Smithsonian Institution

Research Reports

No. 98 Autumn 1999

PALEOBIOLOGY

Computer animation 'reawakens' a 65 million-year-old dinosaur

By Michael Lipske
Special to Research Reports

A new-and-improved dinosaur is on the prowl at the National Museum of Natural History. Three menacing horns sprout from the skull of the giant reptile that has lumbered from the depths of time and into cyberspace, via a desktop computer in the Department of Paleobiology.

"Now that is not your grandfather's triceratops," department chairman Richard Benson says approvingly, as he watches the three-dimensional dinosaur march across the computer screen.

Benson's pride and joy is unlike your grandpa's triceratops for two reasons. The world's first digital dinosaur, easily manipulated and studied on a computer, is directly descended from the world's first fully mounted triceratops skeleton, namely the 19-foot-long fossil that has been displayed for decades in the museum's Dinosaur Hall. Moreover, the new virtual triceratops represents the latest scientific knowledge about how these six-ton vegetarians looked and moved more than 65 million years ago.

"We're going through the process of taking apart, or dismounting, the original triceratops that was done in 1905," Benson says. In the course of that work, undertaken after a conservator warned that the brittle-boned mount was falling apart, museum staff and outside consultants have surface-scanned the original skeleton bone-by-bone and millimeter-by-millimeter, digitally mapping the dinosaur in three dimensions.

"This is the first time anyone has actually attempted to reconstruct a whole skeletal organism in virtual space," says Ralph Chapman, a computer specialist who heads the museum's Applied Morphometrics Lab and who is working on the triceratops project.

The digitally described dinosaur will be a boon to scholars. Until now, if a researcher at a distant museum wanted to examine part of the triceratops skeleton, preparators had to make a cast from the original bone and ship the replica to the other facility. "Now, if somebody says, 'I want to look in detail at your triceratops skull,' " Benson says, "we can drop in a file, and they can pick it right up on their own computer through the Internet."

Scanning the skeleton will also permit preparators to cast synthetic replacements for missing or wrong-size bones in the 1905 triceratops mount. "Corrective surgery" is what Benson calls this fine-tuning of the skeleton based on what has been learned about triceratops since the museum's specimen was assembled. "We have a need to put the animal together as it should have been, to see in some fashion or another how it could operate, what its biomechanics would have been," he adds.

By surface-scanning this 19-foot-long triceratops skeleton, staff at the National Museum of Natural History and outside consultants were able to digitally map the dinosaur in three dimensions, thus making it easier to manipulate and study on a computer screen. (Photo by Dane Penland)

A creature of the late Cretaceous period, the triceratops roamed western North America in herds and tried to stay a step ahead of dangerous carnivores like tyrannosaurus. "It was one of the last dinosaurs that existed," Benson says. "It was the one that probably saw the big bolide that came out of the sky and caused the extinction of dinosaurs at the close of the Mesozoic era."

Put on display in the Smithsonian's Arts and Industries Building 94 years ago, the triceratops skeleton gave Americans their first view of how these ancient horned reptiles appeared. "It's the specimen from which the whole concept of triceratops came," Chapman says.

The mounted dinosaur also was a group portrait, with the bones that compose the skeleton having been quarried from a half dozen places in Wyoming during the 1880s and 1890s. "There may be as many as 16 different animals represented in that single skeleton," Benson says. Unfortunately, that mixed bag of bones made for a poor fit.

For example, in the mount's forelimbs, the right and left humerus came from two different animals and are not the same size. Thus, if the museum's dinosaur somehow sprang back to life, "it wouldn't be able to trot, canter or gallop," Benson explains. Also, the skull is a bit small in proportion to the rest of the mount, and the rear feet are not even from a triceratops. Because none were available when the mount was assembled, feet from another species—a hadrosaur, or duck-billed dinosaur—were substituted.

On top of that, after more than 90 years on the job, the Smithsonian's triceratops was worn out. Vibrations from construction work, humidity from the breath of millions of people who have walked through the Dinosaur Hall and poorly done repairs to bones all had taken a toll on the triceratops—so much so that museum Conservator Kathy Hawks judged the dinosaur in danger of collapse.

On her recommendation, the fragile skeleton has been dismantled. Preparators in the Vertebrate Paleontology Lab have treated the fossil bones with stabilizers and glues. Liquid-plastic casts of the hardened bones are being used to create a new triceratops mount, expected to go on view in the Dinosaur Hall late next summer. Computer analysis of several of the scanned bones will allow better proportioned substitutes to be crafted, yielding a more accurate dinosaur display—a triceratops with a more dynamic pose and correct posture.

Other dividends from the scanning side of the project include the prospect of creating high-resolution, small-scale prototypes of triceratops that can be shared with other institutions, as well as the ability to animate millions of data points from the skeleton into a functioning virtual dinosaur that can be observed, measured and rotated in space on a computer screen.

For the first time, the miniature version of the skeleton is allowing scientists to conduct hands-on analysis of what movements occurred at each of the joints between the bones of the skeleton, Chapman explains. "The virtual triceratops then allows these movements to be integrated together so that we can see how the animal walked, ran, ate and defended itself. Researchers can experiment with different assumptions about how these joints worked and see the results using computer animation," he adds.

The original skull, Benson says, may weigh between 400 and 600 pounds. "Now that's something you can't pick up and throw around to look at it," he says. "But in cyberspace, you can flip it over, turn it around, look at it in detail, and even make sections through it."

Benson says that, of the more than 6 million people who visit the National Museum of Natural History each year, "30 percent, based on our surveys, have decided before they enter the building that they want to come in and see the dinosaurs. We have a chance to leave a lasting impression."

Although the new triceratops mount will be constructed from cast bones, the exhibit in the Dinosaur Hall will include selected fossil bones "to show what some of the parts were like before we changed them," he adds. The exhibit will highlight the museum magic and computer technology that transforms epoxy and other materials into perfect replicas of ancient bone.

"We would like for our visitors to think that what they are seeing is real," Benson says, "but we also want to show them what science has done in reconstructing the triceratops as close as possible to what it might have been when it was alive." ■

Inside...

Research Vistas	2
Native American youth	2
Rain forest diversity	3
Aircraft documentation	4
Technology and change	5
Research Highlights	6
Series, Books & Recordings	7
Off the Shelf	8

RESEARCH VISTAS

While the new Discovery Center at the National Museum of Natural History was still under construction, the foreman guiding a tour noted that the staff cafeteria would be separated from the public Atrium Cafe by a wall of glass. A colleague wryly asked whether there would be a museum label adjacent to this potential diorama, reading something like, "Late 20th- to Early 21st-Century America: Employees of the Smithsonian Institution gathered in common rooms such as these to take nourishment and share camaraderie."

Relieved as everyone was to learn that the glass is frosted and staff dining is not being put to visitor scrutiny, it is no laughing matter that the Smithsonian's richest resource—our community of scholars—is perpetually hidden from public view. The men and women who steward our collections, mount our exhibitions and put on our public programs also are engaged in research.

The differences in research approaches across the museums and research centers of the Smithsonian was a topic of discussion among the Institution's scholars at one of their regular meetings.

Underlying all research at the Smithsonian are questions the staff are trying to answer: What constitutes beauty, and how have human perceptions of aesthetic quality changed over time? How has information technology changed the American way of life? What is the effect of elevated carbon dioxide on tropical rain forests? Questions such as these define the research approach, not the academic discipline.

According to Judith Zilczer, curator of paintings at the Hirshhorn Museum and Sculpture Garden, the questions common to all art historical investigations inquire about the artists' lives and the style and symbolic content of works of art or about how art reflects the social history and culture of the time and place of its creation. Research in art history, however, has grown dramatically in scope and variety since its 16th-century beginnings. Groups and categories once excluded from university study or museum collections now are thriving research specialties.

The distinctive features of research in history are the study of differences over time and the focus on human relationships, social institutions and creations, says Jeffrey Stine, curator of engineering and environmental history at the National Museum of American History. Because the number of permutations among these variables is virtually infinite, he adds, the study of history is complex and defies any fixed approach. In fact, historians have spawned a legion of topical and regional subdisciplines to address the variety of human experience: political history, science history, Southern history and more.

Regardless of specialty, all historians aim to solve a problem. They base their work on exhaustive research in primary sources, aided by their familiarity with the secondary literature. They are critical and questioning of their data, and they look for corroborating evidence. Their work is documented and must withstand the rigors of peer review.

The criteria used to evaluate research in the biological sciences include its novelty, relevance and potential impact, says Senior Biologist Stanley Rand of the Smithsonian Tropical Research Institute in Panama. Yet the process, as in the humanities, still begins with a question. The scientist then puts the research question to the test of originality by reviewing the existing literature. Once funding is obtained, equipment and supplies procured, and a team recruited, the work begins in earnest with the collection of data, development of statistics and drawing of conclusions. Rand notes that often the results do not answer the original question, but still they contribute to our knowledge of the natural world.

At the end of the day, according to Stine, "it is that seriousness in the pursuit of knowledge that cuts across disciplinary borders and links us as researchers here at the Smithsonian."

—Dennis O'Connor, Provost, Smithsonian Institution

Native American youth are using the art of photo documentation to give "voices" to themselves and their community. Andrew Walker, an eighth-grade student at Hays-Lodgepole High School, took this photograph of his classmates, Nikki Snell, left, and Heather Doney.

CULTURAL HISTORY

Native American youth use cameras to focus in on their lives and culture

By Jo Ann Webb
Smithsonian Office of Public Affairs

When George Horse Capture was growing up on the Fort Belknap Reservation in Montana, Indian children had no "voice." Their stories, along with those of their families and friends, were never told through their own eyes. But a photographic documentation project at the National Museum of the American Indian now is giving Indian youth a forum in which to tell and share their personal stories.

A lot has changed since Horse Capture, now deputy assistant director for cultural resources at the museum, was a youngster. "What was important to me as a youngster and even now as an adult may not even matter to these kids. But the photographs will tell us everything that we need to know."

The brainchild of Horse Capture, the project encourages students to take notice of their world—the sights and sounds around them. "All these things," Horse Capture says, "makes them who they are."

Titled "Images and Identity," the 18-week project is designed to train students at Hays-Lodgepole High School, located on the Fort Belknap Reservation, in the art and skill of photographic documentation as a means of giving voices to their culture and their community. Through photography, 13 students in grades 8 and 11 will answer the question, what makes me an Indian?

Horse Capture intentionally selected young people for the photo documentation project rather than adults because he believes that, by working with youth, he has an opportunity to make a greater impact. "There will always be differences between white people and us," he says. "But if those differences are ever going to change, you have to start with the children. By the time you're an adult, it's too late to change opinions."

Katherine Fogden, a photographer at the museum who taught the students about the techniques of photography and using man-

'Youth,' continued on Page 6

Smithsonian Institution
Research Reports
No. 98 Autumn 1999

Published quarterly by the Smithsonian Office of Public Affairs, Smithsonian Institution Building, Room 354, Washington, D.C. 20560-0033, for Smithsonian Contributing Members, scholars, educators, museum personnel, libraries, journalists and others. To request this publication in an alternative format, call (202) 357-2627, ext. 124 (voice) or (202) 357-1729 (TTY).

David Umansky, Communications Director
Kathryn Lindeman, Associate Director
Jo Ann Webb, Editor
Colleen Hershberger, Production Assistant

Telephone: (202) 357-2627
E-mail: researchreports@publicaffairs.si.edu
Internet: www.si.edu/researchreports

* * * * *

Contributing Members who seek information about the Smithsonian or about their memberships may write to The Conrributing Membership, Smithsonian Institution, 900 Jefferson Drive S.W., Room 1479, Washington, D.C. 20560-0410, or call 1 (800) 931-32CM.

Research project measures diversity, dynamics of tropical rain forests

By Shallin Busch
Smithsonian Tropical Research Institute

There has always been an aura of mystery about tropical rain forests—so dense; so impenetrable; so full of exotic sights, sounds and smells. The fact that scientists had only scratched the surface in unraveling that mystery was not a problem until recently. Modern and often human-mediated phenomena, such as large-scale slash-and-burn agriculture, species extinction and climate change, have put rain forests in peril and exposed the gaps in our understanding of these uniquely rich ecosystems.

Despite the public outcry over the potentially grave consequences of rain-forest destruction for the health of the global environment, there remain many basic, unanswered questions: Why do tropical forests host such a high diversity of species? How can that diversity be maintained under conditions of human use? What role do tropical forests play in stabilizing our climate and atmosphere? How can we use forest resources without depleting them?

In 1981, scientists from the Smithsonian Tropical Research Institute in Panama set out to answer these and other concerns with a project to measure a tropical rain forest at a scale and intensity never before attempted. They created a 50-hectare (125-acre) permanent tree plot on Barro Colorado Island, which has now become STRI's primary site for the study of lowland moist tropical forest.

For the preceding century, biologists had monitored tropical forests with a one-hectare (2½-acre) sampling plot. While the one-hectare plot may be appropriate for assessing the diversity and dynamics of the relatively species-poor forests of the temperate zone, it is not an adequate basis to measure the diversity and dynamics of the species-rich forests of the tropics.

The results generated by the first 50-hectare (125-acre) tree plot attracted international attention in tropical biology and forestry communities. As institutions began to recognize the value of this new research method, a movement grew to establish large-scale plots—called forest dynamics plots—throughout Asia, Africa and Latin America. The study of forest dynamics in the plots aims at understanding how forests change over time.

The Center for Tropical Forest Science was created within the Smithsonian Tropical Research Institute in 1990 as an umbrella organization to aid the establishment and standardization of forest dynamics plots. The center represents a voluntary consortium of forestry agencies, universities, research institutes and nongovernmental organizations around the world, each managing or involved in one or more forest dynamics plot programs.

Today, the Center for Tropical Forest Science encompasses 17 forest dynamics plots in 14 different countries and involves some three dozen partner organizations within the host nations and around the world. In addition to monitoring the trees, the center sponsors training programs, scientific meetings, exchanges between sites and a newsletter and Internet communication.

Ironically, the Center for Tropical Forest Science began in a place where human intervention literally changed the landscape. The first forest dynamics plot was established on STRI's main research site—on a hilltop that became an island when the Panama Canal was created. The program has grown into a worldwide network of sites where scientists study how best to manage the environmental impact of other advances in civilization. Through the patience, diligence and perseverance of the center's researchers, the rain forests gradually are lifting their shrouds of secrecy, for their own sake and ours.

"Our mission," says Elizabeth Losos, director of the center, "is to coordinate and promote long-term research in the natural and social sciences, based on standardized data collected in the forest dynamics plots.

Robin Foster, right, formerly a scientist at the Smithsonian Tropical Research Institute, and two fieldworkers conduct tree censuses.

In addition, we want to translate these findings into information useful in forest conservation and management."

The center's forest dynamics plots are unique because of their large size and intensive tree sampling protocol. Plots are typically 50 hectares (125 acres) but can range from 16 to 52 hectares (37 to 128 acres), depending largely on the species diversity of the forest.

During a plot census, every tree larger than one centimeter (four-tenths of an inch) in diameter is marked, measured, plotted on a map and identified according to species. Approximately every five years, each tree is measured again; dead trees are noted; and young ones are added to the plots' database. As many as 360,000 trees are monitored in a single plot.

The research methodology used in each forest dynamics plot is the same, and plot sites are selected on the basis of geological and environmental characteristics shared with other plots. Thus, scientists can compare directly the data gathered at different locations and investigate the similarities and differences of the world's tropical forests.

Because the plots track the fate of every tree, from small saplings to large adults, they are a highly sensitive global monitor of tropical forest dynamics and species diversity. The knowledge derived from this research can be used to distinguish natural forest variation from human-induced changes. For example, data from forest dynamics plots can help determine how climate change, land conversion and timber extraction affect forest integrity, contributing to better tropical forest management and conservation.

In the tropics, where the vast majority of species are rare, the large size of forest dynamics plots is critical for studying populations of individual species. The plots typically produce enough data to conduct statistically rigorous analysis of tree life histories for more than half of the species in a plot. Demographic studies on germination, growth, death and other life-history traits are crucial to understanding how entire tropical forest communities are assembled. Species-specific demographic information can also be utilized to estimate sustainable timber harvesting levels and to select tree species that grow quickly for reforestation projects.

The forest dynamics plots also provide the center's researchers with ideal venues in which to study tropical tree diversity. The center's network monitors more than 2.5 million trees representing about 5,500 species—almost 10 percent of all known tree species in the tropics.

"On top of that, every year, scientists working in the Center for Tropical Forest Science's network discover new tree species in the tropics," Losos says. "Each new species holds untold potential as a new medicine, food, fuel or other resource."

In addition, the long-term data collected from the forest dynamics plots allow researchers to witness unusual occurrences, such as fires, typhoons, hurricanes and El Niño/La Niña events.

"In Puerto Rico," Losos notes, "we were able to look at the structure and composition of the forest both before and after hurricanes Hugo and George. From the information we collected, we can analyze how storms affect the forest and better predict how the forest will react to this kind of stress.

The data collected from these forest dynamics plots is a powerful tool, Losos adds. "It gives us insight into what factors limit the abundance and distribution of individual species and, more broadly, what determines the diversity level in a tropical forest." Using plot data, researchers are comparing a range of hypotheses on how diversity is maintained.

Scientists affiliated with the Center for Tropical Forest Science also are investigating the extent to which species population size is regulated by the density of both its own and other species. Forest dynamics plots in Panama, India and the peninsula of Malaysia have provided the most thorough evaluations yet of how tree density regulates species populations in tropical tree communities. To date, findings strongly suggest that pathogens are responsible for keeping some species population densities below certain levels.

A worker takes a topographic survey of a forest dynamics plot in the Democratic Republic of Congo. (Photo by John Hart)

The success of tropical forest conservation and management strategies often relies on understanding how forest biology interacts with economics. To that end, the Center for Tropical Forest Science's natural and social scientists are incorporating biological information from the forest dynamics plots into economic theory and analysis and can now quantify the role that tropical forests play in some economic and social systems.

For example, by helping decision-makers balance the environmental and financial tradeoffs between carbon storage, timber profits and biodiversity, the Center for Tropical Forest Science promotes improved conservation and management policy based on sound economics and biology.

Forest dynamics plots also play an important role in shedding light on the complex interactions between plants and animals in the tropics. Many animals, from insects to mammals, depend on plants to provide almost all of their necessary life requirements. In turn, rain-forest plants often depend on animals to pollinate flowers, disseminate seeds and nurture growth.

Surveys of animal species abundance can be coupled with forest dynamics plot tree species distributions to determine the habitat requirements of different animals or the associations between plants and herbivores. Knowledge of such relationships can be critical when determining what type of habitat to preserve in order to maintain wildlife populations.

"The fieldwork we do in the forests is relatively simple in technological terms," Losos says. "It doesn't require a lot of elaborate equipment or sophisticated methodology. Yet, our research is providing the whole world with the understanding we need to achieve the best possible balance among people, plants, animals and the forces of nature in our tropical forests—today and for generations to come." ■

Archivists compile authoritative list of aircraft models, designs and makers

By Jo Ann Webb
Smithsonian Office of Public Affairs

What began as a simple filing project at the National Air and Space Museum has resulted in the first-ever aircraft authority list, which cites every aircraft manufactured or designed in the world—thanks to an ambitious undertaking by Dana Bell, his staff and a dedicated group of volunteers.

When Bell, an archivist in the National Air and Space Museum's Archives Division, joined the museum staff in 1981, he immediately recognized the need to clean up the files and organize them in some kind of logical system. There were 130 large file cabinets, he says, jammed with everything from biography files that contained information on people who had played significant roles in the history of aviation to news clippings on space history.

"Material was getting damaged," Bell adds, "because everything was just crammed into acidic folders." The team began by reorganizing the biographical, space history and propulsion files, which were in such disarray that researchers were having a difficult time finding information. Bell saved the aviation files for last, because they were semi-organized and somewhat usable. "Unlike the other files," he says, "the aviation files were reasonably serviceable for researchers."

Within a week of starting the aviation project in 1993, Bell says, "We realized that we were on to something special. There was nothing out there, to my knowledge, that provided this type of concise information on aircraft design and manufacturing."

With the support of the Archives' chief, Thomas Soapes, Bell, along with Archives staffers Allan Janus and Paul Silbermann and a team of volunteers, delved into the project. Six years later, the files have been reorganized and a draft of the aircraft authority list has been made available to aviation scholars in museums throughout the world. The publication, Bell says, will be important to researchers, historians, authors and historical societies, as well as to aviation and space museums.

The listing covers all types of piloted aircraft, including airplanes, gliders, hang gliders, helicopters and autogiros, which are rotorcraft with unpowered rotors. The names, nicknames and code names of these aircraft are indexed. Space vehicles, unpiloted aircraft and balloons are excluded from the listing.

Bell is quick to admit, however, that the published draft is just the beginning. "We want to have other aviation experts read and correct it," he adds. "We know that we have missed some things and misunderstood others. The more people who participate in this project, the more complete and accurate the listing will be."

In conducting research for the book, Bell and his project team began first with information they had on hand in the museum. "We have a treasure trove of knowledge here at the National Air and Space Museum," he says, "which grows from the printed materials in our own archives and library, as well as from the scholars on our staff."

From left, Dana Bell, Paul Silbermann and Allan Janus, who, along with a team of museum volunteers, worked on compiling the first aircraft authority list. (Photo by Carolyn Russo)

For example, Bell says, Daniel Hagedorn, also an archivist in the museum, is building a listing of all U.S. aircraft built and registered in the U.S. Civil Register between 1927 and 1946. "Obviously," Bell says, "the listing helped with documentation of American-owned aircraft. Aside from Dan's project, everyone on the Archives staff and most of the museum's curators have contributed to our success with the project."

The Archives files contained aviation companies' reports, press releases, catalogs and histories. While these files contained a wealth of knowledge, the documents sometimes were conflicting, "especially material on early French aircraft. The same plane may have been called several names at different times, often within the same document," Bell explains.

When information conflicted, the research team looked for commonalties among aircraft, in general, during that period. They researched what other companies in both the United States and abroad were calling similar aircraft.

"In some cases," Bell says, "we'd get lucky, and the company would still be in business. We'd simply call them up and ask for a complete designation system for the aircraft they designed or built."

Because of the nature of aviation history, Bell adds, they often knew about other people who were researching the history of various aviation companies. Thus, the project team was able to draw on their information for clarifications as well.

The team also conferred with many sources outside the museum and researched collections at the National Archives in College Park, Md.

Several stumbling blocks hindered the project, Bell says. For example, prior to World War I, many early designers did not name their aircraft. "It was often enough just to build something and to get it to fly. 'My aeroplane' would suffice for a name. After a second aircraft was built, the first one could become 'last year's aeroplane' or 'aeroplane number 1.' There was no taxonomy, no consistency. We've been looking for whatever names were used, or writing our own descriptions—such as 'Smith 1907 Monoplane'—to document everything we found.

"Until recently," Bell continues, "we found French aircraft, in particular, to be difficult to document. Early French designers were prolific, and many of their designs were poorly documented in this country."

There was the language barrier as well in documenting foreign aircraft, Bell notes. Many early writers didn't recognize a difference between French manufacturers. One example of this is the French manufacturers Liore and Loire. Some writers, he says, just assumed that these were the same company and used the names interchangeably.

In another instance, Bell adds, American intelligence experts wrote about the prolific Russian design firm Samolot and the new Italian company named Velivolo. Both words meant "airplane," and there were no companies with these names.

But most aircraft have markings, which made the manufacturer easier to identify, says Bell, whose specialty is aviation markings and colors. "Every drop of paint on an airplane is there for a reason," he explains. "It tells stories." Bell is the author of 17 books about aircraft colors and markings.

"Once you learn the history of color and markings," he continues, "knowing the aircraft and its manufacturer are easy. No two planes have the same color and markings." Bell's knowledge helped save the research team a great deal of time.

Another difficult aspect of the project was devising a set of guidelines for crediting the manufacturer and the designer. For example, Bell explains, if a company were overtaken by another, the new company would take credit for manufacturing the aircraft when, in fact, design and production began with the old company. In each case, the team tried to determine which company was most accurately, or perhaps most commonly, recognized as responsible for the aircraft.

For example, when Douglas merged with McDonnell in the 1960s, the Douglas DC-9 remained in production, Bell says. Although new aircraft continued to be registered with the Federal Aviation Administration as DC-9s, company literature began referring to them as "MD" (McDonnell Douglas) designations. Later versions of the aircraft were consistently assigned "MD" designations until the company was bought by Boeing, which has assigned the "717" designation to the latest versions. Boeing had used the "717" designation for two other aircraft, Bell says. "We've been trying to recognize and document these confusing designations and minimize confusion for our researchers."

Bell admits that once the authority list was completed, he was somewhat nervous, but hopefully optimistic about how museum scholars and other researchers would accept it. "It's hard to get two people to agree on what you call an airplane," he says. "People can be very contentious about it. We wanted our listing to be seen as a set of conventions, not hard and fast rules for all researchers. In some cases, we're talking about when a hyphen should be used."

It's not enough to identify an aircraft, Bell explains. "We have to find the correct syntax of any designation." In the United States, for example, the F-4D and the F4D are two completely unrelated aircraft. In Germany, the Junkers J1 and the Junkers J.I are two different designs. "With more and more computer searches performed every day," he says, "inconsistent syntax limits the ability of our researchers to connect with our materials."

To see how receptive scholars would be to the project, Bell presented a draft of the listing at the recent "Mutual Concerns of Air and Space Museums" annual seminar. "Our presentation took place right before lunch, when most participants were looking forward to the break. But the response was wonderful, confirming that we were on the right path. Something that we had first conceived for internal use was filling a need for the entire aviation community.

"Our original goal in preparing the authority list," Bell adds, "was to find some consistency for organizing, filing and listing our aviation documents. This would ensure that researchers could find all of our materials related to any subject. We now know that many other museums, researchers and writers have been looking for the same consistency. We're not making rules for everyone to follow, but we are presenting a well-researched set of conventions and explanations about the choices we've made. Many will adopt our authorities outright, others will modify them, but all should find them useful."

Bell hopes to have the book published in 2003—the 100th anniversary of the Wright brothers' first powered flight. Comments from the draft are already trickling in. Questions and comments can be sent to the research team at the e-mail address www.reference.desk@nasm.si.edu. ■

Researcher drawn to intersection of technology and the environment

By Michael Lipske
Special to Research Reports

There's a kind of tension that interests Jeffrey Stine. In fact, his research as a historian looks at the conflict and compromise that occur at "the intersection of technology and environment."

Curator of engineering and environmental history at the National Museum of American History, Stine is the first Smithsonian scholar to study how modern environmental values have influenced the work of engineers building massive, often controversial projects, such as oil pipelines and inland waterways.

While the museum has a tradition of scholarship on the history of engineering, most of that work has examined events of the 19th and early 20th centuries. Stine focuses on our own era—the decades after World War II, when burgeoning environmental values, especially as they have been translated by government into laws and regulations, have played an increasing role in public decisions about the proper uses of technology.

You might think of Stine's field as the study of how society's software (cultural values like environmental protection) shapes its hardware (construction projects like dams and highways).

For example, a recent National Museum of American History exhibition that Stine co-curated told the story of one of the great engineering feats of the 1970s—the building of the Trans-Alaska Pipeline. The 800-mile-long pipe carried Prudhoe Bay oil across mountain ranges, earthquake zones and vast expanses of permafrost.

The pipeline pitted America's need for energy against its desire to conserve land and wildlife. Engineers originally wanted to bury the pipeline along most of its route. But the project's startup coincided with passage of national legislation requiring an environmental impact report for such construction. Contending that the pipeline report was inadequate, conservation groups sued.

"That stopped the project for four years," Stine says. "In that time, this concern for minimizing environmental impact caused the engineers to reassess the project." Research on the potentially harmful effects of burying in unstable permafrost a pipeline that contained naturally warm crude oil led to a major redesign. Half the pipeline ended up being supported above ground on stilts, which included a passive refrigeration system to ensure that the oil's warmth would not melt permafrost and thus cause shifts in the ground that could rupture the pipeline. The project's delay also led to other engineering refinements to safeguard the environment.

Environmentalists hoped to prevent the pipeline from being built at all, and many pipeline opponents still felt they had failed. "But in fact," Stine says, "they pushed substantial design changes and made a project that could have been environmentally disastrous far less so."

The same tension between technology and society led Stine to study the complex history of another mega-project. One of the most expensive public works of the last quarter century, the Tennessee-Tombigbee Waterway is an inland navigation project that stretches across 234 miles of Alabama and Mississippi. First dreamed of in the 18th century, it links the Tennessee River to the Gulf of Mexico. To build the waterway's miles of canal, five dams and 10 locks, men and machines moved more earth than was required to dig the Panama Canal. That was just the engineering challenge.

Construction of the waterway became a lightning rod for the American environmental movement; opponents labeled it an environmental disaster, as well as a financial boondoggle, and twice stopped it in court. Nevertheless, the project's supporters overcame opposition, and the waterway was completed in the mid-1980s for $2 billion.

Jeffrey Stine is the first Smithsonian scholar to study how modern environmental values have affected the work of engineers building massive, often controversial, projects. (Jeff Tinsley photo)

To avoid damaging areas of unstable permafrost, nearly 420 miles of the 800-mile-long Trans-Alaska Pipeline were built above ground. (Photo courtesy of the Alyeska Pipeline Service Co.)

As with the Trans-Alaska Pipeline, opponents of the Tennessee-Tombigbee Waterway felt they had failed. But Stine, whose award-winning book *Mixing the Waters: Environment, Politics and the Building of the Tennessee-Tombigbee Waterway* was published in 1993, says that environmentalists succeeded in some ways. Their opposition led to the use of less damaging dredging and construction methods by the U.S. Army Corps of Engineers, which built the waterway.

Environmentalists also succeeded in increasing public involvement in planning for future projects and tightened rules for the economic justification of Corps endeavors. To Stine, the project "shows how changing values result in changes in the law and the behavior of government agencies."

Stine also has conducted research on how American attitudes have changed toward wetlands. Marshes, bogs, swamps and other soggy acreage were once seen as "even worse than wastelands," Stine says. Wetlands not only impeded travel and the growth of towns but also "were the source of disease and places where criminals hid."

Modern ecological studies have proven wetlands to be highly beneficial. Now, the "wastelands" of old are prized for easing flood damage, purifying drinking water and providing habitat for wildlife. In a forthcoming publication for the Forest History Society, Stine will examine how this benign view of wetlands put forth by scientists has gradually "bled into the rest of society."

Stine believes in the value of what he calls "multidisciplinary interplay," whether among scholars laboring in different subfields of history or between scientists who study the natural world and the engineers who reshape it. As an example of the second kind of interplay, he mentions a lasting lesson from the Trans-Alaska Pipeline.

A major, unforeseen impact of the project resulted from the pipeline's service road. Intended for the pipeline's builders and operators, the road made it easier for people in automobiles to visit the Alaskan countryside, sometimes with unfortunate consequences for the environment. "It let more people in, and that impact has been enormous," Stine says.

Twenty years after the pipeline was built, Smithsonian scientists consulting with companies drilling for natural gas in the Peruvian Amazon have argued against similar new road construction in the jungle, and they have persuaded the companies to bring in supplies by helicopter. "It costs more," Stine says, but it lessens the potential long-term damage to tropical forest.

It also is a hopeful example of how technology can incorporate society's best values, even as engineers continue to make use of the natural world to serve human needs. ■

Student photographer Lindsey Doney snapped this photograph of students enjoying a leisure moment. Doney is one of 13 students participating in a photo documentation project.

'Youth,' continued from Page 2

ual cameras, says that, while the team has some expectations of what it wants to see, "in the end, it is the students who will tell us how they want to be documented and represented. Everything that they photograph will be important to them in their world."

Photography, Horse Capture believes, will entice students to look at the world around them and draw attention to things in their everyday lives that they have probably ignored. By being more aware, he says, it will expand their range of perspectives.

The project has several goals. "We want to provide the kids with training in photographic documentation, a skill that will continue to be applicable in their lives after the project is implemented," Horse Capture explains. In addition, the project will give an introduction to museum practice—research and exhibition development—while fulfilling the museum's mandate of encouraging contemporary artistic expression. It also will allow the museum to obtain contemporary images for its photographic archives.

"Because of their limited world on the reservation," Horse Capture says, "there aren't a lot of opportunities. I wanted to introduce them to photography as a means of preserving their culture and expressing their identities."

The project was woven into the social studies curriculum at Hays-Lodgepole High School. Students were taught about their tribal history and culture, the components of a reservation, the local environment and other relevant topics. By the time Horse Capture; Susan Secakuku, program specialist; and Fogden gave the students cameras and film, they were eager to begin taking pictures. Photojournalist Kenny Blackbird, who was born on the reservation but now works three hours away at a newspaper, also met with students to teach the basics of photographic documentation.

Students were given a list of about 20 suggestions as topics of interest, but there were no set guidelines. "Because their direction was so general, we have to respect what comes back," Secakuku says. "Whatever it is, it's what they feel represents who they are."

"At first, they were all taking pictures of themselves," Horse Capture interjects, "but as the class progressed, they began trying different techniques." After pictures were taken, Secakuku would drive the 160 miles round trip to the nearest photo processing center. When the photos came back, Blackbird and the group would critique them.

"When Blackbird praised the quality of a photograph," Horse Capture says, "you should have seen the face of the kid who had taken the picture. So aside from the technical aspects of the project, we're building self-esteem as well."

The project is ongoing, even though the project team is back at the National Museum of the American Indian's Cultural Resources Center in Silver Hill, Md. At the school, supplies and equipment are being managed by social studies teacher Pierre Sirois. Once students take pictures, their film is sent back to the Resources Center for processing. "This helps us see what the students are taking and how story lines are developing," Horse Capture says. "In the end, a total of about 40 images will be used for an exhibition at their school. The images selected will eventually be used in a museum exhibition."

Because the students have not been given strict guidelines for documenting their culture, the project team looks forward to developing story lines for the exhibition. Depending on the quality of the students' photographs, the team hopes that it also will be able to publish a book of the images.

The team would like to see this project become a pilot for other reservation schools. "We have already begun discussing among ourselves the possibility of exchange programs with other reservation schools that have done some photographic documentation," Secakuku says.

The National Museum of the American Indian supported a similar project on the Hopi reservation in Arizona last summer. The project was structured through youth programs of two Hopi villages. The resulting exhibition, "Real Village Kids: Photographs by Hopi Youth," opened at the Hopi Cultural Center in Second Mesa, Ariz., in October. Secakuku, who grew up on the Hopi reservation, was project coordinator and curator.

Fogden hopes that projects such as these will help students begin looking "outward" to the world around them. "It is my hope," she says, "that one student who had no intention of getting further education will change his or her mind and pursue a professional career, such as photography, and then find a way to bring those skills back to the community."

Funding for "Images and Identity" was provided by the Smithsonian Women's Committee. ■

RESEARCH HIGHLIGHTS

Largest donation ever. The National Air and Space Museum has received a $60 million pledge from Steven Udvar-Hazy, a Hungarian American businessman. It is the largest individual donation in the history of the Smithsonian. His donation will go toward a $130 million capital campaign to build the museum's Dulles Center at Washington Dulles International Airport in Virginia. Upon completion in 2003, the center will be four times the size of the Mall museum. It will be home to hundreds of airplanes and spacecraft that cannot be displayed in the Mall museum because there is not enough room. The center will have an archive and resource center for scholars and the public, educational facilities for school groups, a large-format theater, museum shops and restaurants. Udvar-Hazy, a jet pilot, is head of the world's largest aircraft leasing company, International Lease Finance Corp., based in Los Angeles.

Museum groundbreaking. A groundbreaking ceremony on Sept. 28 marked the start of construction of the dramatically designed 250,000-square-foot National Museum of the American Indian that will occupy the last site on the National Mall. Situated between the U.S. Capitol and the National Air and Space Museum, the new Mall museum will represent the contemporary and traditional stories of the native peoples of the Western Hemisphere from their own perspectives. The museum will open to the public in late 2002.

Marine field station in Belize. Smithsonian research into the biological richness of the coral reefs and mangrove swamps of Belize has resumed with the Aug. 27 rededication of the National Museum of Natural History's marine field station on Carrie Bow Cay. The new 2,400-square-foot, two-story facility replaces the structures destroyed by a fire in 1997. For 25 years, these structures had served as a laboratory and living quarters for an international team of scientists. Construction of the new building began in September 1998 but was interrupted when Hurricane Mitch caused flooding and erosion on the cay. The area is ideal for researchers because it is highly diverse in habitat types and plant and animal species. Over the last 25 years, the field station had earned its rank among the top three reef-based laboratories in the world.

X-ray observatory. The Chandra X-ray Observatory, carrying a high-resolution camera built by the Smithsonian Astrophysical Observatory, was successfully launched aboard the Space Shuttle Columbia on July 23. With a resolution some 50 times higher than any previous X-ray telescope, Chandra is expected to obtain unprecedented images of a host of objects, ranging from comets in our own solar system to quasars at the very edge of the observable universe. It has already transmitted crystal clear images of an exploding star and an X-ray jet streaming some 200,000 light-years into intergalactic space from a distant quasar. During its five-year mission, Chandra's scientific program will be coordinated from a control center in Cambridge, Mass., operated by SAO for the National Aeronautics and Space Administration.

Panama Canal environmental study. After three years, a team of 33 researchers led by the Smithsonian Tropical Research Institute in Panama completed the final report of the Panama Canal Watershed Monitoring Project, which focuses on the environmental health of the canal. The seven-volume report, in Spanish and English, contains the results on the current condition of the forest cover, water, soils, fauna and human populations in the Panama Canal watershed. The project, which began in 1996, is a collaboration among STRI, the U.S. Agency for International Development and Panama's National Environmental Agency. For more information, send e-mail requests to Robert Ibanez, project director, at ibanezr@tivoli.si.edu.

Spencer Baird Society. Smithsonian Institution Libraries recently established the Spencer Baird Society, its premier donor recognition organization. Named for the Smithsonian's second Secretary, the society recognizes those who provide significant philanthropic support for the Libraries' top-priority projects, which may include acquiring unusual or especially important rare books, purchasing new equipment to support digitizing the collections or conservation of rare but fragile volumes. There are three levels of membership: Benefactor ($2,000 per year), Patron ($1,000 per year) and Associate ($500 per year). For addi-

'Highlights,' continued on Page 7

The rebuilt field station on Carrie Bow Cay in Belize (Photo by Don Hurlbert)

Secretary Designate Lawrence M. Small (Photo by Richard Strauss)

'Highlights' continued from Page 6

tional information on membership, call Gwen Leighty at (202) 786-2875, or send e-mail requests to gleighty@sil.si.edu.

New Secretary. The Smithsonian Institution Board of Regents announced on Sept. 13 that Lawrence M. Small, 58, has been elected as the 11th Secretary of the Smithsonian, after a seven-month search. He is currently president and chief operating officer of Fannie Mae, which is the nation's largest investor in home mortgages and operates under a congressional charter. He will succeed I. Michael Heyman, who became Secretary in September 1994 and who will retire in December. Small will assume the office in January 2000. No stranger to the cultural world, Small has served on numerous boards of educational, artistic and museum organizations.

SERIES PUBLICATIONS

The following publications on research in various fields were issued during the period May 1 through July 31, 1999, by Smithsonian Institution Press in the regular Smithsonian series. Diane Tyler is managing editor. Requests for series publications should be addressed to Smithsonian Institution Press, Series Division, 470 L'Enfant Plaza, Suite 7100, Washington, D.C. 20560-0950.

Smithsonian Contributions to Anthropology

• 42 *The Ossuary of San Francisco Church, Quito, Ecuador: Human Skeletal Biology*, by Douglas H. Ubelaker and Catherine E. Ripley, 32 pages, 10 figures, 19 tables.

Smithsonian Contributions to Zoology

• 603 *Biodiversity of Domatia Occupants (Ants, Wasps, Bees and Others) of the Sri Lankan Myrmecophyte* Humboldtia laurifolia *Vahl (Fabaceae)*, by Karl V. Krombein, Beth B. Norden, Melinda M. Rickson and Fred R. Rickson, 34 pages, 70 figures, 1 table.

BOOKS & RECORDINGS

Biology of Marine Mammals, edited by John E. Reynolds III and Sentiel A. Rommel (Smithsonian Institution Press, 1999, $75). Taking an integrated approach to the biology of marine carnivores, cetaceans and sirenians, 22 prominent researchers compare marine mammals with one another and with terrestrial mammals, providing a framework for fundamental biological and ecological concepts.

Conservation and Management of Marine Mammals, edited by John R. Twiss Jr. and Randall R. Reeves (Smithsonian Institution Press, 1999, $60). Emphasizing the diverse issues surrounding the conservation of marine mammals, 31 marine biologists and conservationists review the history, current status and future implications of marine mammal legislation; the concept of ecosystem management; interactions of marine mammals with fisheries; and the contemporary whaling debate.

Tupperware: The Promise of Plastic in 1950s America, by Alison J. Clarke (Smithsonian Institution Press, 1999, $24.95). Tracing the fortunes of Earl S. Tupper's polyethylene containers—from early design to global distribution—the author explains how Tupperware tapped into potent commercial and social forces, becoming a prevailing symbol of late 20th-century consumer culture.

Slacks and Calluses: Our Summer in a Bomber Factory, by Constance Bowman, with illustrations by Clara Marie Allen (Smithsonian Institution Press, 1999, $14.95). First published in 1944 and illustrated with humorous drawings, the book is an account of how two young, spirited female teachers spent their summer vacations working the swing shift on a B-24 production line at a San Diego bomber plant and how they coped with traditional attitudes they encountered along the way.

Aiming for the Stars: The Dreamers and Doers of the Space Age, by Tom D. Crouch (Smithsonian Institution Press, 1999, $29.95). This book explores the motivation, goals, trials and triumphs of the generations of men and women who pioneered "the fearful void" of space.

Russia's Air Power in Crisis, by Benjamin S. Lambeth (Smithsonian Institution Press, 1999, $29.95). Focusing mainly on fighter aviation and drawing on more than two decades of research, the author shows how military air power in Russia has steadily withered since the breakup of the Soviet Union in 1991.

Devil Sickness and Devil Songs: Tohono O'odham Poetics, by David L. Kozak and David I. Lopez (Smithsonian Institution Press, 1999, $45). The authors discuss the O'odham beliefs in devils and anaylze 39 of their devil songs.

Conceiving Spirits: Birth Rituals and Contested Identities Among Laujé of Indonesia, by Jennifer W. Nourse (Smithsonian Institution Press, 1999, $45 cloth; $19.95 paper). For most Laujé of Central Sulawesi, Indonesia, birth spirits are of primary importance. The author describes how Laujé from both modernized coastal and isolated highland villages attribute competing meanings to birth spirits, which hinge on an individual's gender, social class and religion.

Beyond the Prado: Museums and Identity in Democratic Spain, by Selma Reuben Holo (Smithsonian Institution Press, 1999, $39.95). When Spain's dictator Francisco Franco died in 1975, the transitional government set out to create a democracy that celebrated rather than repressed cultural diversity. The author argues that Spanish state and regional leaders consciously used the power of museums to foster democratic identity in the country's citizens.

Northumberland Rant: Traditional Music From the Edge of New England (Smithsonian Folkways Recordings, 1999, $14 CD). Virtuoso musicians from England's northeasternmost county, located in the borderlands between England and Celtic traditions, perform on small bellows-blown bagpipes with a distinctively sparkling sound.

Choose Your Partners: Contra Dance and Square Dance Music of New Hampshire (Smithsonian Folkways Recordings, 1999, $14 CD). A collection of dance tunes played by six New Hampshire groups, this compact disc includes a unique blend of seasoned and young musicians and callers.

This image of folksinger Ella Jenkins, right, and Pete Seeger, taken during a performance at a Smithsonian event, is featured on the back cover of the compact disc "Ella Jenkins and a Union of Friends Pulling Together." (Photo by Jeff Tinsley)

Saints' Paradise: Trombone Shout Bands (Smithsonian Folkways Recordings, 1999, $14 CD). Beyond jazz or gospel as most know these music forms, this compact disc presents a historic anthology of the legendary United House of Prayer for All People's powerful trombone shout bands.

Blues Routes: Heroes and Tricksters, Blues and Jazz, Worksongs and Street Music (Smithsonian Folkways Recordings, 1999, $14 CD). This compact disc is a resonant almanac of blues and blues-related music performed live by master musicians during a series of concerts in the 1990s.

Ella Jenkins and a Union of Friends Pulling Together (Smithsonian Folkways Recordings, 1999, $14 CD; $8.50 cassette). This compact disc introduces the ideas of unity and cooperation through songs, recitation and poetry.

Books published by Smithsonian Institution Press can be ordered from P.O. Box 960, Herndon, Va. 20172-0960. To order by phone or for more information, call 1 (800) 782-4612. There is a $3.50 postage and handling fee for the first book ordered and $1 for each additional book.

Smithsonian Folkways Recordings can be ordered by writing to Smithsonian Folkways Mail Order, 955 L'Enfant Plaza, Suite 7300, Washington, D.C. 20560-0953. To order by phone or for more information, call (202) 287-7297 or 1 (800) 410-9815. There is a $4 fee for shipping and handling of the first three recordings ordered; call for other shipping prices.

Correction

The Summer issue of Research Reports should have referred to the giant squid, which lurks in oceans around the world and has never been seen in its natural habitat or captured on film, as elusive, not illusive.

Off the Shelf

Piano Roles: Three Hundred Years of Life With the Piano

(Published by Yale University Press, 2000, $35)

The piano, according to Noah Adams of National Public Radio, is an instrument of dreams made from wood and ivory and brass and iron and copper and steel and felt. "It is a gift to us from craftsmen and artists of many generations, many countries."

Three hundred years after its invention, what difference has the piano made to the people who have listened to it, played it and lived with its sounds? *Piano Roles: Three Hundred Years of Life With the Piano* examines these questions through essays by James Parakilas, a professor of music and chair of the Humanities Division at Bates College in New England, and 15 contributors. The book, which is slated for release to the public in February 2000, presents a cultural history of the piano. It describes the roles that the piano has played since its invention by Bartolomeo Cristofori around 1700.

Highly illustrated, *Piano Roles* is a lively, up-to-date history of the piano, which examines both its evolution in classical and popular musical cultures around the world and its ever-changing social roles over the last three centuries. Even today, this old instrument has given new "voices" to jazz, avant-garde and popular music.

Parakilas and his colleagues have struck a canny balance between scholarly rigor and popular appeal, with chapters alternating between straightforward historical surveys and informal essays.

At the time of its invention, the piano was already valued for its uncanny ability to imitate the sounds of a stringed instrument, a voice and an entire orchestra. Since then, this ability to duplicate other sounds has made possible the creation of the piano's astonishingly varied repertoire and has helped composers to compose and performers to rehearse. In addition, this same instrument has allowed amateurs to "take" the music they wanted to hear from the concert hall into their own homes.

The piano became the subject of endless innovations in design, manufacturing and marketing. Originally the plaything of European aristocrats, it became a companion to people of all classes, and the forces of Western imperialism brought it into contact and conflict with musical cultures around the world. Songs, stories, paintings and movies—all represented in *Piano Roles*—reflected and promoted the growing roles of the piano in people's lives.

Cynthia Hoover, curator of musical instruments at the Smithsonian's National Museum of American History, contributed to the chapter "Designing, Making and Selling Pianos"—topics she has studied using the Smithsonian's piano collection as primary material.

"I've always been impressed with how the piano, 'born' in the Medici court in Florence, Italy, became available to the working class by the end of the 19th century," Hoover says. "The successful mass production of inexpensive pianos sold by traveling salesmen or through mail-order catalogs can be traced to an American, Joseph Hale, who, in the 1870s and 1880s, assembled pianos from ready-made parts and sent them to new markets, especially in the American West.

"In his forthright manner," she continues, "Hale accused the established makers of charging extravagant prices for pianos with a fashionable name. He, on the other hand, wanted to offer to the 'middle and industrial classes a good instrument at a cheap rate,' causing a democratic revolution that would 'make a piano as easily procured as a cooking stove or a sewing machine.' "

Other similar companies emerged in many countries, making pianos available to almost every household, she adds. It became the instrument, the product, around which the modern entertainment industry was created.

To celebrate the 300th anniversary of the piano, the National Museum of American History is organizing an exhibition titled "Piano 300." The exhibition, slated to open in March 2000 in the Smithsonian's International Gallery, will display 19 pianos from the museum's internationally distinguished collection of some 250 keyboard instruments. Tools, photographs, sheet music and memorabilia will provide a comprehensive look at this invention and its influence on cultures throughout the world.

Performances, publications and workshops also will complement the exhibition. Smithsonian Productions will join Maryland Public Television and other partners in producing two programs: a performance gala and a documentary on the piano.

—Jo Ann Webb

This painting (detail), "The Sun Treader (Portrait of Carl Ruggles)," 1934, by Thomas Hart Benton is named for Ruggles' orchestral masterpiece and portrays a composer using the piano to search for new sounds. It is featured in the book Piano Roles: Three Hundred Years of Life With the Piano. *(Courtesy of the Nelson-Atkins Museum of Art, Kansas City, Mo. Gift of the Friends of Art. © T.H. Benton and R.P. Benton Testamentary Trusts/Licensed by VAGA, New York, N.Y.)*

This fall, all Donor Level and above Contributing Members will receive Piano Roles *as a benefit of membership. For those other than Contributing Members, the book will not be available for sale until February 2000. To order at that time, write to Yale University Press, P.O. Box 209040, New Haven, Conn. 06520, or call 1 (800) 987-7323.*

SMITHSONIAN INSTITUTION
Washington DC 20560-0033
Official Business
Penalty for Private Use $300

Bulk Rate
Postage & Fees Paid
Smithsonian Institution
G-94

Smithsonian Institution **Research Reports**

No. 98 Autumn 1999