, or on tapes or floppy disks.

Regional receiving stations operate in Hawaii in the United States; Casey in Antarctica; and Darwin, Melbourne, and Perth in Australia.

Number of daily satellite passes vs. latitude with two and three Argos satellites in operation.

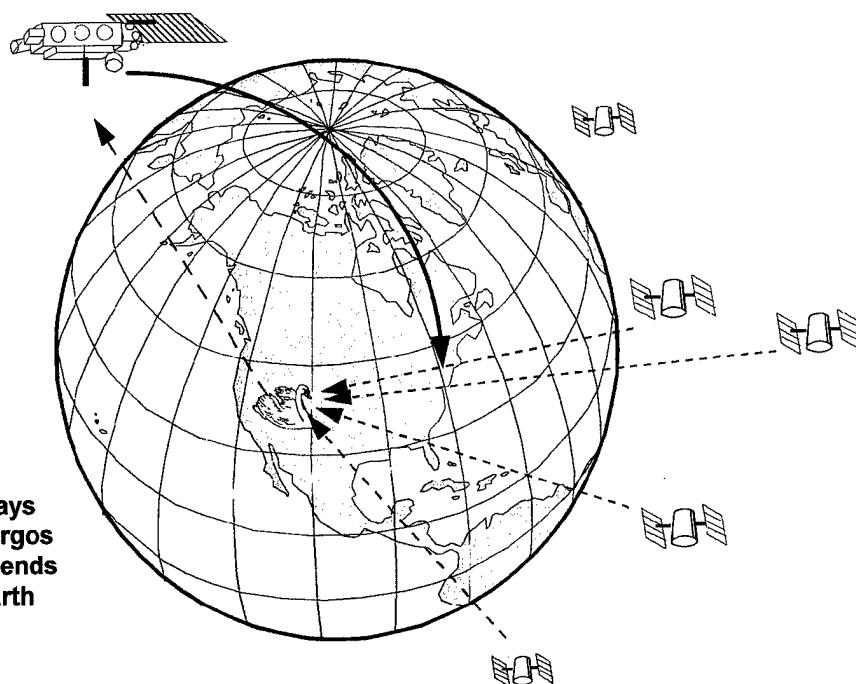


The Global Positioning System (GPS) is a constellation of 24 satellites orbiting the Earth that constantly broadcasts coded signals to pinpoint locations anywhere on the surface of the Earth. At any given time, 21 of these satellites are operational, and 3 are “in reserve.” GPS ground receivers intercept and interpret the satellite signals to determine the receiver’s geographic location with great precision and accuracy, typically within 10–50 meters and almost always within 100 meters. The ground receiver must receive signals from at least three satellites to produce a latitude and longitude location, and a minimum of four satellites to produce latitude, longitude, and elevation estimates. Generally, the GPS receiver’s location accuracy improves as more satellite signals are received.

At best, the Argos system is capable of providing location estimates to within $\pm 150\text{m}$ anywhere on the surface of the Earth (using Doppler algorithms), but locations obtained from tiny, low

power (100mw) Argos beacons mounted on the backs of birds are often less accurate, typically in the range of ± 3 km from the animal's true location. However, Argos PTTs can interface with other sensors and can transmit sensor data to users through the Argos system. The availability of small, commercial GPS receiver modules have now made it possible to combine GPS receivers with the Argos PTTs we already use to track animals. A developmental GPS PTT has been fabricated in a collar design for field testing (see p. 42 for additional information). It should soon be possible to field a GPS PTT package small enough to be carried by a goose-sized bird. Thus, extremely accurate GPS locations obtained through a GPS receiver carried on board an Argos PTT can be transmitted to users via the current Argos system. The GPS location estimates obtained in this manner will be orders of magnitude more accurate than Doppler location estimates. By scheduling the collection of GPS locations throughout the day and storing these positions for later transmission via Service Argos, numerous GPS positions can be transmitted to the user through Argos messages.

PTT microprocessor queries GPS receiver for locations, and relays the message to the Argos satellite which then sends the message to an earth processing center



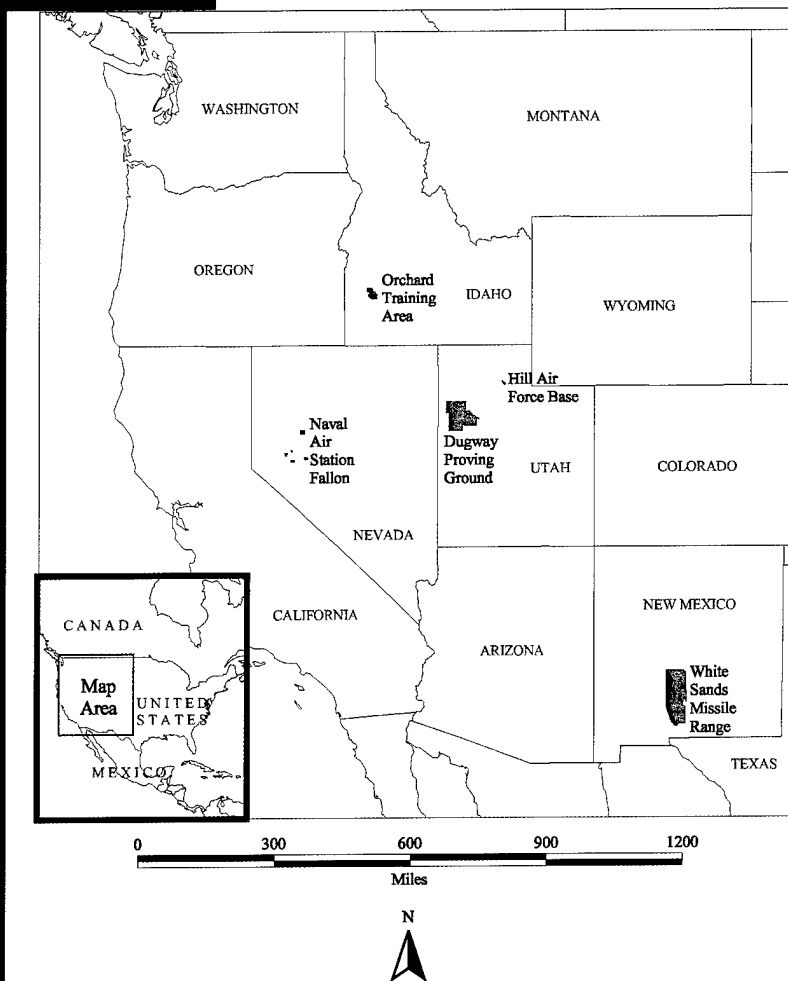
RECENT DEVELOPMENTS

RESULTING FROM CCRT'S LEGACY/SERDP PROJECTS

Beginning in FY94, the DoD's Legacy and SERDP Programs funded joint projects simultaneously (1) to demonstrate existing, satellite biotelemetry capabilities on selected military bases, and (2) to develop innovative new tools (miniature sensors and more precise capabilities) to enhance existing systems. These projects were planned and executed in parallel. Legacy provided support for methodology and protocol development, field demonstrations, and actual applications of existing technologies; and SERDP provided support for basic and exploratory (6.1 and 6.2)

research, as well as advanced development (6.3) of new capabilities. The overall purpose of CCRT's joint Legacy/SERDP effort has been to develop, demonstrate, promote, and improve satellite tracking and remote monitoring systems for resource management and conservation on military lands.

CCRT chose five military bases on which to demonstrate satellite biotelemetry systems, one from the Army National Guard, one from the Navy, two from the Army, and one from the Air Force. ■



Military installations involved in Legacy demonstrations in 1995-1997.

The five Legacy field demonstrations have produced comprehensive tracking and monitoring databases for the target animals. We incorporate this tracking and monitoring information into geographic information systems (GIS) to map animal movements in relation to habitat types, geo-political boundaries, vegetation cover, geomorphology, water resources, military land use activities, and other geographically discrete data bases. In this way, we are providing valuable (and often previously unattainable) resource management information to military land managers. This system can support near real-time monitoring and analysis of animal movements and behavior in relation to military land use activities to enhance research of cause and effect relationships between military activities and wildlife ecology.

**GOALS
ACCOMPLISHED
BY CCRT'S JOINT
LEGACY/SERDP
EFFORT**

Legacy: Develop applicable protocols and methods to apply existing, off-the-shelf satellite telemetry and remote tracking technology for wildlife management on military bases.

Legacy: Demonstrate satellite telemetry technology on selected military bases to help resolve actual natural resource management issues.

Legacy: Promote the use of these advanced technologies as a means of disencumbering military operations and training and thereby enhancing military readiness.

Legacy: Apply satellite tracking methods to the study of neotropical migratory birds that frequent military lands and therefore pose management issues; this objective contributes to DoD's "Partners in Flight" efforts.

SERDP: Design, build, and test advanced biotelemetry equipment; specifically to: (1) develop an acoustic sensor capable of digitally recording and analyzing specific animal vocalizations with time and location data; (2) miniaturize and

integrate a GPS receiver into a satellite platform transmitter terminal (PTT); (3) integrate these two parallel advancements into a single satellite PTT for field testing on a target animal; (4) explore the feasibility of adding a miniature video camera into a PTT; (5) integrate both new and existing sensor technology with rapidly advancing microcomputer capabilities contained within the PTTs; (6) monitor information on animal physiology and behavior, and measure the animals' microenvironment (to evaluate meteorology, environmental contamination, and other anthropogenic variables).

SERDP: Design and develop a Graphical User Interface (GUI) and customized database software to allow for the integration of remote ground and/or space-based radio tracking and monitoring data with GIS.

Legacy/SERDP: Demonstrate SERDP advancements as they become available from the R&D efforts in the Legacy field applications.



Dr. William Seegar (left) and Mr. Gordon Wood (right, Deputy Director of SERDP) applying satellite transmitters on a breeding pair of Tundra Peregrine Falcons near the former location of the U.S. Air Force's Sondrestrom Air Base in western Greenland.

©Blake Henke

WHITE SANDS MISSILE RANGE, NEW MEXICO

White Sands Missile Range (WSMR) is the military's largest all-overland test range in the Western Hemisphere and encompasses 2.2 million acres, which can be extended to 4 million acres (total) by including adjacent federal land holdings. WSMR houses the U.S. Army Research, Development, Test, and Evaluation (RDT&E) Command for weapons and space systems, and components. Within WSMR are the San Andres National Wildlife Refuge, White Sands National Monument (National Park Service), and Joranda Experimental Range (U.S. Department of Agriculture and U.S. Forest Service).

We successfully tracked and monitored Oryx (an introduced African antelope) via satellite on the WSMR to help military land managers comply with National Park Service and New Mexico Game and Fish requirements for managing this exotic species. Management of this species has proven to be difficult for military land managers because of the Oryx's preference for remote, rugged terrain. In addition, the Oryx population on WSMR could potentially effect adjacent natural systems off-base. Continuing Legacy work on Oryx will employ the new, SERDP developed GPS PTTs to track these animals to an accuracy of ± 100 meters throughout the 2+ million acre WSMR installation.

ORYX BACKGROUND AT WSMR

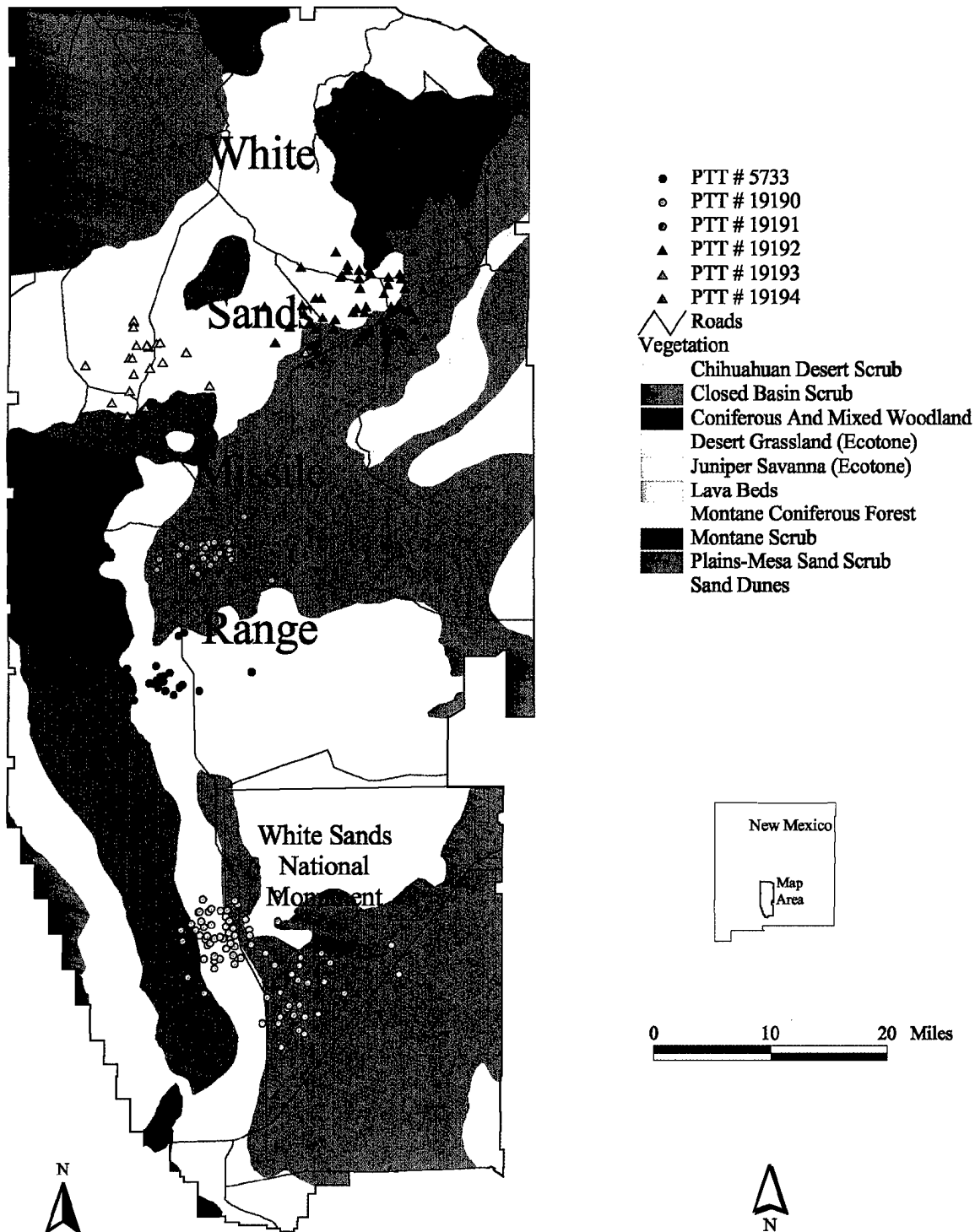
- Introduced 1969
- Big game species (500 lb)
- Population expanding - 2,000
- Jurisdictional boundaries issue



- State and Federal Regulatory Requirements (AR200-3/Sikes Act)
- White Sands Monument, NPS (Exclusion policy)
- Field studies difficult due to WSMR mission
- Oryx use remote inaccessible habitat

Oryx Movements and Vegetation Cover

White Sands Missile Range - April 3, 1996 to January 31, 1997

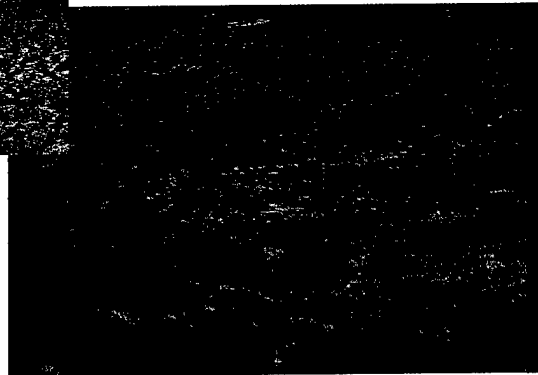


Oryx is an introduced big game species that must be managed by the White Sands Missile Range (WSMR) and kept off adjoining lands, including the White Sands National Monument. This task has proven difficult due to the nature of the WSMR testing mission, the remoteness of the area, and the often inaccessible habitat used by the species. Oryx seem to maintain discrete territories, as indicated by these data.



Capture of feral Horses near Dugway Proving Ground, UT.

DUGWAY PROVING GROUND, UTAH



Dugway Proving Ground (DPG) encompasses 1,300 square miles and houses the U.S. Army RDT&E Command's Chemical, Biological, and Radiological Weapons School, as well as a U.S. Air Force Flight Test Center.

We successfully tracked and monitored via satellite Pronghorn (a big game species) and wild Horses. Military land managers must provide habitat for and minimize environmental disturbance to these species. Our systems provided

information about the movements of these animals remotely, without impacting military activities. Otherwise, the same data would have to be gleaned from field studies on foot, from trucks, or from low-flying aircraft (which would require a high level of coordination with military activities).

We also tracked via satellite several Ferruginous and Swainson's Hawks in the vicinity of DPG to assess potential effects from military activities. ■

PRONGHORN, FERRUGINOUS HAWK, AND SWAINSON'S HAWK BACKGROUND AT DPG

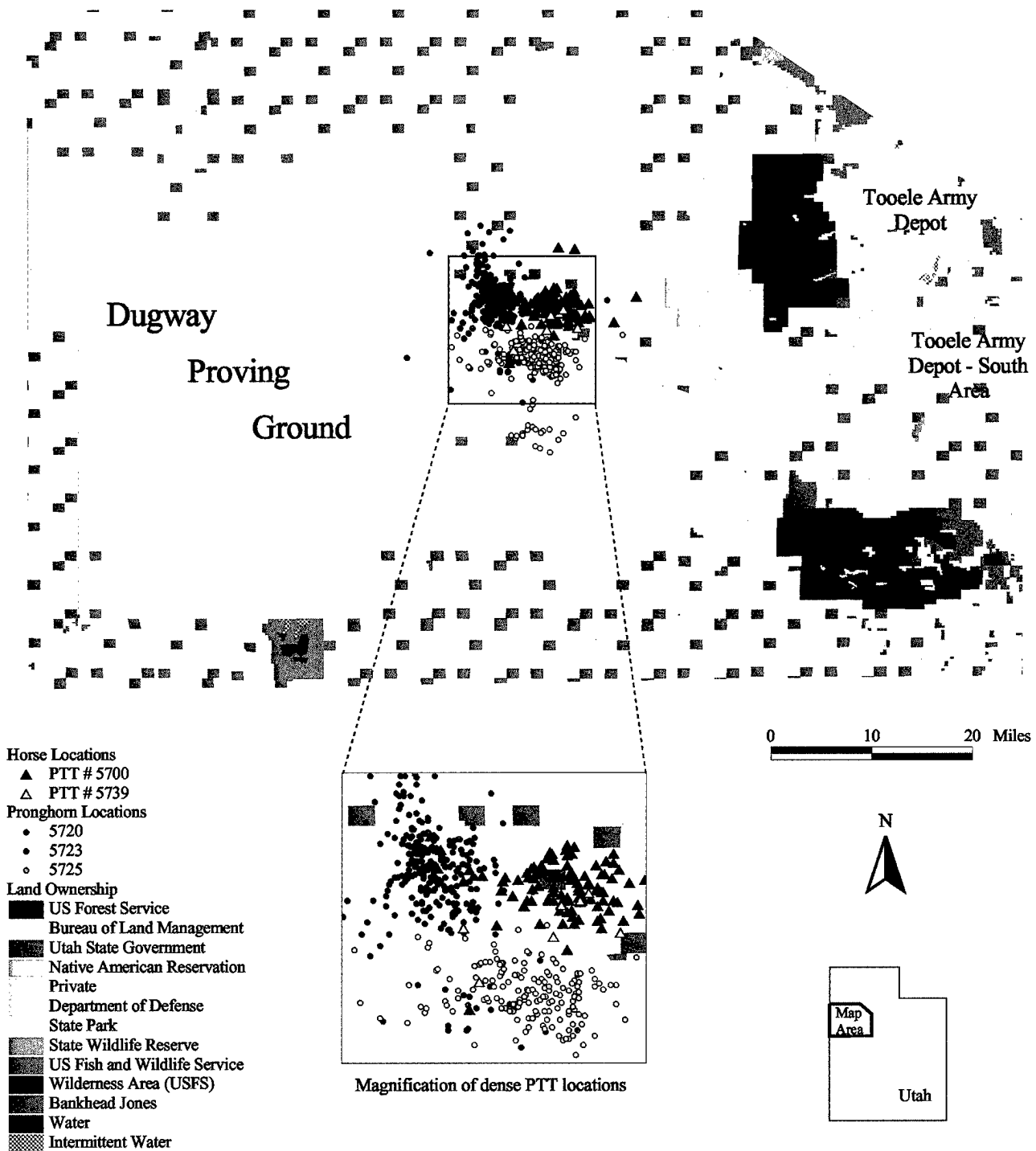
- Game species (90 lbs)
- Year round habitat and important winter range
- Management for habitat utilization
- Seasonality of movement/habitat use
- Assess military effects on habitat use



- Ferruginous Hawk, Category 2 species
- Swainson's Hawk - population decline, neotropical migrant
- Both hawks indicator species for range land
- Ferruginous Hawks sensitive to disturbance
- Relate movements to Training and RDT&E activities
- Determine migration and winter range

Wild Horse and Pronghorn Movements and Land Ownership

Dugway Proving Ground -- February 16, 1996 - January 24, 1997



As indicated in this comparison of Horse and Pronghorn movements vs. land ownership near Dugway Proving Ground, Utah, Horses and Pronghorn share habitat and move through areas controlled by a wide variety of land owners and managers (including the DoD, the Bureau of Land Management, the State of Utah, Native American Reservations, the US Forest Service, and private land holdings). Habitat management for these species thus requires cooperation among multiple organizations in the region.

ORCHARD TRAINING AREA, IDAHO

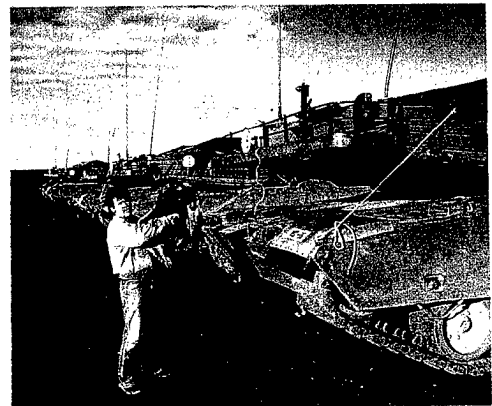
The Idaho Army National Guard Orchard Training Area (OTA) includes 138,000 acres and is centrally located within the 758,000 acre Snake River Birds of Prey National Conservation Area (SRBOPNCA). The OTA is home to an Air National Guard A-10 Air Wing and is currently the third largest National Guard training facility in the U.S. The OTA hosts regular armored vehicle training, live fire and laser training with M1-Abrams tanks, and combined tank and helicopter maneuvers with live fire. The Idaho Army National Guard is directed by Congress to manage for the protection of one of the densest populations of raptors in the U.S. on the SRBOPNCA.

We successfully demonstrated simultaneous tracking of Golden Eagles and military vehicles as a method to study possible training effects on animal movements. Ferruginous Hawks (sensitive species designation) were also tracked via satellite in conjunction with the Deployable-Force-on-Force Instrumented Range System (DFIRST) to demonstrate the feasibility of integrating automated military tracking systems with natural resource management technology.

We also tracked four Swainson's Hawks via satellite from the OTA as part of a larger, trans-continental migration study in conjunction with Partners in Flight. ■

GOLDEN EAGLE, FERRUGINOUS HAWK, AND SWAINSON'S HAWK BACKGROUND AT THE OTA

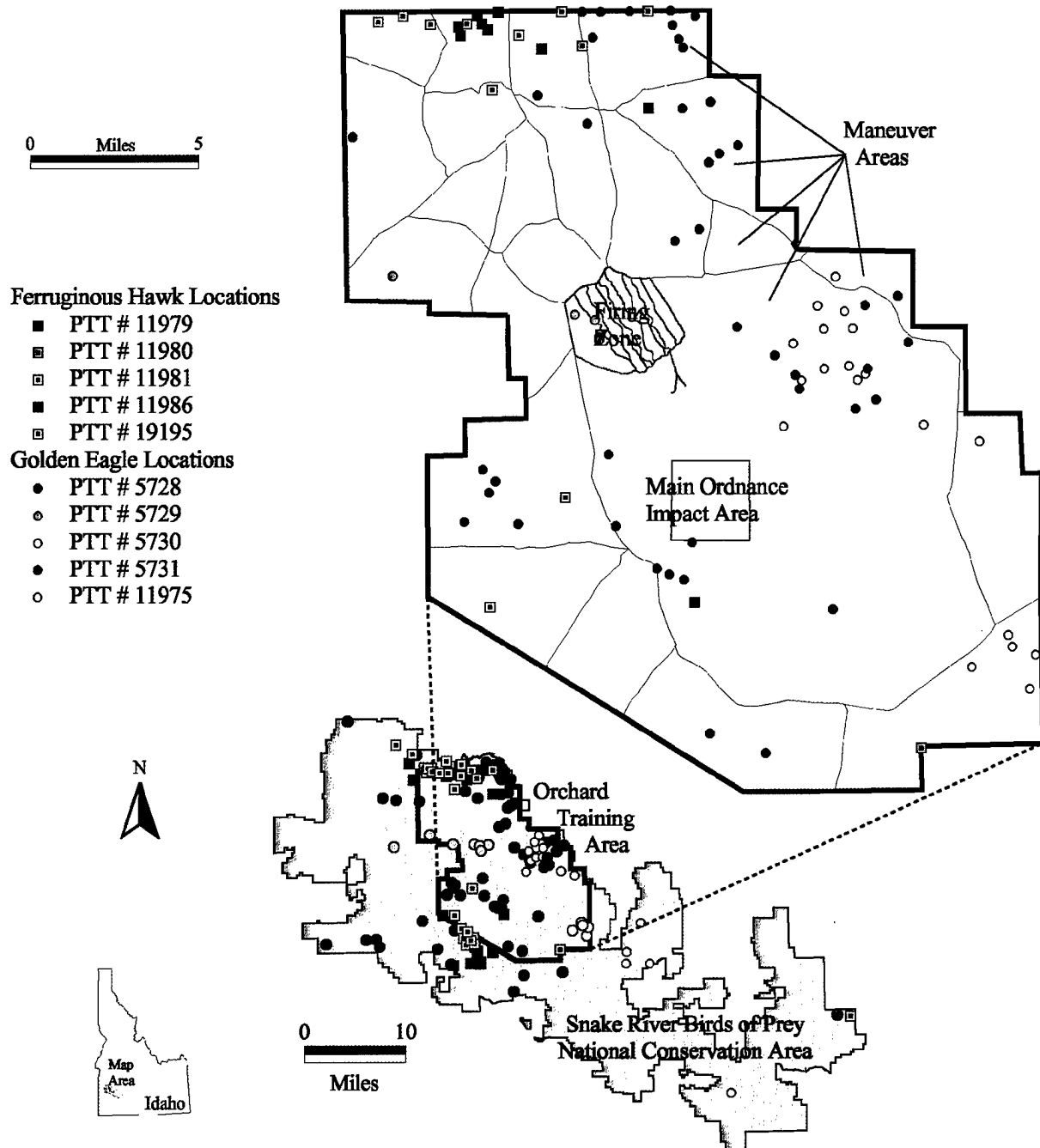
- Golden Eagle, Swainson's Hawk, Ferruginous Hawk
- All breed within or use OTA
- Ferruginous Hawk sensitive to disturbance
- Swainson's Hawk neotropical migrant (declining population)



- Management mandated by Public Law
- Assess training on raptor resources
- Demonstrate overlay of near-real time tracking and monitoring of raptors and military training (DFIRST, Scimitar System)

Golden Eagle and Ferruginous Hawk Movements in Relation to Military Training Areas

Idaho Army National Guard Orchard Training Area and the Snake River Birds of Prey
National Conservation Area -- January 2 - November 14, 1996



Golden Eagles and Ferruginous Hawks extensively use the Snake River Birds of Prey National Conservation Area and the Idaho Army National Guard Orchard Training Area (OTA) to forage; and some individuals frequent maneuver areas, firing zones, and ordnance impact areas. Management for these and other sensitive raptor species on the OTA is mandated by Congress.

Ferruginous
Hawk.



©Michael Colopy

HILL AIR FORCE BASE, UTAH

HILL AFB INFORMATION

Hill AFB is home to the 388th Fighter Wing and the 419th Fighter Wing; both are F-16 Fighting Falcon units. Hill AFB also provides maintenance facilities for C-130 aircraft. Approximately 1 million acres is directly controlled by Hill Air Force Base including a core area of 6,690 acres, the Utah Test and Training Range's (UTTR) 957,750 acres, Little Mountain Testing Facility's 751 acres, and the city of Boulder Wyoming, 51 acres. The Hill AFB Military Operating Area (MOA) comprises the restricted military air space residing above the UTTR and extending over the northwest portion of Utah and into Nevada, covering an area of more than 11 million ground acres.



©Michael Colopy

Ferruginous
Hawks.



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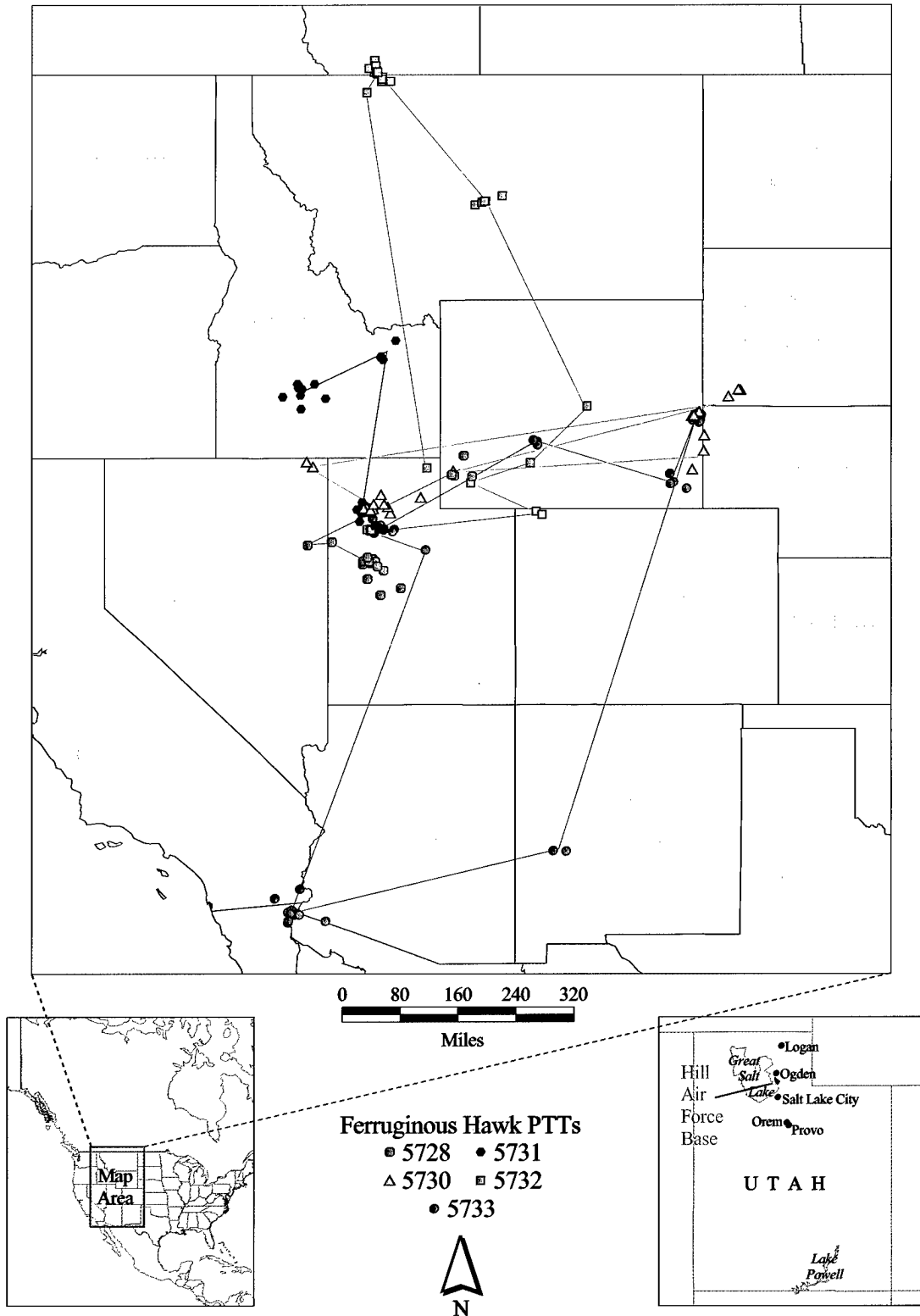
The Hill AFB MOA is located in the basin of the Great Salt Lake Desert between Wendover, Nevada and Salt Lake City, Utah. The MOA supports F-16 flight training, as well as testing of various conventional munitions and missile and aircraft systems. Elevations within the MOA range from about 4,050 feet (where unvegetated salt and mud flats are present) to mountain peaks of over 11,700 feet. The MOA region has been classified as a cold desert due to the low quantities of precipitation and a cold winter climate.

The Ferruginous Hawk is the largest North American *buteo*, and breeds throughout arid regions of the intermountain western United States and Canada, including the Hill AFB MOA. Ferruginous Hawks have also been reported near Dugway Proving Ground and other military installations in the region. The breeding population is reportedly declining throughout its range, which has led to its listing as a federal Species at Risk (U.S. Fish and Wildlife Service 1994), and a state sensitive species in Utah (Utah Division of Wildlife Resources 1992). Habitat loss, disturbance, and prey availability are considered primary causes of Ferruginous Hawk population declines.

During the summer of 1997 we successfully tracked and monitored 5 adult Ferruginous Hawks with satellite PTTs. We also applied conventional, radio transmitters to 2 adult and 25 juvenile hawks. Very little is currently known about this species. The information provided by the PTTs and standard radio transmitters will be the first steps in understanding the movements of this raptor, which have previously been termed 'nomadic'. ■

Ferruginous Hawk Location Estimates

Hill Air Force Base - June 12, 1997 to March 1, 1998



We radio-tagged 5 Ferruginous Hawks during the breeding season of 1997 near the Hill Air Force Base. We tracked their movements through the western United States, Canada, and Mexico using telemetry via satellite. Regardless of the origin of the hawks, all travelled extensively throughout the western United States after the breeding season. Movement patterns were highly variable among the individuals. One individual travelled into Alberta, Canada before moving south in late September, and others travelled to the eastern Wyoming border. The hawks generally arrived in a winter area by early November.

NAVAL AIR STATION FALLON, NEVADA

shorebirds such as American Avocet, Long-billed Dowitchers, Long-billed Curlews, Wilson's Phalaropes, White-faced Ibis, Herons, and Egrets. Many of these species also breed in the valley.

NASF is located within the Lahontan Valley, Nevada which includes the city of Fallon, Fallon Paiute-Shoshone Indian Reservation, Carson Lake, Fallon National Wildlife Refuge, Stillwater National Wildlife Refuge and Wildlife Management Area, and Lahontan Reservoir. This valley is an important foraging area for White Pelicans, Tundra Swans, Geese, Ducks, and thousands of

Altitude information derived from miniature pressure transducers on the PTTs was gathered and used in a single dimension soaring model to predict pelican flight time, location, and altitude to help predict times of high flight in relation to military aircraft travel (see pp. 33-35 for details).

WHITE PELICAN BACKGROUND AT NASF

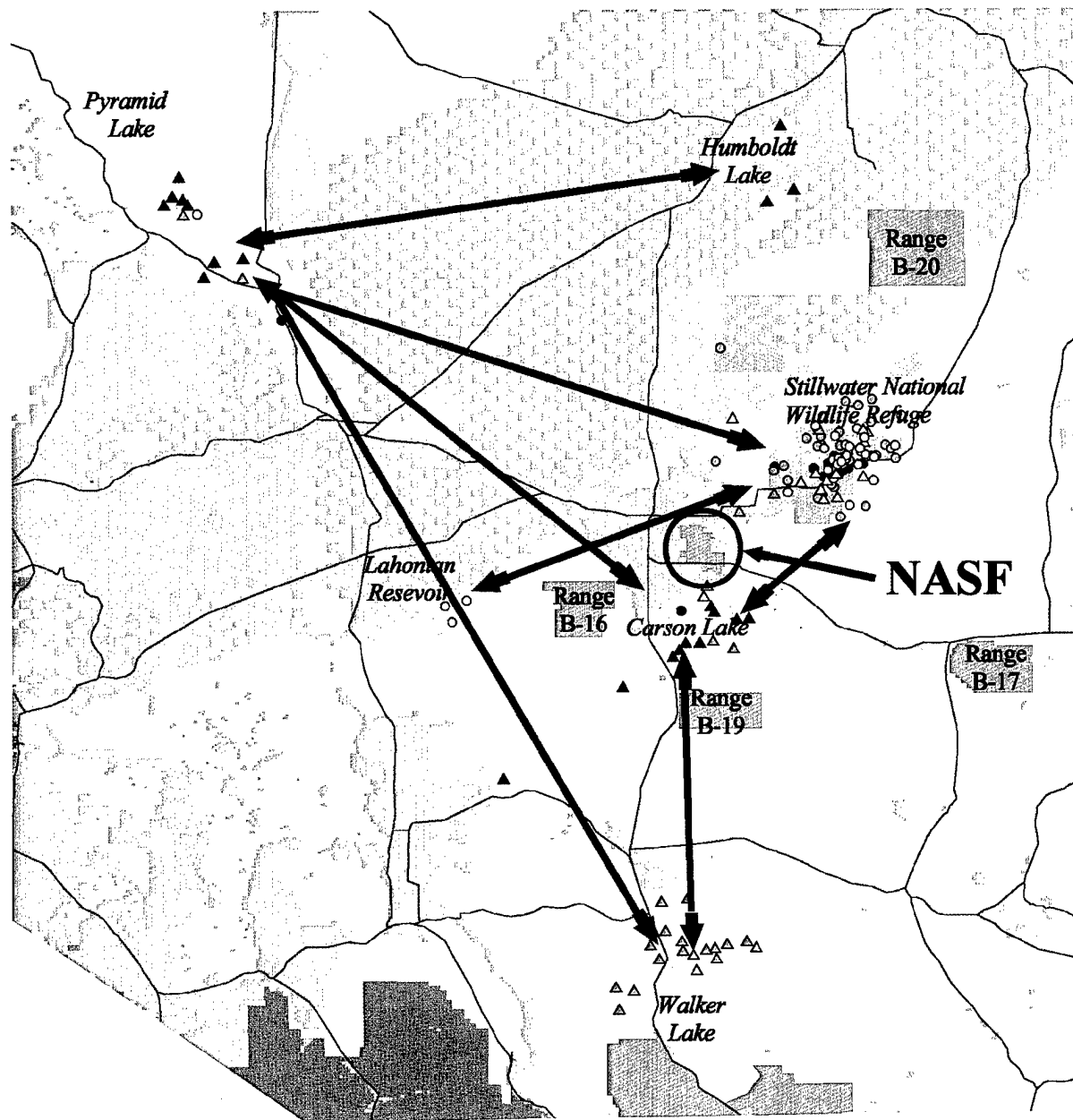
- White Pelican, wing span - 10 ft., 20 lbs.
- Flocking and soaring behavior
- Pyramid Lake supports breeding population (20-30,000)
- Forages up to 200 miles



- Vultures common throughout training area
- Large avian species pose serious threat to aircraft operations through bird-strike damage

Bird Strike Hazards to Military Aircraft

White Pelican Movements in relation to Military Aircraft Training Areas and Low Fly Zones
Naval Air Station Fallon (NASF) -- June 25 - November 19, 1996



Pelican Flight Paths



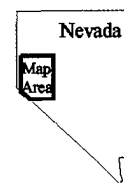
Pelican Locations

- PTT # 5716
- ◐ PTT # 5717
- PTT # 5718
- ◑ PTT # 5719
- ▲ PTT # 11982
- ▲ PTT # 11983
- △ PTT # 11984

- Roads
- Land Ownership
 - Bureau of Land Management
 - County and Regional Parks
 - Department of Defense
 - US Fish and Wildlife Service
 - Water
 - Intermittent Water
 - Native American Reservations
 - Nevada State Government
 - Private
 - US Forest Service

0 20 40

Miles



White Pelicans and waterfowl species frequent the Naval Air Station Fallon (NASF) Military Operating Area and pose a threat to military aircraft. Bird traffic is heavy surrounding NASF, where pilots train at the Naval Fighter Weapons School (Top Gun), the only such facility in the world. Fallon is also the only Naval facility providing Advanced Integrated Carrier Air Wing Strike Training. Bird strike hazards are an important safety and operational consideration in this region.

WHITE-FACED IBIS STUDY INITIATED NEAR NASF

A species of concern to Naval Air Station Fallon (NASF), is the White-faced Ibis (*Plegadis chihi*). These long-legged wading birds feed primarily on invertebrates in the wetlands and irrigated croplands adjacent to military use areas. Many thousands of Ibis move in large flocks throughout NASF airspace as they travel between nesting and foraging areas during the spring and summer.

White-faced Ibis populations in western Nevada are also of extreme concern to the U.S. Fish and Wildlife Service (USFWS). A ban on the use of DDT (an agricultural pesticide) in this country some quarter century ago has resulted in the dramatic recovery of most affected species. Ten years ago, this population of Ibis was found to still be burdened with high levels of DDE, the principal metabolite of DDT. The results were egg shells 18% thinner than normal and a 20% decrease in breeding production. This situation has **not** changed, and it has been determined that these contaminants are **not** being acquired in western Nevada. Just where and how these birds are being contaminated with DDT remains a mystery.

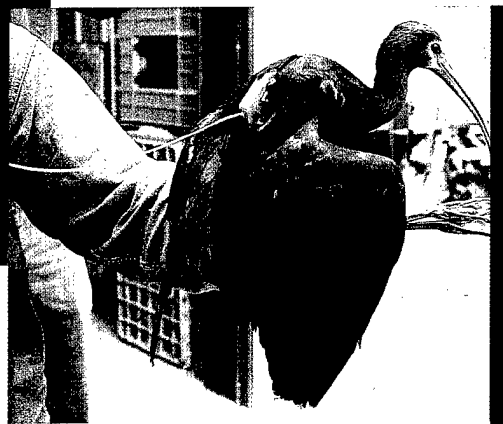
In early June 1997, working with personnel at Stillwater National Wildlife Refuge, we captured eight White-faced Ibis from a breeding colony on the refuge. All individuals were weighed, measured, and wing-traced for analysis of flight dynamics. Two individuals were blood-sampled and outfitted with backpack packages weighing roughly 27 grams each, which included satellite and conventional telemetry transmitters. These birds were monitored daily, along with others involved in a conventional radio telemetry study being conducted by refuge personnel. Argos satellite-derived positions from these two Ibis have confirmed movements throughout the area, as well as some unexpected daytime round-trips over a mountain range to and from foraging areas in an adjacent valley.

NASF will benefit from information gathered by Argos satellites regarding Ibis movement patterns within its Military Operating Area. In time, we will be able to discern migration routes and wintering areas of a segment of this troubled population, enabling USFWS personnel to more effectively investigate the sources of contaminants affecting it. ■



White-faced Ibis
outfitted with
satellite PTTs.

©Mike Yates

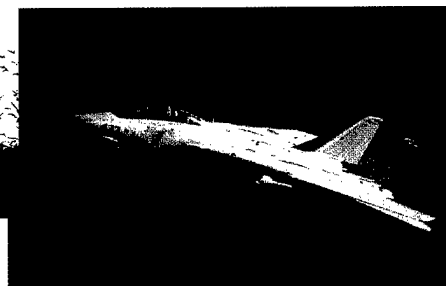


CCRT'S AIRCRAFT BIRD STRIKE HAZARD

HAZARD PREDICTION EFFORTS



©Michael Colopy



Accomplishment of aviation missions with minimum losses of aircraft and personnel requires efficient management of the bird/aircraft collision risk. Minimizing this bird strike danger without unduly compromising the mission requires forecasts of bird activity with lead times compatible with operational planning. The daily cycle of soaring bird activity varies substantially in response to the changing weather. Therefore, reliance on statistical averages of bird behavior while ignoring this variability incurs both excessive risks and undue mission interference. Daily soaring bird forecasts with adequate lead times are therefore essential to meet mission requirements of military aviation units. Recent advances in our studies of soaring bird flight suggest that such forecasts are possible and can be provided in much the same way that weather forecasts are made available to mission planners.

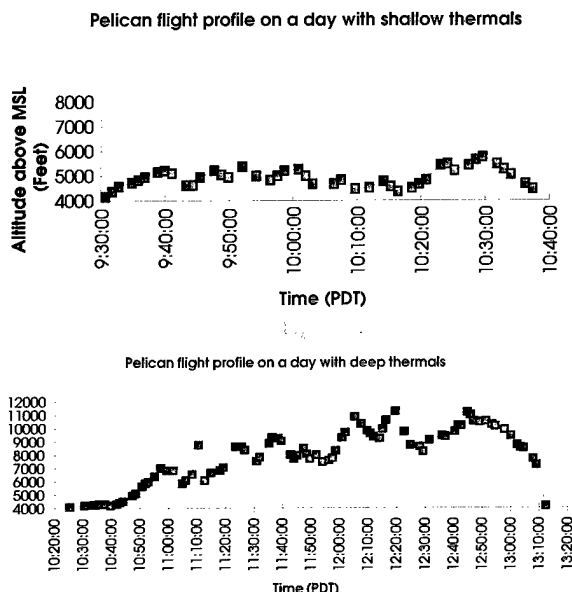
By combining satellite and conventional radio telemetry tracking technology with meteorological observations and models, CCRT is developing a bird flight forecast and information system to predict potentially hazardous bird strike conditions hours and days in advance. Conventional radio telemetry transmitters and altitude/position reporting satellite transmitters have made it possible to locate and identify individually instrumented birds, to track these individuals during local and migratory movements, and to monitor their flight levels on a minute-by-minute basis. Using this capability, we can now record the complete flight profile of individual birds from takeoff to landing on cross-country flights of hundreds of miles. Thus, we can measure the day-to-day changes in bird behavior, including flight ceiling and radius from ground site, that result from the evolving weather conditions. This linking of measured variations in bird flight behavioral patterns with observed changes in the weather provides the basis for a bird strike hazard forecasting system.

SOARING PELICAN AVIAN MODELING SYSTEM

The Soaring Pelican Avian Modeling System experiment was a comprehensive study designed to acquire the ornithological and meteorological data needed for development of a prototype soaring bird forecasting system. Seventeen American White Pelicans were instrumented near Naval Air Station Fallon (NASF) with satellite and conventional radio telemetry transmitters to identify hourly and daily changes in the vertical extent of the soaring bird flight envelope. Aircraft and ground-based, two-person teams radio tracked these birds as they thermaled and glided on long-range flights across western Nevada during extended periods in June and July 1996 and 1997. The Argos satellite system was used to determine the roosting locations of Pelican populations within the area. The tracking teams then drove or flew to these roost sites each day and used conventional radio telemetry signals to home-in on individually radio-marked Pelicans. These teams then followed individual Pelicans as they flew cross-country routes within western Nevada. Throughout these flights, hand-held satellite uplink receivers obtained altitude and flight performance data at approximately 70 second intervals directly from the transmitters attached to these birds. Corresponding meteorological data were acquired, including special soundings from NASF and numerical forecasts from the National Weather Service ETA model. This combined ornithological/meteorological dataset forms the basis for our development of a prototype forecast model for the soaring bird strike hazard.

The data obtained during this field study have given us an understanding of how changes in the weather affect the daily evolution of the vertical extent of the bird strike hazard associated with soaring birds. For example, Figure 1 (next page) shows the temporal evolution of altitude for one radio-tracked Pelican as it flew across NASF from

The bird behavioral and location data obtained during this experiment is currently being combined with a meteorological model of thermal updraft depth to develop a soaring bird strike hazard model.



Stillwater National Wildlife Refuge to Carson Lake on 10 June 1997. The altitude envelope of this flight results from the depth of thermal updrafts the Pelican used to gain altitude, reaching only a few thousand feet above the runway on this day. In contrast, Figure 2 (above) shows the temporal evolution of altitude for another radio-tracked Pelican on a day with weather conditions favoring deeper thermal updrafts. As a result, the second Pelican's altitude envelope reaches much higher flight levels. These figures illustrate how forecasts of the hourly and daily changes in the thermal updraft depth can be used to predict the time-varying vertical extent of the soaring bird strike hazard.

The bird behavioral and location data obtained during this experiment are currently being combined with a meteorological model of thermal updraft depth to predict White Pelican flight in

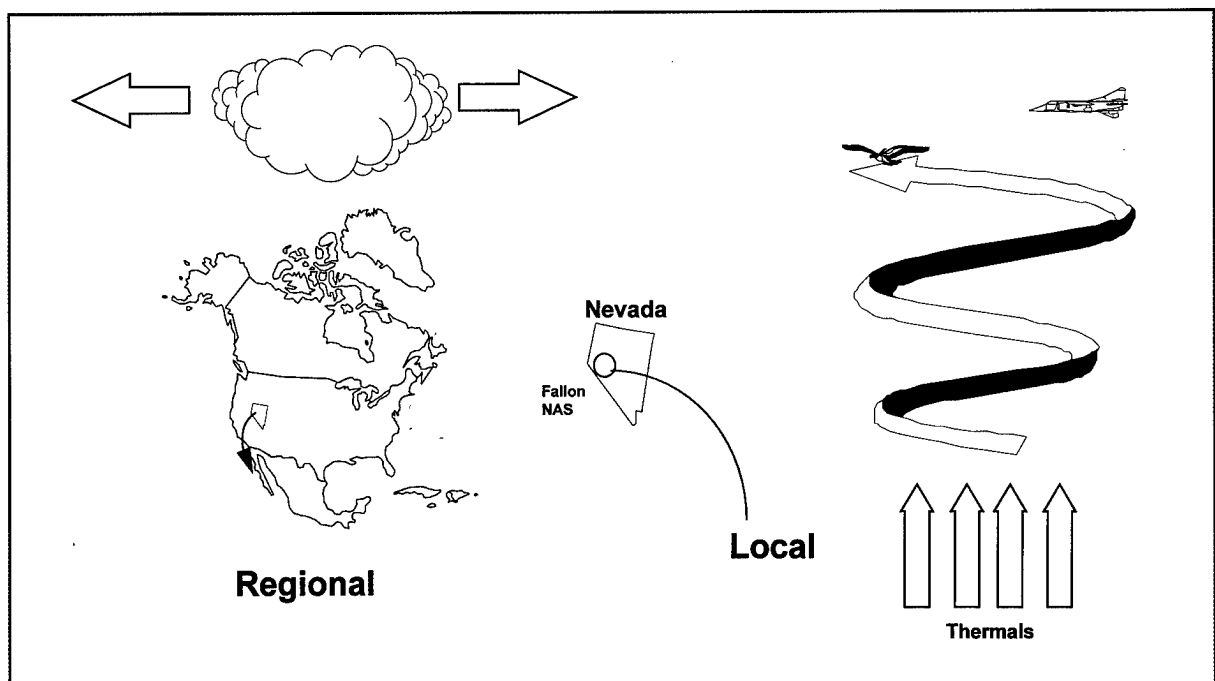
the vicinity of NASE. The meteorological component of this study predicts the hourly evolution of thermal updraft depth in response to day-to-day weather changes as forecast by the National Weather Service's ETA model. The ornithological component predicts the hourly evolution of the soaring bird altitude envelope and flight radius from ground site in response to changing meteorological conditions. These two components are being integrated into a computer model that will forecast the vertical and horizontal extent of avian soaring flight as a function of bird behavioral patterns and changes in the weather (see inset box on next page). As with other forecasts derived from numerical weather prediction models, this prototype soaring bird strike hazard model will be capable of providing quantitative guidance to mission planners with lead times on the order of two days.

Future research will employ this newly developed and precise technology to expand our database to a broader range of avian species. Eventually, comprehensive data will be integrated into our bird flight forecast and information system we are currently developing to provide multi-day predications of hour by hour variations associated with the full range of threat species for the continental U.S. and abroad. The final model will be integrated with real-time telemetry and radar technologies to form a bird flight forecast and tracking center. This center will constitute the world's most advanced capability to monitor avian flight on a local, regional, and global scale. ■

An American White Pelican being outfitted with an Argos satellite transmitter.



©Mike Yates



Predicting
bird flight
behavior with
computer models.

The Legacy Program is supporting the implementation of CCRT's Bird Flight Forecast and Information System at pilot locations in the U.S. and Canada.

APPLYING COMPUTER MODELING TO PREDICT BIRD FLIGHT

CCRT's avian flight model is a dynamic model that forecasts changes in the weather, and then draws upon established avian/atmosphere relationships to predict when, where, and at what altitudes birds will fly. Similar to meteorological models that exclusively forecast the weather, this model is divided into several interacting components to maximize accuracy and efficiency.

The first component is an initialization subroutine. This subroutine downloads real-time weather observation data into the model from weather reporting stations scattered throughout the Northern Hemisphere. Data describing the environment (e.g., soil and vegetation) are also entered into the model. Once these data are entered, the model organizes the data and diagnoses the initial states of the atmosphere and the environment.

The second model component is a forecasting subroutine. This subroutine uses these weather and environmental data to solve meteorological forecast equations, thereby forecasting how parameters such as the

temperature, humidity, and wind speed evolve during the forecast time period. The forecast parameters in the current avian flight model are archived in a file at approximately 2-minute intervals.

The third component of this system is a correlation subroutine. This subroutine forecasts bird flight based upon the forecast parameters in the archive data file. Parameters such as when birds will take off, the direction and speed of flight, the altitude of flight, and the maximum daily travel distance will be forecast based upon changes in those meteorological parameters stored in the archive data file.

Once completed, this avian flight model will be applicable virtually worldwide for a variety of avian species. Expanding this model to other species will simply require the implementation of correlation subroutines catered to individual species of interest, because changes in the environment and weather often affect individual species differently.

CCRT'S PARTNER

ACTIVITIES AND AVIAN MIGRATION STUDIES

CCRT successfully developed a methodology and study protocol for application of satellite-based tracking to Tundra Peregrine Falcons (*Falco peregrinus tundrius*, a formerly threatened neotropical migrant) and Swainson's Hawks (*Buteo swainsoni*, declining population) using the smallest available transmitters (20 gm) that interface with the Argos system. Peregrines frequent military bases across North America, while Swainson's Hawks inhabit military lands throughout the western U.S. and Canada (see success stories on pages 37 and 50).

Swainson's
Hawks.

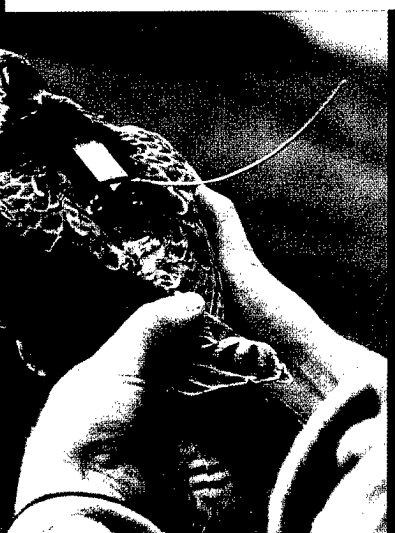


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CCRT pioneered the application of space-based technology for the study of neotropical migratory birds. Work on the Tundra Peregrine Falcon is presently being conducted under the Legacy program to assist in the identification of key migratory and neotropical habitat to support a wide variety of avian species common to both North and South America. This information will enable conservationists to identify key migratory and wintering habitats and to monitor these areas for the conservation of avian biodiversity.

In 1998, CCRT initiated a satellite telemetry study of Common Loons in the Great Basin of Nevada using implantable PTTs to investigate their breeding areas and migration routes. The maintenance of regional water supplies to support Loon migration is a current resource management issue. The natal origin(s) of these migrants is critical information in the development of policy decisions.

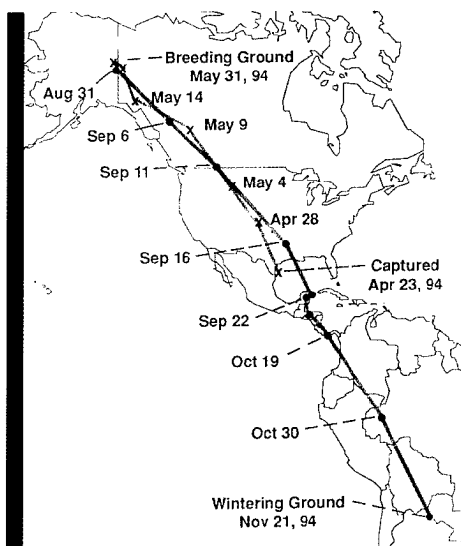
Future efforts include a planned satellite telemetry study of Hudsonian Godwits from northern Canada to discover wintering areas and migration routes. ■



©Blake Henke

Tundra
Peregrine Falcon
instrumented
with an Argos
satellite
transmitter in
Western
Greenland.

One of the first applications of satellite transmitters on Tundra Peregrine Falcons revealed this migration path.



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SUCCESS STORY

UNDERSTANDING TUNDRA PEREGRINE FALCON MIGRATION PATTERNS

As part of the DoD's "Partners in Flight" activities, CCRT has applied dozens of commercially available 27gm and 20gm platform transmitter terminals (PTTs) since the autumn of 1993 to migrating Tundra Peregrine Falcons (classified as "threatened" in the lower 48 states until 1997) along the coasts of Maryland and Virginia and the gulf coast of Texas. PTTs were also applied in Peregrine breeding areas of Greenland and Eastern Canada. In only a few years, these transmitters, tracked via the Argos System, have provided more data of Peregrine Falcon migratory patterns than the past 25 years of conventional field studies and leg band returns. Scientists are now

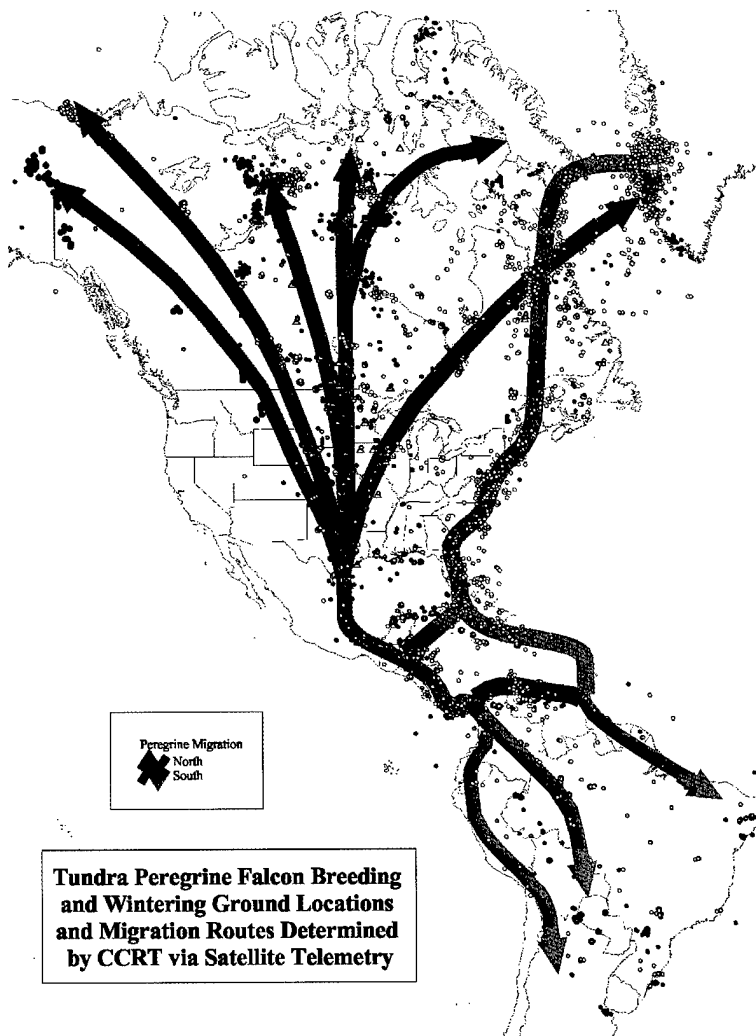


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Tundra
Peregrine
being
outfitted
with a
satellite
PTT.

learning exactly where these birds travel, where they stop along their trek, and what threats may exist to their survival along the way. This research continues a tradition of DoD contributions to the recovery of endangered species, and in the case of Peregrines, a wide ranging species that occurs on military lands and training areas across the continent.

Results of this work have appeared in scientific publications and have been featured in radio and television news programs. This coverage and interest reveals the power of these advanced technology applications to collect valuable information on a globally distributed, transcontinental migrant.



Jim Dayton (left) and Harlan Shannon at Assateague Island, VA.



Bill Seegar and Bill Mattox in West Central Greenland.



SYNOPSIS OF CCRT'S PEREGRINE FALCON RESEARCH

CCRT's contribution to the development of satellite telemetry for use on neotropical migrants stems from our endangered species program now in its twenty-eighth year. During the past three decades, we have conducted a comprehensive study of the Tundra Peregrine Falcon (*Falco peregrinus tundrius*) throughout its breeding, migratory, and wintering range. Field research requirements to track and monitor this transcontinental neotropical migrant shaped the development and application of low power, small Argos platform transmitter terminals (PTTs) now being used by scientists throughout the world.

We have conducted migration studies of the Tundra Peregrine and other sub-species on Assateague Island, VA, since 1970 and on Padre Island, TX, from 1978 to the present day. We have also conducted breeding ground research on the Tundra Peregrine Falcon in West Central Greenland since 1972 near the town of Kangerlussauq, previously known as Sondrestrom U.S. Air Force Base. We have also conducted migration research on breeding Tundra Peregrines in Eastern Canada in Ungava Bay and along the Western shore of Hudson Bay at Rankin Inlet. We have conducted extensive research on the wintering biology of Peregrine sub-species in Peru, Argentina, Chile, and Mexico. The application of satellite tracking for investigation of neotropical avifauna migration patterns and wintering areas will constitute a major conservation tool into the next century.

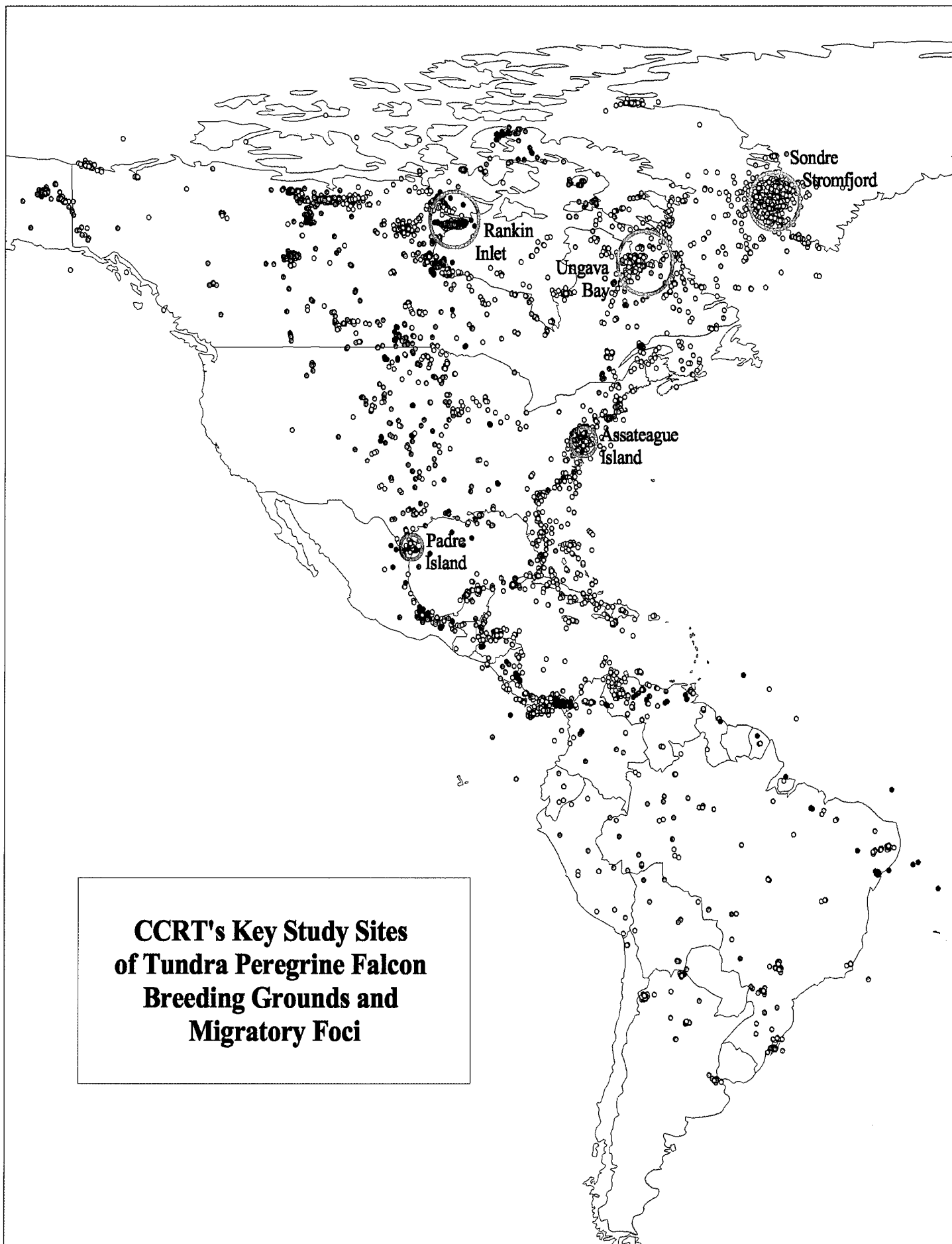
Systematic collection of breeding ground biology and migratory information on these Peregrines in Greenland, Assateague Island, and



© Mike Yates

Padre Island has resulted in the marking of over 10,000 individuals. Our field research has documented the migratory population trends for this species over the past three decades, which can be related to a contiguous data base started in 1938 by North American falconer and naturalist, Alva Nye. This project constitutes the longest running continuous survey of Peregrine Falcons in North America.

Our studies of the breeding biology of the Tundra Peregrine in Greenland represents the most comprehensive, continuous breeding survey of the species outside the United States in this hemisphere. In Greenland we have studied the population dynamics of the Peregrine, as well as many aspects of the breeding ground biology. Greenland has also been the site of our most thorough study of adult survival and their recruitment into the population. During the 1980's we were successful in demonstrating (through scientific means) an actual increase in the density of nesting pairs of Peregrines in our 3,000 square mile study area. Information from this program contributed significantly to understanding the recovery of the Peregrine in North America after DDT induced declines. Today these valuable research and monitoring programs continue with exciting, ever changing research agendas. With new technologies and evolving field methods, we are now better able to understand and fully describe the intricate relationships which exist among key organisms — such as the Peregrine Falcon — their critical habitats, and their broad but declining avian prey base in the Americas. ■



**CCRT's Key Study Sites
of Tundra Peregrine Falcon
Breeding Grounds and
Migratory Foci**

Steller's
Sea Eagle
on its nest
in Russia.



Steller's Sea Eagle.



Dr. Mike McGrady with a PTT-marked
Steller's Eagle.

CCRT'S RESEARCH IN RUSSIA

HISTORY OF OUR INVOLVEMENT WITH RESEARCH AND DEVELOPMENT IN RUSSIA

The U.S. Army, Edgewood Research Development and Engineering Center (ERDEC) and the Department of the Interior (DOI) have been partners in a research and development program that was initiated by ERDEC in the early 1970s with research on the effects of chemical contaminants on Tundra Peregrine Falcon biology. This program provided the impetus for an international collaboration with the Russian Federation. Over the years, the program has included new and innovative technology development, application, and transfer of survey methodologies, biotelemetry, and global radio tracking via satellite. This collaborative program has taken shape under the auspices of the Legacy and SERDP initiatives described in this Resource Managers' Technical Review.

In addition to the Legacy and SERDP supported efforts, DoD and DOI have collaborated in other projects to provide support to the Russian Federation in the area of sensitive, threatened, and endangered species research and conservation. Progress in the Russian Federation has been significant under the auspices of this joint program carried out since the mid-1970s through the Office of International Affairs of the U.S. Fish and Wildlife Service. For example, this program has assisted in the identification of contaminants in the heavily impacted ecosystems of the Western Russian Arctic. During the summers of 1994 and 1995 Tundra Peregrine Falcons were blood sampled and tracked via satellite from their breeding grounds on the Kola Peninsula to wintering areas in Western Europe. These international efforts have continued with

other species, including Steller's Sea Eagles in Russia.

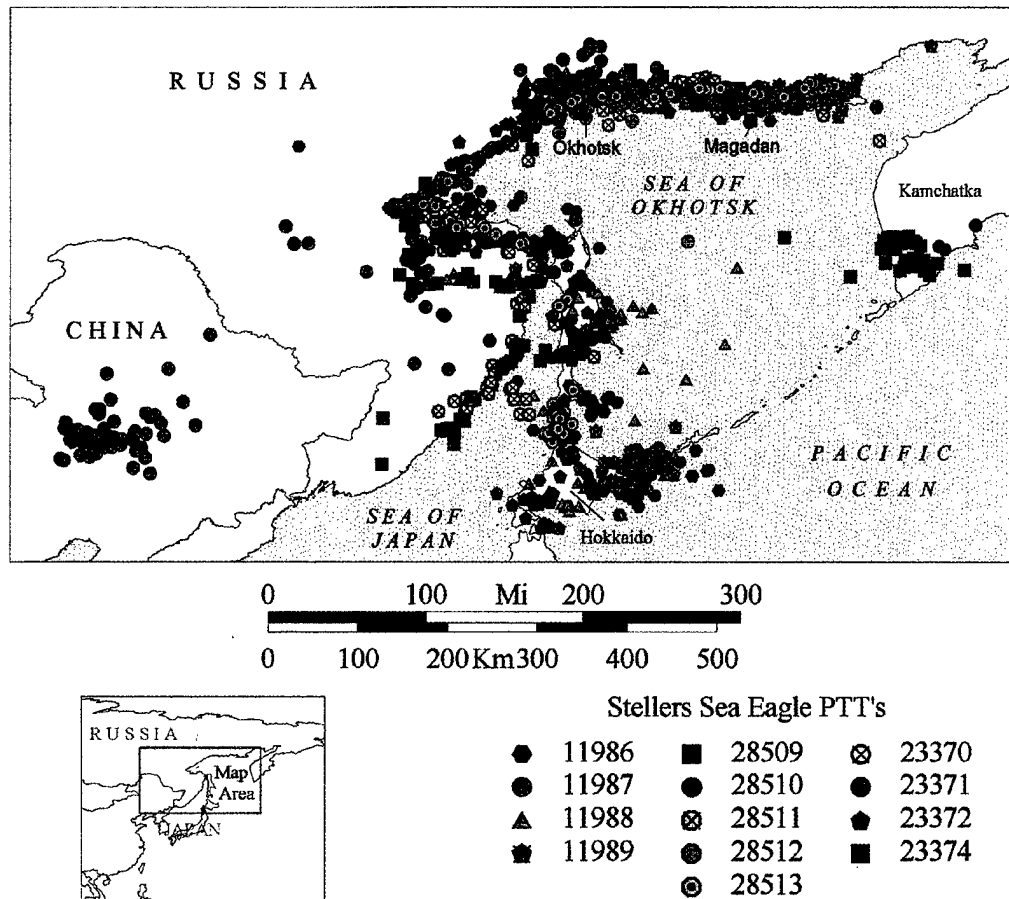
RECENT STELLER'S SEA EAGLE RESEARCH IN MAGADAN REGION, RUSSIA

The Steller's Sea Eagle (SSE) is the largest of all the sea eagles, weighing between 5 and 9 kg with a wing span of 2.2–2.45 m. Despite its large size and distinctive plumage, the Steller's Sea Eagle has been studied little.

The SSE breeds along the sea coasts and rivers of northeastern Siberia from Koryakland south to Kamchatka, along the coast of the Okhotsk Sea, on Shantar and Sakhalin Islands, and in northern Korea. Part of the population over-winters in the breeding range, concentrating around rivers and parts of the sea which remain ice-free. Other groups move south to Japan (Hokkaido), Korea, and along the coast of the Russian mainland north of Vladivostok. SSEs feed primarily upon fish (e.g., salmon), although they will also take medium-large birds (seabirds, capercaillie, ptarmigan, and geese), mammals (hares, fox, seals), invertebrates (crabs and mollusks) and carrion.

At present, the population of SSE appears to be stable and not endangered, however this species has been included in Birds to Watch. Its breeding range is located within remote, restricted areas in Russia, areas where access can be achieved only by air or sea. Indeed, it is most probably the remoteness of these areas that has protected the eagle from large-scale human interference and in-depth scientific scrutiny. The SSE enjoys legal protection in some of the areas in which it is found. Within Russia it is a Red Data Book species, and in theory has complete

Location estimates of Steller's Sea Eagles fitted with PTTs from 21 July 1997 to 13 June 1998



protection there, although enforcement of this sort of protection is virtually impossible. In Japan it is designated as a National Monument and is also given complete protection. In China and Korea, no legislation is known to protect these birds as breeders, migrants, or over-wintering birds.

Political reforms and the need for increased

foreign investment have opened up even the most isolated areas for increased human exploitation of abundant natural resources. So, although relatively pristine at the moment, the area in which SSEs live and breed may not remain that way. It is inevitable that develop-

ment will come to far-eastern Russia, and because few roads exist, it is most likely that the development will establish itself first along the sea and rivers, the very places where SSEs breed.

Recently, CCRT has participated in studies of SSE migration and wintering behavior, and their distribution and breeding dynamics. The use of radio tracking via satellites is particularly appropriate given the remoteness of areas in which this bird lives. During the spring of 1997, we outfitted 14 SSEs with satellite PTTs in the Magadan region of Russia, 1 SSE in the Kamchatka region, and 3 SSE in the Amur region. Two of these PTTs have stopped transmitting, but we are monitoring the movements of the remaining 16 via the Argos satellite system. This study is one of the first PTT applications to SSEs, and the results will undoubtedly prove invaluable in the conservation of this rare species. ■



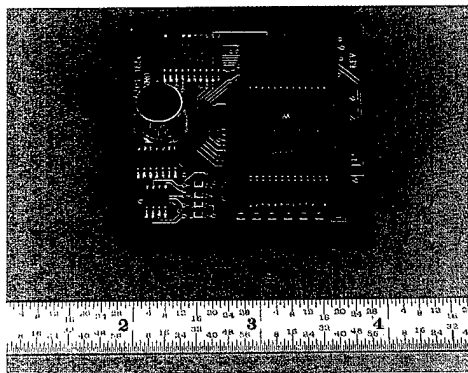
Steller's Eagles foraging amongst ice flows.

CCRT'S SERDP PROJECT ACCOMPLISHMENTS

Project accomplishments resulting from our FY94–FY97 technology research and development effort.

Through support from the DoD's Strategic Environmental Research and Development Program (SERDP), CCRT has developed a GPS-qualified, platform transmitter terminal (PTT) and fabricated an acoustic sensor that will be small enough to be integrated into a PTT to perform a variety of functions. As a result, a new, more capable generation of satellite tracking and monitoring PTTs will soon be available for deployment. Advanced sensors in new PTTs will include a digital audio capture system (an acoustic sensor with pattern recognition software) and sensors to provide temperature, absolute vapor pressure (humidity), and atmospheric pressure. A miniature video camera can be added, and other sensors are also possible (see future development opportunities, p. 55).

Additionally, accelerometers are now being added to our PTTs to gather information related to an animal's changes in speed and/or direction. Such information can be used, in conjunction with our developmental acoustic sensor, to infer possible animal reactions to known or assumed external stimuli, such as human generated noise (including aircraft overflights, sonic booms, single event noise, rocket launches, artillery fire, ground vehicle noise, small arms fire). Such a sensor could also be used to determine bird wingbeat frequency to infer such important factors as power consumption and body weight, which are necessary to predict and forecast bird flight dynamics. The use of accelerometers to evaluate avian flight dynamics may play an important role in the development of predictive forecast models for avifauna. We are currently refining our models to evaluate and predict avian flight in relation to military and commercial aircraft traffic (see page 33–35 for details).



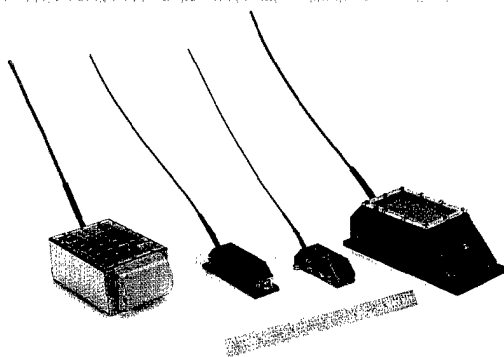
Photograph of the developmental acoustic sensor; the microphone unit on the left. The electronics measure about 2" x 2" and weigh less than 15gm.

Prototype GPS PTT mounted in a collar design being field tested on a Gray Wolf.

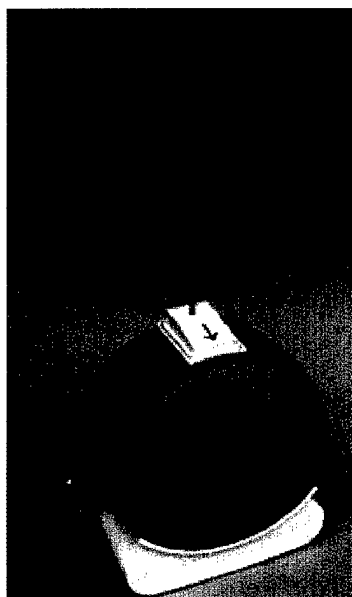


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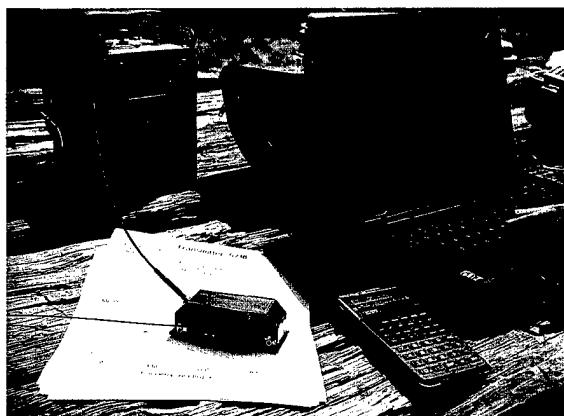
Argos PTTs. From left, early solar-powered PTT (APL), 30- and 20-gm PICO PTTs (Microwave Telemetry, Inc.) and prototype solar-powered GPS PTT (Microwave Telemetry, Inc.)



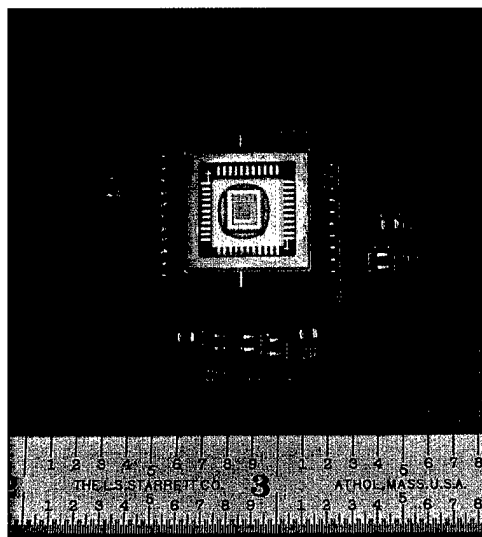
Prototype GPS PTT mounted in a collar configuration. This unit weighs under 700 grams.



The new, GPS qualified PTTs (such as the collar unit pictured at left) will provide location estimates within ± 10 –100 m, which represents a quantum leap forward in the application of radio telemetry to wildlife research. See comparisons of GPS locations and Argos Doppler locations on the following two pages. GPS locations can be collected according to a pre-programmed schedule to dramatically increase the number of positions that are possible via satellite and to enhance our ability to derive important facts regarding species range, habitat use, and anthropogenically generated effects on wildlife species. The developmental acoustic sensor is designed to recognize animal vocalizations, thus *remotely* allowing more thorough study of animal behaviors and activities. By identifying discrete animal behaviors and linking them to specific habitats within an animal's range, valuable information can be collected on species interrelationships and the microhabitat components of their ranges.



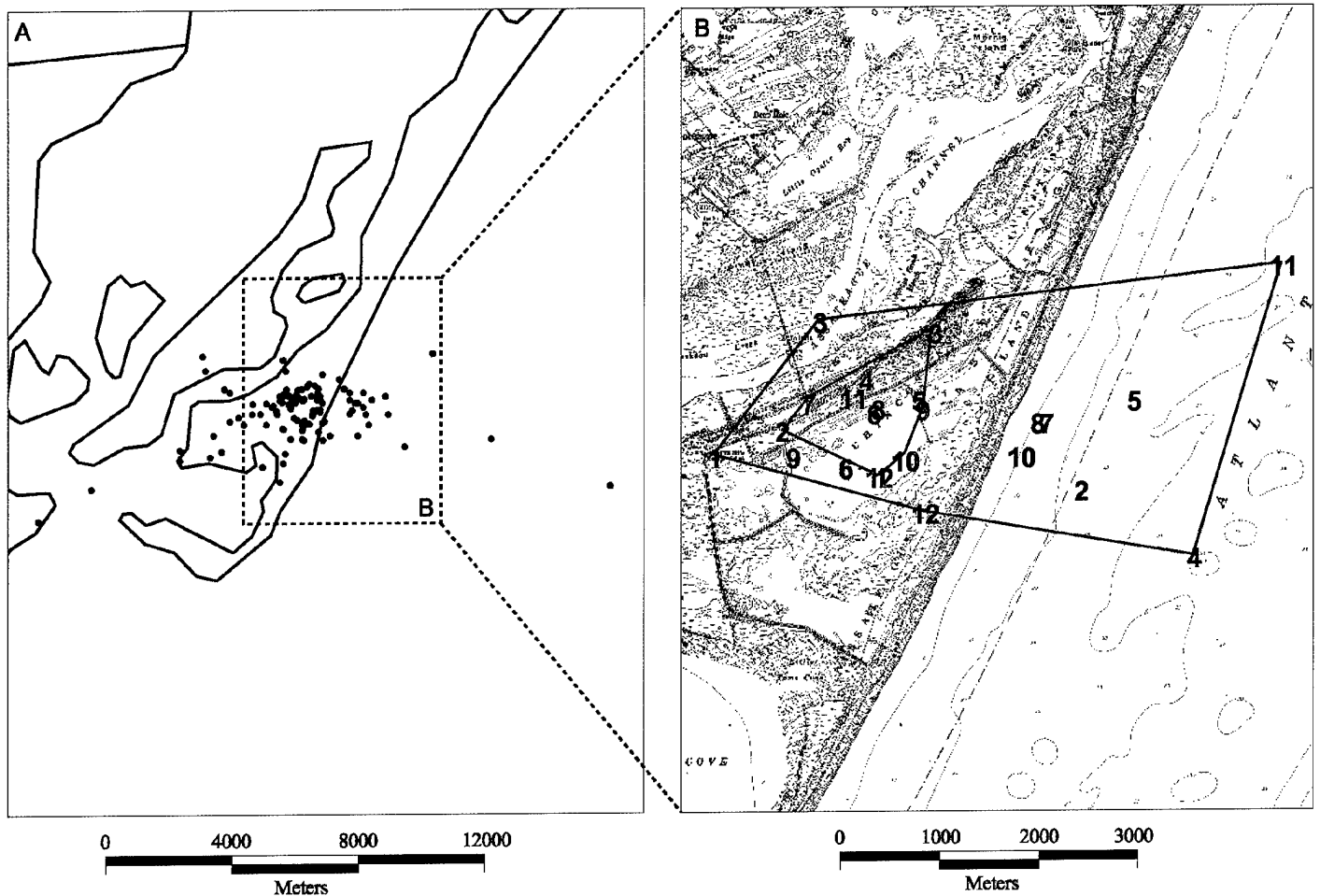
Ground-based message monitor equipment to monitor Argos compatible PTTs directly from the target animal (within close range).



Miniature single-chip camera.

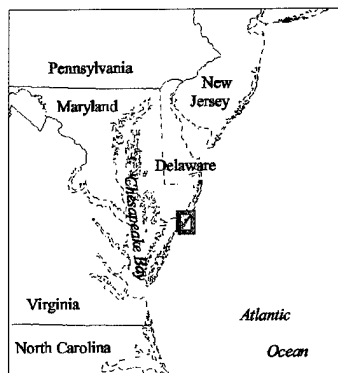
GPS and Doppler Location Estimates

A Comparison Demonstration of GPS and Doppler Location Estimates
of a wild pony on Assateague Island, VA



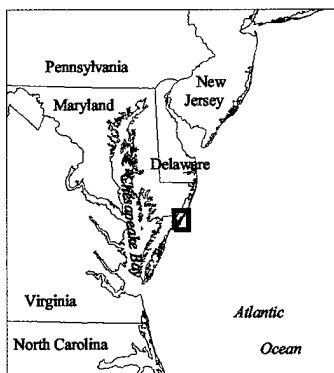
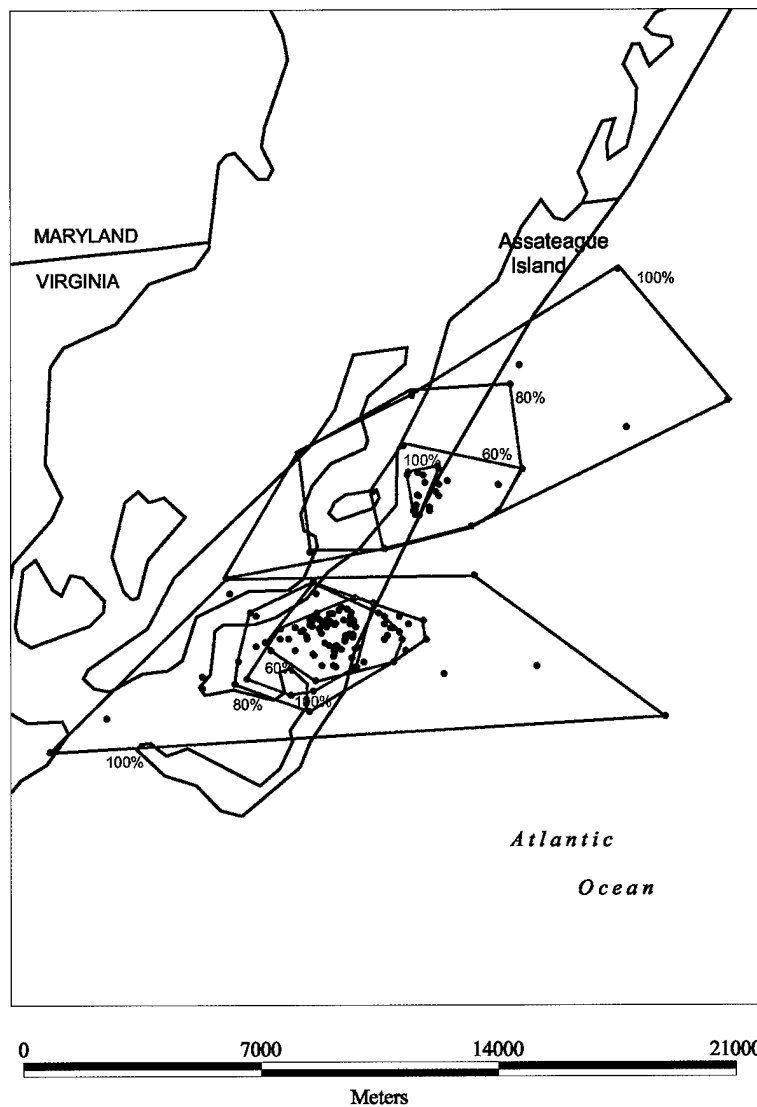
(A) Our experimental GPS PTT collar was placed on a wild pony on Assateague Island, VA for 12 days during the fall of 1997. Figure A presents a general overview comparison of all GPS and Argos doppler location estimates for the pony's time spent on the southern half of the island (the largest dataset from one area). The Argos locations are all of location class 1, 2, or 3. Twelve GPS locations and twelve Argos locations were chosen for point-by-point comparison in Figure B.

(B) This figure represents a magnification of the area enclosed with the dotted line in Figure A. The numbers, referring to correlating GPS (red) and Argos (blue) location estimates, are in chronological order. For example, a red "2," acquired by the GPS receiver, correlates with a blue "2," acquired by the Argos system (correlation = ± 1 hour). The polygons represent the areal extent of these twelve GPS and twelve Argos location estimates.



GPS and Doppler Ranges

A Comparison Demonstration of Wild Pony ranges based on GPS and Argos locations
Assateague Island, VA



This figure describes a general overview of pony ranges derived from GPS and Argos location estimates. The polygons show the areal extent of each dataset and are divided into northern and southern sections, since the pony spent a significant amount of time in two separate regions of the island. The GPS polygons (red) include 100% of GPS locations, while each successively smaller Argos polygon (blue) contains 100%, 80% and 60% of data points, respectively (Argos location classes 1, 2, and 3 only). A preliminary visual evaluation suggests that the accuracy of 60% of Argos location estimates begins to converge with the accuracy of the GPS dataset. Further research and statistical analysis might prove this true, in which case the Argos locations are still less accurate, but may not be less useful, given a larger dataset to establish a core area of accurate points. Because the GPS receiver and Argos transmitter are mounted on the same platform, such a comparison can be performed and statistically evaluated. Post-processing algorithms to improve the accuracy of Argos location estimates may be possible using this kind of comparative data.

CCRT'S CURRENT CAPABILITIES AND STATE OF THE SCIENCE

WHAT CAN BE DONE WITH TECHNOLOGY?

Natural Resource Stewardship and Management

The U.S. military is beginning to integrate natural resource issues and mission planning to foster ecosystem management and biodiversity conservation where such measures are linked to readiness. The new capabilities described in this Resource Managers' Technical Review allow biologists and military operations staff to do so in an effective and meaningful way by providing important natural resource conservation and management information, such as:

- Species home range data;
- Critical habitat identification;
- Breeding and wintering locations;
- Key foraging areas and diurnal/nocturnal timing of animal activity;
- Key geographic areas of overlap between natural resources and military land use activities (spatial and temporal);
- Effects of military land use activities on free-ranging organisms;
- Assessments of noise effects on animal behavior and biology.

The military's Integrated Training Area Management (ITAM) program includes a component—Land Condition Trend Analysis (LCTA)—that requires annual monitoring of natural resources (primarily vegetation) on military training lands. CCRT's remote wildlife tracking and monitoring technologies should provide an effective method of yearly wildlife monitoring (that may also be required on an installation-specific basis) to assess training effects on individual wildlife species, without interrupting military training and testing operations.

Geographic information systems (GIS) enable us to integrate animal locations, PTT sensor data, remote sensing databases, and available geographically-keyed information (such as jurisdictional boundaries, habitat types, geomorphology, and military land use activities) to create a

powerful analytical tool. This tool can be used to monitor, as well as to forecast, events and interactions between environmental and military elements.

These capabilities can enable the early integration of military mission planning with critical natural resource requirements (see example on next page). Such a system can maximize training and testing flexibility on military lands and foster a high state of mission readiness as installations manage for the conservation of biodiversity and habitats. Research protocols to evaluate land use effects on wildlife species can be implemented through the deployment of this near-real-time tracking and data collection system. Scientific information can be collected, synthesized, and rapidly analyzed with state-of-the-art software to provide timely, cost effective results for proactive natural resource management approaches on military lands. This system will also accommodate the simultaneous tracking of military activities and animal movements to monitor for interactions and effects.

SERDP supported developments in satellite PTT hardware will provide greatly enhanced wildlife tracking and monitoring tools. GPS qualified PTTs will provide animal location information that is orders of magnitude more accurate and precise than Argos Doppler locations. And the acoustic sensor will open new possibilities for remote wildlife studies (see pp. 42–45 for details).

Recent advancements in ground-based receiving systems provide the hardware and software to obtain location and sensor information directly from target organisms equipped with GPS qualified transmitters. (Note: This differs from conventional telemetry systems and techniques, in that the wildlife telemetry data does not require triangulation by field teams.) This capability provides the same types of information as tracking via satellite, but near-continuous

SUCCESS STORY

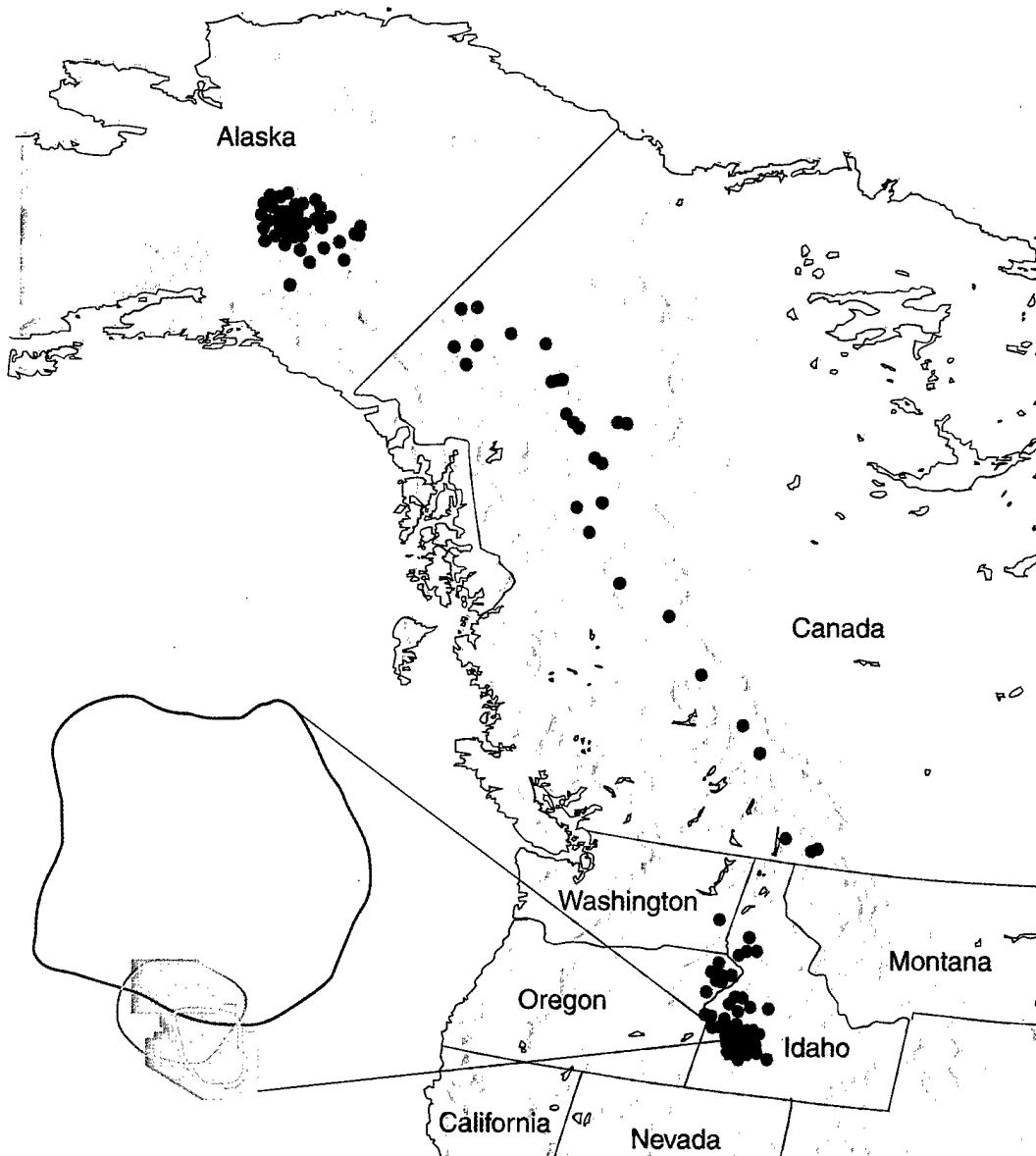
ENHANCING MILITARY READINESS WITH TECHNOLOGY TOOLS



©Michael Colopy

Some of the first applications of satellite platform transmitter terminals (PTTs) to natural resource management issues were with Golden Eagles. In 1990 a comprehensive study was initiated to study Golden Eagles for the Idaho Army National Guard (IDARNG) in the Orchard Training Area (OTA), which is centrally located within the Snake River Birds of Prey National Conservation Area near Boise, Idaho. On the OTA, we examined the spatial relationships of military training and Golden Eagle movements. Telemetry via satellite was employed because Eagles of unknown origin joined resident birds (tagged with conventional transmitters) during

the winter. These new arrivals were tagged with PTTs. Results have shown that some Eagles use the military training area extensively during the winter. Most adult birds that were captured and instrumented in the OTA generally remained on the military area while younger Golden Eagles ranged more widely. During the spring, most adult Eagles that were tracked via satellite migrated to breeding locations in central Alaska and western Canada. Thus, we were able to show that during periods of intense military training activity in the late spring and summer, a large component of Golden Eagles that use the area in the winter are absent and thus not affected by training.



Inset shows the wintering home range of a subadult Golden Eagle (red circle) and two adult Golden Eagles (blue and yellow circles) over-layed on the boundary of the Idaho Army National Guard Orchard Training Area, the large map shows the migration of wintering Golden Eagles to their breeding grounds in western Canada and Alaska.

coverage dramatically increases the frequency and number of locations and sensor data records collected from the transmitters. This capability is particularly useful for localized scientific studies and enhances the cost effectiveness of these tools. Using ground-based receivers, GIS can also import real-time data and provide the basis for up-to-the-minute impact analyses, evaluations, mission planning, and critical management decisions.

Noise Issues

The use of a stand-off system to monitor wildlife and collect environmental data can be very effective in the evaluation of a variety of issues pertinent to military activities. For example, noise effects on people, as well as wildlife, can pose a problem to military installations and may require a significant investment in time and money to resolve. Sensors capable of measuring environmental noise near an organism are being used by the U.S. Air Force to monitor jet aircraft noise and by the Army to evaluate single event noises associated with weapons testing and training. CCRT is designing miniature acoustic sensors that are being integrated into PTTs to dynamically monitor the level of human generated noise (at the organism) and the associated wildlife behavioral responses to noise events. Accelerometers are currently being integrated into these PTTs to enhance identification and characterization of animal responses and startle reflexes. Sensors could also be added to monitor the physiological response of the target animal to assess stress resulting from the noise. This system could make measurements and store or retrans-

mit the data to remote stations (either ground or space-based), and thus provide noise level and animal response data without the proximity of biologists. This technology enhances the study of cause and effect relationships, in near-real-time, to help relate animal responses to discrete military activities.

Aircraft Bird Strike Hazard Management

A bird strike to aircraft was first reported by Orville Wright, who on September 7th, 1908 struck a bird while circling a field near Dayton, Ohio. Since that time, birds and aircraft have shared the air, and collisions between them have lead to loss of life and revenue. Numerous studies have examined the threat that birds pose to aircraft when both occur within the same airspace. Although the losses incurred as a result of aircraft bird strikes are typically only financial (e.g., aircraft damage repair and downtime costs), catastrophic bird strikes have occasionally resulted in the loss of lives and entire aircraft. As recently as 1995, 24 people were killed when a \$180 million U.S. Air Force E-3B Advanced Warning and Control System (AWACS) plane crashed after colliding with Canada Geese near Anchorage, Alaska.

Bird strikes to aircraft will never be totally eliminated. But given the threat that birds pose to aircraft, it is imperative that the best possible bird avoidance capabilities are developed and implemented to mitigate bird strike problems and thereby improve safety and reduce maintenance and repair costs.

For the military, bird strikes not only incur tremendous costs for repairs and parts, but they

also reduce readiness by preventing the successful completion of training missions and by grounding aircraft. Military aircraft spend large segments of their flight training and operational time at the lower altitudes more commonly frequented by birds. In many military training and operating areas (MTAs and MOAs respectively) military training aircraft often fly close to the ground, well below the atmospheric boundary layer under which thermal mixing occurs to support soaring avian flight. It is under these conditions that pilots, crews, and equipment are most at risk.

Aircraft bird strikes have been examined with regard to such variables as avian species, seasonal occurrence, types of equipment and engines, aircraft operations, geography, time of day, altitude, and weather. The results of these studies indicate that the problem is extremely complex and is dependent on a number of factors that dictate how, when, and where both aircraft and birds will occur in the atmosphere together.

While the problem of bird strikes to aircraft is almost a century old, this is a relatively new area for military research and development. It is new because the technology needed to address this problem has only recently begun to mature. Technology tools now exist to track and monitor individuals or flocks of birds in real-time and to synthesize and analyze that information in a computer-based system. Such tools have allowed CCRT to gather extensive information concerning bird soaring behavior. We are currently modeling this behavior in relation to meteorological variables at Naval Air Station Fallon, Nevada and several other locations in the U.S. and Canada (see pp. 33-35 for details).

WHY IS THIS CAPABILITY AND THE INFORMATION IT CAN PROVIDE VALUABLE?

By developing new technology tools and using them with contemporary methods, land managers (such as the DoD) can learn more about the species they must manage and conserve. These technology tools and methodologies also serve to minimize constraints on, and ensure maximum flexibility of military missions.

These innovative technologies and methodologies are valuable because they can:

- Enhance scientific research and provide previously unattainable natural history information for target species;
- Enhance aircraft bird strike mitigation tools and capabilities;
- Leverage other information on animals to prevent population declines and possible threatened and endangered listings;
- Help avoid costly litigation concerning species and habitat management;
- Provide opportunities for proactive natural resource management;
- Allow research of wide-ranging, migratory, or elusive animals that simply could not be accomplished with other procedures;
- Provide information for science-based ecosystem management efforts at a variety of spatial and temporal scales;
- Enable the DoD to comply with applicable laws and regulations in the face of expanding human enterprise and dwindling natural resources;
- Maintain the DoD's reputation as a leader in natural resources conservation to support national environmental quality and health. ■

Where military natural resource management issues have a direct impact on readiness, these capabilities can provide solutions quickly, at low cost, and with minimal interruption to military land use activities.



SUCCESS STORY

SCIENTIFIC RESEARCH RESCUES SWAINSON'S HAWK BEFORE THREATENED OR ENDANGERED STATUS LISTING IS NEEDED

CCRT's Legacy project contributed significantly to radio tracking of Swainson's Hawks (SWHA) with satellite-based technology during 1995 and 1996. We monitored their distribution on and off military installations in the western U.S., where their numbers had been diminishing at an alarming rate for unknown reasons. The Swainson's Hawk is listed as a species of concern by five states and the Bureau of Land Management, and as a special emphasis species by the U.S. Forest Service. Nesting population declines had been reported over much of the hawks' range, including Dugway Proving Grounds. With no obvious reason for this decline, scientists postulated that problems along migration routes or on wintering areas were responsible.

Four SWHA were marked with PTTs near the Idaho Army National Guard Orchard Training Area. SWHAs were also marked near Dugway Proving Ground, UT, Navy land holdings in Oregon, and the Rocky Mountain Arsenal (now a Fish and Wildlife Service refuge) in Colorado. The locations of these hawks were monitored on their North American breeding grounds, Argentinean wintering grounds, and along migration routes. Results of the satellite telemetry study revealed that large numbers of this species, in fact thousands at a time, were being killed on their South American

wintering grounds.

In January of 1996, scientists visited different areas indicated by the satellite derived location data. They counted over 4,000 dead SWHA, killed as an apparent side effect of pesticide applications to croplands, and these scientists believed the actual mortality numbers may have exceeded 20,000. Since adults represented nearly 90% of the dead birds and the entire Canadian SWHA population is estimated between 20-40,000 pairs, this loss represented a serious threat to the survival of the species.

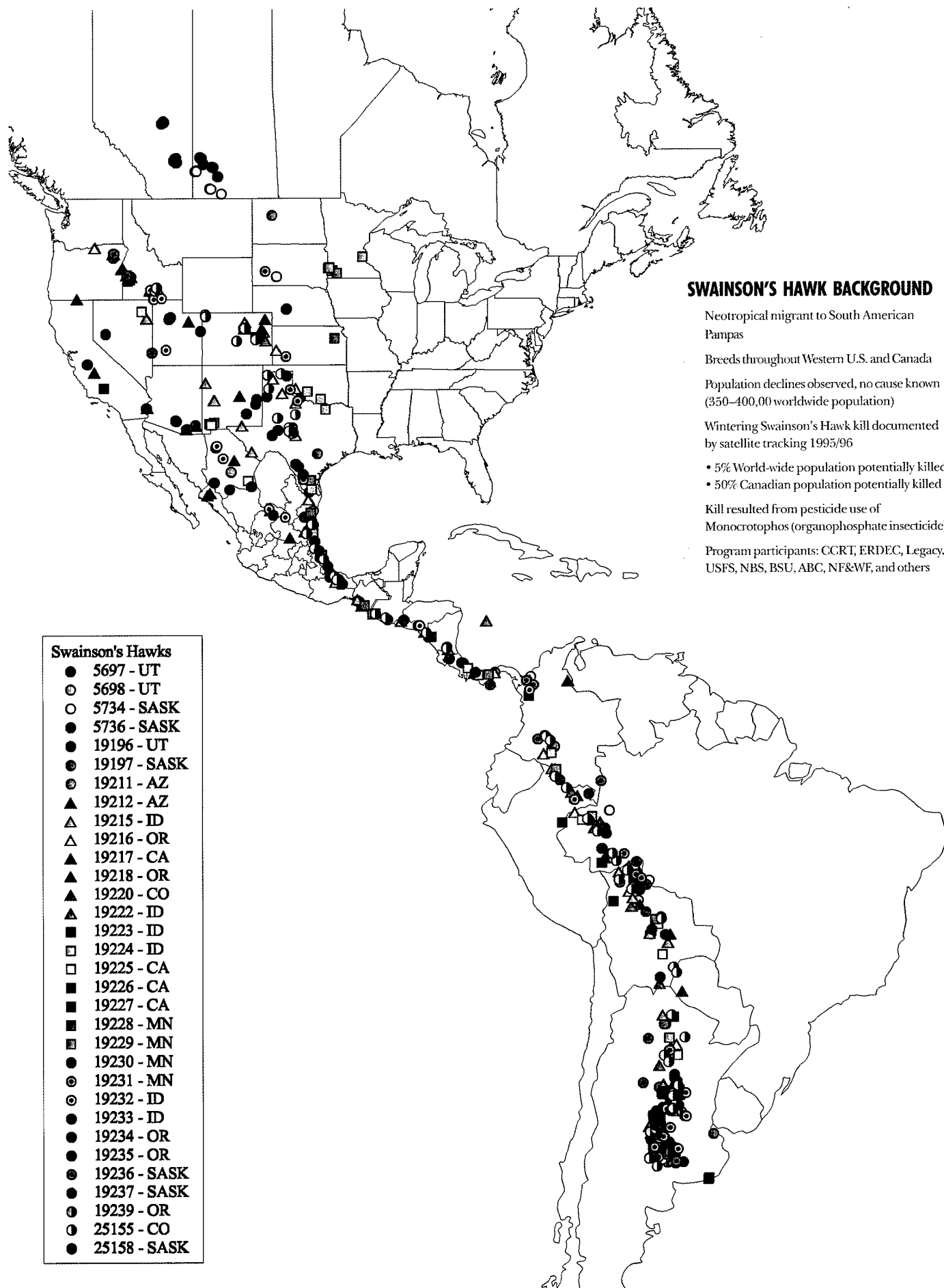
It turned out that this catastrophic population decline resulted from the use of a toxic organophosphate pesticide, recently brought into use on the pampas of Argentina where these hawks winter in communal roosts. Through the use of remote tracking and monitoring technology, this environmental problem was identified and, within 18 months, remedied through collaborative government and private sector management and education. Keeping this raptor off the endangered species list saved millions of federal dollars by avoiding costly large-scale research and recovery programs and related habitat management activities in North America. This application of wildlife tracking via satellite is a perfect demonstration of the unique advantage this technology can provide in the study of a wide ranging species.



Swainson's
Hawks
outfitted with
a satellite PTT.



Migration paths of Swainson's Hawks outfitted with satellite PTTs in the western U.S. and Canada.



TECHNOLOGY

Precursors to the current SERDP and Legacy projects began in the early 1980s with the Bird Borne Program at Johns Hopkins University Applied Physics Laboratory. This program, initiated and managed by the U.S. Army Edgewood Research Development and Engineering Center, sought to design, build, and deploy miniature satellite transmitters to track the worldwide movements of migratory birds.

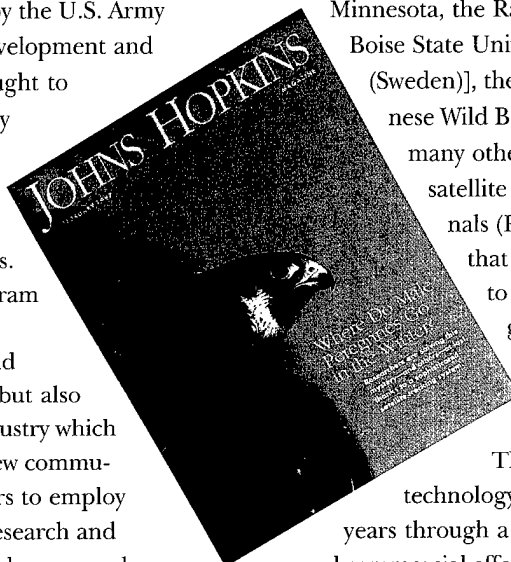
The Bird Borne Program not only succeeded in achieving its research and development objectives but also helped launch a new industry which spawned, over time, a new community of expert researchers to employ these tools for wildlife research and conservation studies. Today, researchers from the U.S. Geological Survey, the U.S. Fish and Wildlife Service, the U.S. Department of Agricul-

ture, The Nature Conservancy, the National Aeronautics and Space Administration, the Audubon Society, numerous universities [including the Raptor Center of the University of Minnesota, the Raptor Research Center of Boise State University, and Lund University (Sweden)], the Peregrine Fund, the Japanese Wild Bird Society, EARTHSPAN, and many other organizations are using the satellite platform transmitter terminals (PTTs)—that are the fruits of that initial Bird Borne Program—to track wildlife species on a global scale. To date, thousands of PTTs have been applied to study dozens of species.

The miniaturization of PTT technology has continued over the years through a combination of government and commercial efforts, shrinking initial prototype PTTs (that weighed close to 200 grams in 1984) down to 20 gram PTTs that are available today from Microwave Telemetry, Inc. Twelve to fourteen gram PTTs may soon be available commercially, in addition to our GPS PTTs (collar mounts). GPS PTTs for birds should also be available soon, weighing in the 150 gram range.

Service Argos, the French operated sensor platform carried on board NOAA weather satellites, is the only system in the world capable of locating tiny, low power satellite PTTs on the surface of the Earth. This is the system that we use. The Bird Borne Program and its successor projects have significantly contributed to the 20-25% of Argos' business now derived from PTTs attached to a wide variety of wildlife species, including many species of birds, mammals, and even fish.

The following examples highlight just a few of



Dr. William S. Seegar at the 1996 SERDP Symposium.



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Mr. Blake Henke at a sustainable development conference in Houston, TX, 1997.

the wildlife research breakthroughs that have occurred through the application of satellite PTTs tracked via the Argos System:

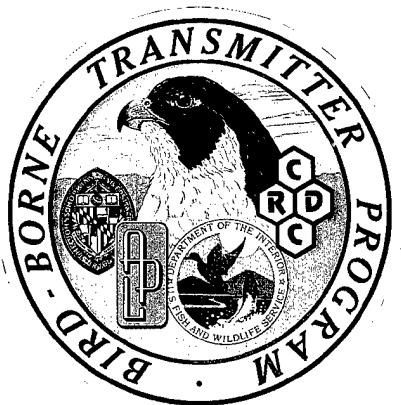
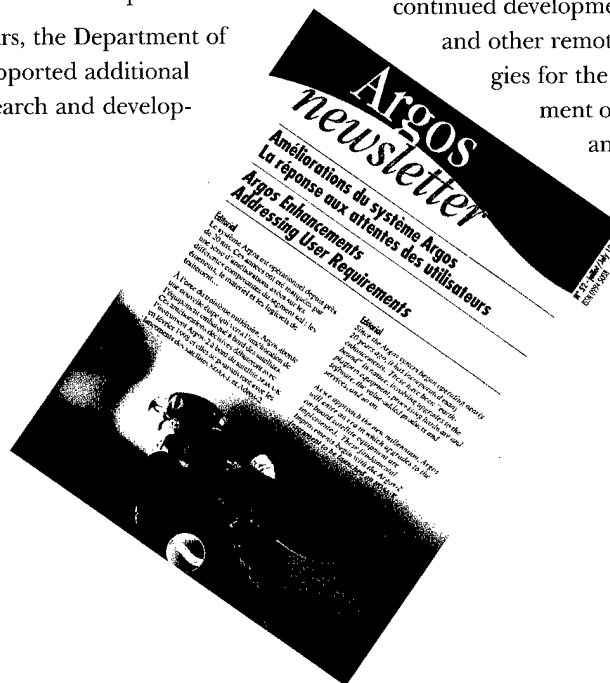
- Complete description of Swainson's Hawk migration; and identification of contamination threats to the survival of this species;
- Description of Tundra Peregrine Falcon migration from arctic breeding areas to locations throughout the southern United States and Central and South America;
- Identification of Spectacled Eider wintering grounds in the Bering Sea;
- Tracking of Bluefin Tuna through the Atlantic to indicate the existence of one population of tuna, rather than the suspected two.

Over the years, the Department of Defense has supported additional technology research and develop-



ment projects that have benefited the military and the wildlife research community by continuing to develop new satellite-based tracking, monitoring, and remote sensing technologies and miniature sensors. Technology transfer has thus proceeded in many directions.

All of this research, development, and technology transfer has culminated in the formation of the Center for Conservation Research & Technology (CCRT). CCRT is a private/university/government partnership dedicated to the continued development and application of these and other remote data gathering technologies for the conservation and management of wildlife species, habitats, and ecosystems in the United States and abroad. ■



ESTIMATED RETURN ON INVESTMENT EVALUATION

ESTIMATED COST SAVINGS

1 The use of advanced, satellite-based tracking and monitoring technologies to acquire natural history information necessary for effective management and conservation of widely ranging animals could save the military roughly 10–30% over currently available best methods (i.e., conventional, ground-based radio telemetry). These cost savings accrue to the military in a variety of ways: through reduced direct costs for personnel, equipment, and field time; through enhanced speed of collection (computer compatible) and accuracy of the data; and through avoiding conflicts with base training and testing operations.

These estimated cost savings to the military are for specific applications and specific information gathering efforts. The actual cost savings to the military by using this technology over other available methods could be much greater in certain situations. Cost savings depend on the types of information being collected, the target species being studied, and the cost of other available technologies and methodologies. It must also be noted that for certain types of scientific studies, conventional methods provide more information than satellite telemetry. CCRT employs both conventional and satellite telemetry methods.

2 Satellite-based tracking and monitoring techniques provide unique advantages over other techniques and methods in a variety of applications. For example, information on migratory species could not be cost effectively gathered in any other way. Similarly, animals that move during inclement weather or into inaccessible areas (or areas that are off limits to field biologists) cannot be effectively tracked with any other technology or approach. And remote data acquisition methods typically do not interfere with ongoing land use activities. It is difficult to assign a dollar value to these advantages of satellite technology, but they

significantly add to overall flexibility during military training operations and material testing and evaluation activities.

3 Regarding the Swainson's Hawk example (see success story, p. 50), it is clear that keeping this species off the Threatened and Endangered Species (TES) list saved the military, as well as other federal land managers in the western U.S., a great deal of time and money in research and management programs, negative publicity, lawsuits (potential), and consultations with the Fish and Wildlife Service. Exactly how much this could have saved the military, however, is open to speculation. The primary threat to the Swainson's Hawk existed in its wintering areas, not in its breeding grounds throughout the western U.S. and Canada. Therefore, it is reasonable to assume that even if this raptor species had been listed under the Endangered Species Act and had received federal support in the U.S., the species would have continued to decline until the poisons on its wintering grounds were discovered and remedied. Based on this logic, costs for recovery efforts, management programs, and research activities could have been quite large over time.

4 CCRT is developing models to assist in the forecast and prediction of bird flight associated with military and commercial aircraft traffic (see pp. 33–35 for details). Our technologies will support the development and implementation of a bird flight forecast model. The model will operate in parallel with a near-real-time monitoring system to reduce the probability of bird strikes and to enhance safety for aircraft pilots and passengers. Any reduction in aircraft bird strikes that we could facilitate with our technologies and modeling efforts will provide significant benefits to the military on the safety issue alone. ■

POTENTIAL APPLICATIONS

AND FUTURE DEVELOPMENT OPPORTUNITIES

LARGE-SCALE ECOLOGICAL RESEARCH

These remote data acquisition capabilities will contribute significantly to large-scale ecological research to enhance ecosystem management on military bases and their surrounding national and international regions. Migratory or wide ranging animals do not recognize geo-political boundaries as they forage and travel. Therefore, it is imperative that natural resource and land managers from different countries, states, organizations, government departments and agencies, work together to maintain critical habitats and ecosystems. Knowing where important species spend their time and why is crucial to effective long-term management and conservation of biodiversity; and this concept will likely gain importance as growing human populations and development place greater and greater demands on the landscape and ecological communities.

SENTINEL ANIMAL APPROACH

Free-ranging animals equipped with biotelemetry can act as sentinels for their populations and indicators in their ecosystems. These sentinels provide a sample that can reflect the activities of many animals. Use of sentinels is a proactive approach to enhance biological knowledge. Such approaches can, for example, lead to the ability to predict bird flight patterns and therefore to reduce bird strikes by military and commercial aircraft. The Legacy Program will demonstrate this concept, see pp. 33–35 for details.

SENSOR DEVELOPMENT

This new system has the potential to monitor behavioral and physiological parameters (e.g., motion, core temperature, heart rate, and muscular motility), as well as the potential to monitor selected chemical contaminants surrounding the target organism. Additionally, the incorporation of a miniature camera has been

deemed feasible as a result of a SERDP supported technology investigation.

DIODE-BASED RADAR TRACKING

One potential enhancement of existing and developmental remote data acquisition capabilities involves the application of diode-based radar tracking. Diode-based radar tracking is a new technique that has been successfully employed to track small insects over short distances. It offers the ability to inexpensively track individual animals in a defined area, as well as the ability to track extremely small birds and insects. Diode-based radar tracking should be able to provide real-time monitoring and identification of tagged individuals. The system works as follows: a specially tuned radar transmitter sends out a pulse in a given direction. If that pulse encounters a diode that has been designed to interact with that pulse, it sends back a harmonic signal that can be separated from the rest of the radar return signal. The location data derived from the use of diode radar tracking can be imported into a GIS (in much the same way that satellite location data is imported) and used to relate animal movements to geographic variables. Such a system can enhance natural resource management by extending remote data gathering tools to small avian species that cannot be tracked easily in other ways. This capability will greatly enhance the ability to track, monitor, and study a vast array of small, avian, neotropical migrants to better understand them and to develop new strategies for their conservation.

Diode-based radar tracking can also be effective in the development of an aircraft bird strike hazard monitoring system to supplement other real-time tracking and monitoring tools. This is a technology area that we are exploring with others in the pursuit of better aircraft bird strike avoidance capabilities. ■

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Advanced biotelemetry capabilities that incorporate the latest innovations in microelectronics, geographic information systems (GIS), remote sensing, and computer modeling offer great promise (through sound research planning) in helping to define and characterize human effects on species and ecological communities and to identify strategies to ensure their sustainability in the face of expanding human enterprise. The U.S. military has determined that in order to effectively manage its natural resources in pursuit of maximum training and operational flexibility, it must take a holistic, ecosystem management approach. It is hoped that such an approach will help to identify and remedy natural resource management issues before they affect mission readiness.

The SERDP Program has supported the development of new, advanced satellite telemetry hardware and sensors, while the Legacy Program has supported the demonstration and implementation of existing technologies on pilot military bases. Through support from these programs, CCRT is defining the cutting edge of remote tracking and monitoring capabilities. And most

importantly, we are using these advanced systems and the resulting data to provide comprehensive analyses and new approaches to pressing wildlife management concerns, as well as to applied operational and safety issues such as aircraft bird strike avoidance.

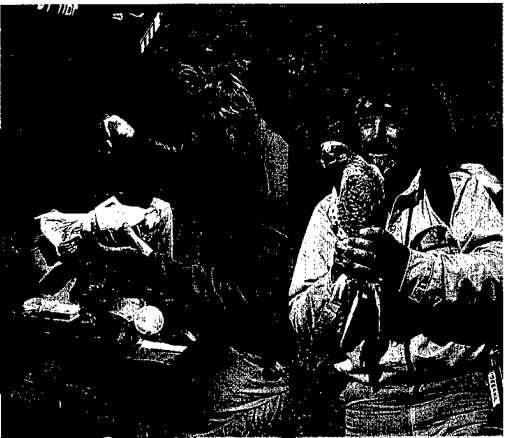
These technology-based systems are now poised to foster the early integration of military mission planning activities with critical natural resource information. And CCRT stands ready to employ these tools to provide comprehensive research protocols, methods, hardware, and systems to enable planners and managers to meet military and environmental requirements quickly, cost effectively, with accurate information, and with minimal interruption to regular base activities.

If according to Aldo Leopold, "The last word in ignorance is the man who says of an animal or plant: 'What good is it?' If the land mechanism as a whole is good, then every part is good, whether we understand it or not." Then it is the aim of CCRT to use new emerging technologies in the context of sound science to enhance our understanding of the land mechanism so that we may work together to conserve biodiversity and habitats on a global scale. The systems we have developed (and are continuing to refine) and their utility as tools for resource management and conservation continue to be defined and advanced, and the potential applications are practically limitless. ■



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ATION RESEARCH & TECHNOLOGY

WHAT WE DO

We develop, test, and apply advanced technologies and scientific methods for the conservation and management of natural resources. We specialize in stand-off technologies designed for remote data acquisition. We have the expertise to develop and implement scientific research to conduct basic, applied, and manipulative studies.

We deploy satellite and ground-based tracking and monitoring capabilities and associated technologies—such as remote sensing, satellite imaging, diode-based radar tracking, remote acoustic monitoring, and geographic information systems (GIS)—to study, manage, and conserve wildlife species that have proven in the past to be difficult to study.

We specialize in:

- Technology development, test, and evaluation;
- Methodology development for new hardware applications;

- Basic and applied research protocol development;

- Computer modeling of natural resources and land use effects;

- Application of advanced tracking and monitoring technology to study:

- migratory animals and wide ranging species;
- elusive or rare animals;
- threatened and endangered species (and candidate species) and species of concern;
- animals that frequent inaccessible habitats or extremely rugged terrain.

We require less extensive field time than traditional, field based methods because we can gather data remotely. We provide solutions to the most pressing wildlife management issues with minimal interruption to ongoing land use activities.

WHAT WE CAN DO FOR YOU

Our expertise and technical capabilities foster the early integration of critical natural resource information into land use planning. This enables military mission planners, for example, to maintain a high state of readiness while managing for the maximum level of environmental compliance. If you have or anticipate concerns about wildlife, we can quickly apply a variety of methods and technology-based solutions. We can provide comprehensive research protocols, scientific methods, hardware, and systems enabling you to meet mission and environmental requirements quickly and cost effectively, with accurate information, and with minimal interruption to land use activities. From simply providing raw data to the full development and implementation of a research program—including GIS analyses and resource management planning—we can suit your unique needs.

We have the capability to track and monitor target animals by satellite or ground-based stations to individualize studies to meet specific needs of military organizations or activities.

We address noise issues by combining our remote tracking and monitoring capabilities with newly developed acoustic sensors to evaluate military noise at the organism level and to assess associated cause and effect relationships.

We perform research focused on reducing aircraft bird strike incidents. We have developed models to assist in the forecast and prediction of bird flight associated with military and civilian aircraft traffic. We also can assist in the development and implementation of a near-real-time monitoring system, to operate in parallel with a bird-flight forecast system, to reduce the probability of aircraft bird strikes and to enhance the safety of aircraft pilots and passengers. ■

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CCRT ACCOMPLISHMENTS AND HISTORY

THE CENTER FOR CONSERVATION RESEARCH & TECHNOLOGY (CCRT)

CCRT is a private/university/government partnership dedicated to the continued development and application of advanced technologies for the conservation and management of wildlife species, habitats, and ecosystems. CCRT consists of wildlife biologists, ecologists, geographic information systems analysts, remote sensing experts, microelectronics engineers, radar engineers, computer modelers, meteorologists, and environmental scientists existing as a single, multi-disciplinary team. CCRT has offices in Baltimore, MD and Boise, ID. CCRT is headquartered at the University of Maryland Baltimore County. CCRT's primary purpose is to develop and apply innovative technology tools and data synthesis/analysis capabilities to unite wildlife and ecological research with practical decision-making and natural resources planning.

CCRT's experience and accomplishments include the following projects:

- Bird Borne research and development on satellite platform transmitter terminals (PTTs)—Johns Hopkins University Applied Physics Laboratory (1981-Present).
- Endangered Species Program—Peregrine Falcon breeding, wintering, and migration studies (1970 to Present).
- Snake River Birds of Prey National Conservation Area—Idaho Army National Guard Raptor Studies (1992 to 1996).
- Development program for reconnaissance and remote data collection—Unmanned Aerospace Vehicle (UAV) (1988 to 1990).
- Remote Environmental Sensor Technology Program (REST) for advanced sensor development (1990–Present).
- Biogenetics development of genetic markers to determine natal origins of avian migrants (1985–1992).
- Development and Implementation of a Pulse Coded Computer-based Tracking System (1985–1988).
- Trace element analysis to determine natal origins of avian migrants for resource management plans (1987–1993).
- Conservation of Golden Eagles in Canada in relation to HydroQuebec construction activities (1988–1990).
- Conservation of Bald Eagles in Glacier Bay and the Chilcat River concerning copper mining issues (1987–1989).
- Conservation of Golden Eagles concerning mercury toxicology in Eastern Idaho (1989–1991).
- Peregrine Falcon Conservation—studying “Peregrine Populations” as an indicator species for neotropical migrants and habitat (1993–Present).
- Partners in Flight—tracking continental migrations of Tundra Peregrine Falcons and Swainson's Hawks (1993–Present).

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The Center for Conservation Research & Technology (CCRT) is a private/university/government partnership dedicated to the continued development and application of advanced technologies for the conservation and management of wildlife species, habitats, and ecosystems. CCRT has offices in Baltimore, MD and Boise, ID. CCRT is headquartered at the University of Maryland Baltimore County. For additional information, please contact Dr. William S. Seegar at (410) 436-2586, e-mail: WSSEEGAR@aol.com; or Mr. Blake Henke at e-mail: blakehenke@msn.com.

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