Making the Case for a Next-Generation Digital Information System to Ensure America's Leadership in Agricultural Sciences in the 21st Century

A Background Document
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Barbara Hutchinson on behalf of the Task Force
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List of Acronyms

ADEC	American Distance Education Consortium
AgNIC	Agriculture Network Information Center
CGIAR	Consultative Group on International Agricultural Research
CIARD	Coherence in Information for Agricultural Research and Development
CSREES	Cooperative State Research, Education, and Extension Service
ECOP	Extension Committee on Organization and Policy (NASULGC)
FAO	Food and Agriculture Organization of the United Nations
IAALD	International Association of Agricultural Information Specialists
IISAST	International Information Systems for Agricultural Science and Technology
LGU	Land-Grant Universities
NAL	USDA National Agricultural Library
NALDR	National Agricultural Library Digital Library
NALT	National Agricultural Library Thesaurus
NAREEEAB	National Agricultural Research, Extension, Education, and Economics Advisory Board (USDA)
NASULGC	National Association of State Universities and Land-Grant Colleges
NIH	National Institutes of Health
NLM	National Library of Medicine
NRC	National Research Council
NSF	National Science Foundation
SAES	State Agricultural Experiment Stations
USAIN	United States Agricultural Information Network
USDA	United States Department of Agriculture
WSIS	World Summit on the Information Society

Executive Summary

United States agriculture and farm policy is critical to national security and economic prosperity. It ensures a reliable domestic food supply and is essential to a strong, growing economy. Some 25 million jobs or nearly 20 percent of American paychecks are generated by the food and fiber industry, $3.5 trillion in economic output, and 15 percent of U.S. Gross Domestic Product. Agriculture is also one of the few areas in the nation's economy without a trade deficit.

Most people think agriculture is farming or ranching, or other forms of food, animal feed, fiber and ornamental production, processing, and consumption. However, modern agriculture encompasses much more. Agriculture and agricultural science touch every aspect of American society from the individual consumer's health and safety to the nation's welfare, security, and environmental sustainability. Increasingly, agricultural research is fueling innovation in many parts of the economy not generally associated with agriculture, such as energy, electronics, plastics, and pharmaceuticals.

At the same time, there is a trend toward funding animal and plant biotechnology research at agricultural universities and colleges through agencies such as National Institutes of Health (NIH) and National Science Foundation (NSF), rather than the U.S. Department of Agriculture (USDA). This has long-term knowledge management issues, with some agricultural research data and information flowing into databases maintained by the National Library of Medicine (NLM) and some into agricultural databases. This adds to fragmentation of agricultural biotechnology information and has implications for archival, retrieval, and discovery services.

Concurrent with this trend is the continuing move to digital technologies and the increasing sophistication of user demands. Almost all scientific and technical literature is now created in digital form ("born digital") and large quantities have been converted to digital retrospectively ("reborn digital"), while new Federal guidelines require open digital publication of research results. This raises questions of how best to support the life cycle management of research and learning materials; how to develop greater systems integration among learning, library, and administrative systems; and how to integrate information skills into learning and knowledge generating activities.

Libraries in general, and agricultural libraries in the Land-Grant system along with the USDA National Agricultural Library (NAL), have moved vigorously over the past decade to invest in a technological infrastructure that will support delivery of digital content and create high-tech, people-friendly environments. Associations such as USAIN and IAALD as well as such initiatives as the National Preservation Program for Agriculture Literature, the Agriculture Network Information Center (AgNIC), and the agriculture component of the Million Books Project, have provided the basis for a collaborative next generation digital information system for agriculture. There are also new opportunities for the U.S. agricultural information community to become more involved in international coherence initiatives on technical standards and content development that will improve information sharing and interoperability.

To this end, USAIN calls upon the leadership of USDA, NASULGC, the agribusiness industry, and others with interests in a vital agricultural sector to strongly support a process for bringing together key players in the U.S. agricultural information system (Land-Grant Universities, NAL, Cooperative Extension, members of the private sector, concerned policymakers, scientists at the cutting edge of the information industry, and others), to develop a detailed implementation plan and phased road map for a national digital agricultural information system for the 21st century. This process should result in

1. a framework for collaboration
2. defined technical standards and system requirements
3. determination of associated costs and timeframe for reaching milestones
4. a long-term sustainable management plan. This initial investment will ensure a successful outcome in measurable new research and educational products and in knowledge gained of value to economic growth, security, and environmental sustainability.

The Time to Act is Now!

The Case for Change

Making the Case for the Next-Generation Information System to Ensure America's Leadership in Agricultural Sciences in the 21st Century

> *"I can report to you in all sincerity that I don't think any other experience could have highlighted for me in such a very powerful way the diverse architecture of American agriculture."*
>
> **Agriculture Secretary Mike Johanns**
> reporting on 52 2007 Farm Bill public forums in 48 states.[1]

Agriculture is the world's largest economic sector. On a worldwide basis, more people are involved in agriculture than in all the other occupations combined. Even now, United States agriculture and farm policy is critical to national security and economic prosperity. It ensures a reliable domestic food supply and is essential to a strong, growing economy. Some 25 million jobs or nearly 20 percent of American paychecks are generated by the food and fiber industry, $3.5 trillion in economic output, and 15 percent of U.S. Gross Domestic Product.[2] Agriculture is also one of the few areas in the nation's economy without a trade deficit.[3]

In the preliminary call for comments on the 2007 Farm Bill, the U.S. Department of Agriculture (USDA) identified six areas as priorities for the U.S. agriculture sector and asked American citizens to provide their perspective on how to increase effectiveness in these areas:

1. U.S. competitiveness in global markets
2. Ensuring the next generation of farmers
3. Fair and effective distribution of assistance to producers
4. Conservation and environmental goals
5. Development of rural areas
6. Agricultural product development, marketing and research

The nation's ability to deliver on these goals and generate cutting-edge, commercially-applicable research depends on its capacity for technological and scientific innovation, which in turn depends on the competencies of the institutions and agencies that are primarily responsible for supporting agricultural research, education, and development.[4] At the same time, advances in digital technologies provide an unparalleled opportunity for creating new research and education environments, tools, and products. For this reason, stakeholders in the nation's agricultural information system have been working to develop a shared vision for the next-generation infrastructure that must be developed to support new modes of scholarly inquiry and communication, without which the U.S. cannot maintain its competitive, leadership position in the world economy.

These stakeholders primarily include the USDA National Agricultural Library (NAL), the libraries of U.S. State Land-Grant Universities (LGUs) and colleges of agriculture and life sciences, and other USDA programs such as Cooperative Extension and Agricultural Experiment Stations. Collectively, they provide the core knowledge infrastructure that drives agricultural education, research, outreach, and economic development in the United States.

During the past six years, there has been increasing interest among these groups to determine how to better serve their constituencies' information, research, and educational needs. This interest has been fueled by rapid changes in research and technology in network and systems design, human computer interaction, artificial intelligence, information organization and retrieval, machine translation, and semantic web applications to facilitate data, information, and knowledge exchange. Developing a digital agricultural information system that is distributed, drawing on multiple stakeholder resources, yet integrated through powerful user interfaces, will require bringing together the best minds and talents of subject specialists, library professionals, computer and information scientists, and policymakers.

To this end, the United States Agricultural Information Network (USAIN) proposes to bring together key players in the U.S. agricultural information system (universities, NAL, Cooperative Extension, members of the private sector, concerned policymakers, and scientists at the cutting edge of the information industry), to develop a detailed implementation plan and phased road map for a national digital agricultural information system for the 21st century. USAIN also calls upon the leadership of USDA, NASULGC, the agribusiness industry, and others with interests in a vital agricultural

sector to strongly support these efforts. This initial investment will ensure a successful outcome in measurable new research and educational products and in knowledge gained of value to economic growth, security, and environmental sustainability. The following outlines important issues, trends, and challenges for effectively and efficiently managing agricultural information and research.

Agriculture and the BioTech Century

> *The 21st century is being called the "Biotech Century," and it is extremely important to acknowledge that agricultural research and development organizations have as big a role to play as academic medical centers and other leaders.*[5]
>
> **Battelle Memorial Institute**

Most people think agriculture is farming, ranching, or other forms of food, animal feed, fiber and ornamental production, processing, and consumption. However, modern agriculture encompasses much more. Agriculture and agricultural science touch every aspect of American society from the individual consumer's health and safety to the nation's welfare, security, and environmental sustainability. (Box 1 Appendix A).

Increasingly, agricultural research is fueling innovation in many parts of the economy not generally associated with agriculture, such as energy, electronics, plastics, and pharmaceuticals. Part of the impetus comes as agriculture continues to move into genomics, genetic transformation and other forms of plant and animal biotechnology, with applications that transcend the traditional definition of agriculture. Many major drug therapies, like Taxol for breast cancer and Artemisin, used to cure malaria, are based on plant derivatives.[6]

Similarly, crop biomass engineering is showing promise for providing a larger share of the energy currently supplied by the petrochemical industry.[7] Scientists also are working on ways to use biotechnology for environmental preservation and remediation using plants to detect, monitor, absorb and store toxic and hazardous substances. Other products currently under development include: proteins and enzymes for diagnostic, therapeutic and manufacturing purposes; modified fatty acids and oils for paints and manufacturing; and biopolymers as substitutes for plastics. In fact, it is predicted that what fossil fuel-derived energy was to the 20th Century, biology and biotechnology will be to the 21st Century.[8]

Three important trends are becoming evident

1. Genomics and biotechnology are dramatically widening the already broad scope of agriculture. As noted above, research in plant- and animal-based genomics and genetic engineering has been expanding for many years, putting agricultural research at the cutting-edge of many non-food and fiber industries such as energy and pharmaceuticals (Box 2 Appendix A).

2. Agbiosciences[9] is a rapidly growing sector of the national economy. According to a Battelle study, between 1998 and 2003, the number of agbioscience companies grew by 23 percent across the nation. In 2003, almost 84,000 companies were actively engaged in the agbioscience sector and accounted for more than 2.8 million of the workforce in the U.S.[10] Evidence of this growth can also be seen in patenting trends. Over the period 1976-2000, patenting in agricultural biotechnology has grown faster than the rapid increase in U.S. utility patents. Private firms, universities, and the federal government all increased patenting in agricultural biotechnology[11] (Figure 1 Appendix A). Over this period U.S. universities' rate of patenting in agricultural biotechnology increased even more quickly than did patenting by private firms. Universities now hold a greater proportion of agricultural biotechnology patents than they do of patents in general[12] (Figure 2 Appendix A).

3. Lines are blurring between agbioscience, human and animal biotechnology, and industrial biotechnology. The blending of these disciplines can be observed in the large-scale mergers in the corporate arena. Novartis, for example, was formed in 1999 from the $27 billion merger of pharmaceutical company Sandoz and agrochemical company Ciba-Geigy, making it the world's largest agrochemical company, the second largest seed company, the second largest pharmaceutical company, and the fourth largest veterinary medicine company.[13] Monsanto, which merged with the pharmaceutical company Pharmacia and UpJohn in 2000, and was then spun off as a new independent agribusiness company, recently entered into a collaborative research partnership on bioenergy and biofuels with Sandia, a National Nuclear Security Administration laboratory.[14]

These trends highlight both the critical importance of and the challenge in managing the already diverse and distributed knowledge resources that are the basis for scientific innovation in the United States.

Crisis in Funding and Impact on Knowledge Management

> *Our ability to generate and collect digital information continues to grow faster than our means to organize, manage, and effectively use it. This trend is likely to continue without focused research and development.* [15]

National Science Foundation

Until World War II, agricultural science held a privileged position. As late as 1940, almost 40 percent of Federal expenditures for R&D ($29.1 million of $74.1 million) went to USDA in-house and state agricultural experiment stations (SAES)-based research.[16] Ever since then, public investment has been responsible for 75 percent of all growth in U.S. agricultural productivity.[17] Much of that expansion occurred through the research and outreach activities centered in the U.S. Land-Grant University, Agricultural Experiment Stations, and Cooperative Extension system, a system that has become the world model for progress and innovation. ***In fact, in some states, the Land-Grant University accounts for almost 100 percent of all of agricultural sciences research conducted in that state.***[18] According to the USDA's Economic Research Service, most studies are consistent in finding high rates of return (40 to 60 percent) for public investment [http://www.ers.usda.gov/publications/aer735] in agricultural research and development (R&D).[19]

However, federal support for agricultural research at universities and colleges has been steadily decreasing and is now only about 4 percent of the total R&D Expenditures ($408 million of $10 billion).[20] Similarly, funding for NAL has remained flat at near $20 million each year since 1995, representing a 21 percent decline in appropriation levels. This, in spite of the fact that a number of studies, including one from the National Research Council (NRC), have indicated that library expenditures are associated with increased faculty research productivity, particularly in the biological sciences, physical sciences, and mathematics.[21] At the same time, as funding for agricultural research, extension, outreach, and education has diminished, funding for health research and development has exploded.[22] (Figure 3 Appendix A) & (Figure 4 Appendix A). Federal dollars for medical research through NIH have tripled in real terms since 1990, while research dollars for agriculture have barely held steady. FY 1998 appropriations for NAL were $19 million and $162 million for the National Library of Medicine (NLM).[23] In FY 2006, NAL was allocated $22.8 million whereas NLM received $315 million.[24]

Increasingly, animal and plant biotechnology research at agricultural universities and colleges is being funded through agencies such as National Institutes of Health (NIH) and National Science Foundation (NSF), rather than USDA. This has long-term knowledge management issues, with some agricultural research data and information flowing into databases maintained by the NLM and some into agricultural databases. This adds to fragmentation of agricultural biotechnology information and has implications for archival, retrieval, and discovery services. For instance, many diseases and public health issues being investigated by NIH in the U.S. and developing countries, such as avian flu, are directly related to food/agriculture in their cause or cure. There is a need for better cross-sectoral collaboration to ensure that all vital information is easily available to researchers and the public alike.

Recently the National Agricultural Research, Extension, Education, and Economics Advisory Board (NAREEEAB), which provides advice to the Secretary of Agriculture and land-grant colleges and universities on top priorities and policies for food and agricultural research, education, extension and economics, urged that:

> *"USDA's federal funding for food and agricultural research, extension, education, and economics should be enhanced to meet*

pressing needs in FY06 and beyond. This recommendation is justified by the huge dividends paid to the United States and the world, particularly in the latter part of the 20th century, from our Nation's investments in food and agricultural research."[25]

Increased funding for NAL was also strongly advised by the Board:

"The USDA National Agricultural Library (NAL) is the world's foremost agricultural library for fundamental information on food and natural resources, health, nutrition and diet, and the impacts of agriculture on the environment. This library is paramount to the total research effort worldwide in these subject matter areas. We encourage REE and the Department to continue to strengthen the role of the NAL and to increase where possible the NAL budget so that it can keep pace with maintaining these valuable collections and become even more engaged in making this critical information available to its users by electronic means."[26]

Changing Scale of Information and User Demands for Access

Whatever the benefits to personal lives, the ubiquity and ever-present nature of the Web and the billions of pages of content accessible in this matrix of information are both boon and bane. There is a subdued sense of having lost control of what used to be a tidy, well-defined universe evident among those who work in this information environment. Many are pessimistic, some are optimistic, but one theme persists: The landscape has changed and the maps have not been published yet. [27]

Online Computer Library Center (OCLC)

Just as funding for national agricultural research and the institutions that support it is decreasing, information is exploding. The exponential growth in computing, storage, and networking power along with concomitant growth in digital information and data are having a major impact on research, education, and library functions. Increasingly the Web is overtaking print as the medium for communication.

Almost all scientific and technical literature is now created in digital form (termed "born digital") and large quantities have been converted to digital retrospectively (termed "reborn digital"), while new Federal guidelines require open digital publication of research results. This raises questions of how best to support the life cycle management of research and learning materials; how to develop greater systems integration among learning, library, and administrative systems; and how to integrate information skills into learning and knowledge generating activities. The traditional linear, batch processing approach to scholarly communication is changing to a process of continuous refinement as scholars write, review, annotate, and revise in near-real time across the Internet.

Research and educational materials are produced throughout universities, research labs, Agricultural Experiment Stations and Cooperative Extension offices. The diversity is immense: courseware, documents, databases, data sets, and simulations. They are hugely variable in approach, in technologies, in scope, and in complexity. Information also comes in many formats from print to digital to microfilm and audio/visual formats. Libraries expanding digital resources require new and improved tools for collaboration and for working interactively with all types of artifacts of scientific progress. This includes observed and simulated data; taxonomies; mathematical expressions; molecular, chemical and genomic expressions; structural, physical, and computational models; tables, graphs, charts, maps and images; field and laboratory notebooks; monographs and other scholarly documents; critical reviews and discourse; ontologies; bibliographic references; and remotely sensed imagery as well as sensor-generated biophysical spatial data.

As the library community works together with other organizations to develop strategies for providing efficient and effective archival, preservation, and delivery services to this plethora of information and data, user expectations have continued to expand and drive increasingly sophisticated systems for access. The majority of U.S. households now have personal computers and Internet access. According to OCLC, the graduating class of 2007 grew up with computers, multimedia, the Internet and a wired world. Twenty percent of the students began using computers between the ages of 5 and 8. By the time they were ages 16 to 18 all of them had begun using computers.

> *"Their world is a seamless infosphere where the boundaries between work, play and study are gone. The compartmentalization of leisure activities from work activities that their parents still mostly adhere to is largely unknown to the current group of college students. Today's digital kids think of information and communications technology as something akin to oxygen and to some degree it has been supporting their learning activities since before they could spell or write."*[28]

This will have major implications on how they interact with information in the future.

Response from Land-Grant Agricultural Libraries

> *The real heroes of the digital revolution in higher education are librarians; they are the people who have seen the farthest, done the most, accepted the hardest challenges, and demonstrated most clearly the benefits of digital information. In the process, they have turned their own field upside down and have revolutionized their own professional training. It is a testimony to their success that we take their achievement for granted.*[29]
>
> **Edward L. Ayers & Charles M. Grisham**

Libraries in general, and agricultural libraries in the State Land-Grant system along with NAL, have moved vigorously over the past decade to invest in a technological infrastructure that will support delivery of digital content and create high-tech, people-friendly environments.

To increase communication (interoperability) among disciplines, there are major efforts in the library world to develop and adhere to collection standards, classification systems (schemes), common metadata[30] structures, and other types of tagging so that eventually researchers can search, analyze and model across all platforms and formats simultaneously. Increasingly, too, academic libraries have moved from the traditional service role of the library into project management; database design and management; interface programming; metadata generation; copyright clearance; and website hosting. Libraries are also supporting new directions in scholarly communication such as open-access publishing and self-archiving; partnerships between libraries, university presses, publishers and software developers; and the creation of institutional repositories to preserve, maintain, and provide access to institutional intellectual resources.

Working with administrators, information technologists and scholars are taking a leadership role in developing policies and programs that contribute to a coherent, institution-wide knowledge management system. There is an emerging emphasis on integration among systems that support learning, research and administration, and a corresponding interest in campus architectures, repository and portal frameworks, and common services such as authentication and authorization.

Even as individual land-grant libraries have been focusing on improving services to their mandated in-state constituencies, there have been efforts to work collaboratively to create a more integrated system. Such initiatives as the National Preservation Program for Agriculture Literature, the Agriculture Network Information Center (AgNIC), and the agriculture component of the Million Book Project, have provided a sound basis for a collaborative next generation digital information system for agriculture. The following are short summaries of these efforts:

National Preservation Program – A National Preservation Program for Agriculture Literature was formulated under the auspices of USAIN [http://www.usain.org/Preservation/preservinitiative.html]. Cornell University, on behalf of USAIN, and in cooperation with other land-grant university libraries, has received four grants totaling $4.5 million from the National Endowment for the Humanities (NEH) to preserve the most significant published materials on the history of state and local agriculture and rural life through partnering with scholars and librarians to identify and preserve the most significant agricultural literature of a state. To date this has involved 29 states in preserving 35,000 volumes on microfilm, with the latest phase involving two land-grant libraries that will expand the program by digitizing their historic agricultural content.

AgNIC – Begun in 1995, this voluntary alliance and partnership of 51 member institutions and organizations offers access to quality agricultural information and sources through the AgNIC portal and its more than 60 partner websites covering such topics as aquaculture, water quality, rangeland management, sustainable agriculture, animal welfare, and a variety of crops [http://www.agnic.org]. AgNIC is supported, in part, by the NAL through provision of the AgNIC Secretariat and other program support, as well as extensive in-kind contributions from member institutions. The AgNIC portal is a gateway for presenting selected content through specific services. These services include a resource database, a calendar of events, a news service, specialized announcements (such as Plant Disease announcements), and direct access to subject experts. In addition, AgNIC is currently developing the AgOAI service that "harvests" metadata from full-text, open repositories, now numbering 13 data sources, through a simple user interface [http://www.agnic.org/agoai].

Million Book Project – The Million Book Project, led by Carnegie Mellon University, aims to digitize one million books to create a free-to-read, searchable digital library of books in many languages and scripts [http://www.archive.org/details/millionbooks]. Already over 600,000 books have been scanned. Working with university, government and research partners in India, China and the U.S., the project will provide a wide array of content, but one of its strengths will be agriculture. In partnership with the Food and Agriculture Organization of the United Nations (FAO), NAL in the U.S., and university libraries with quality agriculture collections, the project is digitizing materials and developing plans for a knowledge network to improve rural community access to critical agricultural information [http://www.library.cmu.edu/Libraries/MBP_FAQ.html].

Response from USDA, National, and International Organizations

> *Rather we hope that you are inspired by a vision …of achieving new human goals by changing the way that information is used in the world. Digital libraries are about new ways of dealing with knowledge: preserving, collecting, organizing, propagating, and accessing it—not about deconstructing existing institutions and putting them in an electronic box.* [31]

Ian Witten & David Bainbridge

The primary information collection, management, and dissemination units in USDA are NAL and Cooperative Extension. Other organizations facilitate coordination and collaboration among these and other groups, as well as work to develop broad-based outreach initiatives and technical infrastructure. Notable are the U.S. Agricultural Information Network (USAIN) and the American Distance Education Consortium (ADEC). Internationally, FAO, the Consultative Group on International Agricultural Research (CGIAR), and others have spearheaded efforts to disseminate information and provide educational opportunities for agriculturalists and rural communities throughout the world. These entities have been setting new directions in the development of customized services to meet the research, information, and life skills needs of their constituencies for today and for future generations and there have been efforts to work with multiple stakeholders toward more "coherence" in the field.[32]

USDA National Agricultural Library (NAL) – The vision for a national digital library for agriculture was formally described for the first time in the "Report on the National Agricultural Library 2001."[33] The report recommended establishing a dynamic national agricultural information system coordinated by NAL. The system – composed of academic, government, and industrial libraries – would include extensive digital collections; tools to organize and describe the content in the collections; search facilities to aid in the discovery and use; and services to help customers of all levels find and use the knowledge.

The creation of institutional repositories is an important first step necessary to build a national agricultural information system. To that end, NAL has launched the development of its own institutional repository called the National Agricultural Library Digital Repository (NALDR) [http://naldr.nal.usda.gov/], which contains primarily historical work published by USDA and other agriculturally important collections. NALDR was released in 2006 in the first phase of a multi-year initiative. In the next phase, NAL will develop a larger scale repository to capture USDA's published works.

To fulfill the vision outlined above, these collections must be organized and described in a way that will facilitate their discovery and structured to maximize the re-use of their content. NAL developed the Web accessible, agricultural thesaurus (NALT) as a key resource. Descriptions of objects down to the article level are essential as customers are increasingly less likely to browse books on a shelf, but instead rely on librarians and others to recreate this experience in a virtual sense [http://www.nalusda.gov/].

USAIN – "The United States Agricultural Information Network is an organization for information professionals that provides a forum for discussion of agricultural issues, takes a leadership role in the formation of a national information policy as related to agriculture, makes recommendations to the National Agricultural Library on agricultural information matters, and promotes cooperation and communication among its members" [http://www.usain.org/]. Since its creation in 1988, USAIN has taken a leadership role in efforts to facilitate agricultural information initiatives such as:

1. initiating the National Preservation Program for Agriculture Literature of an historical nature (see above)

2. sponsoring ten national conferences

3. testifying before the U.S. House Appropriations Sub-committee that led to additional funding for NAL and preservation and digitization initiatives

4. conducting national surveys[34]

5. establishing Memorandums of Agreement with AgNIC and related international associations.

ADEC – The American Distance Education Consortium (ADEC) is a 501(c)3 non-profit organization owned and operated by approximately 65 state universities and land grant colleges, with other domestic and international partners, that seeks to make accessible educational content beyond the traditional boundaries of the university to virtually anyone who seeks it, through high-quality, economical distance education programs and services [http://www.adec.edu/]. These are delivered using appropriate combinations of technologies such as Internet2, satellite uplinks, downlinks, VSATs[35], digital television, and video and audio conferencing. ADEC's primary focus is on the traditional areas of competitive advantage for land-grant institutions, with equal emphasis on the land-grant pillars of teaching, research, and service. Specifically, this includes programs related to food and agriculture; nutrition and health; environment and natural resources; community and economic development; and children, youth, and families. ADEC is currently developing a digital information infrastructure program in cooperation with AgNIC and other organizations.

eXtension – The eXtension initiative is a recent effort led by the Extension Committee on Organization and Policy (ECOP) of the National Association of State Universities and Land-Grant Colleges (NASULGC) as part of the move to advance the science and practice of engagement and outreach of land-grant colleges and universities to the people of the states they serve [http://about.extension.org/]. The eXtension website provides a vehicle for interested individuals to ask questions, provide suggestions and participate in developing this common vision for the future and to help design an on-line Extension information system for the next generation of users. The first Community of Practice, Horses, was released in August 2006, along with an extensive frequently asked questions (FAQ) section. There are now 10 additional Communities of Practice, or Resource Areas, covering community, family, and farm topics. Similar to other initiatives, eXtension is a land-grant based system, although managed through a centralized structure.

International Initiatives – In October 2005, an Expert Consultation was hosted by FAO entitled "International Information Systems for Agricultural Science and Technology (IISAST) - Review of Progress and Prospects". This meeting brought together representatives of various international, regional, national and thematic initiatives to consider how agricultural information professionals can work together more effectively to influence national and regional policy frameworks and to improve coherence in agricultural information systems at all levels. The expert consultation suggested that an organized global partnership is required to bring together the existing range of initiatives into a more cohesive alliance.[36] [http://www.fao.org/gi/gil/consultations/consult_infosys_en.asp]

The December 2005 World Summit on the Information Society (WSIS) subsequently tasked the FAO to formulate follow-up to an initiative dubbed "e-agriculture", whose objective is to ensure the systematic dissemination of information using ICTs (information-communication technologies) on agriculture, animal husbandry, fisheries, forestry and food [http://www.itu.int/wsis/c7/e-agriculture/]. The ultimate purpose is to provide ready access to comprehensive, up-to-date, and detailed knowledge and information, particularly in rural areas.

At a meeting in June 2006, participants including FAO and WSIS members agreed to establish mechanisms to engage all global stakeholders to generate a better understanding of e-agriculture. In September a global survey was launched to solicit views, ideas and experiences that will help better define the role that digital technologies can have in improving information exchange and communication related to agriculture. The results indicated that stakeholders felt there was a strong need for "improvements in processes such as information dissemination, access, and exchange; and communication, participation, and network/community-building activities amongst rural stakeholders. In contrast, only a third mentioned technological tools, such as mobile phones, computers, or the internet."[37] The survey results were the basis for an "e-agriculture" week of meetings and conferences held at FAO in September of 2007, including a 2nd IISAST Expert Consultation, to promote greater collaboration and coordination of efforts in meeting the information needs of the agriculture community. A January 2008 follow-up meeting in Paris among seven major international agricultural information organizations resulted in agreement to write a manifesto for more "Coherence in Information for Agricultural Research and Development" (CIARD).[38]

The CGIAR, made up of 15 international agricultural research centers located throughout the world, has been a key participant in the IISAST and e-agriculture meetings. The organization recently created an information, communication, and technology knowledge management program (ICT-KM) with the goal of improving the effectiveness of the CGIAR System by "connecting people, technology, and knowledge for agricultural innovation" [http://ictkm.cgiar.org/]. New initiatives in the ICT-KM program include an institutional knowledge sharing project and the sponsorship of workshops to provide opportunities for staff and partners to explore and experiment with knowledge sharing methods.

Also involved in the international coherence efforts and taking a leading role in facilitating communication among all interested parties is the International Association of Agricultural Information Specialists (IAALD). The mission of IAALD is to "enable members to create, capture, access and disseminate information to achieve a more productive and sustainable use of the world's land, water, and renewable natural resources" [http://www.iaald.org/]. To this end, the Association utilizes a variety of online communications platforms for information dissemination, exchange and knowledge sharing; convenes world congresses and regional meetings to facilitate dialogue among all agricultural information stakeholders; and collaborates with members and other partner organizations throughout the world, including USAIN and AgNIC.

The Need to Act Now!

In a world where cuts in materials budgets are commonplace and where content is not scarce, trends suggest that "clear description and downright valuation" of libraries must place them squarely and unambiguously in the larger network of learning resources that includes museums, public broadcasting and community organizations that are part of a knowledge-based society.[39]

Robert S. Martin, Director Institute of Museum & Library Services

Despite these promising collaborative initiatives, the information landscape in the agricultural sciences continues to show a confused and fragmented picture with a great number of scattered and overlapping services. Due to this, there are significant risks and costs to the research, education, and producer communities that depend on the U.S. agricultural information system. If political and agricultural information stakeholders do not act quickly and at a sufficient level of investment to address the challenges outlined above, there will be significant dangers including:

- permanent loss of observational data due to lack of well-curated, long-term archives;
- lack of interoperability and cross-over innovations among disciplines;
- redundant system-building among universities and agencies with major cost implications;
- lack of synergy among information technology research and disciplinary science users;
- adoption of incompatible data formats in different fields impeding advances in research;
- falloff of research and economic vigor resulting in economic deficiencies;
- potential duplication of research efforts;
- inadequate support of educational activities and knowledge transfer; and
- a piecemeal agricultural cyberinfrastructure creating a greater divide.

Developing a Digital Agricultural Information System for the 21st Century

Of the 109 public comments received on The Report, 68% were from scientists and librarians. The highest priority for NAL was increasing and maintaining current electronic access and working toward a National Digital Library of Agriculture. The National Library of Medicine (NLM) should be used as a model for NAL. [40]

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The Panel's analysis makes a case for … a dynamic national agricultural information system. As has occurred with the National Library of Medicine, this system would draw on innovative technologies to directly link users to quality content (abstracts, full-text, data, and information packages) in all areas … in the support of the total U.S. food and fiber enterprise. Included would be a complementary mix of services … 24/7 document delivery, and all interconnected through a powerful search interface providing users with the closest approximation possible to a "one-stop-shopping" reality.

Larry N. Vanderhoef, Panel Chair
Chancellor, University of California
August 2001, Executive Summary & Panel Recommendations,
Report on the National Agricultural Library [41]

A January 2006 meeting of the Planning Group for the Leadership Council for Agricultural Information and Outreach, a group convened by NAL and other interested stakeholders, continued the ongoing process of visioning a national digital agricultural information system. In the summary of the meeting, the goal was described as providing "seamless access and discovery to a broad scope of authoritative collections and services across a flexible, networked, and collaborative system."[42] The key requirements for such a system were documented in the brainstorming sessions and included many of the following capabilities.

A National Digital Agricultural Information System

- Collect, store, organize, share, synthesize and offer computational features for huge volumes of widely disparate and distributed digital information. This includes scholarly journals, monographs, textbooks, learning objects, abstracts, manuscripts, maps, Internet resource descriptions, still images, geospatial images and other kinds of vector and numeric data, as well as moving picture and sound collections.
- Offer a federated network of institutional repositories which allows seamless, "one-stop shopping" interfaces with persistent links from a course reading list or other learning objects to the most appropriate copy of an information resource.
- Determine how different people need to analyze and find information and adjust to their "contexts."
- Include formats and delivery channels that enhance use of information.
- Provide new knowledge management tools for collaboration and for working interactively with all artifacts of scientific progress.

Technical Requirements for a National Digital Agricultural Infrastructure

- Develop and deliver an integrated set of networked services that allows end-users to **discover**, **access**, **use** and **publish** digital and physical resources as part of their learning and research; requires a technical architecture with an extensive set of agreed on standards and protocols.
- Link and relate different types of information that make it possible for people to mine and harvest data leading to new knowledge, require new paradigms for information classification, representation (e.g., standards, protocols, formats, languages), manipulation, and visualization (techniques used for creating images, diagrams, or animations for improved communication).
- Develop middleware, standard or interoperable formats, and related data storage strategies. Although each discipline is likely best suited to creating and managing such repositories and tools, interoperability with other disciplines is essential, through the creation and adherence to standards, and other means.
- Include long-term, distributed, and stable data and metadata repositories that institutionalize community data holdings. These repositories need to provide tutorials and documents on data format, quality control, interchange formatting, and translation, as well as tools for data preparation, fusion, data mining, knowledge discovery, and visualization.
- Provide interoperability among these localized units (Land-Grant Universities, Cooperative Extension, and Agricultural Experiment Stations and others) through the adoption of shared standards. This means as noted above, good communication of the standards and operational policies.
- Maintain stewardship for scientific data through ongoing creation and improvement of the metadata by people cross-trained in scientific domains and knowledge management. Additionally, greater emphasis needs to be given to the digitization and stewardship of legacy data.

A Proposed Model for a National Digital Agricultural Information System

The intention is not to reinvent the wheel but to build on existing accomplishments, while scaling up, becoming more strategic and comprehensive, and identifying the technological enhancements essential to creating a more integrated system. The series of Heatley papers culminating in *The Plan to Develop a Digital Information Infrastructure to Manage Land Grant Information*[43] provide a basis from which to build and implement this new vision and bring it to reality[44] (Appendix B). In addition, there are two newly established committees involving Land-Grant Universities, AgNIC, ADEC, and others whose purpose is to design, identify funding options for, and implement projects to maintain and provide access to agricultural "born digital" and "reborn digital" resources. At the same time, there are opportunities for the U.S. agricultural information community to become more involved in the international coherence initiatives described above by collaborating on technical standards that will improve information sharing and interoperability.

Proposed Next Steps

The U.S. agricultural information community has made a commitment to rethinking the current agricultural information infrastructure and moving toward the development of a national digital agricultural information system. However, discussions on how to do this to date have been addressed in the context of different bodies, (USAIN, AgNIC, NAL, and international arenas). Single-purpose coordination is necessary to proceed in the most cost-effective and rapid manner.

Thus, as stated in the "Case for Change", USAIN calls upon the leadership of USDA, NASULGC, the agribusiness industry, and others with interests in a vital agricultural sector to strongly support a process to develop a detailed implementation plan and phased road map for a national digital agricultural information system for the 21st century. This process should result in (1) a framework for collaboration (who does what), (2) defined technical standards and system requirements, (3) determination of associated costs and timeframe for reaching milestones; and (4) a long-term sustainable management plan.

- Included in this process should be selected key players from the Preservation Program, Land-Grant Universities/AgNIC, NAL, ADEC, Cooperative Extension, Agricultural Experiment Stations, NASULGC, private sector, and a representative(s) from the newly formed international CIARD collaboration.
- Also involved should be leading information scientists and potential partners from the information industry who will provide the technical details needed to develop a detailed implementation plan and phased road map.

There is considerable momentum building within the membership of each of the organizations identified in this paper to actively engage in bringing to reality the vision for a national digital agricultural information system. It is also clear that no one organization or person can build this system alone. By combining forces as equal partners, each with a specific and important role to play, and through the collective will, energy, and commitment of the agricultural information community as a whole, a digital agricultural information system for the 21st Century will be achieved. While that end is a worthy goal in itself, the ultimate benefit will be in an increased capacity to contribute to research, education, and outreach programs that will contribute to economic prosperity while at the same time ensuring a safe and abundant food supply and the conservation of our natural resources.

Appendix A

Box 1: U.S. National Agricultural Emphasis Areas

Agricultural & Food Biosecurity

- Animal & Plant Biosecurity
- Related Programs
- Food Safety & Biosecurity
- Invasive Species

Agricultural Systems

- Manure & Nutrient Management
- Organic Agriculture
- Precision Farming
- Small Farms
- Sustainable Agriculture
- Workforce Development & Safety
- Related Programs
- Agricultural Markets and Trade
- Biobased Pest Management
- Ecosystems
- Farm Financial Management
- Global Change and Climate
- Integrated Pest Management
- Invasive Species
- Rangelands
- Sustainable Development

Animals & Animal Products

- Animal Breeding, Genetics & Genomics
- Animal Health
- Animal Nutrition & Growth
- Animal Products
- Animal Reproduction
- Animal Well-being
- Aquaculture & Related Programs
- Agricultural Markets and Trade
- Animal & Plant Biosecurity
- Fish & Wildlife
- Food Safety & Biosecurity
- Integrated Pest Management
- Manure & Nutrient Management
- Microbial Genomics
- Organic Agriculture
- Precision Farming
- Rangelands
- Sustainable Agriculture

Economics & Commerce

- Agricultural Markets and Trade
- Farm Financial Management
- Financial Security
- Public Policy
- Small & Home-based Business Related Programs
- Environmental & Resource Economics
- Rural & Community Development
- Small Farms
- Sustainable Agriculture
- Sustainable Development
- Workforce Development & Safety

Families, Youth & Communities

- Child Care & After-School Programs
- Communities at Risk
- Family Science & Human Development
- Housing & Indoor Environment
- Leadership & Volunteer Development
- Rural & Community Development
- Urban Programs
- Youth Development & 4-H
- Youth Education Related Programs
- Financial Security
- Health
- Information Technology Education
- Nutrition
- Public Policy
- Workforce Development & Safety

Biotechnology & Genomics

- Bioinformatics
- Biotechnology
- Microbial Genomics Related Programs
- Animal Breeding, Genetics & Genomics Ecosystems
- Nanotechnology
- Plant Breeding, Genetics & Genomics

Food, Nutrition & Health

- Food Safety & Biosecurity
- Food Science & Technology
- Health
- Hunger & Food Security
- Nutrition
- Obesity & Healthy Weight Related Programs
- Biobased Pest Management
- Biobased Products & Processing
- Integrated Pest Management
- Nanotechnology
- Organic Agriculture
- Pesticides
- Sensor Technology

Natural Resources & Environment

- Air Quality
- Ecosystems
- Environmental & Resource Economics
- Fish & Wildlife
- Forests
- Global Change and Climate
- Rangelands
- Soils
- Sustainable Development
- Water Related Programs
- Biobased Pest Management
- Integrated Pest Management
- Invasive Species
- Manure & Nutrient Management
- Rural & Community Development
- Sustainable Agriculture

Pest Management

- Biobased Pest Management
- Integrated Pest Management
- Invasive Species
- Pesticides Related Programs
- Agronomic & Forage Crops
- Animal Health
- Horticulture
- Organic Agriculture
- Plant Breeding, Genetics & Genomics
- Precision Farming
- Sustainable Agriculture

Plants & Plant Products

- Agronomic & Forage Crops
- Biobased Products & Processing
- Horticulture
- Plant Breeding, Genetics & Genomic Related Programs
- Agricultural Markets and Trade
- Animal & Plant Biosecurity
- Biobased Pest Management
- Food Safety & Biosecurity
- Forests
- Integrated Pest Management
- Invasive Species
- Manure & Nutrient Management
- Organic Agriculture
- Pesticides
- Precision Farming
- Rangelands
- Soils
- Sustainable Agriculture
- Water

Technology & Engineering

- Agricultural & Biological Engineering
- Information Technology Education
- Nanotechnology
- Sensor Technology Related Programs
- Air Quality
- Animal Breeding, Genetics & Genomics
- Biobased Products & Processing
- Biotechnology
- Ecosystems
- Food Science & Technology
- Global Change and Climate
- Microbial Genomics
- Plant Breeding, Genetics & Genomics
- Precision Farming
- Workforce Development & Safety
- Agricultural & Food Biosecurity

> Note: USDA Cooperative State Research, Education, and Extension Service (**CRSEES**) manages a portfolio of programs defined as National Agricultural Emphasis Areas (see above). A quick review demonstrates the range of issues agriculture encompasses and the degree to which every American resident's life is affected. http://www.csrees.usda.gov/nea/emphasis_area.html

Box 2: Major Potential Breakthrough Areas in Medicine, Energy, Industry and the Environment

Plant Biotechnology

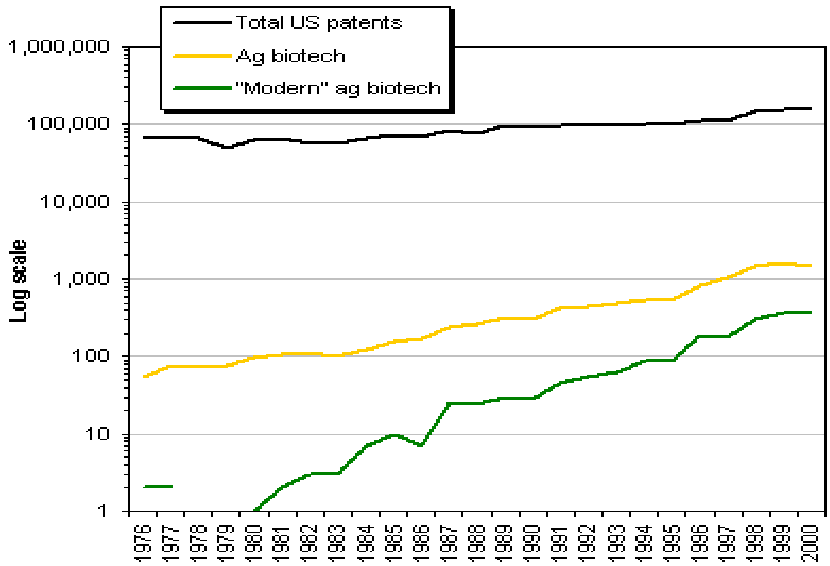
- Pest- and disease-resistant crops
- Increased crop yield and desirable quality characteristics
- Lengthened growing seasons via cold resistance or reduced light tolerance
- Enhanced shape, texture, flavor, and processability characteristics
- Technologies to reduce the required application of fungicides, herbicides, and insecticides, functional foods and nutraceuticals
- Genetic resources for development of biologics, drugs, and pharmaceuticals
- Genetic resource (germplasm) preservation and storage technologies
- Development of biosensors for industrial and commercial applications
- Biopharming and the production of novel and useful chemicals via plant pathways
- The novel application of animal and plant genetic resources to new technologies such as biological computing
- Development of sustainable bio-based fuels
- Development of advanced biomaterials for use in construction and other industrial applications
- Development of degradable plastics from plant starch, protein, and fermentation-produced monomers
- Bioremediation and environmental protection via plants
- Enhanced biosecurity

Animal Biotechnology

- New approaches to animal disease diagnostics, prevention, and treatment
- Increased food animal meat yield and desirable quality characteristics
- Improved technologies for food preservation and the prevention of spoilage and food-borne diseases
- Genetic resources for development of biologics, drugs, and pharmaceuticals for human and veterinary applications
- Xenotransplantation and tissue engineering, providing organs and tissue for human medical applications via animal pathways
- Development of engineered species, such as customized predator insects, to control pests and diseases
- Development of biosensors for industrial and commercial applications
- Bioremediation and environmental protection via microbial pathways
- The use of animal waste and byproducts as renewable energy and chemical production resources
- Enhanced biosecurity

Source: Battelle Memorial Institute. April 2004. OARDC's Competitive Positioning Strategy: A Development Path for the Future. Prepared for: Ohio Agricultural Research & Development Center, The Ohio State University. April 2004. Battelle Memorial Institute, Columbus, Ohio.
https://kb.osu.edu/dspace/bitstream/1811/5971/1/battelle-oardc-phase-II.pdf

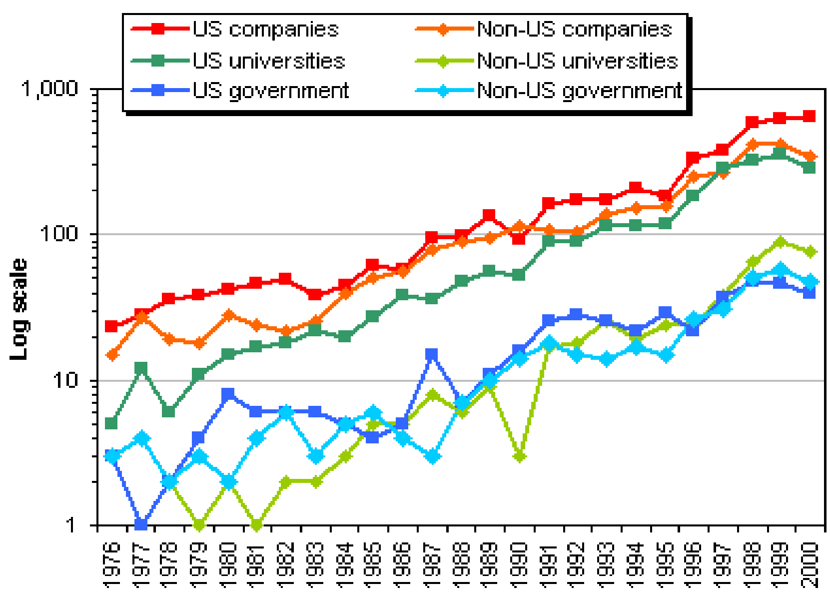
Figure 1: Trends in Agricultural Biotechnology Patenting



Note. Data from ABIP database (USDA ERS, 2004) and the United States Patent and Trademark Office. Blanks in series indicate a zero count, not missing data. These are not recorded because of the logarithmic scale.

Source: *AgBioForum, 8(2&3): 73-82. ©2005.* http://www.agbioforum.missouri.edu/v8n23/v8n23a03-heisey.htm

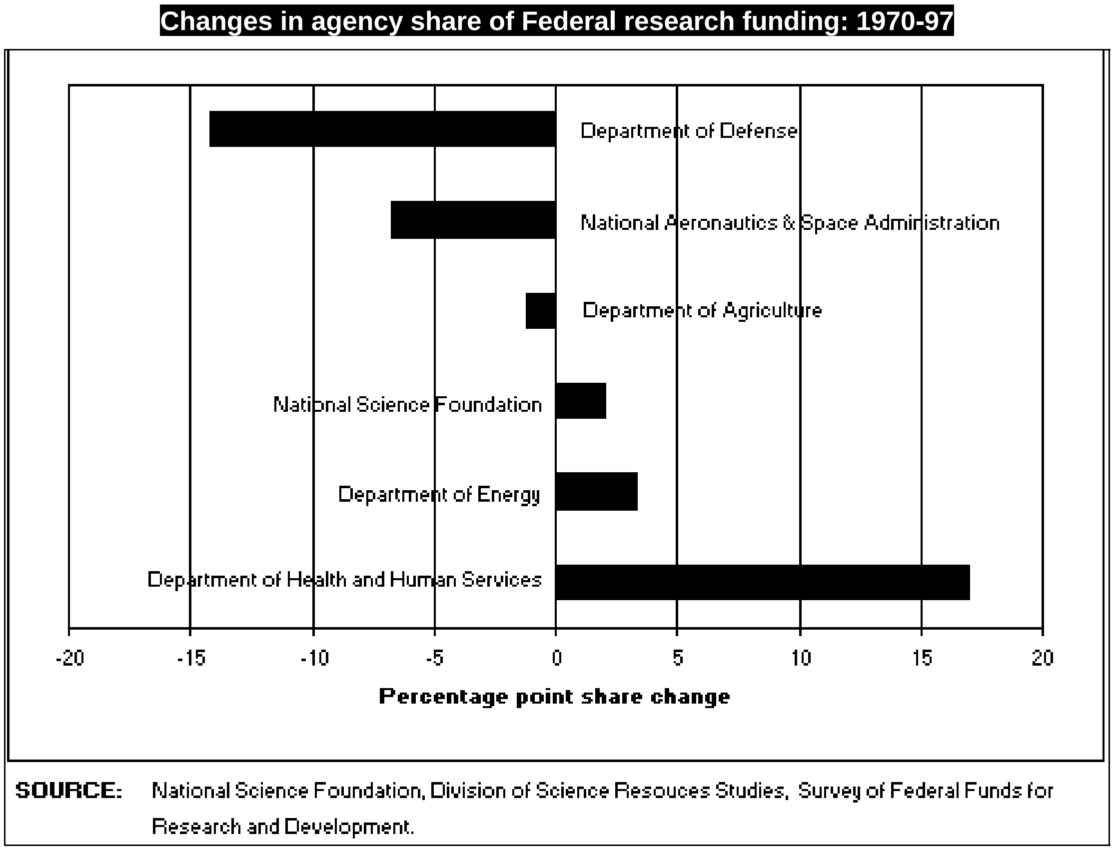
Figure 2: Broadly Defined Agricultural Biotechnology Patents by Sector



Note. Data from ABIP database (USDA ERS, 2004).

Source: *AgBioForum, 8(2&3): 73-82. ©2005* . http://www.agbioforum.missouri.edu/v8n23/v8n23a03-heisey.htm

Figure 3: Federal Funding Trends for Agriculture and Health



Source: Alan I. Rapoport. 1999. How Has the Field Mix of Federal Research Funding Changed Over the Past Three Decades? Division of Science Resources Studies, *Issue Brief NSF* 99-328, February 17, 1999. National Science Foundation, Directorate for Social, Behavioral and Economic Sciences.

Figure 4: President's FY 2008 Budget Requests 1% Increase in R&D Funding

TABLE 1. Federal R&D budget authority, by budget function: FY 2003–08

Funding category	FY 2003 actual	FY 2004 actual	FY 2005 actual	FY 2006 actual	FY 2007 preliminary	FY 2008 proposed	% change FY 2007-08
Current $millions							
All categories conducting R&D	112,544	121,867	126,601	131,624	137,026	138,332	1
National defense	63,048	69,593	74,047	78,037	81,667	82,383	0.9
Nondefense	49,495	52,274	52,554	53,586	55,359	55,949	1.1
Health	26,517	28,251	28,824	28,797	29,481	29,242	-0.8
Space research and technology	7,355	7,612	7,300	8,204	8,933	9,506	6.4
General science	6,129	6,466	6,570	6,691	7,185	7,752	7.9
Natural resources and environment	2,151	2,168	2,168	2,120	1,932	1,944	0.6
Agriculture	1,708	1,750	1,820	1,869	1,824	1,629	-10.7
Energy	1,403	1,343	1,296	1,195	1,581	1,468	-7.1
Other functions[a]	4,232	4,684	4,576	4,710	4,422	4,408	-0.3
FY 2000 constant $millions							
All categories conducting R&D	106,294	112,309	113,158	114,128	115,878	114,220	-1.4
National defense	59,547	64,135	66,184	67,664	69,063	68,024	-1.5
Nondefense	46,746	48,174	46,974	46,464	46,815	46,197	-1.3
Health	25,044	26,035	25,763	24,969	24,931	24,145	-3.2
Space research and technology	6,947	7,015	6,525	7,114	7,555	7,849	3.9
General science	5,789	5,959	5,872	5,802	6,076	6,401	5.3
Natural resources and environment	2,032	1,998	1,938	1,838	1,634	1,605	-1.8
Agriculture	1,613	1,613	1,627	1,621	1,543	1,345	-12.8
Energy	1,325	1,238	1,158	1,036	1,337	1,212	-9.3
Other functions[a]	3,997	4,317	4,090	4,084	3,740	3,640	-2.7

[a] Other functions include transportation; veterans benefits and services; education, training, employment, and social services; income security; commerce and housing credit; international affairs; administration of justice; and community and regional development.

NOTES: Data reflect budget information collected through April 2007. Data for FY 2003-06 reflect final budget authorization. Preliminary budget authority for FY 2007 reflects all past congressional actions as of preparation of this table. Proposed budget authority for FY 2008 from the Bush administration will be revised to reflect congressional appropriation and actual program-funding decisions. Detail may not add to total because of rounding. Percent change derived from unrounded data.

Sources: Agencies' submissions to the Office of Management and Budget, agencies' budget documents, and supplemental data obtained from agencies' budget offices.

Source: President's FY 2008 Budget Requests 1% Increase in R&D Funding
http://www.nsf.gov/statistics/infbrief/nsf07327/

Appendix B

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