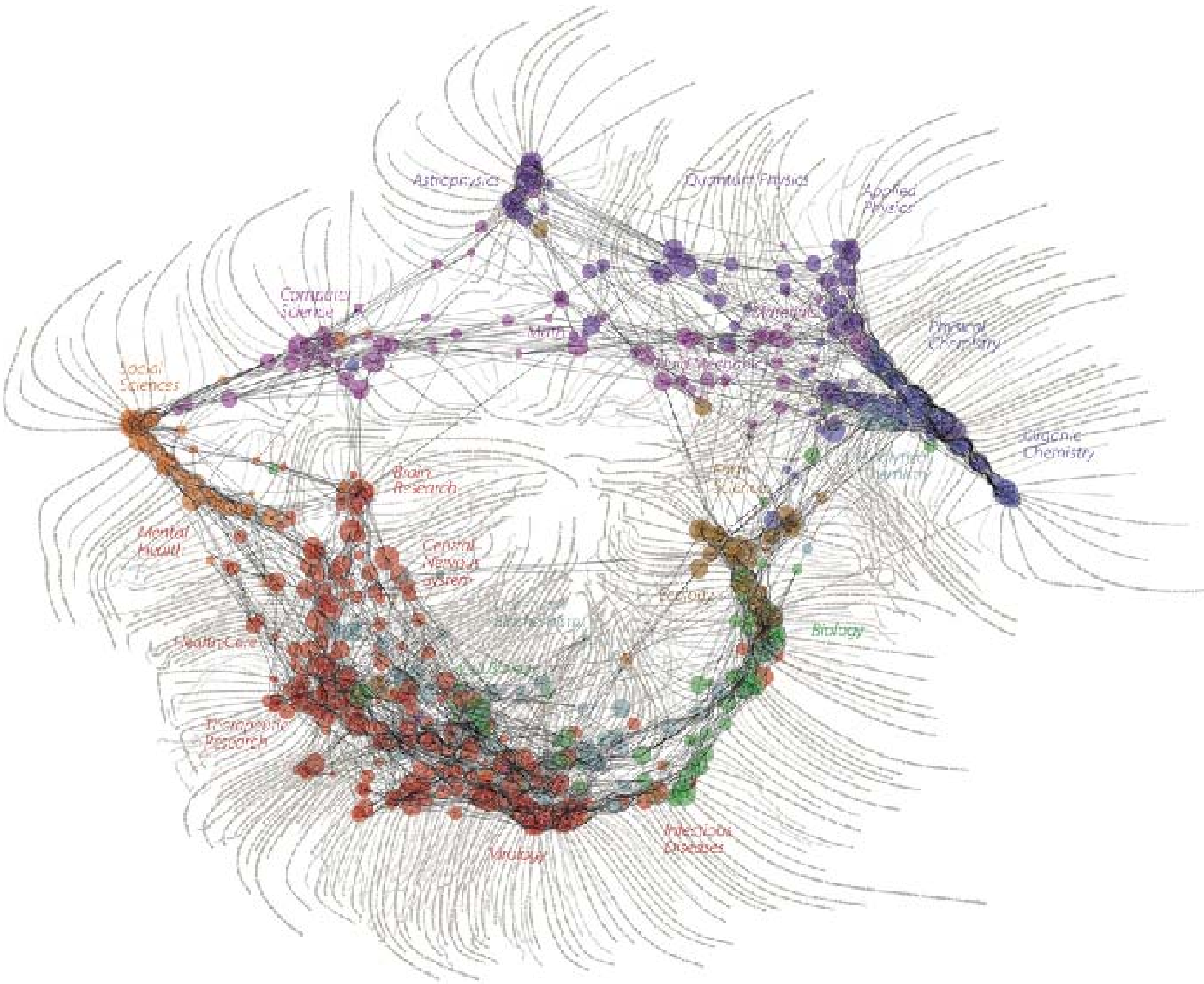
Addressing Complexity: Fostering Collaboration and Interdisciplinary Science Research at the Smithsonian

Volume I: Summary Study Report



Report prepared for the Smithsonian Under Secretary for Science by the Smithsonian Office of Policy and Analysis

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Cover: Relationships Among Scientific Paradigms

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Acknowledgements

This report synthesizes some important insights about collaboration and interdisciplinary scientific research. The Office of Policy and Analysis hopes that these ideas will strengthen science at the Smithsonian Institution, address the challenges of pursuing research that draws together diverse disciplines and crosses organizational boundaries, and link the Institution's research to the successful resolution of some of society's challenging issues.

The talent and skills of many contributed to this effort. The debt I owe to my extraordinary staff is substantial. Their thoroughness, knowledge, and professionalism are exemplary. Kathleen M. Ernst, a senior analyst, managed the project and, as always, did a wonderful job. Whitney Watriss provided a great deal of assistance during gathering, reduction, and analysis of data and contributed enormously to writing the report. Lance Costello, a steadfast, systematic researcher who participated in all of the project's stages, and James Smith, a brilliant senior editor, went the extra mile to finish the report. As always, we benefited greatly from the comments and suggestions of one another.

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It is a pleasure to thank the many internal and external interviewees who cooperated and provided perspectives that were so essential to this effort. Their generosity, honesty, and rapport with members of the team were noteworthy.

Finally, I have been at the Smithsonian for nearly a decade and am grateful to have had the opportunity to look at organizational and managerial issues related to science. Before that, over a 15-year period, I had the opportunity to work with several Federal research organizations and learned much about their structures, management practices and processes, flow of knowledge, and idea and product creation. It has been a pleasure to return to the province of science and listen to voices who can improve the quality of our lives through research.

Carole M.P. Neves
Director
Smithsonian Office of Policy and Analysis

List of Acronyms

AIB	Arts and Industries Building
ARS	Agricultural Research Service (U.S. Department of Agriculture)
CDI	Cyber-Enabled Discovery and Innovation Program (National Science Foundation)
CEPS	Center for Earth and Planetary Studies (National Air and Space Museum)
CISS	Center for Interdisciplinary Smithsonian Science
FY	Fiscal year
HHMI	Howard Hughes Medical Institute
IDR	Interdisciplinary research
IGERT	Integrative Graduate Education and Research Traineeship Program (National Science Foundation)
IT	Information technology
MIT	Massachusetts Institute of Technology
MCI	Museum Conservation Institute
MSN	Marine Science Network
NAI	National Astrobiology Institute
NAPA	National Academy of Public Administration
NASA	National Aeronautics and Space Administration
NCEAS	National Center for Ecological Analysis and Synthesis
NIH	National Institutes of Health
NMNH	National Museum of Natural History
NOAA	National Oceanic and Atmospheric Administration (U.S. Department of Commerce)
NRC	National Research Council (National Academies)
NSF	National Science Foundation
NZP	National Zoological Park
OCFO	Office of the Chief Financial Officer
OCIO	Office of the Chief Information Officer
OCon	Office of Contracting
OD	Office of Development
OF	Office of Fellowships
OGR	Office of Government Relations
OHR	Office of Human Resources
OP&A	Office of Policy and Analysis
OPA	Office of Public Affairs

OPMB	Office of Planning, Management and Budget
OSP	Office of Sponsored Projects
OUSS	Office of the Under Secretary for Science
PAEC	Professional Accomplishment Evaluation Committee
SAO	Smithsonian Astrophysical Observatory
SERC	Smithsonian Environmental Research Center
SIGEO	Smithsonian Institution Global Earth Observatories
STC	Science and Technology Center (National Science Foundation)
STRI	Smithsonian Tropical Research Institute
USGS	U.S. Geological Survey (U.S. Department of the Interior)
USS	Under Secretary for Science

Introduction

Over the past decade or more, there has been a marked shift toward scientific research that spans disciplines and organizational boundaries and is carried out by teams rather than individuals. One reason is the complexity and scope of the big challenges facing the world today—global problems such as human diseases, climate change, and the rapid loss of natural resources resulting from human activities and population pressures cannot be addressed by individual scientists working alone within single disciplines. Moreover, it is evident that the innovative and "transformative" science that leads to breakthroughs often happens at the intersections of disciplines. Some fields, such as conservation biology and astrophysics, are inherently interdisciplinary. In response to these realities, government policy and research funding has increasingly emphasized multi-organization, interdisciplinary research (IDR) aimed at solving or mitigating global problems and at transformative advances in science. Spurred by these trends, universities and other research organizations have taken measures to promote interdisciplinary research, including setting up new IDR centers, institutes, and programs.

In early 2008 the Office of the Under Secretary for Science (OUSS) at the Smithsonian asked the Office of Policy and Analysis (OP&A) to look into ways to better facilitate collaboration and IDR at the Institution—within and across its science[1] (and potentially non-science) units, and with outside organizations. When the current Secretary, Wayne Clough, came onboard in July 2008, he fully supported the study and a move toward more IDR. In his installation remarks in January 2009, Secretary Clough noted the Smithsonian's potential to tackle complicated issues necessitating interdisciplinary work that occurs at the boundaries between disciplines, as well as the need to find new ways to utilize its great assets to become more deeply and visibly engaged with the important issues of our day (Smithsonian Institution, 2009).

The study team investigated both the policies, procedures, incentives, and mechanisms that foster collaboration and IDR, and the bureaucratic, administrative, cultural, and other barriers that impede it, within the Smithsonian and at external organizations. More generally, the study team looked at how the nature of scientific research is changing and what factors and conditions increase the chances for innovation and scientific breakthroughs.

1 Smithsonian science units included in this study are: Museum Conservation Institute, National Air and Space Museum's Center for Earth and Planetary Studies, National Museum of Natural History, National Zoological Park, Smithsonian Astrophysical Observatory, Smithsonian Environmental Research Center, and Smithsonian Tropical Research Institute.

This Summary Study Report, Volume I of *Addressing Complexity: Fostering Collaboration and Interdisciplinary Research at the Smithsonian*, consists of conclusions, recommendations, and findings; two appendices contain the bibliography from the study and a list of organizations at which interviews were conducted. Volume II, Detailed Findings, provides additional information and quotes from interviewees and the literature as well as other background material in a series of addenda.

The sources of data for this study include: the 2002-2003 reports of the Smithsonian Science Commission, National Research Council (NRC, part of the National Academies), and National Academy of Public Administration (NAPA); a literature review of published and unpublished documents, Smithsonian materials, and websites pertaining to collaboration and interdisciplinary research and education (Appendix A); and interviews with 92 Smithsonian scientists, managers, and administrative staff and 43 senior executives from external science organizations (Appendix B); data on Smithsonian science budgets, grants and contracts, scholarly awards, staffing, and fellowships; and analysis of Smithsonian scientist co-authorship data. The OP&A study team completed the data collection in the fall of 2008, and conducted the analysis and writing in early 2009.

For purposes of the study, the study team defined "interdisciplinary" as encompassing the creation and integration/synthesis of data, theory, techniques, perspectives, and concepts to address issues that require input from more than one discipline (National Academy of Sciences, 2004; Tress, et al., 2003, as referenced in Graybill, et al., 2006).

Conclusions

Smithsonian Science

1. Scientific research is a vital part of the Smithsonian that has resulted in major contributions in a number of fields and is reputed for integrity and objectivity. The scientific staff, which encompass a wide range of disciplines and expertise, include recognized leaders in their fields of endeavor. The Institution is home to world-renowned science facilities that are go-to places for research, professional development, and collaboration. Its collections, living and conserved, are exceptional. The Smithsonian affords a wealth of professional training and is playing a major role in capacity building nationally and internationally. Much of the research is carried out in collaboration with non-Smithsonian scientists and organizations around the world, creating an extensive network of contacts; staff have close affiliations with many universities. Recently the Smithsonian has become part of important global consortia and formal partnerships that offer access to still more resources and expertise.

2. A great deal of the Smithsonian's scientific research directly addresses contemporary challenges—the Smithsonian Environmental Research Center's (SERC) Chesapeake Bay work and National Zoological Park's (NZP) biodiversity conservation programs are just two examples. Much of this work is necessarily interdisciplinary because it involves a systems perspective and the interaction of man and nature. Given the range and quality of its resources and its network of colleagues and partners around the world, the Smithsonian can play a greater role in understanding and mitigating contemporary challenges. And there is a need for pragmatism—much of the Smithsonian's funding comes from grants from government and private sources, and they tend to go to research on global problems. Similarly, the post-docs and other academic appointees who benefit the Smithsonian enormously very often are interested in that type of research. Among Smithsonian staff, there is evidence of unfulfilled interest for undertaking additional projects that engage directly with complex issues of global import.

3. Given its wealth of resources and experience, the Smithsonian arguably should be having greater impact, and be far better recognized for its accomplishments, than is the case. It has not kept pace with the shift toward collaboration and IDR, with notable exceptions, and is not known for working at the boundaries and intersections

of disciplines where important breakthroughs commonly take place. In this regard, it is losing ground to other leading research organizations. The study team identified a number of reasons for this situation, many of which have been cited in previous studies.

4. With few exceptions, the Smithsonian has not emphasized an integrated approach to its scientific research, such that the whole is greater than the sum of its parts. Research directions and projects have been guided not by an overarching vision of intended impact or clear mission, goals, and strategies, but largely by individuals' decisions. Individual scientists do high-quality research, but their work does not come together across disciplines and too often is not synthesized or made available in a way that others can easily use. Research domains are narrowly defined and innovative opportunities too seldom sought. The result has been a panoply of organizations, disciplines, functions, projects, and data that are not mutually reinforcing. A key question is whether the Smithsonian can develop into a research entity that integrates its expertise and resources and spans disciplines and organizational boundaries, such that it can bring critical mass to bear on understanding the world and universe beyond, and apply that knowledge to today's challenges.

5. Absent awareness of the Smithsonian's science, and a roadmap that communicates clearly what the Smithsonian intends to accomplish in the future, soliciting financial support in a highly competitive funding environment will be an uphill battle.

Leadership

6. Change begins with leadership. With exceptions at some units, Smithsonian science has suffered from a lack of sustained and effective leadership. In part the reason lies with entrenched norms that govern how business gets done. There has been insufficient attention to the need in a dispersed organization to provide central direction and guidance for science, promote an integrated approach to research, and set sound priorities and criteria to inform decision making. Too often the main criterion has been avoidance of discord and resistance. A tradition of consensus has led to lowest-common-denominator decision making and a thousand flowers blooming. Even where plans are issued and decisions made, there has been an absence of committed follow-through, leading to pervasive skepticism and unwillingness within the workforce to support central plans and decisions.

7. Thus strong leadership at all levels, particularly by the Secretary and Under Secretary for Science (USS), is a prerequisite for redirection of Smithsonian science, no matter what path is chosen. Priority needs are:

    a. *A clear vision and direction for science, analysis-based priorities and decision making criteria, and sustained follow through.* The latter means, in particular, ensuring the resources for implementing decisions are made available, providing strong advocacy for change, and holding staff accountable for achieving goals. There is a need to guard against the reversals of direction that seem inevitably to accompany changes in internal and external environments.

    b. *Cultural transformation.* The Smithsonian needs a 21st century culture that embraces creativity, innovation (and by definition, risk-taking), openness to learning and growth, collaboration, and IDR, while maintaining the values of integrity and excellence. This culture is slowly emerging in many places, and change will likely accelerate as younger scientists infuse the Smithsonian with their contemporary approaches and outlook. What likely will be hardest to change is the culture of competition across and within units and its replacement with a commitment to the greater impact that is possible with an integrated Smithsonian.

    c. *Increased awareness among stakeholders about the value and relevance of Smithsonian science.* A strong and sophisticated capability to communicate the strength, relevance, and value of the Smithsonian's scientific research to stakeholders across the board—the public, government (notably the Executive Branch, Congress, and the Office of Management and Budget), foundations, individual donors, and other funding bodies—is essential to build support and compete for resources. Equally important is to raise awareness about the strategic vision and directions the Smithsonian will pursue and what impact it intends to have.

8. Transforming the organizational culture and gaining buy-in for new directions and initiatives will be easier if managers have in place a well-crafted implementation strategy. A key element of such a strategy is to pursue a top-down, bottom-up approach to defining vision and research directions and to selecting strategic initiatives. Ideas generated by staff are a critical element in informed decision making by leadership; input from external experts is similarly valuable. Also important are an implementation plan with realistic but practical milestones, incentives to encourage participation by researchers, active participation by informal leaders and influence brokers within the scientific community, and early successes that inspire confidence and illustrate leadership's commitment.

Management

9. Successful implementation of change will require full-time, qualified, professional managers at the central and unit levels. Too often the Smithsonian has selected managers based on excellence in scholarship or using a rotation system. Management becomes a collateral and not necessarily desirable duty on top of a heavy research workload. Nor is there a program to ensure that inexperienced managers receive mentoring and professional development opportunities, or to nurture potential managers—and leaders—from among Smithsonian staff.

Organizational Structure

10. To a large extent, the Smithsonian's organizational structures are not well-aligned to undertake large, complex challenges, develop critical mass to bear on issues, carry out integrated research projects, synthesize results, and operate cost effectively. The institutional mechanisms to facilitate linkages internally and externally are limited; much relies on the initiative of individuals. Internal communication systems have not been up to the task of keeping the scientific community informed of the scope of research being undertaken, facilitating the identification of opportunities for collaboration, and sharing information, perspectives, ideas, technologies, and new knowledge.

11. Carrying out interdisciplinary programs and playing a role in national and global science priorities require flexible, responsive, and coordinating organizational mechanisms that tap into and share the Smithsonian's range of resources. No single organizational structure for promoting and supporting collaborative and interdisciplinary research emerged from the study as preferable. Most organizations have opted for a central IDR office to provide focus and identity and provide administrative support, as well as common space where researchers can work and interact. Beyond that, some IDR centers have their own research staff and/or "share" staff with home departments and even external organizations. At some centers, particularly those with open labs, research takes place onsite; at others both onsite and at multiple organizations in and outside the United States. There are even virtual centers.

12. Likely the Smithsonian will use a variety of organizational models, and both decentralized and centralized structures will be important. A central unit offers benefits for coordinating research; facilitating Smithsonian-wide communication; identifying potential collaborations; leveraging resources; addressing administrative

obstacles; fundraising; raising awareness; and handling other functions where there are economies of scale and need for integration. A central presence could also initiate, support, and in some cases manage Smithsonian-wide scientific research initiatives of varying scale and duration, and perhaps shared labs and equipment. The locus of most research necessarily resides with the units, but they can do more to facilitate and support teams from multiple Smithsonian science units and external organizations that want to work on joint projects. In some cases, projects that are centrally funded might be located centrally, and in other instances be placed within a science unit, or perhaps outside the Institution.

13. While partnerships are typically not included as part of an organization's structure, it seems reasonable to do so here to bring greater focus to their importance and likely role. The scope and complexity of today's challenges exceed the knowledge base and resources of single organizations, even multi-unit ones such as the Smithsonian. The Institution, for example, does not have depth in economics and other social sciences and engineering. For the Smithsonian, partnerships are a critical element of research that addresses human interaction with the natural world and sustainability issues. Recent partnerships entered into by the Smithsonian at the central and unit levels illustrate the valuable resources and exchanges that result. But partnerships have to be approached cautiously to ensure the costs and benefits balance out.

Human Capital

14. An infusion of new ideas, perspectives, knowledge, skills, etc. is vital to collaboration, IDR, and the professional development of Smithsonian researchers. Absent the possibility of hiring new staff on a regular basis, bringing diversity and innovation into the system will require a range of other approaches, including: hiring criteria that emphasize collaboration and IDR; more academic appointments such as fellows and interns; rotating and term appointments for visiting external scientists; sabbaticals for Smithsonian staff within and outside the Smithsonian; and shared staff. Of particular importance is a robust post-doc program; the Smithsonian would benefit from increased numbers of post-docs and more three-year appointments rather than one- to two-year terms.

15. Also important is creating a work climate that is competitive with other potential employers and a performance evaluation system aligned with collaboration and interdisciplinary research. Rather than stimulate and facilitate collaboration and IDR, the human resource and performance evaluation systems undercut these activities. In particular, the performance evaluation system does not acknowledge

the transaction costs and productivity constraints of, and does not have adequate mechanisms for assessing performance of, collaboration and IDR.

Funding

16. Expansion of collaboration and IDR will undoubtedly require dedicated funding both for implementation of additional directions for Smithsonian science and as an incentive for collaboration and IDR. The best approach would be to raise new funds specifically for this purpose, rather than drawing from current budgets. Funding for science is not plentiful, and drawing off existing funds will generate significant resentment and opposition. At the same time, units will likely have to realign their budgets to some extent to support achievement of Smithsonian goals and strategies. In this regard, regular review of research portfolios can help ensure that the best projects receive adequate support and identify those that are least productive or misaligned.

Physical Infrastructure: Building, Labs, and Equipment

17. Much of the Smithsonian's physical infrastructure was not designed to support interdisciplinary research. The geographic dispersion of units is also a challenge, although one that other organizations have successfully overcome. It does not seem either feasible or necessary for the Smithsonian to construct or acquire a building specifically for IDR. However, there is a strong case for having an identifiable physical IDR presence with space for researchers and ready access to conference rooms to support workshops, symposia, etc. Options might include dedicated space in a renovated Arts and Industries Building (AIB) and development of/access to new space through partnerships.
18. Some centralization of labs and equipment to reduce costs, ensure broad and efficient use (including of technicians), and, again, foster contact across disciplines and units is appropriate. Clearly, however, off Mall units need to have some of their own facilities. Coordination of purchases of like equipment across all Smithsonian units will facilitate maintenance, generate cost-savings, and improve deployment of technical staff. Priorities to guide the allocation of resources for equipment, supplies, technical staff, and maintenance can help maximize the value of investments. Also worth exploring are opportunities to engage with partners to share labs and equipment and thereby leverage costs.

Administrative Support

19. The central administrative systems currently in place frustrate and hinder, rather than support and facilitate, scientific research, particularly collaborative and interdisciplinary. Particular areas requiring review with an eye to alignment with the realities of scientific research are the information technology (IT) environment and support, travel arrangements, hiring processes, particularly with respect to more rapid processing of short-term employees, contracting, and financial management at the project level. In many areas the ratio of administrative support personnel to scientists is low.

Recommendations

Smithsonian Science: An Agenda for Change

Smithsonian science must change if it is to remain competitive and relevant on the national and international stage. The Secretary should set in motion a process for increasing collaborative and interdisciplinary research at the Smithsonian through strategic IDR initiatives that include addressing complex issues of global impact.

Leadership

I. The Secretary should ensure that effective, committed, and sustained leadership is in place to motivate, support, follow through on, and advocate internally and externally for strong collaboration and interdisciplinary scientific research. The Secretary should:

1. Play an active role in energizing collaboration and interdisciplinary research throughout the Smithsonian, including advocacy internally and externally, generation of resources, sustained follow through on plans and decisions, attention to sound criteria-based and cost-effective decision making, support for change in organizational culture, and accountability.
2. Appoint an Under Secretary for Science who has deep understanding of collaborative and interdisciplinary science, personal experience with large-scale organizational and cultural change, and standing and respect within the scientific and donor communities.
3. Task the USS with responsibility for strengthening and integrating collaborative and interdisciplinary research throughout the Smithsonian.

II. The USS should develop and implement a plan for strengthening and expanding collaboration and IDR and a plan for implementing the strategy.

1. The plan should include at least the following:
    a. A statement of desired outcomes and impacts of Smithsonian IDR in general.

b. An overview of what integrated IDR research means within the context of scientific research at the Smithsonian, particularly the relationship of long-term, foundational research to IDR efforts.

c. Identification of areas where scientific research can benefit from critical mass and leveraging of resources.

d. Development of alternative IDR program statements of purpose and recommendations for submission to the Secretary. The statements of purpose will identify the scope, near-term outcomes, and long-range impacts related to proposed strategic IDR initiatives.

e. Changes in organizational structure required to support implementation of the plan, including creation of a central IDR presence and definition of functions and resource requirements (e.g., technology, space, and people).

f. Description of a Smithsonian scientific culture that supports forward-thinking, 21st century research.

g. Increased access to Smithsonian data.

h. Requirements and standards for an administrative support system capable of facilitating collaborative and interdisciplinary research.

i. Action steps for implementing the plan that address required changes in science and infrastructure, along with a timetable and milestones against which to measure progress. Each unit and central administrative support office should be asked to provide a plan of action that details how they will contribute to implementing the plan and accomplishing its goals.

2. The plan should be based in part on:

    a. Inputs from the Smithsonian science community in defining: directions and priorities for IDR research, including recommendations on strategic questions and Smithsonian-wide initiatives related to critical contemporary challenges; problems in which the Smithsonian can make significant contributions; areas in which the Smithsonian can advance the science needed to address them; optimal roles for a central IDR unit; and administrative and work environment requirements to foster and support collaboration and IDR.

b. An assessment of scientific research at the Smithsonian to identify key opportunities for cross-unit collaboration and interdisciplinary research, and identify the best collaborations and IDR efforts on which to build.

c. A study to identify key opportunities for raising funds and leveraging resources, including through partnerships, to include ways to take better advantage of Smithsonian-wide pools of experts, such as organismal biologists, and on marketing what the Smithsonian can bring to the table.

d. Consultation with senior members of offices that will have key roles in facilitating the program initiatives, such as the Office of External Affairs (OEA) [Office of Development (OD) and Office of Sponsored Projects (OSP)], Office of Communications [Office of Government Relations (OGR) and Office of Public Affairs (OPA)], Office of the Chief Information Officer (OCIO), Office of the Chief Financial Officer (OCFO) [Office of Contracting (OCon) and Office of Planning, Management and Budget (OPMB)], Office of Human Resources (OHR), and Office of Fellowships (OF).

e. Input from external experts on both IDR research and organizational change.

Organizational Structure

III. The USS should establish a Center for Interdisciplinary Smithsonian Science (CISS) within the OUSS, to be responsible for implementing the IDR plan, facilitating collaboration and IDR throughout the Smithsonian, and supporting and in some cases managing research aimed at mitigating pressing global problems and advancing related research methods.

1. The CISS should:

    a. Implement the functions specified in the IDR plan.

    b. Take responsibility for overseeing CISS-funded IDR programs, projects, and other activities and functions.

    c. Work with and coordinate the activities of the administrative and infrastructure offices having a role in supporting and facilitating collaboration and IDR.

d. Be provided with adequate support staff and funds to ensure efficient and timely implementation of CISS functions and strategic IDR initiatives.

e. Maintain a fund for competitively awarded research projects, with preference to proposals that involve two or more Smithsonian units and external collaborators and that address the Smithsonian-wide strategic IDR initiatives.

f. Emphasize and facilitate the use of partnerships with Federal agencies, universities, and other organizations to strengthen program initiatives and leverage resources.

g. Be functioning within two months of approval of the IDR plan.

2. Home units should support involvement with CISS by their scientists.
3. To ensure the long-term stability of the center and IDR endeavor in the face of changes in the Smithsonian's operational environment, the Secretary should include the Center in the Institution's strategic plan.
4. Continued realization of the IDR plan should be a critical factor in selecting future Secretaries and other Smithsonian leadership.

Management

IV. **The USS should create an Assistant Under Secretary position to manage the CISS and serve as point person for the IDR endeavor.** The Assistant Under Secretary for CISS should:

1. Have full-time management responsibility for the IDR endeavor and CISS.
2. Be a scientist with an understanding of the requirements and management of interdisciplinary scientific research, experience with undertakings of this type, ability to work with people from different disciplines and administrative areas, and experience with partnerships.

V. **To accomplish the collaboration and IDR plan, Smithsonian science managers should be selected based on a set of attributes that include a record of success in managing collaborative and interdisciplinary research.**

VI. **The USS should establish a program of regular assessments of IDR programs and projects, including those conducted under CISS, by external reviewers**

to ensure continued relevance and impact and guide decisions on resource allocation.

VII. Goals and objectives related to collaborative and interdisciplinary research, including CISS, should be part of the annual performance plans of leadership and management; both should be held accountable for their accomplishment. A reward structure to encourage collaboration and interdisciplinary research should be established.

VIII. The CISS should ensure that a system is in place throughout the Smithsonian for effective review of proposals and performance involving collaboration and interdisciplinary research, particularly with respect to fellowship awards and performance evaluation.

IX. Because the IDR endeavor will involve significant organizational changes, including its culture, the USS should formulate a carefully thought-out set of strategic approaches to form the core of the undertaking.

1. Best practices suggest that the strategies should include: a bottom-up approach that emphasizes input and recommendations from the key players who will be affected by or have roles in the effort, combined with firm leadership and timely decision making at the top; a limited timeframe for implementation with milestones that are included in the performance plans of key participants; near-term implementation of specific changes that can be accomplished quickly and at little cost to show commitment and engender confidence; adoption initially of just one or two initial strategic IDR program areas by CISS; use of influence brokers and leaders within the Smithsonian scientific community; and financial and other incentives, including funds for competitively awarded grants.
2. If the new USS and Assistant Under Secretary for CISS are not in place as the IDR endeavor moves forward, the Secretary should consider bringing in an outside expert with relevant experience to advise on the process.

Human Capital

X. The Secretary should task the USS with ensuring that the Smithsonian has a workforce of permanent and non-employee[2] research staff with the knowledge,

2 Includes research associates, post-docs, pre-docs, undergraduate students, term appointees, and similar designations.

skills, and attitudes required to carry out high quality interdisciplinary research.

1. The CISS, working with the unit directors, representatives of the Smithsonian scientific research community, OHR, and other offices as required should develop a long-term human resources plan that defines the workforce the Smithsonian needs to accomplish its IDR research goals and mechanisms for carrying out that plan. The plan should cover employees and non-employees, including researchers, technicians, research support personnel, and central and unit-level administrative staff.
2. The CISS, in conjunction with OHR, should provide ongoing opportunities for the professional development of researchers and other staff to strengthen their ability to engage in collaborative and interdisciplinary research, using a variety of mechanisms, including conferences, training, internal and external sabbaticals, joint appointments, networking, and access to post-docs.
3. The CISS should give priority to maximizing opportunities to host academic appointees and other non-employee researchers at the Smithsonian, and to support temporary assignments of employees to different Smithsonian units and external organizations.
4. The CISS should develop a marketing and communications effort that effectively demonstrates the value and accomplishments of Smithsonian science.
5. The Smithsonian should establish a system for identifying, training, and mentoring new leadership from within the workforce.

Funding

XI. The USS should establish and carry out a fundraising plan to assure adequate funds to support a robust IDR endeavor and implementation of the IDR plan.

1. The USS, in conjunction with the Secretary, should develop a funding plan that provides the funding needed by units and administrative offices to ensure timely implementation of the IDR plan.
    a. The Secretary should make raising new funds for implementing CISS a high priority.
    b. Adequate funding should be available for the initial years of CISS staffing.

c. CISS should have funds for awarding competitive grants for IDR research projects; some funds should be available for high-risk, innovative research.

2. The USS, working with the Office of External Affairs, Office of Communications, unit development offices, and the scientific community, should identify, prioritize, and solicit diverse and likely funding sources, including foundations, corporations, individual donors, partnerships with universities to access National Science Foundation (NSF) funds, Federal agencies, and the Congress.

3. The central and unit Development Offices and the Office of Sponsored Projects should strengthen their capacity and expertise for science fundraising, to include providing scientists support for grant writing.

4. The USS, working with the Office of External Affairs (OD and OSP) and the Office of Communications (OGR and OPA) should strengthen communication of the value of Smithsonian science to Federal agencies, universities, the public, donors, and other stakeholders.

Work Environment and Infrastructure

XII. The Secretary should task the USS with ensuring that the Smithsonian provides a work environment and infrastructure that encourages, facilitates, and sustains collaboration and interdisciplinary research throughout the Smithsonian, including projects sponsored by CISS, and improves its efficiency. This effort should be a high priority.

1. The OUSS should create a positive work environment that motivates the workforce and establishes the Smithsonian's reputation as a highly desirable place to conduct research.

   a. The OUSS should undertake a systematic exploration of incentives and rewards, monetary and other (such as priority access to post-docs), that can be used to encourage collaboration and interdisciplinary research. These should be available at the unit, department, and individual levels.

   b. Particular attention should be paid to a climate that supports younger scientists realize their expectations and is consistent with their values, such as creativity, risk-taking, interaction across the Smithsonian research community, and ability to cross boundaries—unit and discipline—with ease.

2. Administrative offices (particularly OHR, OCIO, OF, OEA [OD and OSP], Office of Communications [OGR and OPA], OCFO [OCon and OPMB], and OP&A), and the Smithsonian scientific community, should establish a working group to identify key obstacles to efficient collaboration and interdisciplinary research, identify solutions, and develop a plan for timely reforms.[3] Particular priorities are the IT environment and support, travel arrangements, purchasing authority, and the hiring process. The Secretary should be prepared to address staffing shortages that might delay strengthening of administrative systems.
3. As needed, and particularly where there are precedents at other Federal agencies, the Smithsonian should make it a priority to get exceptions to Federal rules that are significant barriers to collaboration and interdisciplinary research.
4. The Secretary should ensure that CISS has dedicated office and meeting space for staff engaged in its strategic program areas and projects. The potential for using space in AIB should be explored.
5. To the extent that the Secretary determines the Smithsonian should increase its role as a convening authority, it is likely that the Smithsonian will need to enhance its conference facilities. Again, consideration should be given to space in AIB.
6. The OUSS should explore opportunities to partner with other organizations that have access to funding for scientific physical infrastructure that could be used to construct new facilities on its property or that can provide the Smithsonian with access to their physical infrastructure, particularly labs and equipment.
7. The OUSS should prioritize the allocation of resources for labs, equipment, and technical staff and coordinate the use of these resources to reduce costs and increase efficiency.

3 The OP&A study team firmly believes that investment in these reforms will benefit all endeavors at the Smithsonian, inasmuch as complaints about administrative shortcomings are common in all areas of operations.

FINDINGS

A Shifting Paradigm for Science Research

Over the past decade or more, scientific research has shown a marked shift from primarily single principal investigator, single-discipline work to collaborative, problem-based, interdisciplinary teams that span institutional boundaries. The change has been driven to a large extent by the recognition that innovative and "transformative" science often happens at the intersection of disciplines (National Science Foundation, 2006; Rhoten and Pfirman, 2007), and that contemporary problems in human health, climate change, neuroscience, systems biology, loss of biodiversity, population pressures, degradation of the oceans, and so on cannot be addressed through scientists in single disciplines working independently (Whitfield, 2008b; National Academy of Sciences, 2004; Klein, 2005; Graybill, et al., 2006). Financial incentives from government funding sources and foundations to promote partnerships and interdisciplinary research that addresses critical global problems have also been a significant impetus for the shift. In response, many research organizations, including Federal agencies and universities, have undertaken structural changes to facilitate and promote interdisciplinary research (Bozeman and Boardman, 2003; Jones, Wuchty, and Uzzi, 2008). It is also clear that today's post-secondary students are very oriented toward interdisciplinary, team-based research that addresses the world's critical issues; their interests tend to span departmental and organizational boundaries. While some Smithsonian interviewees expressed consternation with the push toward more IDR (discussed in detail below), others insisted it must be the future of the Smithsonian.

Smithsonian Science: Comparative Advantage and Relevance

Identified Strengths

An important part of defining the proper role for IDR efforts at the Smithsonian is identifying the Institution's areas of comparative advantage vis-à-vis other research organizations. Speaking generally, NRC (National Research Council, 2003) concluded that the Smithsonian "plays an important role in the overall U.S. research enterprise and contributes to the healthy diversity of the nation's scientific enterprise." It characterized the National Museum of Natural History (NMNH), National Zoological Park (NZP), and Museum Conservation Institute (MCI, then the Smithsonian Center for Materials Research and Education), as "unique" and making "special contributions." NRC described three units—Smithsonian Astrophysical Observatory (SAO), Smithsonian Environmental Research Center (SERC), and Smithsonian Tropical Research Institute (STRI)—as "world-class institutions" meriting stable Federal support.

More specifically, three external reviews (National Research Council, 2003; National Academy of Public Administration, 2002; Smithsonian Science Commission, 2002) and comments from interviewees and the Smithsonian strategic planning survey of 2008 noted specific areas in which Smithsonian science plays a leadership role nationally and internationally, as well as areas where it has strong potential.

Collections and comparative biology. The Smithsonian's collections were seen as having no equal: particularly vital to answering questions about global issues are the national biological collections and the Zoo's living collections (see also National Research Council, 2003). Some interviewees saw foundational work in comparative biology as a great strength.

Long-term focus. The Smithsonian's relatively stable Federal funding base enables Smithsonian researchers to undertake long-term, baseline monitoring studies in stable locations that are critical to answering big-picture questions, an area of research few other organizations engage in (National Research Council, 2003). The Smithsonian's research databases are "extraordinarily valuable" and have only begun to be tapped.

Breadth of disciplinary and geographical foci. The Smithsonian was said by some to bring global leadership in a number of fields, such as tropical biology, paleobiology, astrophysics, systematic study of biodiversity, marine sciences, volcanology, human origins, and materials research, and to have a large body of specialists well-recognized within the scientific community. Interviewees noted that the Smithsonian has the largest corpus of organismal biologists—more than 300—of any organization, a fact that often goes unnoticed because of their dispersion across the Smithsonian. Some interviewees thought that the Smithsonian has a potential role in rapid response work related to emerging crises, such as disappearing amphibians, avian disease, and invasive species. NRC noted the pre-eminent work of NZP scientists in wildlife disease; assisted reproduction, cryopreservation, and endocrinology; and population genetics and small population management. The Smithsonian is a recognized leader in the study and conservation of certain species, such as Asian elephants, tigers, migratory birds, and giant pandas. Also a noted strength is the Institution's extensive experience in regions such as the tropics, North American coasts, Alaska, and Southeast Asia, and lab facilities at many locations.

Convenor. Owing to these assets and reputation for objectivity and integrity, in the view of some interviewees the Smithsonian is uniquely positioned to draw together experts to synthesize and interpret data, identify gaps in knowledge, and formulate action plans to address those gaps. It is a logical venue for discussions of sensitive issues. An example is the tropical science symposium hosted by the Smithsonian in January 2009, where the scientific community debated the magnitude of future species extinctions in the tropics. There was a sense that the Smithsonian has not done nearly enough in this regard.

Education and professional development. The Smithsonian has earned a reputation for exceptional educational opportunities for post-secondary students and post-docs/ fellows, including in some fields not typically included in university curricula, such as comparative biology, captive populations, and zoo veterinary medicine. There is a large unmet demand for greater access to Smithsonian professional training. Through its professional training, the Smithsonian has contributed importantly to capacity building around the world and has an extensive network of contacts with practitioners and policy makers alike.

Identified Weaknesses

Along with those strengths, the three reviews from 2002-03 identified weaknesses that the Smithsonian has targeted in its Science Strategic Plan—*Science Matters: Priorities and Strategies 2005-2010*—and through other changes. But many of the weaknesses persist as fundamental barriers to collaboration and IDR (and science excellence in general) (National Research Council, 2003; National Academy of Public Administration, 2002; Smithsonian Science Commission, 2002; and echoed by many interviewees):

Lack of vision, strategy, and coordination. No underlying strategy drives the Institution's research efforts, and the whole is not greater than the sum of the parts, despite many areas of world-class excellence. This situation has impeded collaboration and IDR, mobilization around large collaborative projects, and rapid responsiveness to the big challenges the world faces today. The blame tended to be placed at the feet of senior leadership, which has not set and funded strategic priorities and emphasized achievement of synergies. Leadership has also not addressed the inflexibility that characterizes systems, processes, structures, and—most importantly—culture.

Poor communications. Units are too often only vaguely aware of what is going on at other units (and in some cases, across departments within their own unit). This insularity is a longstanding element of the Smithsonian culture. Communication with external research organizations has been better, and the Smithsonian has promoted access to its science library and other resources. At the same time, access—particularly electronic—to databases is not always easy.

Low awareness of Smithsonian research. Potential funders and supporters in Congress, foundations, industry, and the general public usually do not appreciate the scope and importance of scientific research at the Institution. Among other effects, it puts the Smithsonian at a competitive disadvantage with regard to raising funds.

In addition to the general weaknesses discussed above, Institution scientists cited a number of practical barriers to collaboration and IDR, including uneven management, excessive bureaucracy, weak central administrative support and systems, and infrastructural limitations (facilities, equipment, and laboratories).

Relevance: an Ongoing Discussion

There has been ongoing discussion in recent years about the need for relevant programming at the Smithsonian. Smithsonian science has been part of this discussion, with a core issue being the emphasis funders place on research that addresses societal problems and shorter term impacts. For many interviewees, "interdisciplinary research," with its focus on bringing diverse perspectives to bear on solving complex problems, is one path to greater relevance. However, for others the term carries a more negative connotation of eroding existing disciplines. The Gates Foundation describes its grants as "problem-oriented, difficult … complex" and not "interdisciplinary." "Interdisciplinary research" is often conflated with problem-oriented applied research, whereas the Smithsonian is described as deeply identified with curiosity-driven basic research. Some interviewees were ambivalent about the idea of IDR, fearing that it would come at the expense of "inherently non-interdisciplinary" research, for example, taxonomy. Mace (2004), among others, notes that effective conservation depends on a strong and well-funded science base in taxonomy and systematics. Brooks and Hoberg (2006) make the case that the crisis of emerging infectious disease stems from the absence of comprehensive taxonomic inventories of the world's parasites, which includes the world's pathogens. There was emphasis on the critical link between the work of taxonomists and systematists to applied research in ecology and other areas because of the need for deep basic knowledge of the organisms at issue.

More generally, interviewees cautioned against losing sight of the importance of traditional curiosity-driven basic science, which often results in unforeseen practical applications (see, for example, National Research Council, 2008). An example is the immense value of the long-term data, including carbon storage data, collected by STRI's Center for Tropical Forest Science—now known as the Smithsonian Institution Global Earth Observatories—to climate change research. It was not uncommon to hear scientists argue for both curiosity-driven research and applied IDR.

At the same time, a number of people pointed out that the Smithsonian has done a poor job of communicating the importance and relevance of curiosity-driven and long-term basic research, and the fact that it is one of the few organizations that still carries on that type of research. In this regard, communication between scientists and support offices such as development and public relations needs to be strengthened, and people who can translate technical scientific information into layman's terms are needed. And it will be necessary to overcome a culture that eschews that type of outreach.

Collaboration, IDR, and Smithsonian Science

There has always been a great deal of interdisciplinary work at the Smithsonian; however, it has tended to be informal in nature, flowing from the shared research interests of Smithsonian scientists. During the 1960s and 1970s and into the 1980s, a series of interdisciplinary pan-Institutional offices were created to stimulate and coordinate this research, but they never fit well within the Institution's structure and were eventually closed. In addition, success depended on two contingencies—adequate funding and a change in the culture of individualistic research—that proved difficult to realize (Henson, 2008). Interviewees recalled more recent attempts to coalesce around big interdisciplinary projects or integrate work in a geographical region, but they, too, petered out.

Nevertheless, the OP&A study team encountered many Smithsonian scientists who were already highly collaborative and interdisciplinary, as well as others who wanted greater opportunity to be involved in interdisciplinary research teams tackling complex questions. As an example, a recent strategic planning exercise at NMNH that asked staff for "big ideas" produced 30 different proposals, many interdisciplinary to varying degrees. The team was also given copies of a number of proposals for pan-Institutional programs and centers that are indicative of eagerness for IDR and understanding of its benefits. Examples are the establishment of a pan-Institutional Smithsonian Conservation Biology Institute (included in the current science strategic plan); deepening of the existing Pacific Science Network consortium that includes anthropology, biology, geology, and planetary science studies in the Pacific with close to 100 collaborating institutions; creation of a Smithsonian Planetary Science and Education Center that would draw from all the science units; a Smithsonian Network for Human Ecology Research and Education whose organizing principle is that sustainability efforts need to incorporate the point of view of the people living within specific environments; and a National Center for Synthesis in Biological Evolution to address the fragmentation of knowledge within evolutionary biology and questions of public concern.

Smithsonian science encompasses areas of research that are, by their nature, more likely to involve collaboration, interaction, and integration across disciplines. Examples are astronomy, astrophysics, and planetary science, where there has been a long history of collaboration between the physics and astronomy communities, as well as engineering, computer science, and other areas, because of the complexity of the research questions and the sophistication of the facilities and instrumentation required to address them. Another example is environmental and conservation sciences, where collaboration is required to address large-scale ecological problems at the level of ecosystems, landscapes, and even continents or the whole globe. Several Smithsonian scientists suggested that extensive rethinking of traditional disciplines would be needed if the Smithsonian is to move to pragmatic conservation activities. Applied work in this area of necessity needs to bring in the human dimension and associated fields of politics, social science, economics, etc. (Hellinger and Hellinger, 2008). In general, however, these non-natural science dimensions have not been integrated in any major way with natural sciences at the Smithsonian.

As noted, the Smithsonian has done better at collaborating, and entering into formal partnerships, with the external sector, be it universities, Federal agencies, private sector organizations, and consortia. It appears, anecdotally, that compared with other research organizations, Smithsonian collaborations and partnerships are on a lesser scale. There was a sense that it can do much more to leverage its resources and extend its contributions to larger scientific endeavors through increased partnerships.

Leadership

The need for effective, sustained leadership at all levels emerged in the interviews and literature as critical, particularly when an organization is contemplating new directions or emphases that require major changes. Particular issues have been an absence of direction for science research, a failure of leaders to make hard decisions or follow through on ones they have made in an effort to achieve consensus, leaders too often chosen for political reasons or academic stature rather than leadership and management skills, and new leaders not being provided with the mentoring they need to get up to speed. In recent years there has been frequent turnover of leadership.

The interviewees and the literature pointed to several critical elements of effective leadership that have not been carried out well at the Smithsonian.

Providing direction. It is axiomatic that a foremost role of leaders is to provide a sense of direction to an organization, something that many interviewees said was absent at the Smithsonian with respect to science, although a science strategic plan was issued in 2004. Several fundamental and long-standing values questions emerged from the study that bear on future directions, particularly with respect to IDR and research directly focused on helping to find answers to today's big problems.

- *What should "interdisciplinary" mean at the Smithsonian?* For example, should the Smithsonian orient itself more toward broad interdisciplinarity, say, incorporating social sciences and humanities with science, or continue to work primarily in its existing areas of disciplinary strength—say, teaming sub-disciplines of biology? Should it mean different disciplines working alongside one another at the same location, or working in a way that integrates the work such that the whole is greater than the sum of its parts—what one person called "real intellectual interdisciplinary engagement?"

- *What would be the role of curiosity-driven research within an interdisciplinary Smithsonian?* Does the Smithsonian see itself as "a science-for-science's-sake" organization with individual interests driving inquiry, or should all its research be focused on defined questions or geographic areas for critical mass, engaging multiple disciplines in the process? Should it continue along both tracks?

- *Should the Smithsonian engage with global societal concerns?* Does the Smithsonian have a responsibility to help find solutions to major global problems where it has particular expertise, with a more immediate, practical focus and near-term impacts? Or should it continue to do the long-term foundational research that it is better positioned than most to carry out, given that it is largely taxpayer-supported with a steady base of Federal funding?

- *Is it politically possible for the Smithsonian to pursue national priorities and emerging issues?* Is it wise for the Smithsonian to take a leadership role on today's critical problems, which are politically sensitive because adoption of policies ultimately lies in the political realm? Or does its reputation for integrity and neutrality make it a perfect candidate for that role?

Many interviewees thought the scientific research endeavor at the Smithsonian lacked vision. What does the Smithsonian want to be known for? What impact should its science have on the world 15 or 20 or 30 years out?

Both the literature and employees talked about how leadership should go about providing direction. Several points emerged:

- *Ask for input, but make the hard decisions.* A prevailing message was the need for a bottom-up process to identify the good questions that should drive scientific research at the Smithsonian—*and* a strong leader willing to make final decisions and stick with them. Allowing creative ideas and innovation to "bubble up" from the scientific community was seen as important both for generating innovative, challenging, and important questions and getting buy-in. In the end, however, it is leadership's responsibility to decide what questions the organization's research should address and what impact it should aim for. There was a strong sense that the collegial decision making that characterizes the academic world—and the Smithsonian—can be stultifying.

- *Build on the Smithsonian's strengths and resources.* A logical consideration in making decisions on direction is the organization's comparative strengths and resources, so that it can deliver what it promises.

- *Set priorities.* Smithsonian leaders have shown an unwillingness to face up to hard decisions about Institutional priorities to avoid controversy. A frequently mentioned obstacle to setting priorities—and to good decision making generally—is the quagmire of consensual, committee-based decision making, which is deeply embedded in the Smithsonian's culture.

Following through on decisions, regardless of their popularity. Leadership's failure to follow through on decisions came up frequently, principally with respect to not holding to decisions or ensuring the funding and other resources needed for implementation are available. Many staff were dismissive of decisions by the central administration, believing they could be undermined by opposition or that leadership can be waited out. In contrast, a pervasive characteristic of successful external IDR organizations was ongoing commitment from leaders within a defined timeframe. Overcoming that skepticism will, interviewees noted, require inspirational leadership—an ability to convince people to join the research agenda and work for something larger than themselves and their department or unit.

Sustaining the commitment. There is an understandable tendency for new leaders to change existing directions and priorities in an effort to put their own imprint on the organization. This is a particular concern at the Smithsonian because of the frequency with which its leaders have changed in recent years, and also because of the potential impact that the results of national elections can have. Interviewees called for measures to ensure stability over time and across changes in leadership. Absent sustained commitment and support, staff tend to draw back into their own interests.

Linked to sustained commitment is a need for much stronger advocacy for science at the Smithsonian than has been seen in recent years, particularly with Congress, but also with the public more generally. But advocacy is also seen as an internal issue, with leaders needing to exercise a stronger voice at the table for support of scientific research.

Management

> *Without management continuity, there is limited opportunity for individual researchers to develop trust in the organization and become comfortable moving beyond their established areas of expertise (National Academy of Public Administration, 2002).*
>
> *Well, I think when you are a scientist you tend to in fact ignore or even not pay a lot of attention on management issues. You think that because you have such a logical mind that basically if you just say what you think loud enough, people will line up and believe in what you say and just do what you say. And I think that is a very common misunderstanding about the need to align people and the need to really win the intellectual debate first and foremost before just thinking you own the truth (Zerhouni, 2005).*

External interviewees, and the literature, emphasized management issues more so than did Smithsonian ones; in the case of the latter, the main focus tended to be the Institution's excessive and stifling bureaucracy. Key points were the importance of investing in qualified managers, choosing the right strategies to accomplish organizational change involving scientists, emphasizing boundary-spanning, creating a positive work climate that promotes and sustains collaboration and IDR, and holding people accountable for desired results.

Investing in Qualified Managers

A recurrent theme is that management is a specialized function and that managing collaboration and IDR is different from traditional management—and it therefore must be treated as a full-time job, not a collateral duty. Often the organization doesn't recognize that and both assigns people to be managers who are destined to fail and continues with management processes and systems that undermine collaboration and IDR. An interviewee discussed an external organization that had begun to develop a "collaborative leadership series" to train potential managers in the competencies they would need to effectively foster and support IDR, such as conflict resolution, team building, and intellectual property law. This organization also set up interdisciplinary mentoring committees. Another interviewee recommended looking for more senior scientists who don't have to worry about building a reputation and are more willing to cope with paperwork, meetings, marketing, etc. Saxberg and Newell (n.d.) commented that managers must be willing to move more toward being a generalist than a specialist and become oriented toward application. Bozeman and Boardman (2003) report that the smoothest running university IDR centers are those with a clear delineation between the managerial tasks of the center director and the administrative director, where the center director focuses on research direction, linkages, and the procurement of funds, and the administrative director oversees tasks that do not require scientific knowledge and expertise, such as budgets, reporting requirements, and event logistics. Also, hiring a research general manager, for example, with a MBA or comparable degree, can facilitate interdisciplinary research activity and strengthen accountability.

Managing Effectively

The research raised several functions that are important to collaboration and IDR.

Skill building. Collaboration, particularly interdisciplinary collaboration, often brings together people with significantly different backgrounds, as reflected in how they communicate and define words and their methodologies, standards, philosophical context, etc. Team members are often unaware of those differences, let alone how to handle them. Some interviewees suggested the that the value of training or orientation in collaboration across disciplines is not well understood at the Smithsonian since a culture of IDR does not currently exist. In contrast, the Urban Ecology Integrated Graduate Education and Research (IGERT) Program at the University of Washington uses a variety of methods for IDR skill building, including hiring a professional facilitator to conduct workshops on group management skills, interpersonal communication strategies, and creative problem solving, and providing institutional support such as

PhD committees comprising multiple disciplines (Graybill, et. al. 2006). The NSF builds in start-up time and orientation sessions for its interdisciplinary proposal review and performance evaluation teams. Building interdisciplinary teams involves cultural changes, such as openness to learning about different perspectives, a willingness to take the time to understand what another person brings to the table, and acceptance of a very different group dynamic.

Supporting the unique characteristics of collaboration and IDR. For Smithsonian management, engaging in IDR requires recognition and acceptance of processes that run counter to some of the entrenched norms, processes, and measures found with the traditional academic model of discipline-specific research. Start-up takes longer; IDR requires greater flexibility and acceptance of risk to accommodate the breaking of new ground; there has to be a willingness to understand and support a different group dynamic; and performance measures are needed that specifically align with the nature of IDR.

Being a broker. Managers of collaborative and interdisciplinary research often find themselves in the role of brokers. They help connect staff to opportunities for acquiring new knowledge, skills, and approaches. They work to identify and create linkages between collaborators and potential partners. This brokering occurs not just with the external world, but also internally. Recognizing that fragmentation and siloed organizational structures are significant obstacles to IDR, a number of universities have restructured their recruitment, hiring, and promotional policies and practices, such as setting up offices tasked with better communication and more collaboration across disciplines. One permits multi-authored dissertations. Ten research universities joined to set up the Consortium on Fostering Interdisciplinary Inquiry to share best practices. The literature discusses informal structures such as networks/communities of practice (National Academy of Sciences, 2004; Ackerman, Pipek, and Wulf, 2003), expanded peer groups (Sharp, n.d.), and greater openness and problem broadcasting (Lakhani, et al., 2007; Lagace, 2006). Organizations can draw on a range of "synthesis activities" to address fragmentation of knowledge, for example, working groups, research fellows, informatics teams, annual meetings and workshops, electronic tools and research resources, web presence, and public and professional outreach (Erwin, 2004).

Some leaders identify boundary-spanning and knowledge-brokering as among their most important roles, while other organizations, including some government agencies, employ staff specifically for those functions. The research points out the importance of selecting the right people for these roles. They have to be deeply knowledgeable about both their organization's internal and external environments, have expertise in gathering, filtering, interpreting, and transmitting information in written and verbal form, and have excellent interpersonal skills.

To a considerable degree the structure of Smithsonian science units reflects the traditional academic departmental model, and several Institution interviewees cited this fragmented structure as a source of problems with communication, access to information, dysfunctional competitiveness, and failure to share lessons learned, new knowledge, technologies, etc. Growing recognition of the cost of this situation is evidenced in recent efforts to forge stronger connections. For example, one Smithsonian scientist created an international listserv to facilitate intellectual exchange that includes 620 people and has led to joint research and publications. A successful initiative by STRI was the appointment of liaisons—one located in Washington, DC and the other in Panama—to enhance exchanges among researchers and external partners. A 2005 external review of SERC lauded its scientists for their participation in a diverse and geographically dispersed array of research and advisory networks.

Periodically, the Smithsonian has attempted to use boundary spanners at the Institutional level to facilitate collaboration. In almost all cases, the assignment was collateral duty, and the prevailing culture made buy-in very challenging. Use of informal boundary spanners has met with better success, such as former Secretary Dillon Ripley, who frequently visited the units and asked scientists about their research, sometimes suggesting connections and cross pollinations. Several interviewees saw Scott Miller, currently Senior Program Officer in the OUSS, and former STRI Director and Acting Under Secretary for Science Ira Rubinoff, as other examples. At the same time, interviewees pointed out that the Smithsonian has never regarded boundary-spanning as a critical organizational strategy. As a result, collaboration has depended mostly on the initiative of individual scientists.

Creating a positive work climate. A congenial and personally satisfying work climate is important to hiring, retention, and productivity, all objectives of effective management. Obvious factors are financial rewards, good salaries, and promotions. But other more intangible factors are critical, such as academic freedom, compelling research opportunities, the personal satisfaction of teaching and mentoring younger researchers, professional development that occurs from working with interesting and knowledgeable colleagues, including post-docs and other non-employee researchers, and having a voice in program decisions.

- *Enabling professional and personal satisfaction.* Many interviewees emphasized that compelling research questions can be a strong motivator for researchers.

Post-docs were seen as a foremost driver in developing innovative and exciting research projects. Scientists also spoke of the personal satisfaction they got from educating students and younger scientists and initiating side projects important to their field of work but not necessarily part of their formal job, such as setting up coordinating groups, and the lack of support and recognition they got for these endeavors.

- *Meeting people on their ground.* Particularly in the case of younger employees, whose backgrounds and interests are quite different than those of many older scientists, it is important to understand and work within their frames of reference, such as their use of electronic media, interest in making a difference to their world, cross-cutting perspectives, energy, and excitement at trying something new. This means, among other things, facilitating innovation, valuing risk-taking, providing incentives for creativity, and accepting failure as part of the cost of innovation. Whatever the age of the scientist, opportunities to provide input into decisions that affect their work are important, rather than being forced blindly to follow new directions.

- *Recognition and rewards.* Besides funds, interviewees spoke of awards for exceptional performance; publicity for important research results; nominations of scientific staff for external rewards; sabbaticals; and priority in getting post-docs.

- *Professional development.* Interviewees wanted opportunities not only to stay abreast in their own areas of expertise, but also to expand their knowledge of other fields and ways of doing research. Having access to new and varied people, particularly post-docs, emerged as critical in this regard.

Assuring excellence. Many interviewees noted the importance of regular assessment of programs and projects (staff performance is discussed later) to reconfirm the value of the undertaking, the validity of the approach, the need to update relative to advances in the field, or to bring the work to a close. In its 2003 review, the NRC stated that "regular in-depth reviews by external advisory committees are essential for maintaining the health, vitality, and scientific excellence of the Smithsonian Institution." Some Smithsonian scientists thought that that type of review is missing at the Institution and that there is a tendency to hold to the status quo—"there have been sort of straight allocations [of funds] and not much review about whether programs work or if they don't."

Why Researchers Collaborate

Funding emerged as the main incentive for collaboration, but a number of other reasons were noted.

Self-interest. Collaborations happen when scientists want or need them to happen. They have to be a win-win situation, which most often involves a common research interest, complementary set of skills, or funding opportunity. Base erosion in funding for research has increasingly forced scientists to look outward for support, as has the desire to go after big grants. Some interviewees commented that the Smithsonian could better compete for large grants if it were more collaborative. One Smithsonian interviewee talked about areas of collections research at the Smithsonian that would not be possible without contributions from outside the Institution.

Expanding research horizons. Collaboration and IDR allow both individual research organizations, and the scientific enterprise as a whole, to grasp hitherto missed opportunities and expand horizons. They provide a way to bring in the skills and expertise needed to pursue interesting, complex research questions.

Leveraging resources. Collaboration is seen as a good investment because it serves to leverage resources across organizations. This point is often made with respect to expensive equipment and laboratories.

Prestige and visibility. Much of the most visible, impactful, and prestigious research going on today is interdisciplinary, as evidenced by the increase in multi-authored papers.

It is also important to note how often interviewees mentioned that, in the case of younger scientists, collaboration, IDR, and teamwork are second nature; they are totally geared toward developing innovative, challenging research projects at the boundaries of disciplines and very entrepreneurial in finding funds and collaborators to carry them out.

Why Researchers Don't Collaborate

Many interviewees emphasized two broad points. First, collaboration is not an end in itself and cannot be mandated. Second, the Smithsonian and the units put many barriers in the way of collaboration and IDR and do little to promote or support it. Other practical and cultural barriers were noted as reasons for not collaborating and engaging in IDR.

Practical barriers. In the case of the Smithsonian, often a scientist cannot find anyone internally with the needed expertise or skills with whom to collaborate. Some research has a very narrow, specialized focus that doesn't call for collaboration or IDR. Other barriers include crossing the disciplinary divide, which poses issues discussed earlier; personal satisfaction with existing projects and reluctance to go outside that framework; the geographical dispersion of Smithsonian research units; the time-consuming nature of collaboration and IDR, particularly if administrative support is limited or unavailable; existing research commitments; administrative hurdles (discussed at greater length later); and a performance evaluation system that does not reward collaboration and IDR (also discussed below).

Cultural barriers. There was considerable concern at the possibility that the central administration might "force" more collaboration or IDR; this point was almost a matter of principle, as well as a practical matter. But many interviewees also described a culture characterized by: fierce protection of academic freedom; a tradition of individual work and of competition for individual prestige and credit within peer communities, particularly among older scientists (the "publish or perish" ethos); rivalry across and within units, fueled especially by the competition for funding, post-docs, equipment, and other resources; very weak allegiance to the Smithsonian as a whole and strong allegiance to personal research projects/department/unit; cynicism about getting involved in some announced central strategy that will never be supported; risk-intolerance by management; insularity with respect to the outside world; a sense of entitlement (related to steady federal funding); and a kind of scientific elitism whereby curiosity-driven, basic research scientists are perceived to look down on their peers engaged in more applied work. Some interviewees suggested that this culture is more pertinent to older scientists who are more likely to have a self-enclosed mindset than many of the younger scientific staff who come from another culture.

Organizational Structure

> *The real question that you always have in government management, and also a large organization management that recurs, is a common theme. How do you coordinate? How do you make sure you have the synergies?...I think the best of both worlds is when you have both decentralization which allows innovation, autonomy, creativity, but at the same time synergy in what I call the common areas… (Minton-Package, 2005, quoting Zerhouni).*

To provide fertile ground for this type of research, interdisciplinary centers need not only to be well-funded but to have an independent physical location and intellectual direction apart from traditional university departments (Rhoten, 2004).

Until fairly recently, scientific research organizations, particularly universities, were typically organized into disciplinary departments (and schools) with their own staff, budgets, and space. This structure results in strong departmental autonomy; intellectual compartmentalization and a failure to address the big picture; departmental rather than organizational loyalty, fueled by the competition for funds and staff; decision making by consensus that results in least-common-denominator results; an insular culture highly resistant to change; managers selected for scholarly accomplishment and not managerial competence; stagnation that results from low staff turnover; and personalistic decisions about research directions. Many Smithsonian interviewees noted these same characteristics when talking about the Institution and the negative impact on internal collaboration and information sharing.

As research organizations move to address today's complex problems and increasingly recognize the interconnectedness of natural phenomena, they have had to adopt organizational structures that are better able to support interdisciplinary research and afford greater flexibility to respond to change and emerging issues. Rather than focusing on a specific discipline, they tend to have a broad focus on a field such as human health or the environment, a theme like poverty or sustainability, an emerging technology, e.g., nanotechnology, or an immediate global problem like climate change or loss of biodiversity. In fashioning an organizational structure, a common goal has been to create an environment that maximizes the ability of people from different disciplines to come together around specific research projects, but also more informally to foster intellectual ferment by providing opportunities for diverse scientists to share ideas, approaches, technologies, skills, etc. A second goal is to facilitate the needed transformation to a more team-based, adaptive, organic, and open-minded culture.

There is no typical pattern for how IDR centers relate to the parent organization in terms of placement within the larger organizational structure, reporting lines, and home base of the researchers. Universities and museums vary in where they have located their IDR programs—including IDR units associated with disciplinary departments, non-departmental centers and institutes that sit outside of traditional departments and where faculty associate voluntarily with the centers, and interdisciplinary units that operate as distinct departments in their own right. The centers variously report to provosts/vice provosts for research, deans, department chairs, and others (see, for example, Bozeman and Boardman, 2003 with respect to (NSF-funded) Multipurpose, Multidiscipline University Research Centers). A center may, in addition to management and administrative support staff, have its own corps of faculty/researchers, share faculty/researchers with other departments/schools, or allow departmental staff to affiliate with the center and conduct research under its auspices. Some centers award grants to external researchers to work onsite, but also at their home organizations, or both. In the case of multi-university centers, typically there is a single management entity with a director and support staff; this is true also for virtual centers. A few centers are degree-granting.

Government agencies have not been immune from the shift in research focus and related structural changes. Many mission-oriented agencies like the Environmental Protection Agency, National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), and Agricultural Research Service (ARS) were once organized along disciplinary lines, but to varying degrees have begun to refocus along big question/problem-oriented lines requiring interdisciplinary approaches, and that has led to restructuring or to use of a matrix management system.

Following are a few examples of different types of organizational structures (see also the profiles of 37 IDR organizations addendum in Volume III):

"Campus"-based Models

- Arizona State University has begun regrouping traditional departments into "transdisciplinary" institutes such as the School of Sustainability, where professors from 35 disciplines engage in urban development research.

- The King Abdullah University of Science and Technology, to open in Saudi Arabia in 2010, will operate with four interdisciplinary research institutes—biosciences, materials science, energy and the environment, and computer science and math.

- The degree-granting Massachusetts Institute of Technology (MIT) Operations Research Center has co-directors from the School of Management and the School of Engineering, affiliated faculty from around the MIT campus, and 50 graduate students. It has built in the flexibility to quickly form teams of internal and external researchers to respond to new opportunities.

- Harvard University's Center for the Environment has a director and managing director and more than 100 affiliated faculty from different academic departments and museums. The center provides seed money for IDR, holds seminars, maintains a post-doctoral fellowship program, and hosts events to bring scientists from different disciplines together.

- Stanford University's Bio-X constructed a new building with 40 open labs that are a home base to faculty from departments across the university. Bio-X funds "seed"-type projects, offers fellowships to visiting early and mid-career scientists, and promotes relationships between industry and Stanford researchers.

- The Nicholas School for the Environment at Duke University, the product of the merger of several older units and functions, has 3 research divisions and 11 research centers and programs. Of the 105 faculty, some are members of the school, while others are departmental faculty affiliated with the school. Since the Nicholas School is largely self-supporting, it is treated as a quasi-autonomous entity.

Distributed Research Models

The distributed research model involves a typically small core "center" that manages and facilitates approved research projects carried out by teams of external scientists, each of which focuses on some part of a complex and time-sensitive question or challenge. Participants do most of the research at their home organization, convening at regular intervals at the centers to share and synthesize their results. The center facilitates the work of participating researchers on that common project and monitors progress. A number of the centers in this category—the National Center for Ecological Analysis and Synthesis (NCEAS), National Evolutionary Synthesis Center, and the Santa Fe Institute—are hybrid models that support both on-campus and dispersed researchers. In addition, projects involve the synthesis of existing data rather than the development of new data.

- NCEAS's main business is making competitive awards to teams of external researchers, but it also has its own small research staff. Some scientists come to work at NCEAS on two-year appointments or on their sabbatical. Other teams of researchers from diverse organizations work at their home bases on their parts of a larger research project, often convening sub-teams there, and come together at NCEAS twice a year and at the end of the project to share and integrate their work.

- The Santa Fe Institute has four to eight resident faculty and close to 100 more at different organizations. Although the institute has physical space for onsite work, the bulk of the work is carried out at scholars' home bases—universities, government agencies, research institutes, and corporations.

Virtual Model

Perhaps the ultimate dispersed research model is the virtual one. The National Aeronautics and Space Administration (NASA)-funded National Astrobiology Institute (NAI) was implemented as a virtual, distributed organization of competitively-selected teams of researchers whose work was guided by an Astrobiology Roadmap. The physical part of NAI is located at NASA Ames and supports 14 research teams with a total of 600 investigators from 150 institutions.

Matrix Management Model

Most matrix management structures employ joint planning processes and dual assignments for managers. For example, the director of a department may also be given responsibility for running a project that involves both his/her own and one or more other departments, or at least staff from other departments. The matrix management model formalizes the sharing of specialized skills and talents, strengthens coordination of multiple dispersed activities, and facilitates responding rapidly to changes in the environment that require diverting resources from one area of operations to another.

On the downside, a matrix structure may create confusion because of unclear expectations and reporting requirements, role conflicts, complicated performance reviews, and difficult appeals processes. They may tend toward disorder. The formative stage generally requires additional personnel and therefore more funds. Sometimes staff do not want to leave their home unit or join another project; one issue is whether they have the right to decline an assignment.

Some governmental agencies/offices, described below, are changing their organizational structures to facilitate interdisciplinary research using matrix management models. NOAA, for example, now uses a matrix management approach to align the staff in its five line organizations (weather service, fisheries service, ocean service, research, and satellite and information service) with its new problem-oriented strategic objectives. Under this approach, a staff person paid through fisheries may also be assigned to work with the ocean service on coastal erosion. The matrix approach is also intended to get staff to identify with NOAA rather than home offices. Eleven years ago ARS instituted a national program system to facilitate interdisciplinary, cross-locational research (it has a widely dispersed network of research offices), better leverage resources to address national problems, and strengthen its ability to respond to high-profile emergencies. ARS has also implemented matrix management, intersecting the more narrowly focused line organizations with some 20 national programs grouped under the four overarching program areas of natural resources, crops, animals, and food safety and nutrition. Line managers are responsible for scientific quality and performance; the national office holds the program leaders responsible for program performance, impact, and relevance.

Consortium Model

Interdisciplinary research consortia enable member organizations to gain access to a range of expert talent in different disciplines, physical facilities, laboratories, and other resources available at member organizations. Knowledge transfer among consortium members generally occurs through research publications, program reports, newsletters that are circulated via the Web, and face-to-face meetings. Typically the consortium retains a small central staff to provide administrative support. Researchers are integrated into research teams with multiple principal investigators. The 30 year-old STRI-originated Smithsonian Institution Global Earth Observatories (SIGEO, formerly Center for Tropical Forest Science) is a network of forest dynamics plots administered by STRI but led and managed by over two dozen partner institutions in 15 tropical countries around the world. NMNH hosts the Encyclopedia of Life consortium, which has six major partners. Scientists from all over the world provide data, images, and feedback. The Consortium for the Barcode of Life, also hosted by NMNH, includes 160 member organizations from 50 countries. The consortium aims to develop the potential of DNA bar coding as a tool for species identification, biodiversity studies and conservation, and other applications. Ten research universities, led by the University of Minnesota, make up the Consortium on Fostering Interdisciplinary Inquiry. Its purpose is to break down traditional departmental and other interdisciplinary research barriers and identify best practices to advance change at consortium members' and other organizations.

Structural Challenges

As noted, interdisciplinary centers that reside within a parent organization but cut across departments/institutes/schools generally have to deal with turf, administrative, and logistical challenges, examples being who contributes to performance reviews, the implications of non-departmental research on getting tenure, and how to allocate staff time between departments and the center. Interviewees shared examples of how their organizations have tried to address such issues. The University of Minnesota Graduate School established an Office of Interdisciplinary Initiatives to identify and implement institutional policies, programs, and best practices that encourage collaboration and interdisciplinary inquiry. It also set up a Network of Interdisciplinary Initiatives to bring together leaders of IDR centers or other enterprises at the university that work on interdisciplinary grants that support labs, post-docs, etc. At Duke University, an Office of Interdisciplinary Program Management was set up to ensure efficient and effective administrative staffing and processes in support of the seven university institutes and centers and for interdisciplinary activities within, across, and beyond them. The Network of Interdisciplinary Initiatives at the University of Washington brings together faculty, staff, and students from the three campuses to identify challenges to IDR and initiate measures to resolve them. The National Institutes of Health (NIH) has an Office of Portfolio Analysis and Strategic Initiatives, reporting to the director, to improve management of research portfolios; help identify research opportunities and challenges; and coordinate NIH-wide evaluations (National Institutes of Health, 2008). At NSF, foundation-wide programs like the Science and Technology Centers (STCs) and Cyber-Enabled Discovery and Innovation Program (CDI) organizationally report to an Office of Integrative Activities under the NSF director.

The Smithsonian Workforce

> *Again and again, it seems to me that it comes down to the human capital. If you don't have people around who know new things, or who have different ideas about how you might answer a question, then it's difficult.*

A great many interviewees saw the workforce as the underpinning of high quality collaborative and interdisciplinary scientific research at the Smithsonian. For this study, "workforce" included not just permanent Federal and Trust employees, but other categories of non-employee researchers, whose numbers exceed those of permanent employees. Virtually all interviewees strongly emphasized that Smithsonian science would be much reduced were it not for these other classes of personnel. A further point is that fellows and post-docs in particular are a critical pool from which the Smithsonian hires permanent staff.

One theme stood out from the comments of Smithsonian interviewees—there is a profound need for generational change within the Smithsonian's aging research staff. Younger scientists were described as inherently collaborative, hard-wired to cross disciplines and think outside traditional boundaries, entrepreneurial, and energetic—

"The people you recruit have those new ideas and technologies because that's what the universities and post-doc positions are producing these days. You don't have to actively seek someone different from yourself. There is no one left like me [a long-time scientist at the Smithsonian]."

Two other human capital-related themes also were prominent. (1) The Smithsonian needs a constant inflow of people, particularly fellows and post-docs, to augment the limited number of permanent research staff and keep up-to-date. (2) The Smithsonian is not set up to accommodate interdisciplinary research when it comes to appointing fellows, hiring interdisciplinary researchers, sharing staff, and evaluating performance.

An Overview of the Smithsonian Scientific Research Workforce

Smithsonian Employees. The number of permanent scientific research staff, Federal and Trust, has fallen significantly over the last 10-15 years. According to National Finance Center data, in January 2008 the Smithsonian employed 659 full-time permanent and temporary Federal and Trust science researchers and technicians, 12% lower than the 751 employees in January 1993. When only full-time permanent Federal employees are taken into account, the decline is more severe—22% overall, and 26% for science technicians specifically. This decrease in full-time permanent Federal research staff was partly compensated for by a 4% increase in Trust, term, and part-time employees (including intermittent ones). The most pronounced decline occurred at NMNH, which saw a 32% drop in full-time permanent Federal researchers and 26% in technicians.

Over the same period, the age distribution of these cohorts has become increasingly skewed toward older personnel. The average age of full-time permanent Federal researchers, for example, was 49.6 years and that of technicians 42.1 years in 1993, and 56.4 and 52.3 years, respectively, in 2007. There was a small drop to 55.7 and 51.7 years, respectively, in 2008. The relevance of this profile is that older researchers are seen as less likely than younger ones to engage in interdisciplinary science, emphasize innovation, and be entrepreneurial. There was also a very slight grade creep over the same period.

Non-Employee Workforce. Non-employee researchers[4] come to the Smithsonian through a variety of programs, including paid academic appointments such as centrally- and unit-funded fellowships, unfunded academic appointments, including emeritus Smithsonian scholars and volunteers, and research associate appointments. NMNH gives an indication of the numbers: in FY 2008 the museum had 48 Smithsonian Fellows, 113 unit-funded fellows, 21 externally-funded fellows, 87 visiting scientists and students, 272 undergraduate interns, 162 research collaborators, and 251 research associates, for a total of 754 non-employees. Emeritus NMNH researchers, interns, and volunteers would increase this number if included. Based on the comments of Smithsonian researchers, the opportunities for interaction and discussions about different methodologies, technologies, scientific advances, perspectives, etc. makes the presence of these fellows very beneficial.

Two problems with the fellowship programs were noted with frequency:

- Most centrally-funded Smithsonian Fellowships run from several months to one year, with a few awards running two years, especially in the science units. Interviewees emphasized that terms of less than two years did not support the best research projects; ideally, the term should run three years.

- Generally, fellowship appointments are made competitively. Because the Smithsonian is not set up to review proposals for interdisciplinary research, they almost never get funded. The Smithsonian Fellowship program, for example, has no interdisciplinary review committees.

Importance of Staying Up-to-date

Many interviewees, as noted, very strongly emphasized the importance of a continual influx of new people with different perspectives, ideas, knowledge, skills, etc. Post-docs were singled out as being particularly vital as they support ongoing research; are catalysts for collaboration; afford professional development for permanent staff because of their different approaches, perspectives, skills, knowledge, and technical expertise; and are potential hires. Despite the obvious and oft-cited benefits of post-docs, the Smithsonian was said to offer far too little financial support for post-docs and did not market itself

4 Because there is no single database that accurately tracks the non-employee categories of the science workforce, the OP&A study team did not attempt to quantify the numbers of people involved (except for fellows) or the amount of hours of work they represent. In November 2008, the Smithsonian initiated the Smithsonian On-Line Academic Appointments System, which, when fully operational, and assuming all Smithsonian units participate, is intended to offer a comprehensive integrated database for the non-employee workforce.

well to attract them. Nor is the Smithsonian adept at handling post-docs proposing IDR.

Other categories of non-permanent Federal researchers were also referenced, such as research associates, undergraduates (often interns), professors on sabbatical, term employees, joint/shared employees, Trust appointees (Trust positions offer greater flexibility in deploying human resources than do permanent Federal ones), and rotating positions (external researchers coming to the Smithsonian and vice-versa, and Smithsonian staff moving around internally).

Beyond greater access to younger scientists, interviewees suggested a number of workforce options for keeping permanent staff abreast of new developments and challenged by new ways of thinking:

Sabbaticals/rotating positions. These were seen as one way to address the rigidity posed by permanent Federal researcher positions and need for fresh voices. One interviewee suggested two-year appointments for university professors on sabbatical. Other interviewees suggested a program of internal sabbaticals, both to acquire new knowledge and skills and help bridge the divide across units. One of Duke University's interdisciplinary institutes offers semester-long internal sabbaticals, paid for by the institute.

Shared positions, either hires or academic appointments. It was noted that this type of sharing faces major administrative obstacles because of Office of Personnel Management rules and, in the case of Trust positions, record-keeping issues. Further, units fear that they will permanently lose the position that is being shared, and questions arise as to how to conduct performance evaluations and share credit for work performed. Some interviewees thought, however, that the main issue was the intense competitiveness across units. As an alternative to departmentally based hiring, the University of Wisconsin-Madison's Cluster Hiring Initiative has created almost 150 new faculty funding lines allocated to developing interdisciplinary "clusters" of faculty to facilitate cross-disciplinary work.

Temporary Federal employees. Temporary employees offer a way to ensure a regular infusion of "new blood," and at least one unit is exploring the possibility of converting permanent Federal positions into temporary three-year term ones. Some oppose this change for fear the department/office would lose the position.

Trust employees. Trust funds offer greater flexibility—the positions don't have to be competed, hiring is faster, and termination is easier. The downside is getting people to accept these sometimes short-term positions for which there is no job security. Using Trust funds for salaries also ties up the most flexible pool of money.

Partners. Interviewees described how important partnerships with external organizations have been as sources of fresh ideas, perspectives, etc. And partnerships provide a vehicle for applying for grants for which the Smithsonian is ineligible on its own and for handling logistics more easily than is possible under the Smithsonian's cumbersome bureaucracy. In addition, the Smithsonian lacks the capacity to support really large-scale projects.

Support staff. A few interviewees emphasized the importance of investing in support staff, particularly technicians. Absent these personnel, research can take much longer, and equipment is underused. One obstacle to hiring more technicians is that today's equipment is very sophisticated and requires more expensive, high-grade people.

Re-configuring the Smithsonian Workforce

Many interviewees reiterated that the Smithsonian needs to restructure its scientific research staff to bring it more in line with the type of research being undertaken in today's world. Key themes were what the Smithsonian should be looking for in new hires, what new hires are looking for in an organization, and how to make the transition to a new type of workforce.

Interviewees' comments made clear that encouraging more collaboration and IDR had to begin with a workforce characterized by a broad outlook, creativity, strong belief in collaboration and interaction, new knowledge and skills, entrepreneurism in going after grants and other revenue sources, and a good fit with the organization and what it needs.

For its part, the Smithsonian needs to offer a compelling workplace that can compete with other organizations. One university interviewee commented that graduate students look for cross-cutting programs that have applications to the world's challenges. They want opportunities to do interesting projects. Some interviewees questioned whether the Smithsonian is a competitive workplace, given its lack of support for IDR and intrusive bureaucracy. To facilitate the transition to a different workforce, one interviewee suggested doing more to support entrepreneurial scientists already on staff, engaging in Institution-wide vs. unit human resource planning, and hiring staff at lower, less costly grades and nurturing them for promotions. A cautionary note addressed the hiring process itself, which some saw as set up to emphasize more of the same and not to look for people who challenge the status quo.

A Biased Performance Evaluation System

The Smithsonian's performance evaluation system came up frequently as an obstacle to collaboration and interdisciplinary research, although not everyone was of this opinion. The most common complaint was that the performance evaluation system was biased against collaboration and IDR in terms of the criteria being used or the inconsistent way in which they were applied in reviews. For example, the system did not acknowledge the "transaction costs" of collaboration and IDR, which can lower productivity in terms of raising grants and publishing. Particularly in the early stages of a project, collaboration and IDR were likely to involve time spent putting a team together, more start-up meetings, and time spent learning how to work with people from different disciplines (Bozeman and Lee, 2003). Rhoten and Pfirman (2007) noted that lower productivity can affect chances for promotion, especially in the case of younger, less-established researchers. There was also the question of whose name appears on a publication, and in what order, although multi-authored papers are becoming more commonplace. And collaboration and IDR involved more risk of failure, which most performance evaluation systems don't accommodate. Here, too, junior researchers had more at stake than established ones.

An interviewee described a two-track performance evaluation set up at one university to address these biases, with one track addressing teaching and the other research. The latter emphasizes research progress, funding, amount of collaborative work being undertaken, and evidence of value to colleagues. A negative research result is seen as a positive; the reviews look for "multiple-authored papers across three or more units that produce new insights or that disseminate the knowledge beyond its original field." Another organization looks at the funds raised on the basis of the results of seed grant-funded projects and research awards, honors, and the job track. Russell (1983) discussed the difference between "scientific merit (quality of research) and scientific contribution (applicability to the discipline), and also economic quality of research (multiple spillover effects and impact of change)." He also noted the difficulty of assessing IDR—because it "is frequently undertaken to probe new issues, expected outcomes are sometimes ill-defined [and] the benefits are occasionally found primarily in the process itself… successfully completed IDR may result in recommendations for several disciplinary approaches to subsequent analysis, or a reformulation of the definition of the problem. Contributions such as these would be absent from traditional measures of research productivity."

Even where the right criteria appear on paper, Smithsonian interviewees thought they did not always get applied in practice. There is still, for example, over-emphasis on the number of papers published. Some comments suggested that the issue related in large part to who was conducting the performance review, with some supervisors more supportive of IDR than others. Professional Accomplishment Evaluation Committees (PAECs) do not always include the right mix of disciplines and experience to do good IDR reviews.

Interviewees and the literature noted other ways in which the performance evaluation system seemed inequitable: failure to recognize research conducted as a service function; failure to reward or support interdisciplinary initiatives that benefit the area of research but are not specifically part of a person's job description (such as setting up an interdisciplinary information-sharing group); an emphasis on "bean counting" (number of papers) instead of impact, creativity, and mentoring; and problems with the composition of review panels and ability to work well as an interdisciplinary team (see also National Academy of Sciences, 2004; Russell, 1983).

Not all interviewees thought the performance evaluation system was a problem. Some thought the PAEC review process offers researchers considerable latitude to include what they think is relevant and important, that the nature of collaboration and IDR is taken into account, and, most fundamentally, that the process works in assessing the quality of research. Some researchers, most often senior ones, simply felt that the outcomes of reviews, whether good or bad, had little meaning in practice.

Funding

The general perception among interviewees was that scientific research has not been an Institutional priority on a par with facilities and exhibitions. One result is the decreasing pool of central funds for research and diversion of funds once reserved for science—notably the Scholarly Studies Program. The shortage of funds has discouraged cross-unit collaboration and IDR, despite evidence of interest in interdisciplinary projects. Instead, units and departments have focused on funding their own projects. Scarce funds also proscribed travel to geographically distant Smithsonian units that would enable regular contact with colleagues. The NAPA study concluded that "the Secretary has an opportunity to demonstrate support for the 'increase of knowledge' by tying specific institution level fundraising initiatives to scientific endeavors as part of the strategic planning process (National Academy of Public Administration, 2002). Money was seen as the most powerful motivator for buy-in for new collaborative and IDR initiatives.

Grants, Contracts, and Philanthropic Funds

The NAPA study found that the Smithsonian received substantial funding from external sources (National Academy of Public Administration, 2002). The report noted the ways in which Smithsonian researchers compete for external funds, such as partnering with university researchers, serving as adjunct professors to get research funds through the university, and submitting their own grant proposals. According to Smithsonian data, from FY 2004 through FY 2008, the Smithsonian science units brought in approximately $560 million in grants and contracts for research projects. Of this amount, $456 million supported SAO. From FY 2003 through FY 2007, philanthropic funds for research conducted at Smithsonian science units amounted to $46 million, or roughly 7% of all funds raised; in FY 2007 the figure was 12%.

According to interviewees, increasing funding from grants, contracts, and philanthropic gifts will require strengthening in three areas, and an investment in funds and staff to accomplish it. One is better communication aimed at building awareness of, and support for, Smithsonian science among the public, Congress, and potential donors. This may require hiring science writers who are adept at translating technical research results into laymen's terms. Second is more support for researchers in finding grant opportunities and writing proposals. Third is an increase in personnel dedicated to fundraising for science. Interviewees also noted a lack of incentives for Smithsonian scientists—especially those who have been with the Institution for some time—to seek outside funding. One reason was that their Federal salary gave them a sense of entitlement, particularly in light of the amount of time soliciting grants took away from research. Grants generally came with a lot of administrative requirements, and specified research that did not fully overlap with the researchers own goals or those of the Institution. For many older scientists, grant-writing was not something that was expected or seen as necessary, although that mindset may be changing. Younger hires, in contrast, are very entrepreneurial. There was also resentment that in some units the overhead from grants did not reach the departments or researchers. In contrast, university departments get significant funds through overhead that allows them more operational flexibility.

A further deterrent to collaboration was doubt about the stability of funding streams within the Institution. For example, funding has been redirected from one project to another, or to infrastructure and operations. Many interviewees spoke of the need to diversify funding sources as a means of ensuring more stable funding for IDR projects. But they also did not feel the Institution has done as good a job as it could in securing more funding for science from Congress. It would help if the Smithsonian could communicate an overarching vision that reflects the breadth of research across the units and makes a case for funding, and better communicate the Institution's scientific accomplishments. Interviewees also brought up the detrimental effects of operating under continuing resolutions, which compress the timeframes in which to spend appropriated funds. Some interviewees saw endowments as the best long-term funding mechanism but didn't see science as an Institutional priority in this regard. External organizations with more endowment funds at their disposal were able to direct the proceeds toward ambitious new ventures, while the Smithsonian could only provide small internal grants.

Most interviewees acknowledged that even with an increase in Federal appropriations or endowment funds, other science research funds would still be necessary. Leveraging Federal and endowment funds will be vital. Partnerships were mentioned as one way to leverage resources, particularly when pursuing grants or engaging in projects that required disciplines not found at the Smithsonian such as economics, political science, and engineering.

In this regard, the lack of access of a number of departments/disciplines to NSF funds was very challenging. Both the 2002 NAPA and 2003 NRC studies noted considerable inconsistency in how NSF program managers treated Smithsonian proposals (National Academy of Public Administration, 2002; National Research Council, 2003).[5] When Smithsonian scientists could not apply directly for NSF funds, they sometimes worked with non-Federal partners such as universities to do so, but then the universities got all the overhead.

Some scientists got funding through contracts with Federal agencies such as the U.S. Department of Defense and Federal Aviation Administration. Interviewees also noted that corporations were increasingly interested in cost-reimbursable research and suggested the Smithsonian might cautiously explore opportunities in this area, taking care not to compromise its scientific integrity. Mapel (2008) saw a chance for the Smithsonian to capitalize on the "corporate social responsibility" movement (also referred to as sustainability movement) and pursue a role in working with corporations to conduct research and understand the science behind their business decisions. Some external interviewees cautioned against letting a business model drive scientific relationships and allowing crisis-oriented searches for short-term funds to overshadow the Smithsonian's commitment to its mission.

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5 Interestingly, the 2002 NAPA study found that NSF awarded funds to the Smithsonian at about the same rate as all other researchers.

Competitive Smithsonian Grants

A common suggestion was for a central pool of seed money, specifically earmarked for interdisciplinary and cross-unit projects, to motivate the growth of IDR. It would also allow researchers to produce the preliminary data or test a research approach that could then be parlayed into a grant proposal. Some scientists wanted seed money to bring in graduate students or post-docs. Seed money could help initiate efforts to weave together multiple disciplines into programs that build upon current work of units and departments, and fund cross-cutting centers that develop out of interdisciplinary workshops. Some researchers thought a seed fund should cover high-risk proposals as well, similar to what is done at some Federal science agencies. Other suggestions included increasing the amount of an award based on the number of units involved or the scope of the proposed project, and using a multitiered approach that accommodated small and large projects. Many Smithsonian researchers surmised that current funding concerns at the Smithsonian would make any financial incentive very popular.

There were also cautionary comments: a lack of follow-up funding can lead to frustration; the Institution needs to be very selective about the direction in which it hopes to move research; and the importance of ensuring that funds go to good science, rather than to projects aimed solely at getting money through collaboration. A few researchers expressed concern that the projects not supplant current research. Some interviewees thought the proposals ought to be peer reviewed to insure accountability and access by women, minorities, and young researchers, but others argued not to burden small sums of money with too many hurdles.

The literature described a number of funds that provide grants for the full cost of a project. The Howard Hughes Medical Institute (HHMI) set up a competitive four-year, $40 million pilot program, the Collaborative Innovation Awards, for teams of scientists to pursue collaborative, potentially transformative research (Howard Hughes Medical Institute, 2008). Former NIH Director Zerhouni created the NIH Common Fund to support research that addresses fundamental knowledge gaps, transformative tools and technologies, and innovative approaches to complex problems. In the process, NIH can test new ways of fostering innovative science. Zerhouni also set up the NIH Director's Pioneer Awards that go to highly creative scientists wanting to pursue "high-risk, high-reward" research through projects that "may be too novel, span too diverse a range of disciplines, or be at a stage too early to fare well in the traditional peer review process." The Director's New Innovator Award similarly supports a small group of unusually creative researchers in the early stages of their careers (National Institutes of Health, 2008).

The Smithsonian has three significant internal programs for competitive science grants: Scholarly Studies, Restricted Research Endowments, and Marine Science Network (MSN). The Office of Fellowships administers the first two in collaboration with OUSS, and OUSS administers MSN. While researchers appreciated having the Scholarly Studies Program, they commented that the size of the grants was too small, barely covering a post-doc's salary.

Administrative Support

Support Services

A widely repeated criticism of Smithsonian researchers was that the administrative support systems undermine collaboration and IDR, as well as initiative and productivity in general. The lack of effective support was cited as evidence that the Smithsonian does not value or understand researchers and their needs. Having to deal with bureaucratic red tape consumed increasing amounts of researchers' time and energy, be it arranging for travel, hiring staff for time-sensitive projects, handling financial transactions, or arranging for conferences. The IT environment and support were cited as particularly onerous obstacles to scientific research generally, but also to collaboration, especially with external scientists. Interviewees realized the need for ongoing governance and other reforms but expressed concern about the ultimate cost on research. Some wondered if the impact on individuals' work was even considered in fashioning reforms. Scientists at other Federal agencies did not seem to face such extraordinary administrative roadblocks and questioned whether top management spent enough time advocating for systems that would better serve scientists' needs. A large number of Smithsonian scientists described using partnerships or adjunct faculty status at universities to circumvent burdensome Smithsonian rules.

There was concern that a culture where administrative matters consumed too much research time would reduce the Smithsonian's ability to attract and retain quality scientists. There were examples of former Smithsonian staff leaving their jobs in part because of frustrations over administrative support. One scientist spoke of moving a conference to another organization because the travel was too hard to implement through the Smithsonian; plane fares under GovTrip were routinely more expensive than could be obtained commercially.

Researchers praised the administrative personnel in their departments and recognized that they were too few in number and often overwhelmed with work and bureaucratic red tape. One interviewee commented that the effort to maintain a stable number of researchers meant cutting into support personnel. Several external scientific research managers said they paid particular attention to building their support staff to ensure researchers got the support they needed and could devote their time to science. Senior managers across the Institution also commented that low levels of administrative staff limited responsiveness, for example, in OHR, OCFO, OCon, and OCIO.

Infrastructure and IT Environment

Investment in infrastructure has also been squeezed, to the detriment of research. Some scientists believed inadequate infrastructure made the Smithsonian less competitive in winning grants, particularly large ones.

Many scientists pointed to the IT environment and support as the key infrastructure problem. The Smithsonian's IT support model seemed to be designed for the typical office environment and simply did not meet the needs of research scientists. Scientists warned that a failure to address the radical disconnect between their IT needs and OCIO services could result in the Smithsonian falling ever further behind its scientific peers. Specific issues were insufficient bandwidth, lack of support for the Macintosh platforms needed for some software programs and types of research, problems with connectivity, and excessive limitation on email attachment size and mailbox capacity; the latter two posed significant impediments to collaboration. Here, too, scientists noted that trying to work around these limitations meant a loss of research time, and many researchers resorted to working at home where they didn't have these encumbrances. Security and funding concerns were thought to delay the adoption of new technologies. In 2008, OCIO conducted a scientific research IT needs assessment to guide planning and allocation of resources. And in fairness, scientists at Federal agencies have encountered similar problems.

Space and IDR

Many interviewees and the literature spoke about the importance of providing opportunities for scientists from diverse fields to come together in common venues to hear about one another's fields of research and specific projects, discover new approaches for their own research, learn about emerging technologies and their applications, identify potential collaborations, and so forth. Beyond conferences, workshops, and the like, a traditional means of fostering interdisciplinary interaction is to provide common, congenial space, which today often includes not just office space and labs, but social areas, fitness centers, and restaurants. Nowadays, virtual space is used increasingly, although behind it is at least a physical administrative support office.

Physical Space as a Catalyst to Interdisciplinarity

A number of the interdisciplinary centers have chosen to construct new buildings or renovate and redesign existing ones specifically to maximize contact among researchers from diverse disciplines. A common space also provides identity to the center. At one extreme of new construction is HHMI's Janelia Farm research facility in Virginia. At the heart of this residential 689-acre campus is a very large building that encompasses not just research space custom-built to meet the specific needs of the researchers, but also auditoriums, seminar rooms, a library, dining room, restaurant and pub, fitness center, and other communal spaces. The goal is to maximize the time available for research and for interaction. Stanford University's interdisciplinary Bio-X program is in a new, ultra modern building that features open labs designed to accommodate multiple researchers from different disciplines, as well as ample communal social space. According to staff, the building's design contributes to many productive encounters among researchers.

Some centers have opted not to construct new buildings. NCEAS occupies dedicated physical space in a building off campus in downtown Santa Barbara, which provides long- and short-term offices and facilities for researchers. NCEAS sees having this neutral territory for interaction away from home offices as a critical feature of its environment. Duke University's Institute for Genome Science and Policy in Durham, North Carolina, provides offices in an existing space for the affiliated departmental faculty who choose the Institute as their home base, as well as communal office space for affiliated faculty who choose to retain their offices in their home departments. According to an interviewee, this mix of spaces contributes to efficiency, avoids duplication, and cuts down on the cost of work space.

Several internal and external researchers talked about virtual research projects, where scientists from different locations "meet" in cyberspace to conduct and share their research. An example is the NAI. Team members use Web 2.0 and a variety of other sophisticated technologies to communicate. A physical center at NASA's facility in Ames, California, is the locus for the virtual program; it employs about 16 people. One scientist who is part of the Astrobiology Institute team noted, however, that the members still got together physically on a regular basis.

Physical Space at the Smithsonian

Office Space. Several Smithsonian scientists spoke of the Institution's geographic dispersion as a physical barrier to collaboration. NZP and NMNH both have two spatially separated campuses; in the Zoo's case both are off the Mall. Other units are outside Washington, DC (SAO in Cambridge, MA, SERC in Edgewater, MD, and STRI in Panama). Beyond this dispersion, scientists complained about a serious lack of research space and the poor quality of a lot of the space they do have. A scientist at the National Air and Space Museum's Center for Earth and Planetary Studies (CEPS) noted that expansion of CEPS's research is impossible given space limitations. At NMNH the convoluted network of departmental office spaces are cut off from one another. Renovation of the building is underway, but one scientist was concerned that the building's redesign is not being configured to encourage greater interaction and collaboration. Some interviewees cautioned that meaningful interactions require far more than an engaging building or space.

Labs. In addition to being a locus of research, labs and equipment can spark interdisciplinary research. Labs bring researchers across an organization together, often from different subfields of a discipline or from totally different disciplines. As noted, one external center designed its open lab space to be too big for any one disciplinary group, so that there will always be room for a variety of researchers.

The main concerns about Smithsonian labs were outmoded buildings that impose constraints, such as inadequate electrical systems. A 2005 SERC external review committee concluded that the center needed "major upgrades in infrastructure... instrumentation, cyber infrastructure, information management, lab and residential space" and that without them, it would be hard for SERC to remain competitive (Ducklow, et al., 2005). Plans are now underway for renovation of some of SERC's facilities, including lab space. A 2007 external review of the NMNH's Anthropology Department similarly noted issues relating to labs and related technology, including an absence of modern approaches and technologies that "will become necessary if the Smithsonian is to retain its reputation as a leader in anthropological research" (Cordell, et al., 2007).

One interviewee thought the labs were easy targets in times of scarce funds. Scientists at some labs described a "tug and pull" between the labs' desire to be an "intellectual unit that has a strong research presence" and scientists' need for a service unit. A recurring Smithsonian theme—centralization vs. decentralization—emerged with respect to labs. The issue related to having onsite labs for quick access or having shared labs so as to leverage resources and achieve synergies. The concept of shared labs raised issues of who pays for what and how access is decided when the lab is fully utilized. In February 2009 the OUSS announced that the Smithsonian now had two pan-Institutional mass spectrometry facilities for analyzing stable isotopes—an existing laboratory at STRI and a new one at MCI in Suitland. The STRI facility accepts samples from all interested users, with preferential rates for Smithsonian scientists, fellows, and visitors. Use of the MCI lab is reserved for Smithsonian staff, fellows, and research affiliates; samples accepted for analysis through May 2009 are free of charge but eventually there may be a modest fee-per-sample charge to support the lab.

Equipment. While acknowledging the costs, many researchers spoke of the need for state-of-the-art equipment that provides faster, richer, and more accurate analyses if the Smithsonian is to remain at the forefront of science. One interviewee thought the Smithsonian wasn't competitive when it came to equipment and instrumentation and wasn't advanced enough to attract people to come to the Institution. The situation was exacerbated by a shortage of technicians to run and maintain the machines. The number of permanent employee technicians has decreased significantly, as noted; those hired under grants generally are terminated when the grant expires, leaving behind equipment with no one dedicated to running it. This situation argues for sharing equipment or, where that isn't possible, for at least purchasing like equipment that could be more easily serviced. It also argues, according to some interviewees, for centralizing technicians. At the very least, Smithsonian researchers acknowledged that the Institution must do a better job of planning and coordination of the purchase and use of equipment, particularly given its expense.

Data Use and Access

Smithsonian scientific research has generated huge amounts of data, and it was common to hear people criticize the lack of accessibility. Many researchers asserted that greater data sharing and integration of datasets into a single system across the Institution would encourage collaboration and interdisciplinary research. One interviewee suspected that 90% of the data is not fed to the intranet in a usable form. The fact that journals increasingly don't publish the data underlying an article reinforces the importance of this issue.

At least part of the problem was seen to be cultural—Smithsonian scientists tend to think of data as their own, and not the Smithsonian's, and they fear someone else will use it and publish before they do. Another part is a lack of data standards that everyone follows so that the data are accessible. An external researcher commented, "standardizing metadata—that's making metadata and their data interoperable—is a huge problem and needs to be taken really seriously." External interviewees described how their organizations specifically focus on making all data easily accessible through a central repository, or how they worked on "re-tooling of their databases to standardize their collection protocols" so that now they have a network that allows people to use each other's data. One NSF-funded external center was charged with making sure that the standards for its ecological data repository would be generalizable to other sciences, including social sciences. At the Smithsonian, OCIO is currently collaborating with Rensselaer Polytechnic Institute and San Diego Supercomputer Center on a grant proposal for funding from NSF's DataNet program, whose goal is to find ways to fold a multitude of data repositories together to create one massive repository.

Informatics Capacity

Building an informatics capacity is important for the Smithsonian's success, one researcher said, and merits greater investment in a core capacity. A researcher pointed to an effort to create "field management applications" such that data collection can be entered at the time specimens are collected. The researcher wanted a "whole informatics umbrella to capture" data from where and when an item was collected, to photos and analyses that were performed, to where the item ended up. To accomplish this capability, the Smithsonian is going to need to hire informatics experts. The failure to invest in IT support for informatics was cited as yet one more example of the Institution's tendency to lag behind other organizations in adopting new technologies.

Again, the question came up whether an informatics capability should be centralized or decentralized. Arguments for the former included leveraging resources in a very expensive area, the importance of having a central facility as the "glue" holding things together, and there being a central support office both to help individuals and to identify common issues and solutions across the Smithsonian. Ultimately, whether established as an office or a decentralized capability, the goal would be for Smithsonian scientists to be able to ask different and interesting questions and start synthesizing the masses of data related to those questions to understand the bigger picture. Also arguing for centralization was that informatics work cannot be completed without computational facilities and computer programmers. An obstacle interviewees saw was that developing an internal informatics capacity would require dealing with the excessive security restrictions and other IT environment limitations. Right now, these problems have led some Smithsonian researchers to work through outside partnerships and contractors.

A Smithsonian proposal for NSF funding called for a coordinated effort to remove barriers to data synthesis by providing informatics resources—"be they datasets, tools, references and journals, network access or communication lines"—through a center that would function as a resource hub. The proposal cites the wealth of information currently available as both a challenge and an opportunity that requires new tools to analyze and filter the information and allay the risk of drowning in data. Center functions would be making needed reference datasets, reference databases, modeling software, and scripting programs, as well as algorithms for the comparison, statistical treatment and visualization of results available through remote access to existing systems, as well as a central repository of results and methods, discussions and drafts. The center would also develop new informatics tools for synthesis (Smithsonian Institution, National Museum of Natural History, 2004).

Strategies to Facilitate Organizational Change

Interviewees, particularly external ones who had been involved in major organizational realignments toward more interdisciplinary and problem-oriented research, noted the complexity of the process and described some of the strategies they used.

Head off Resistance, Get Buy-in

Organizational change always meets with resistance, and the culture within the scientific community, as expressed by interviewees, exacerbates that tendency. Scientists strongly dislike being told what to do; academic freedom is comparable to a birthright. Following are strategies employed to deal with resistance and engender support.

Use a mix of top-down and bottom-up. Providing scientists opportunities for input was a common strategy. Sometimes they were asked just for ideas, but in other cases they had a role in defining goals and objectives, developing strategic plans, designing programs and initiatives, and creating action plans. A second benefit of this strategy is that it can lead to the emergence of exciting ideas (Metzger and Zare, 1999). At the same time, some interviewees acknowledged that the top must play a strong role and take responsibility for final decisions. It's a matter of finding the right balance between top-down and bottom-up. This point was seen as particularly relevant to the Smithsonian, whose reliance on consensus decision making has led to endless discussion and suboptimal decisions.

Use leaders/influence brokers. Interviewees talked about involving people within the organization whose status, professional and personal, will lead others to join the effort.

A similar strategy is to develop an advocacy network of staff and others engaged in interdisciplinary activity (Dubrow, n.d.).

Inspire scientists to become part of something bigger. A number of people emphasized that if you offer scientists compelling research questions or opportunities, couched so that each individual believes in the importance of the endeavor, of being part of something bigger than themselves, they will readily join in. This strategy works especially well when coupled with incentives, such as seed money.

Create win-win situations. Scientists must feel that they are getting something out of their participation in someone else's program. A number of interviewees and the literature pointed to funding as a critical motivator (Dubrow, n.d.; Bozeman and Boardman, 2003). Smithsonian interviewees cautioned emphatically that funds should not be pulled from existing unit or department budgets.

Build in—and on—early successes. Success begets success is an old adage. Thus finding things that can be carried out quickly, easily, without a lot of resources, and with a high probability of success is important in the early stages of a new initiative. Examples are bringing performance evaluation criteria into line with the nature of collaborative and interdisciplinary research, changing a thesis requirement to permit multi-authored theses, and leveraging resources through strategic partnerships.

Build Collaboration and IDR Capacity

External interviewees described a range of ways in which their organizations had to create or strengthen their capacity to foster and sustain collaboration and IDR. Techniques included: developing a system for reviewing IDR proposals and evaluating collaborative and interdisciplinary research; creating common physical spaces and facilities and means of linking scientists to one another; establishing reward systems and incentives, monetary and other; providing better administrative support, tailored to the needs of interdisciplinary science; giving staff flexibility to work at different units; and paying attention to IDR skill building.

Address the Silos and Inadequate Communication

Perhaps one of the most challenging aspects of organizational change at academic-oriented organizations is breaking down the rigid divisions across departments, schools, etc. Universities that have set up IDR centers have, as discussed, employed a range of approaches: constructing new buildings, labs, and common spaces designed to maximize interaction; allowing researchers to remain within their home camp while also working in the new IDR camp; arranging social and other types of get-togethers; facilitating the natural inclination of younger researchers to be collaborative and cross boundaries; sharing staff across departments/units through joint appointments and sabbaticals; including collaboration and IDR in performance plans and performance evaluation criteria; providing financial incentives; establishing varied means of communication and information-sharing across boundaries; forming cross-department/unit teams, working committees, and advisory groups; and giving priority access to funds for post-docs.

A number of the comments that emerged from the Smithsonian 2002 science strategic planning survey of biologists and from interviewees in the current study focused on the need to fix the very inadequate communications across the Institution. One scientist suggested a centrally facilitated mechanism to improve communications. Other ideas were get-togethers of people from multiple units, workshops and meetings uniting scientists with common research interests, and a list, updated annually, of the research projects currently underway at the Smithsonian, that goes to every scientist.

Eliminate the Culture of Winners and Losers

One interviewee spoke of a highly respected manager at the Smithsonian who got key leaders from across the Institution to sit down and negotiate resource allocation. They would agree on who would get their request this year, who would get it the next year, and so forth. Another interviewee talked about the role a strategic plan plays in getting people to talk with one another.

Cultivate Trust and Respect for Diversity

IDR requires dealing with the cultural differences of other disciplines, units, generations, etc. across the different organizations and across researchers in different disciplines. NSF addresses this by creating teams of representatives from its directorates and programmatic offices that allows trust to develop and for individuals to endorse a larger program or goal. One interviewee commented on the fact that there is no Smithsonian identity; rather, the Institution is tribal. Thus it is important to build teams that are diverse in terms of gender, career stage, geographic distribution, research viewpoints, and disciplines. Still another called for having different disciplines represented on steering committees or using rotating leadership.

Be Flexible

Interviewees stressed the need to balance an overall strategy and plan with the need for flexibility and an ability to adapt to rapid changes in science with new tools and new ways of thinking.

Choose the Right Start-up Timeframe

One interviewee's organization opted for a "shock approach" because of a short timeframe to get an initiative going. But an underlying theory of the organization's leadership was also that stress would tend to coalesce the team, and this proved accurate. The team itself established a valuable rule: only bring solutions, not problems, to the table, the assumption being that staff have the knowledge for solving problems. Verdin and Van Heck (in Conceição, et al., 2000) discussed a shock versus a slow and steady approach to integrating knowledge across dispersed units at three corporations active in Europe (one conclusion of the study was that a medium-paced process worked least well). Whatever path is chosen, the authors emphasized the importance of management preparing the way by working to achieve buy-in and building a learning culture. Some interviewees recommended a gradual process in which participation was voluntary, based on the theory that committed scientists were more likely to succeed, and their success would draw others in. With its STCs, NSF built in a year-long start-up phase to put the management and administrative structures in place and to build the team. It also required full-time managers and administrative support staff.

Hire the Right People

The study made clear that some people embrace collaboration and IDR and others don't. Thus an organization needs to emphasize hiring the people most likely to operate in that way. One university also pointed to the importance of leadership in influencing culture—the people at the top all supported IDR, and it had a pervasive effect throughout the organization.

Reward Contributions to Institutional Goals

One science manager reflected that while scientists should have a high degree of freedom, they can also be asked to do things for the good for the organization. ARS offers a Scientist of the Year award; the Smithsonian also gives out a number of awards such as the annual Distinguished Research Lecture Award honoring the sustained achievement of one Smithsonian scholar, and the Secretary's Research Prizes that encourage interdisciplinary and collaborative research. Another interviewee pointed out the need to be realistic—some people just aren't cut out to collaborate or engage in IDR, and there is no point in pushing them.

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Appendix B: List of Interviewees' Organizations

Smithsonian Institution

Museum Conservation Institute
National Air and Space Museum
National Museum of American History
National Museum of Natural History
National Postal Museum
National Zoological Park
Office of the Chief Information Officer
Office of Development
Office of Fellowships
Office of Human Resources
Office of Interdisciplinary Studies (former)
Office of International Relations
Office of Sponsored Projects
Office of the Under Secretary for Science
Smithsonian Astrophysical Observatory
Smithsonian Institution Archives
Smithsonian Environmental Research Center
Smithsonian Institution Libraries
Smithsonian Tropical Research Institute

External Organizations

Academia

Duke University, Nicholas School of the Environment, Institute for Genome Sciences & Policy, and National Evolutionary Synthesis Center (NESCent)
Harvard University, Center for the Environment
Massachusetts Institute of Technology, Operations Research Center
Stanford University, Bio-X Program
University of California, San Francisco, California Institute for Quantitative Biosciences (QB3)
University of California, Santa Barbara, National Center for Ecological Analysis and Synthesis (NCEAS)
University of Maryland, Behavior, Ecology, Evolution, and Systematics Program
University of Michigan, Life Sciences Institute
University of Minnesota, The Graduate School

Consortia

Consortium for the Barcode of Life
Consortium on Fostering Interdisciplinary Inquiry
Encyclopedia of Life

Federal Agencies

National Aeronautics and Space Administration
National Institutes of Health
National Institute of Standards and Technology
National Oceanic and Atmospheric Administration
National Science Foundation, Science and Technology Centers Program and Cyber-Enabled Discovery and Innovation Program
U.S. Department of Agriculture, Agricultural Research Service
U.S. Department of Defense
U.S. Department of Energy, Office of Science
U.S. Department of the Interior, Fish and Wildlife Service and U.S. Geological Survey
U.S. Environmental Protection Agency, Ecological Research Program

Museums

American Museum of Natural History
Field Museum
Museum of Comparative Zoology (Harvard University)

Private Research Organizations and Foundations

Janelia Farm (Howard Hughes Medical Institute)
H. John Heinz III Center for Science, Economics and the Environment
Indo-US Partnership for Science and Technology
National Academies, Keck *Futures Initiative*

Smithsonian Institution
Office of Policy and Analysis
www.si.edu/opanda