Smithsonian Institution

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Testimony of Dr. Eva J. Pell
Under Secretary for Science, Smithsonian Institution
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Thank you for the opportunity to testify and share information on the scientific research of the Smithsonian. As you know, the statutory mission of the Smithsonian is "the increase and diffusion of knowledge." Our research activities are the fulfillment of the first part of this mandate. From observations of the early universe to recent discovery of the olinguito, the Smithsonian is engaged in fundamental research about the constituent parts of our planet and universe and how they fit together. The research has developed new exciting cross-disciplinary and collaborative approaches to discovery in order to respond to the great challenges of our time. We are thankful to the Congress for its support.

The Smithsonian helps shape the future by preserving our heritage, discovering new knowledge, and sharing resources with the world. Our expertise is expansive as we work in disciplines that focus on sciences, biological and physical, that explain all facets of natural history; and in scientific and engineering disciplines needed for a comprehensive astrophysics program. We then use this research for the other half of our mandate—to inspire and educate children and families through engaging exhibitions both in our museums and online. We train and develop scholars at every level of their study, whether they visit the Smithsonian for a one-day field trip, a semester internship or extended post-doctorate research. And through premiere educational resources and lesson plans set to state standards in use by teachers across the country, we enhance the scientific literacy in America and beyond.

While some research institutions work in fields similar to those of the Smithsonian, we fulfill our mission in a way that is complementary to federal agencies and universities with which we partner. The federal appropriation we receive has allowed us to approach research from a long-term perspective. We can establish observatories that allow data collection for many decades; and from those studies come continually growing collections for use by scientists and citizens nationally and throughout the world.

Our scientific research complements but does not duplicate that of our partner federal agencies like U.S. Departments of Agriculture, Interior, Commerce, and Defense, all of which have staff in residence at our facilities; or our contracted partners such as the United States Navy, United States Air Force, Federal Aviation Administration (FAA), Environmental Protection Agency (EPA), and the Bureau of Ocean Energy Management (BOEM), for whom we develop the national collections

and shared expertise to enhance the quality and impact of federally-funded science for natural resource management. Our exceptional scientific staff collaborates regularly with research universities in the U.S. and beyond as faculty benefit from participation in our long-term research studies and we enjoy the complementary expertise these scientists bring to our programs.

Whether we are looking closely at the Earth to detail the impact of an invasive species on an ecosystem, or if we are looking back on the Earth to measure atmospheric pollution from space, the Smithsonian is steadily evolving, learning and sharing. We provide an interface that connects students and scholars, citizens and scientists, decision makers and the public, in dialogue about questions and challenges of yesterday, today, and tomorrow.

When the Smithsonian undertook the articulation of a new Strategic Plan in 2009 we framed our work around four broad "Grand Challenges" that reflect and focus the scholarly work of the Institution: *Understanding the American Experience, Valuing World Cultures*, and the science-focused challenges: *Understanding and Sustaining a Biodiverse Planet* and *Unlocking the Mysteries of the Universe*.

We have seven units that fall under the aegis of science at the Smithsonian: the National Air and Space Museum (NASM); the National Museum of Natural History (NMNH); National Zoological Park (NZP) which has two campuses, one at Rock Creek Park and the other the Smithsonian Conservation Biology Institute (SCBI) at Front Royal, VA; the Museum Conservation Institute (MCI) in Suitland, MD; the Smithsonian Environmental Research Center (SERC) in Edgewater, MD; the Smithsonian Astrophysical Observatory (SAO) in Cambridge, MA; and the Smithsonian Tropical Research Institute (STRI) in Panama.

To most people, the Smithsonian conjures a public place on the National Mall. We are a tourist destination but behind that is a world-class research infrastructure making a difference in the lives of everyday Americans. The Smithsonian is the curator of extensive scientific collections acquired and maintained primarily for the purpose of long-term research, enabling experts in each generation to address such significant challenges facing society such as the effects of environmental change, the spread of invasive species, and the loss of biological diversity and its impact on the global ecosystem. Last year we had more than 45,000 research visitor days to our collection holdings.

The Washington D.C.-based museums and the National Zoo are complemented by our expansive field sites and ecologically oriented research units viz. STRI, SERC and SCBI. Annually, more than 900 visiting scientists from academic and research institutions in the United States and around the world visit our Tropical Research Institute (STRI) facilities in Panama. Although STRI is based in Panama, research is conducted throughout the tropics and these sites provide a unique opportunity for long-term ecological studies. The continuity of their long-term programs enables in-depth investigations that attract an elite group of fellows and visitors.

The Smithsonian Astrophysical Observatory (SAO) has developed and operates world-class astronomical facilities in Massachusetts, Hawaii and Arizona. SAO's telescopes and instruments utilize forefront technologies operating across the electromagnetic spectrum, and enable one of the most productive astronomy programs in the world. SAO trains the brightest young astronomers who then take their experience and expertise with them into astronomy programs around the nation. In the past decade SAO fellows have taken up faculty positions at top flight, private and public universities in fifteen states.

Closer to home, the Environmental Research Center (SERC) sits on the western shore of Chesapeake Bay. It spans 16 miles of shoreline and 2,650 acres of forest. Scholars work alongside students and volunteers to run the world's longest running field experiment on atmospheric increases in carbon dioxide affecting plant communities, and the world's longest data record on the increase of ultraviolet solar radiation. SERC research forms an important base for understanding links between the natural and agricultural communities and with STRI enable the Smithsonian to pull together important knowledge of how systems work on a landscape level.

The digital information we have created from the Smithsonian collections, long term research sites, and astrophysical observations form national assets which both plumb fundamental questions of physics, biology, and environmental science, while providing the basis for education, learning, and wonderment.

The strategic plan has enabled us to leverage this fundamental work and information from the collections, research sites, and scholars into larger programs to understand life on this planet, the planet itself, and the universe within which it sits.

UNDERSTANDING AND SUSTAINING A BIODIVERSE PLANET

One of the Smithsonian's scientifically driven Grand Challenges is Understanding and Sustaining a Biodiverse Planet. Four units (NMNH, SERC, STRI and NZP) use the diversity of natural history and living collections, as well as strong ecological research and field facilities to tackle this grand challenge from a myriad of perspectives and from unprecedented long-term research data sets. The Smithsonian collaborates with U.S. Federal and state agencies, universities, research centers, and museums across the globe to tackle projects too complex for any one institution to undertake alone.

Our research helps to unlock the secrets of the past, but Smithsonian science is also keenly focused on the global challenges of the present and future. The Smithsonian is exceptional in its ability to undertake long-term studies that require large-scale data gathering. Research carried out over years and even decades is now recognized as fundamental and vital, both to scientific understanding and to society's ability to make informed policy choices about such issues as species conservation or coastline protection. According to National Oceanic and Atmospheric Administration (NOAA),

the shoreline accounts for less than 10 percent of the land available in the U.S. (excluding Alaska) yet at least 39 percent of the U.S. population lives in counties directly on the coastline.. Coastal areas are substantially more crowded than the U.S. as a whole, and population density in coastal areas will continue to increase in the future. Hurricane Sandy and other natural disasters have demonstrated, such populations are vulnerable to extreme weather incidents.

Global Earth Observation

In 1980, the first large-scale tree plot was established in Panama in an effort to understand why tropical forests were so diverse. Each tree with a trunk diameter greater than 1 centimeter was identified and measured within a 50-hectare area. All 230,000 trees in the plot have since been remeasured every 5 years. This plot seeded the idea for a global forest observatory system. ForestGEO (formerly called SIGEO) has become the foremost forest ecosystem observatory system in the world with 53 plots in 23 countries and over 80 partner institutions. This program is answering major questions on species diversity and survival, and the role of forests in global water and carbon cycles. Just last year, researchers from ForestGEO network produced 137 publications. From this work we have learned that the impacts of changing climate are complex. For example, in some temperate forests carbon is being taken up at an increasing rate; yet in tropical forests the reverse is true as trees are growing more slowly.

The program not only offers answers to basic science questions, but it also serves as an important platform to build capacity throughout the world through training and education. Federally appropriated funds toward SIGEO have leveraged significant private philanthropic support and competitive grant funding—more than $39 million to date.

NEON

NEON, the National Ecological Observation Network, is a large recent investment by NSF to create a continental observatory network aimed at understanding environmental patterns and processes in a coordinated and comparative long-term fashion. For 30 years starting in 2017, a series of 60 towers, laboratories in the sky, will continuously measure many variables in 20 different types of ecosystems in a precise and comparable fashion. The Smithsonian is honored to have its facilities in Front Royal chosen as the hub of the Mid-Atlantic foundational site, with a satellite site planned for the Chesapeake environs at our SERC facility. This will build on the ForestGEO program and enable new depth of analysis of important environmental patterns. At each NEON site researchers will monitor atmospheric, chemical, and soil conditions while collecting biodiversity samples of insects, birds, plants, small animals and microbes to better understand the diversity of the United States. Annually, airplanes carrying laser equipment will fly over the forests to create high-resolution digital scans of the tree canopy so scientists can track its density and growth. The NEON project will also incorporate data from 46 aquatic sites to paint a

more complete picture of our ecosystem nationwide. This partnership of unprecedented comprehensive scale leverages federal investment in the facility and builds on our history and success in long-term research sites.

Marine Global Earth Observatory Network

In parallel to terrestrial monitoring, the Smithsonian recently received a $10M gift for an endowment from a private donor to launch the Tennenbaum Marine Observatory Network. It is designed to measure biodiversity in coastal marine environments and to measure the physical parameters important to this critical habitat for all manner of organism. The Smithsonian is initiating sites on the Chesapeake at SERC, at the Ft. Pierce Marine Station, part of NMNH, in Belize where the Smithsonian has 30 years of active marine research and in Panama both on the Caribbean and Pacific coasts. Environmental parameters to be measured will include temperature, salinity, pH, and dissolved oxygen; biodiversity will be measured through sampling of plankton, sea grasses, invertebrates etc. Specimens will be deposited in the Smithsonian collection. In addition, the sites will monitor plant productivity, grazing and other measures of biological activity. We anticipate quick expansion of the program to include partnerships on the West Coast of the U.S. and throughout the rest of the world, just as in the successful ForestGEO program discussed above. This work was planned over the last few years in consortium with colleagues at NOAA, EPA, and universities and fills a gap in coastal observations that has long been recognized.

Genomics as a tool to understand biodiversity

The Smithsonian has recently expanded our genomic collections and research capabilities, including a new laboratory housed at the Natural History Museum. There are many uses for genomic information including a much deeper understanding of the taxonomy and systematics of the species on our planet. But there are also very practical applications of this type of knowledge. For example, there are specific gene sequences that are unique to individual species. These small sections of DNA can work just like a bar code in the grocery store to identify species with great precision. Researchers are using barcoding to discover new species, refine our understanding of species we've already found, and provide ecologists, other scientists and society with a cost-effective way to identify species.

The Consortium for the Barcode of Life (CBOL) is an international initiative devoted to developing DNA barcoding as a global standard for the identification of biological species. CBOL has 200 member organizations from 50 countries and operates from a secretariat office located in the Smithsonian's National Museum of Natural History in Washington, DC. The Fifth International Barcode of Life Conference was held in October 2013 in China, and demonstrated how rapidly this international initiative has grown.

CBOL catalyzes international partnerships and the use of barcode data for the benefit of science and society. The impacts of this research may contribute a critical tool to protecting endangered species. More than 35,000 of the world's 1.8 million named species are in danger of regional or global extinction. Intercepting wildlife as they are transferred across borders is critical to slowing illegal trade, but current detection tools are inefficient, expensive and unreliable.

Google through their Global Impact Awards has recognized the promise of DNA barcoding in protecting wildlife. In 2013, CBOL received a $3 million grant to help create a 'DNA barcoding' library so law enforcement officials can easily identify illegal trade species and better protect the world's most endangered wildlife.

This two-year project devoted to protecting endangered species will involve six country partners, including South Africa, Kenya, Nigeria, and Mexico, and will help to train enforcement officials to disrupt illegal animal trade.

Wildlife Conservation

The Smithsonian is engaged in conservation at many levels, from fundamental research to understand loss in species biodiversity, to public outreach and education, to domestic and international training. As an example, the National Zoo has embarked on a major amphibian conservation effort. Since 1980, 122 amphibian species are thought to have gone extinct with huge implications for insect control, compared to the loss of just five bird species and no mammals over the same period. This is an unprecedented rate of species loss and deserves an unprecedented conservation response.

In Panama, our collaborative research has identified the microscopic chytrid fungus is to blame in the unprecedented decline of amphibians worldwide. The fungus works by infecting the skin of the animal and starving it of oxygen. To mitigate this threat, researchers are hard at work to capture and breed the endangered frogs. The hope is to learn to raise these animals in captivity until enough is known about the disease to allow researchers to release amphibians into the wild once again.

In November, staff moved into our new Amphibian Rescue Center (ARC) in Gamboa. Panama. Our partnerships with zoos, aquariums, grantors and private industry are evident at this new center. Seven donated shipping containers that once ferried ice cream and frozen vegetables around the world, now house a most precious collection of endangered Panamanian frogs—often the sole survivors of their species. The new world-class facility enables us to more effectively tackle the amphibian conservation crisis. Since 2006, patient researchers have successfully bred and raised 18 Panamanian amphibian species to adulthood including the iconic Golden Frog. This is a major milestone for conservation efforts, and one worth celebrating. The center sponsors an annual Golden Frog Festival, with events throughout Panama that unite locals and visitors from around the world in a single mission: celebrating and conserving Panama's amphibian treasures.

The Smithsonian is engaged in conservation at all levels. For the past year scientists at the Smithsonian Conservation Biology Institute (SCBI) have been working with aviation and aerospace leaders, led by Airbus Americas, Inc., to launch the "Partners in the Sky" program using aviation and aerospace technology to create a first-of-its-kind global animal tracking system.

We are also engaged in the interdisciplinary field of conservation medicine, which integrates veterinary medicine and environmental science. Zoonotic diseases are contagious diseases spread between animals and humans, caused by bacteria, viruses, parasites, and fungi that are carried by animals and insects. Examples are Avian Influenza, HIV/AIDS, SARS, often Influenza H1N1, Lyme disease, malaria, and West Nile virus infection. The CDC reports about 75% of recently emerging infectious diseases affecting humans are diseases of animal origin, and approximately 60% of all human pathogens are zoonotic. In the context of modern globalization, these diseases can travel very quickly, posing serious public health, development and economic concerns.

To respond to zoonotic disease threats, University of California Davis, Eco health Alliance, MetaBiota, Wildlife Conservation Society and Smithsonian are part of a USAID-funded program called PREDICT. The PREDICT project seeks to identify new emerging infectious diseases that could become a threat to human health. PREDICT partners locate their research in geographic “hotspots” and focus on wildlife that are most likely to carry zoonotic diseases—animals such as bats, rodents, and nonhuman primates.

PREDICT has compiled the most comprehensive data on the risk of zoonotic disease emergence throughout the world and a highly refined global risk map. PREDICT also ventures across the world to support local researchers and actively builds local capacity. To conduct surveillance in wildlife for zoonotic pathogens, a basic level of in-country capacity is needed. Field samples must be collected, transported to diagnostic labs and analyzed for identification of known and novel pathogens. Through PREDICT, more than 1,600 people in 20 countries have been trained in these roles, creating an extensive field and laboratory infrastructure, and a substantial, long-term wildlife surveillance footprint.

PREDICT partners work with scientists and policymakers in each country to create a network of research, communication, and response partners on a local, regional, and global level. For example, PREDICT helped identify and respond to a Yellow Fever outbreak in March 2012 after five howler monkey carcasses were found near a wildlife sanctuary in eastern Bolivia. The PREDICT network responded quickly. DNA sequencing confirmed that the infections had been caused by two Yellow Fever viral strains, both of which were related to human cases in Trinidad and Tobago and Brazil.

Only eight days passed between the onset of outbreak and notification of the Bolivian government. Preventive measures were promptly implemented in the

affected area, including vaccination campaigns, public outreach and mosquito control. Thanks in part to the fast response no human cases occurred during the outbreak.

Invasive species and ecosystem protection

One of the acknowledged environmental impacts of speedy international commerce and travel is the spread of invasive species. Many parts of the U.S. government monitor and protect our land and shores as much as possible. Our natural history collections are used for identification, and long-term partnership between the Smithsonian Environmental Research Center (SERC) and the Coast Guard has developed a program that contributes key data and information about coastal and marine invasive species.

Ballast water is a vector for marine species throughout the world. Biological Invasions (the movement of species beyond their historical range) are a major force of ecological and evolutionary change. These invasions have increased dramatically in recent time, and their impacts dramatically change the structure of ecosystems around the world. That change, in turn, impacts many dimensions of human society.

SERC is actively evaluating the national status and trends of invasive species in our coastal marine ecosystems. This includes ongoing field surveys of ships' ballast water and hulls for invasive species that make their way from one ocean to another. SERC's research program investigates several different facets of ballast-mediated invasions including: (1) the abundance, diversity, and dynamics of organisms in ballast tanks and (2) the effectiveness of management tools used to slow the rate of invasion due to ballast water discharge.

SERC has also partnered with the United States Coast Guard on a joint program called the National Ballast Information Clearinghouse (NBIC) in which they collect, analyze, and interpret data on the delivery of ballast water and the management practices of commercial ships that operate in the waters of the United States. The NBIC characterizes ballast water practices for over 100,000 commercial ship arrivals to US ports each year.

More broadly, the NBIC seeks to understand biological invasion patterns and processes in marine ecosystems. NBIC characterizes patterns of marine invasion across space, time, and taxonomic groups for over 500 species that have colonized US waters. NBIC uses these data to identify factors that drive invasions and enhance the nation's predictive capability about the spread and impacts of non-native species in marine ecosystems. Both the ballast data and invasion data are made available as a public resource, online.

One of the most interesting aspects of our collaborative work is documenting the occurrence of pathogens (of humans and marine wildlife) in ballast water. This includes various bacteria and protists, and it suggests a possible role of this

transport in epidemiology and disease outbreaks—especially for marine wildlife. While a fair amount is known about transfers of larger organisms, like macroinvertebrates (crustaceans, molluscs, etc), relatively little is known yet about the diversity and consequences of microorganism transfers.

UNLOCKING THE MYSTERIES OF THE UNIVERSE

The Smithsonian Astrophysical Observatory (SAO), the National Air and Space Museum (NASM) and the National Museum of Natural History (NMNH) focus on applying the integrative research to today's big questions regarding the origin and evolution of the Earth, planets, stars, galaxies, and the universe.

Areas of specific focus include the study of the origin and evolution of the Earth and solar system; the effects of geologic and meteoric phenomena on Earth's atmosphere and biosphere; research into the discovery and characterization of exo-planets in the habitable zone; research using our rich collections, including the national meteorite collection; and research into the next generation of ground- and space-based astronomical telescope mirrors and instrumentation that will enable the next generation of research.

SAO's partnership with Harvard University to form the Harvard-Smithsonian Center for Astrophysics has, since 1973, grown to be the most powerful astronomical program in the world. SAO is the largest Smithsonian unit with 900 employees who staff observatories in Arizona and Hawaii, and partner in Chile with universities throughout the United States and abroad to include Harvard, Arizona, University of Chicago, University of Texas, Texas A&M, and the Carnegie Institution for Science, and universities in South Korea, Australia, and Taiwan among many other collaborators.

SAO's pioneering efforts in the development of orbiting observatories and large ground-based telescopes, in the application of computers to astrophysical problems, and in the integration of laboratory measurements, theoretical astrophysics, and observations across the electromagnetic spectrum have contributed greatly to unveiling the secrets of the universe. These efforts have principally been supported by competitively awarded contracts and grants from NASA and NSF buttressed by our federal appropriation. From studying planets around other stars to charting galaxies moving at almost the speed of light, SAO scientists remain dedicated to the increase of knowledge about those physical processes that shape the natural world, and to the diffusion of this knowledge to the scientific community, to teachers and students, and to the general public.

SAO's research spans from studies of the characteristics of the solar environment to studies on the origins of the universe among many other topics, including the intriguing search for habitable planets. Instrumentation development is a great strength of SAO. Armed with that prowess, SAO has been called on by NASA to collaborate on some of the most prominent research investments of our time:

TEMPO

In November 2012, SAO was selected by NASA to build the Tropospheric Emissions: Monitoring of Pollution (TEMPO) instrument, the first space-based instrument to monitor major air pollutants across North America, from Mexico City to the Canadian tar sands and from the Atlantic to the Pacific, hourly and at high spatial resolution. TEMPO will be launched into a geostationary orbit in 2017 and will become part of a global constellation of satellites that include missions from Europe and Asia to monitor air quality.

Chandra

In July, Chandra, NASA's flagship mission for X-ray astronomy began its 15th year of operation. SAO hosts the Chandra X-ray Center that operates the satellite, processes the observations and distributes the data to scientists around the world for analysis.

Recently, Chandra has made exciting new discoveries in a variety of fields of astrophysics, from planets around other stars (known as "exoplanets"), to the birth and death of stars, to giant black holes in the centers of galaxies, and to clusters of galaxies, the largest objects in the universe held together by gravity. For example, astronomers used Chandra to show that the remains from the explosion of a star may contain the most recent black hole formed in the Milky Way galaxy. Chandra was also used to take a major step in explaining why material around the giant black hole at the center of the Milky Way galaxy is extraordinarily faint in X-rays, a discovery that holds important implications for understanding the growth of the biggest black holes. Closer to home, X-ray observations from Chandra have detected an exoplanet passing in front of its parent star, the first X-ray transit observed since exoplanets were discovered almost 20 years ago. This transit teaches us about the atmosphere of this distant world.

On the much larger scales of the Bullet Cluster, Chandra and other observatories were used to show for the first time that dark matter, a mysterious invisible substance, can be separated from normal matter when clusters of galaxies collide. This provides direct evidence for the existence of dark matter. Similar objects might be observed in a collaborative program called the Frontier Fields, where Chandra observations, along with Hubble Space Telescope and Spitzer Space Telescope observations have been planned to look deep into the early Universe. Astronomers will observe enormous clusters of galaxies, exploiting a phenomenon known as gravitational lensing, to learn about very distant galaxies whose light is magnified and brightened as it passes through a massive cluster. The Chandra observations will image the hot gas in the clusters, to help determine whether it remains close to the galaxies and dark matter, or is stripped away by collisions, as in the Bullet Cluster.

Center for Earth and Planetary Studies

Through research and direct involvement in active planetary missions, scientists in the National Air and Space Museum's Center for Earth and Planetary Studies (CEPS) seek to expand our knowledge of geologic processes across our solar system and how these processes may contribute to habitable conditions on other planets.

CEPS scientists are on the teams of NASA's Mars Science Laboratory (Curiosity) rover, the Mars Reconnaissance Orbiter, the Lunar Reconnaissance Orbiter, and the MESSENGER mission to Mercury. Other CEPS scientists conduct research on the Earth, Venus, and asteroids.

CEPS scientists study the rocky planets in our solar system and beyond, to gain insight into the geologic evolution of the Earth and Earth-like planets. For example, CEPS scientists used radar sounder data from the SHARAD instrument on the Mars Reconnaissance Orbiter to construction the first three-dimensional views of buried young channels on Mars formed by gigantic floods due to the catastrophic eruption of groundwater. The results were published in the journal *Science*.

During its second and final extended mission, the MESSENGER spacecraft's orbit around Mercury will be changed to allow very high resolution imaging of the surface that was not possible before. CEPS scientists will lead the effort to search for evidence of small-scale faults that cannot be detected in the current orbit. These faults may be evidence of very recent, and possibly current, tectonic activity on Mercury.

In November 2011, a geologist at NASM was selected by NASA to be a Participating Scientist on the Mars Science Laboratory Curiosity mission. Since *Curiosity* landed in August, 2012, he has served as a Long Term Planner charged with working to establish the strategic goals and plans for the science team and rover. He also works with data from Curiosity to understand the processes responsible for shaping the landing site in Gale crater. Scientific papers describing results from Curiosity were published in Science in December 2013, including 4 co-authored by this CEPS participant. These papers describe evidence for past environments on the floor of Gale crater that could have been habitable. Moreover, results include some of the first absolute age dating of surfaces on Mars and show that these habitable environments persisted until ~3.5-3.0 billion years ago, younger than had been previously assumed for Mars.

SAO/NASA Astrophysics Data System

We also help to connect scholars to information to expand knowledge. The SAO/NASA Astrophysics Data System (ADS) is a network of online portals to astronomical literature that spans from Jakarta to Kiev, from Munich to Beijing. ADS recently celebrated its twentieth anniversary of providing free, open digital access

to the entire archive of astronomical publications, some going back to the early 1800s. The ADS corpus consists of 10 million bibliographic records, 60 million citations, and nearly 3 million full-text documents—the world's most complete collection of scholarly content in the physical sciences.

More researchers now read more content through ADS than through all astronomy libraries in the world combined. With nearly 10 million different visitors annually, ADS is a key provider of astronomical publications to both professional scientists and the general public. The UN General Assembly recognized that "the mirror sites of the NASA-funded Astrophysics Data System (ADS) . . . had become important assets for developing countries …" by providing free access to the scientific literature for those not able to afford costly subscriptions.

ADS embodies the principles and goals of Smithsonian's mission to increase and diffuse knowledge. ADS is a pioneer in utilizing digital tools to rapidly ingest and disseminate the scientific literature, to serve the world community of scientists and interested public, and to set an example of balancing the needs of publishers and the open community of scholars.

Meteorites

The Antarctic Meteorite Program is a cooperative agreement between the National Science Foundation, NASA, and the Smithsonian to provide for the collection, curation, distribution, and long-term storage of meteorites recovered during annual U.S. expeditions to Antarctica. Returning more meteorites in the last 30 years than were collected over the entire Earth in the previous 500 years, the Antarctic Search for Meteorites (ANSMET) is an inexpensive yet guaranteed way to recover meteorites from the Moon, Mars, and previously un-sampled asteroids. These rocks are critical to our understanding of the history of the Solar System, providing essential "ground-truth" for our study of the asteroids, planets, and other bodies of our solar system.

Small meteor fragments fall from the sky frequently, but the idea of more substantial objects impacting Earth makes frightening headlines in the popular media. Rest assured, the Smithsonian is doing its part to keep you safe. The Smithsonian Astrophysical Observatory houses the Minor Planet Center (MPC), a single worldwide location for receipt and distribution of positional measurements of minor planets, comets and outer irregular natural satellites of the major planets. The MPC is responsible for the identification, designation and orbit computation for all of these objects. Funded by NASA, the MPC receives observations of transient objects, computes their orbits, communicates with observers and warns of impending impacts. An impact detection scale shows we should be safe from the objects we know about for the next 100 years or so. In the mean time, SAO and the MPC will continue to collect and disseminate data on existing and newly discovered objects that might pose a hazard to Earth.

Giant Magellan Telescope

Beyond NASA, the Giant Magellan Telescope (GMT), is a next-generation ground-based telescope, is being built collaboratively by an international consortium of 10 leading universities and science institutions, including the Smithsonian Astrophysical Observatory. The first 8.4-meter mirror segment has been completed, thus retiring a key technical risk to the project. SAO is building the first focal-plane instrument to be commissioned during the Phase 1 science operations, scheduled to begin in 2019. This 10-ton instrument, G-CLEF, is an extremely versatile fiber-fed spectrograph with the capability of detecting Earth-sized planets in the habitable zone around stars like our Sun.

"Time and Navigation"

We also bring these activities back to our visitors. The exhibition "Time and Navigation" opened last spring at the National Air and Space Museum (NASM) and explores the connections between place and time. Whether you are using a smartphone to locate a destination or a sextant and stars to navigate the oceans, you need an accurate clock to determine where you are. "Time and Navigation," developed by NASM and the National Museum of Natural History, takes the visitor (both in the museum and on-line) through the history of "getting from here to there," showing how early navigators needed special training and equipment, while today's travelers rely heavily on a suite of more than 30 Earth-orbiting satellites that carry atomic clocks and form the Global Positioning System (GPS).

EDUCATING THE NEXT GENERATION

The Smithsonian asks and answers questions about science, art, history and culture, exciting the learning in everyone, every day.

Much of the Smithsonian's research is aimed at understanding and sharing information about scientific questions that are as yet unresolved. Critical to this multi-faceted approach is inspiring, training and educating the next generation of scientists.

Smithsonian offers top internships and fellowships

The Smithsonian extends its educational capacity to improve scientific literacy through fellowships and internships in every discipline. Smithsonian Fellowships offer opportunities to visiting professionals and scholars for independent study and research with a Smithsonian advisor that makes use of Smithsonian collections and research facilities. Across all disciplines, the Smithsonian hosted 745 fellows this year who represented 51 countries and 37 states, DC and PR. Smithsonian also hosted 1,339 interns this year from 38 countries and 42 states, DC, USVI and PR. In

Fiscal Year 13, Smithsonian also hosted 539 research associates from 13 countries and 300 universities. While these figures reflect a pan-Institutional educational endeavor, our science units host the most students. Fellows flock to NMNH, SAO, NZP, and STRI where they frequently stay or return as research associates. The Smithsonian mentors and trains the next generation of researchers and scholars.

Conservation education

The National Zoo's Smithsonian Conservation Biology Institute (SCBI) provides a variety of training and capacity building programs for students and professional audiences, specifically targeting individuals and institutions from developing countries and underserved communities.

SCBI scientists and research associates have taught training courses in the United States and at more than 20 international locations for over three decades, reaching nearly 6,000 individuals from more than 116 countries.

Here at home, through a partnership with George Mason University, the Smithsonian-Mason School of Conservation (SMSC) was built to engage undergraduates, graduate students and professionals from around the world in a range of compelling, transdisciplinary programs in conservation biology. The participants thrive in an atmosphere of creative, critical and analytic thinking on how to search solutions to some of the most intractable conservation problems facing society today. The School's integrated approach unfolds in a modern, innovative gold LEED-certified educational facility within the 3,200-acre SCBI. The SMSC is rapidly becoming a benchmark for innovative education for current and future generations of conservation biologists, policymakers, and global conservation leaders.

Smithsonian Science Education Center

Twenty-eight years ago, the Smithsonian Institution and the National Academies jointly established the National Science Resources Center (NSRC). These widely respected scientific institutions provided a unique platform and the resources to catalyze change at all levels of the education system. In 2010, Secretary Clough created the Smithsonian Office of Education and Access, which is charged with coordinating all K-12 educational programs throughout the Smithsonian. As an integral part of this focused education initiative, the NSRC was fully integrated into the Smithsonian and is now known as the Smithsonian Science Education Center (SSEC). SSEC is uniquely positioned to bring all of the cutting edge science from the world's largest museum and research complex to children in the classroom. SSEC is nationally and internationally recognized for the quality and impact of its programs on K–12 science education.

Our expertise and experience as a research Institution and as an educational Institution coupled with our international reach and ability to convene stakeholders uniquely positions us to take on global challenges.

Museum-based education and outreach

The Smithsonian seeks to bring content experts and educators together to help strengthen American science education. The Smithsonian serves as a laboratory to create models and methods of innovative informal education and link them to the formal education system. As the Secretary detailed, Q?rius is a first-of-its-kind interactive and experimental environment, and we have other learn-by-doing activities in all of the museums.

The Smithsonian has a variety of content, resources, and educational materials spread across its website and those of our museums for learners of all ages. Museum educators offer several virtual learning experiences to students across the globe.

For example, the National Air and Space Museum offers an abundance of science-focused programs. Museum "Explainers" conduct demonstrations daily on the science of flight in the *How Things Fly* gallery. Lecture series feature scientists and astronomers from around the country. At the Udvar-Hazy Center, children learn about a variety of aviation- and space-related topics at the monthly Super Science Saturdays. Science subjects are often the topic of discussion at the Museum's Ask Expert talks, and the youngest children learn by listening to "Flights of Fancy" stories. In addition, a regular series of Family Days takes place, offering themes such as exploring the universe, planetary studies, and space exploration.

The Science Education Department (SED) of SAO develops curricula and materials that reflect current scientific and educational philosophy. The center plays a leading role in the study of the nature of learning. Major projects include the development of misconception-based assessment instruments, and research into identifying measurable factors that predict levels of achievement. SED research and materials are widely available online and in print, and at workshops and teacher conferences. Through its efforts, the SED aims to advance the public's understanding of astronomy and the physical sciences.

The Smithsonian is an active partner in the broader efforts to coordinate STEM efforts across the federal government. We have worked closely with agencies such as NASA, NIH, NOAA and the U.S. Forest Service to improve programming at our own museums, better inform their outreach, and on joint initiatives such as Waterways, a project that increases individual awareness about the environment and eco-stewardship.

Conclusion

On land, water or beyond our atmosphere, Smithsonian science is engaged in the world's greatest challenges. Whether they are protecting ecosystems that are threatened, discovering new planets, or assessing the consequences of environmental change, Smithsonian scientists apply what they learn to improve the quality of life on Earth and to understand our place in the universe. We broaden access and reach new audiences by bringing the resources of our museums and research centers to people where they learn and live. The collections are our window on the past and our legacy for the future. Smithsonian is paramount for protecting this legacy for reanalysis and new understanding. As stewards, scholars, collaborators and conveners, the Smithsonian strives to address important issues in science today and improve the lives of all Americans.