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Science**

U.S. Department of Energy

Pluralism as a Foundation for U.S. Scientific Preeminence:

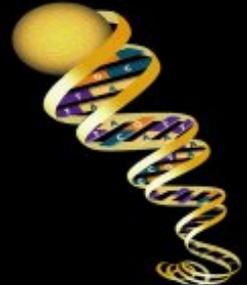
**“Advancement of knowledge and the
freedom and happiness of man”**

Dr. Raymond L. Orbach

Director, Office of Science

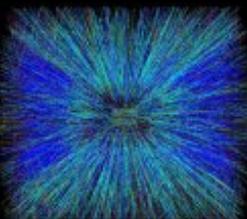
The Arnold O. Beckman Lecture in Science and Innovation

May 5, 2004



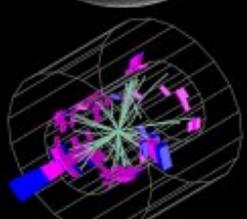
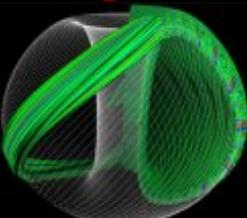
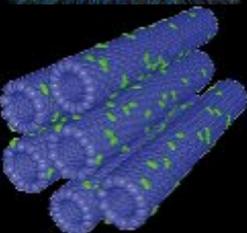
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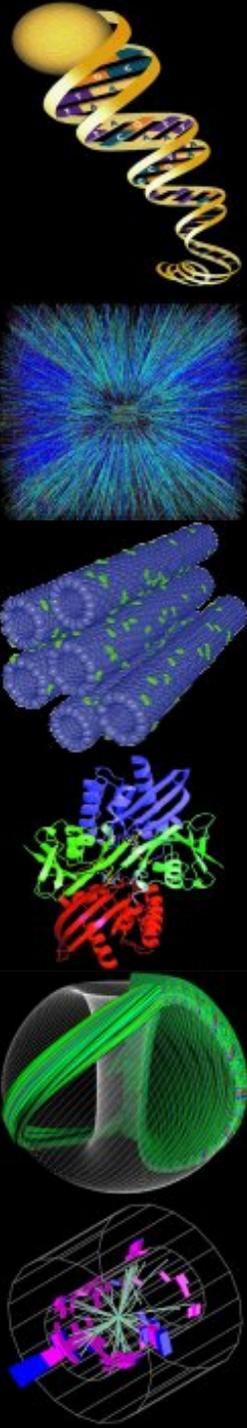
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ABSTRACT

The dominance of American science and scientists in the latter half of the 20th century is directly related to the pluralism of U.S. funding and funding sources, research and development institutions, and the scientific workforce. The competitive nature of the scientific establishment, coupled with this diversity, has allowed unconventional ideas and people to flourish, leading to innovation and discovery. Trends are emerging which threaten this historic strength, with deleterious consequences for U.S. scientific innovation, economic strength, and security.

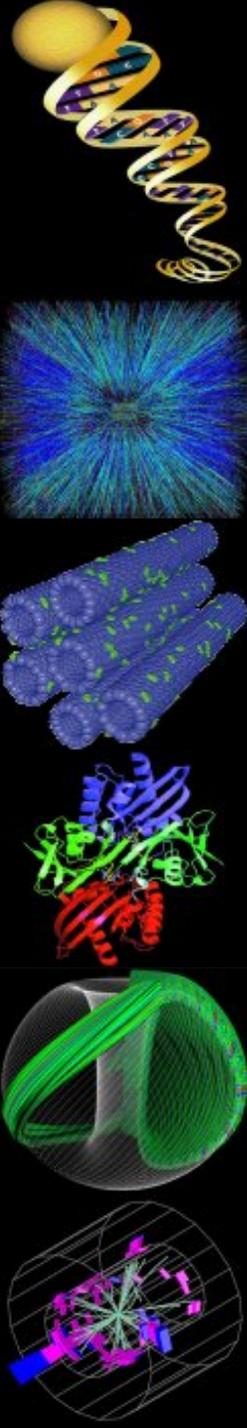




Pluralism of American Science

The strength of the U.S. scientific enterprise is due in large extent to its “diversity” -- the diversity of its workforce, the diversity of its research approaches, and the diversity of its support base. Nowhere else in the world does one find such multiplicity of possible sources for funding research concepts. Most countries have centralized management of the research enterprise, driven by a sense of simplicity, or avoiding “duplication of effort.” That is to say, they desire to promote “efficiency.” But science is not neat: it defies categorization and, often, even organization.

The survival of revolutionary proposals, achieving paradigm shifts in scientific understanding and challenging conventional wisdom depend upon alternative sources of support so that they can be “shopped around.” The very presence of multiple agencies to which an investigator can turn “...protects the freedom of the investigator (who can go elsewhere if turned down by one agency), stimulates healthy competition and dynamism in the system, and prevents the rise of any autocratic center of power.”



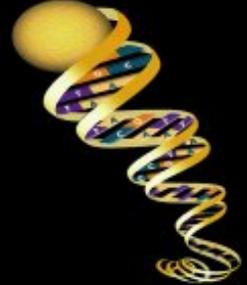
Pluralism of American Science

By encouraging a multiplicity of interests “...*you make it less probable that a majority of the whole will have a common motive to invade the rights of other citizens; or if such a common motive exists, it will be more difficult for all who feel it to discover their own strength and to act in unison with each other.*”

- James Madison, Federalist Papers #10, 1787

“The purposes of science are the advancement of knowledge and the freedom and happiness of man.”

- Thomas Jefferson



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Proposal-Driven Agencies

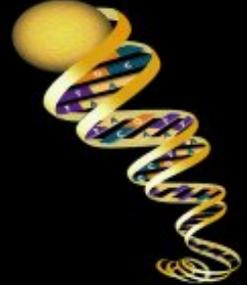
Proposal-driven agencies formulate areas for support in response to proposals from their respective scientific communities.

Proposal-driven agencies have produced magnificent scientific discoveries. Conservatism can creep into the system.

Mission-Driven Agencies

Mission-driven have a defined mission. Research areas are targeted to support that mission.

Mission-driven agencies are often characterized by high risk-high payoff research.

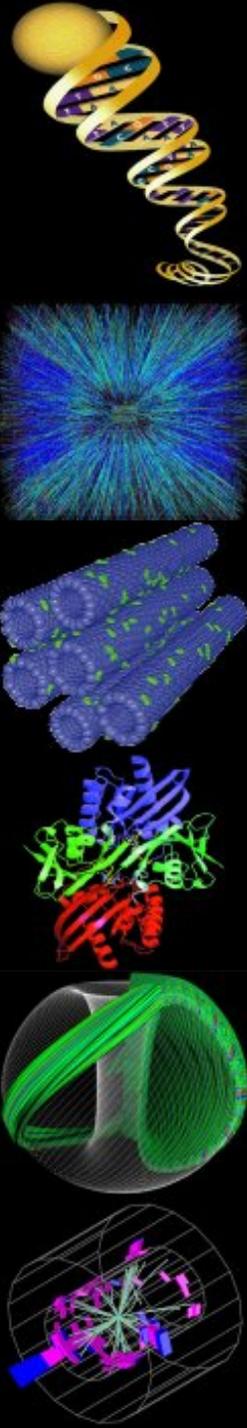


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The beauty of the American system lies in its pluralism and the clash of interests that pluralism can inspire.

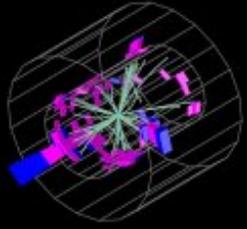
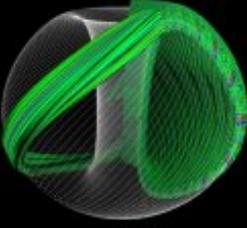
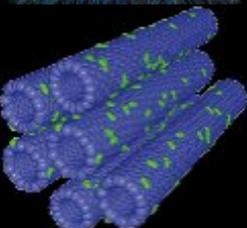
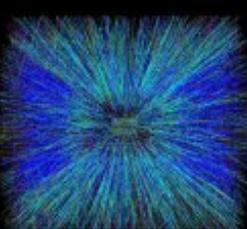
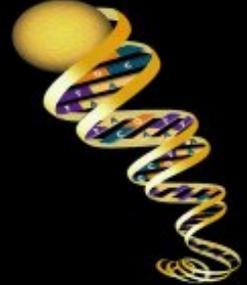
Proposal-driven agencies coupled with mission-driven agencies accomplish Jeffersonian ends through Madisonian means.



Accomplishments of a Pluralistic Research Environment

I. Private Company Examples

- Bell Telephone Laboratories: sound motion pictures, stereo recording, the transistor, the first fax machine, the touch-tone telephone.
- GE Laboratories: the modern X-ray tube, the first television broadcast, the man-made diamond.
- IBM: the automatic sequence controlled calculator, the first computer disk storage system, the floppy disk, solid state optical scanning and later the bar code scanners in supermarkets, electron tunneling and later the scanning tunneling microscope.



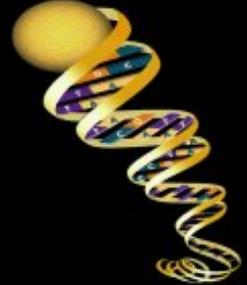
II. Foundation Examples

- Howard Hughes Foundation: identified the genes related to cancer, heart disease, obesity, cystic fibrosis, muscular dystrophy, and Huntington's disease.
- Cold Springs Harbor: developed the first hybrid corn and formed the basis of modern agricultural genetics; developed the first cure for Addison's disease; enabled the recombinant DNA revolution.

III. U.S. Government Agency Examples

Proposal-Driven

- NSF: "Mosaic" internet browser, artificial skin that bonds to human tissue, self-assembling polymers, Antarctic ozone hole, sequence of the Arabidopsis genome, presence of enormous black hole at center of our galaxy, Computer-Aided Design and Computer-Aided Manufacturing, Doppler RADAR (with NCAR), edible vaccines, effects of acid rain, fiber optics, modern DNA fingerprinting.



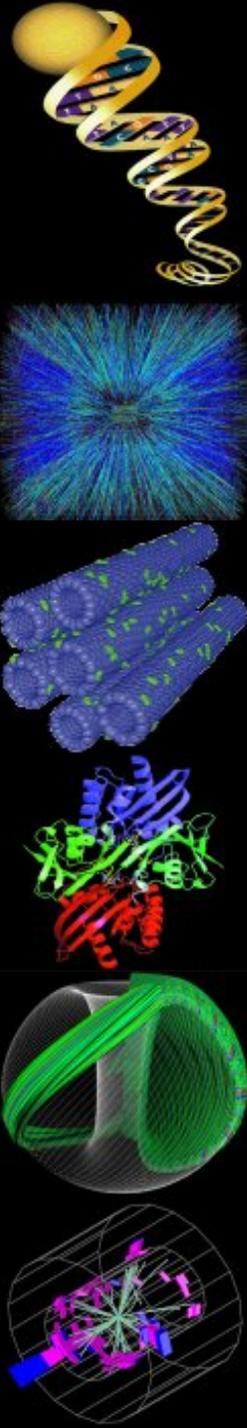
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- NIH: turning mouse embryonic stem cells into cells that produce insulin, anthrax genomes sequenced, identified the genes and developed genetic test for hereditary breast cancer, discovered cholesterol's role in heart disease.

Mission-Driven

- Office of Naval Research: Atomic clock, first laser in ruby; freeze storage of blood, biometrics.
- Air Force Office of Scientific Research: Maser, integrated circuit, self-healing plastics.
- Defense Advanced Research Project Agency: the internet, GPS, MEMS, speech recognition technology (with NSF).
- DOE: discovery of the chromosomal basis for sex determination in mammals, artificial pancreas, artificial retina, nuclear medicine and proton therapy, human genome project and genome sequencing/computation technologies, fate of the dinosaurs, positron emission tomography (PET).

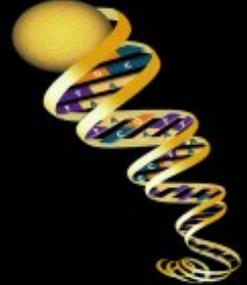


An Example of a Pluralistic Research Environment: Physical Science Contributions to Health Care

President George W. Bush, American Association of Community Colleges Annual Convention, Minneapolis, MN, April 26, 2004:

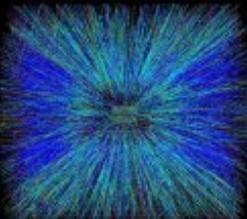
“Many of you have seen the advances of -- close hand of medical research. Just think of some of the advances that are coming. We’re using a gene chip technology to help for cancer treatments. The world is changing dramatically in the field of medicine in many exciting ways. We’re using brain imaging to discover the physical causes of mental illness. We’re using tissue engineering to restore damaged or diseased tissues. And these are all incredible changes, and America is on the leading edge of change in medicines. And we need to keep it that way.”

Each of these advances referred to by the President are either direct contributions of the DOE Office of Science or supported by the DOE Office of Science.



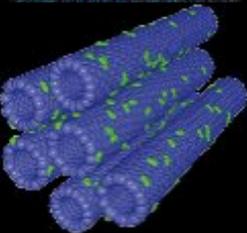
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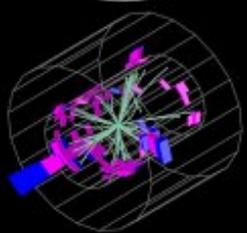
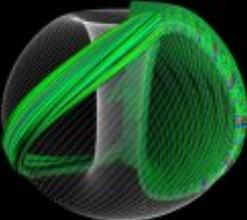
“We’re using a gene chip technology to help for cancer treatments...”

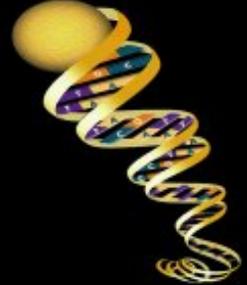
- Gene chip technology is a product of the Human Genome Project, launched by DOE.
- DOE has pushed the development of sequencing technologies to identify genes.



“We’re using brain imaging to discover the physical causes of mental illness...”

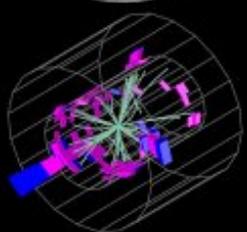
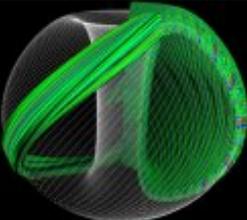
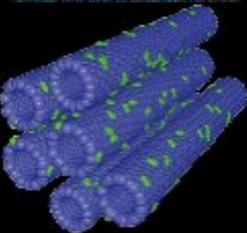
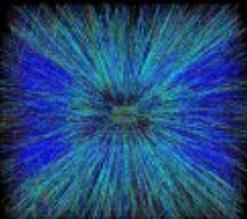
- DOE’s work on brain-imaging led to the development of the PET scan.
- A chemical developed by DOE has helped generate the first functional map of the human brain at work.





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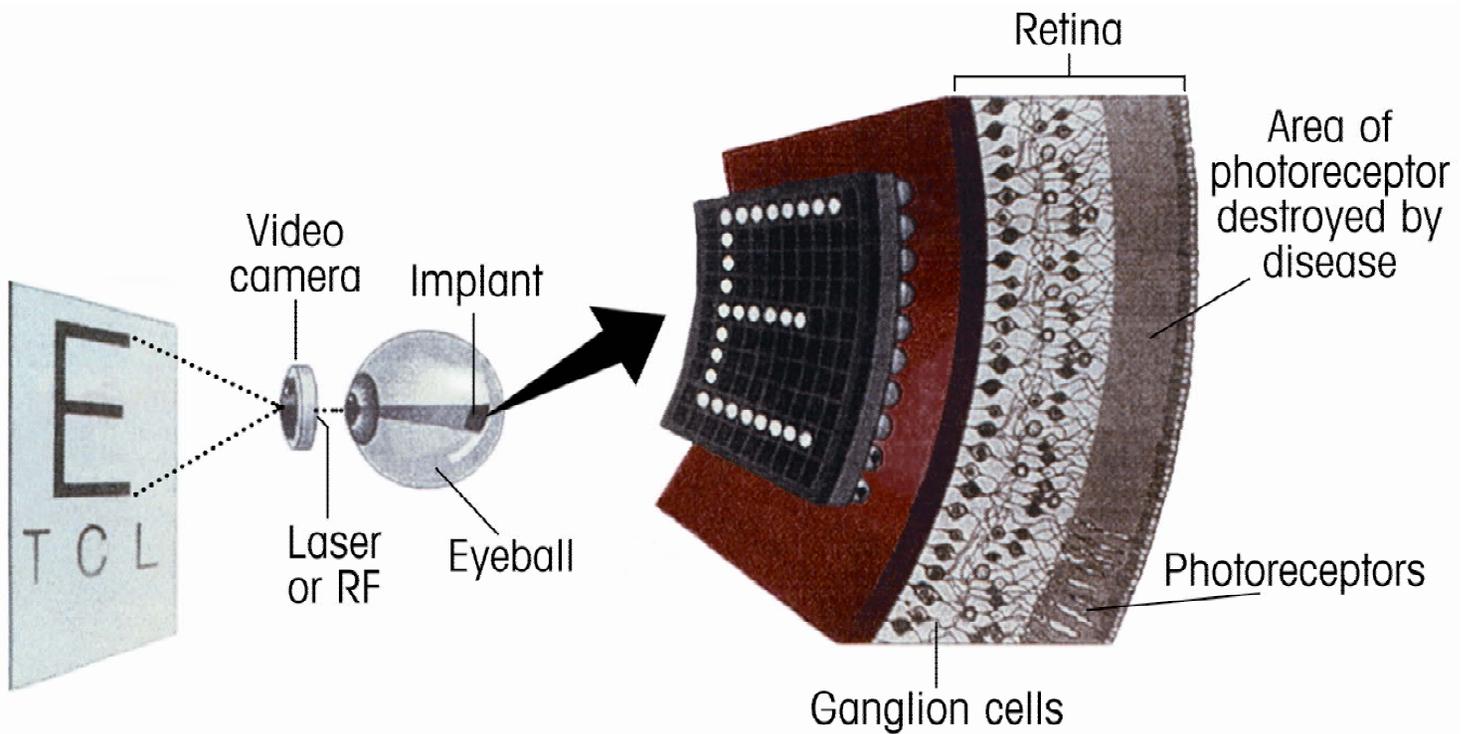
“We’re using tissue engineering to restore damaged or diseased tissues...”

- The artificial retina project will be a triumph of the Office of Science system of rallying multidisciplinary teams of scientists from DOE laboratories, the private sector, and academia to attack a specific problem: the promise of restoring sight to the sufferers of macular degeneration and retinitis pigmentosa.



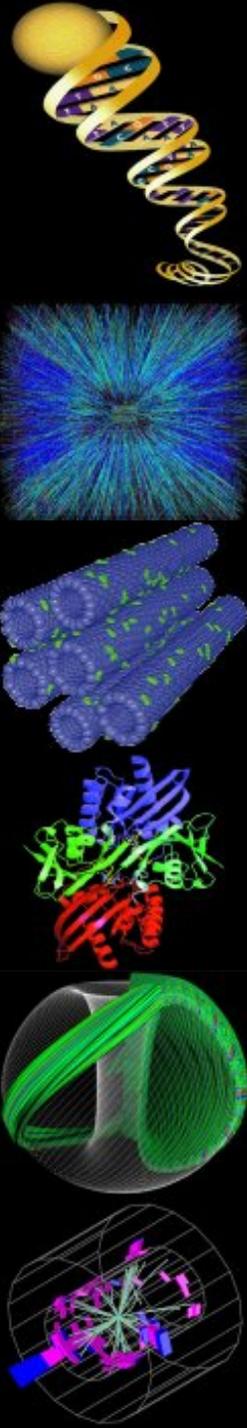
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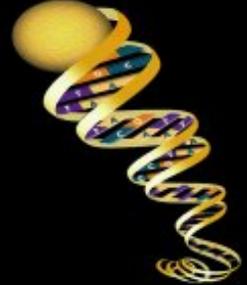




Dangers to Pluralism

1. Lack of long-term investment in basic research by industry.
2. Pressures to “simplify” support of basic research into a single government agency.
3. Changes in funding patterns amongst federal agencies.

Taken together, they can lead to deleterious consequences for U.S. scientific innovation, economic strength, and security.

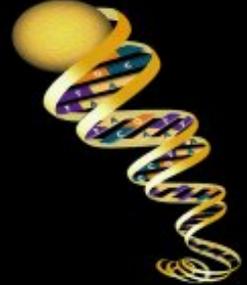


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I. Lack of long-term investment in basic research by industry

Industry today accounts for more than two-thirds of U.S. research and development investment. However, the private sector has sharply reduced basic research funding over time. The intimacy of top quality long-term and short-to-medium term research in an industrial environment appears to have been lost. Has this pillar of innovation been sacrificed to short-term “bottom line” concerns? Have we “changed a winning game?” Can universities and government agencies take up the slack?



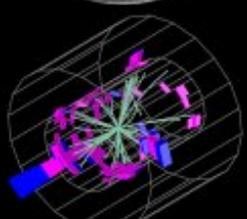
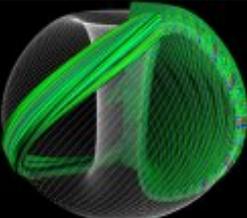
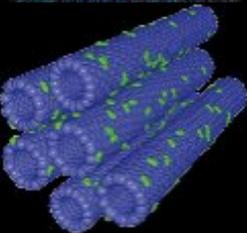
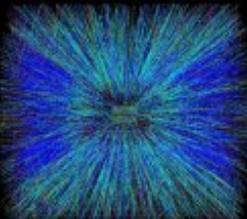
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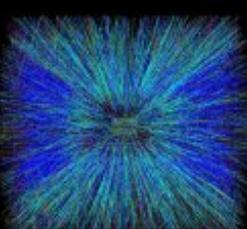
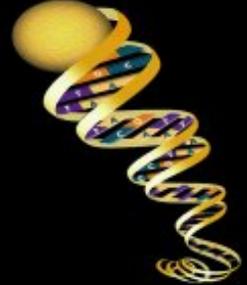
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II. Pressures to “simplify” support of basic research into a single government agency

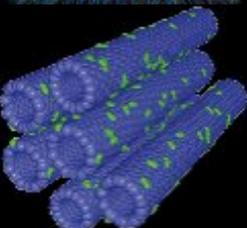
From time to time, pressures have arisen for the creation of a single *Department of Science and Industry*. “The principal arguments are that a science department would mean more bureaucratic clout for science activities, improve Americans’ ability to mobilize efforts to address urgent priorities, create synergies across existing jurisdictional lines, and eliminate duplication of effort. The counter argument states that scientific activities in themselves have no claim on public resources, and the nation has supported R&D only because it advances other objectives. R&D thus should not be separated from the missions of the agencies that support it.”

Turf battles threaten the inter-agency richness enjoyed in a pluralistic environment. Basic research in the physical sciences has led to spectacular advances in medicine. Yet, there are pressures to limit this relationship: “...Nothing in this section shall authorize the Secretary to conduct any research or demonstrations...designed to have any application with respect to human cells or human subjects.”





III. Changes in funding patterns amongst federal agencies

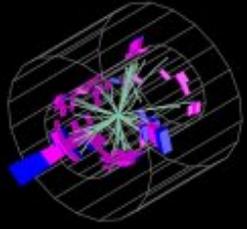
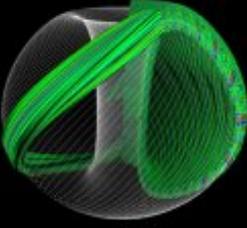


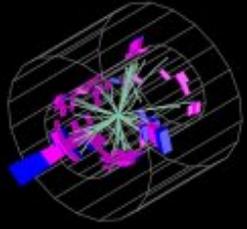
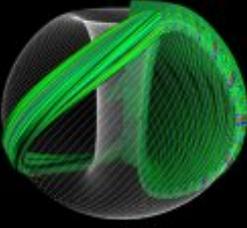
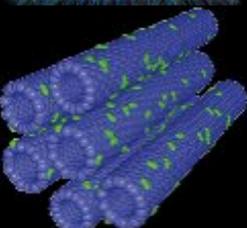
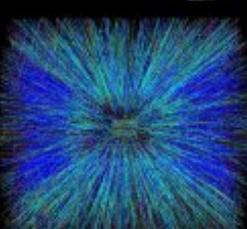
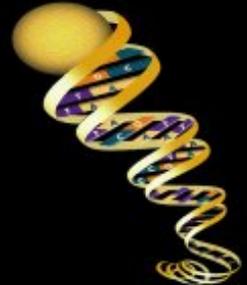
The benefits of pluralistic American science research support could hardly be more evident than in the achievements of U.S. Government agencies. Surprises abound:

Freeze storage of blood (ONR); development of the integrated circuit (AFOSR) creation of the internet (DARPA); initiation of the human genome project (DOE). All of these agencies have different missions, but all of these outcomes are related to the advancement of knowledge and freedom and to the happiness of man. Their basic research support has led to critical advances in innovation, economic strength, and security.



But trends in relative agency funding do not auger well for continuation of this pluralism.

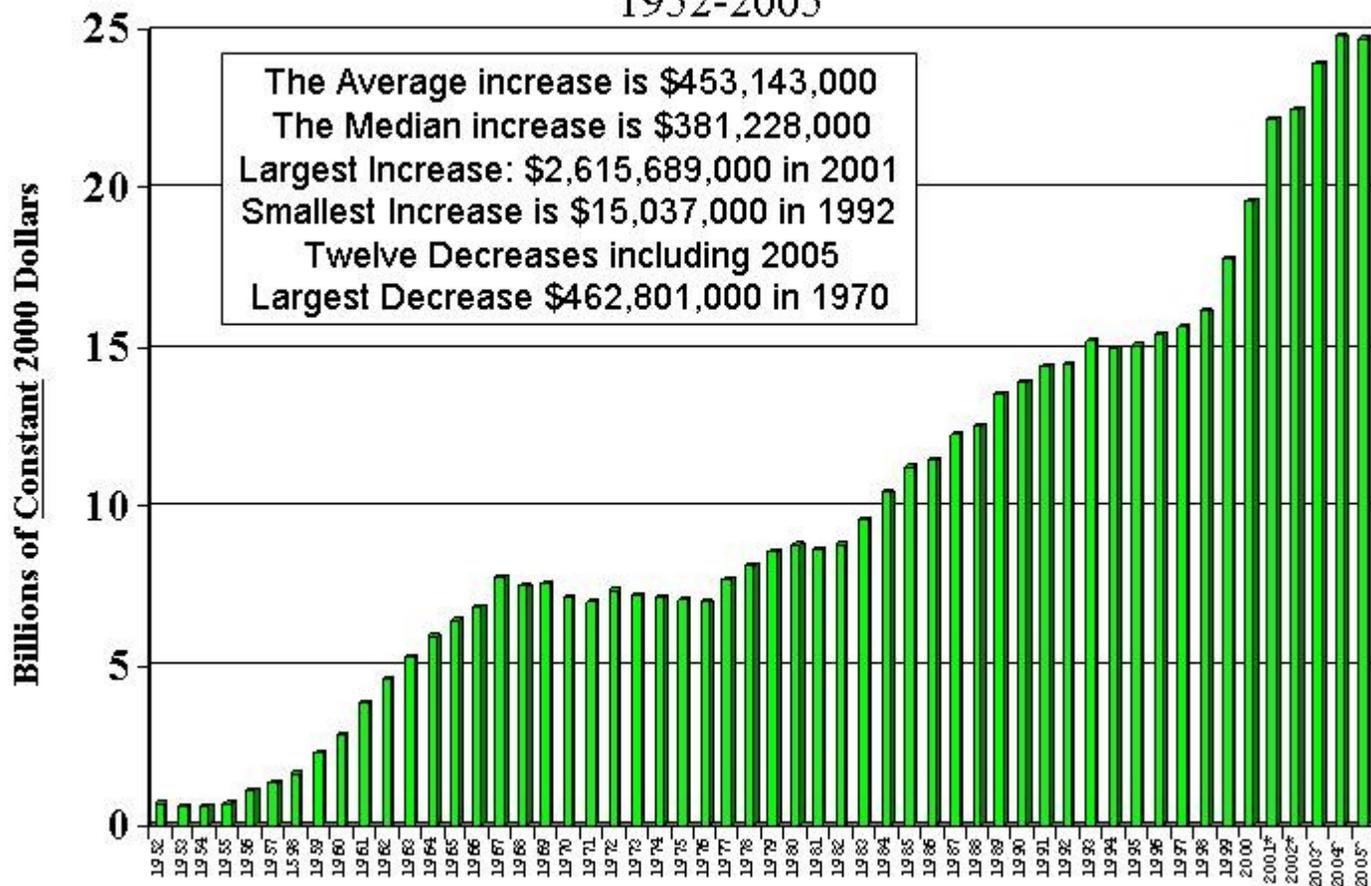




In constant 2000 dollars:

Total Federal Basic Research

1952-2005

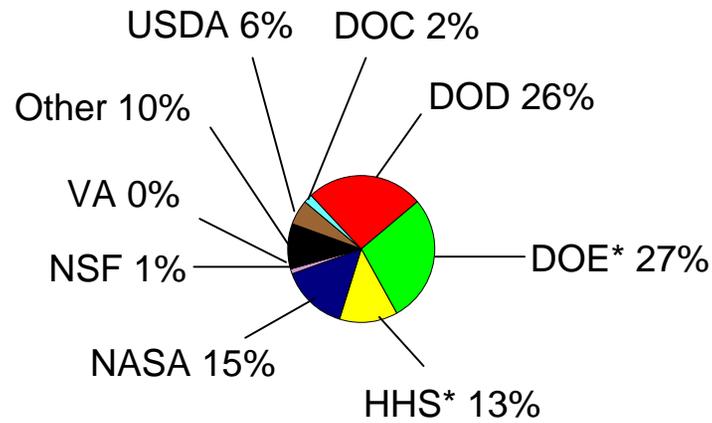


The Average increase is \$453,143,000
The Median increase is \$381,228,000
Largest Increase: \$2,615,689,000 in 2001
Smallest Increase is \$15,037,000 in 1992
Twelve Decreases including 2005
Largest Decrease \$462,801,000 in 1970

Source: NSF Federal Funds Tables
Except ^AAAS R&D in the Federal Budget
Deflators from OMB FY 2005 Budget

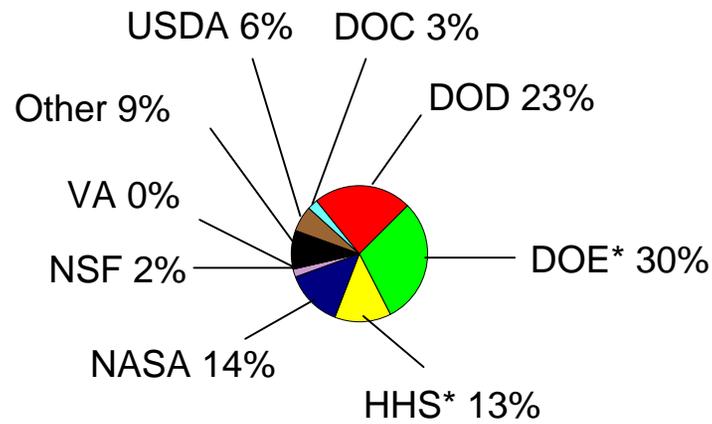


1952 - TOTAL Basic Research \$0.67 Billion Constant FY 2000 Dollars



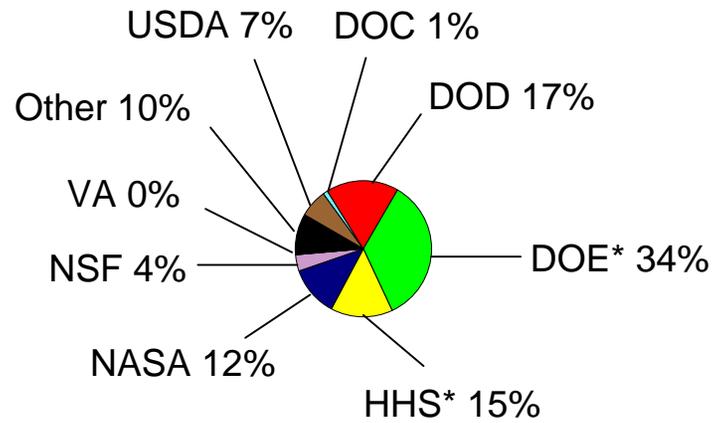
* Includes Predecessor Agencies

1953 - TOTAL Basic Research \$0.64 Billion Constant FY 2000 Dollars



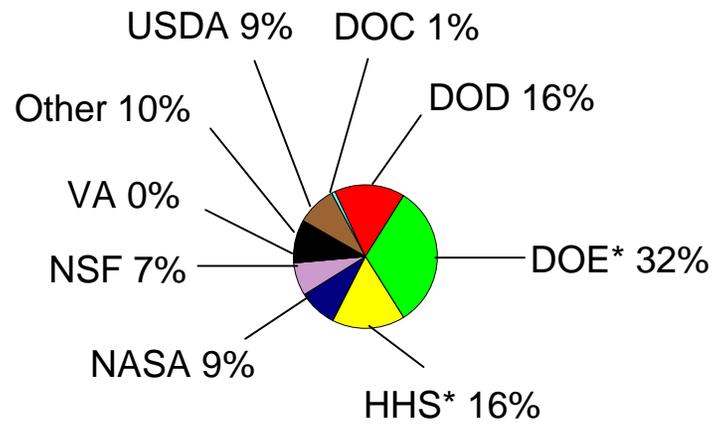
* Includes Predecessor Agencies

1954 - TOTAL Basic Research \$0.63 Billion Constant FY 2000 Dollars



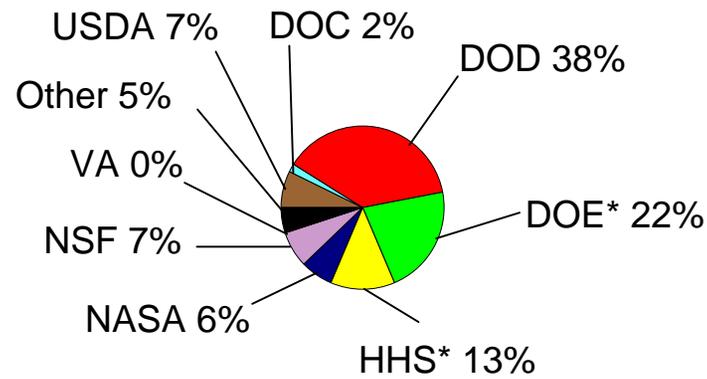
* Includes Predecessor Agencies

1955 - TOTAL Basic Research \$0.70 Billion Constant FY 2000 Dollars



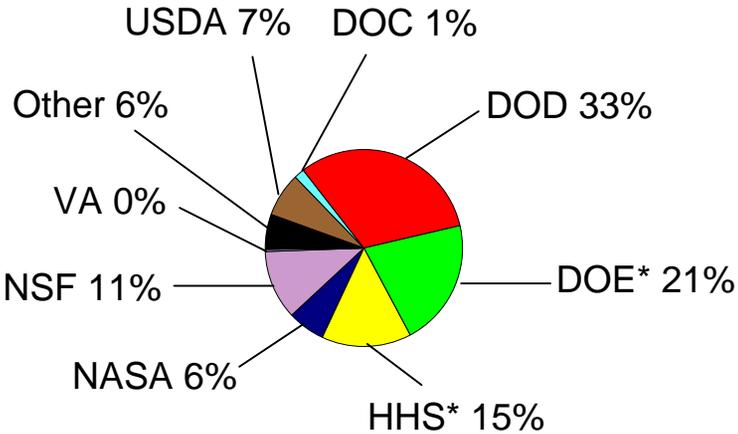
* Includes Predecessor Agencies

1956 - TOTAL Basic Research \$1.08 Billion Constant FY 2000 Dollars



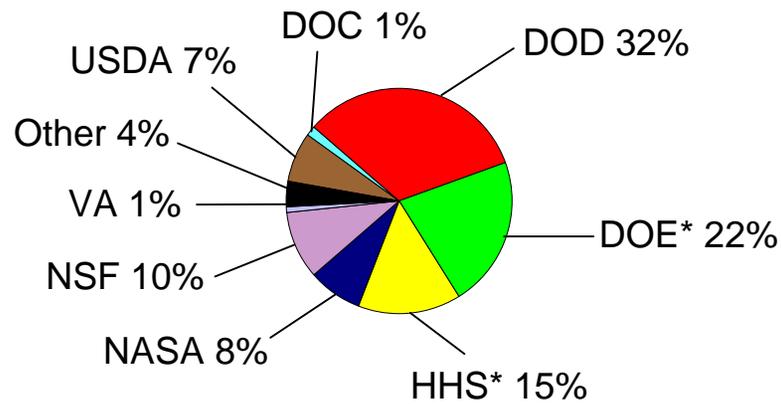
* Includes Predecessor Agencies

1957- TOTAL Basic Research \$1.32 Billion Constant FY 2000 Dollars



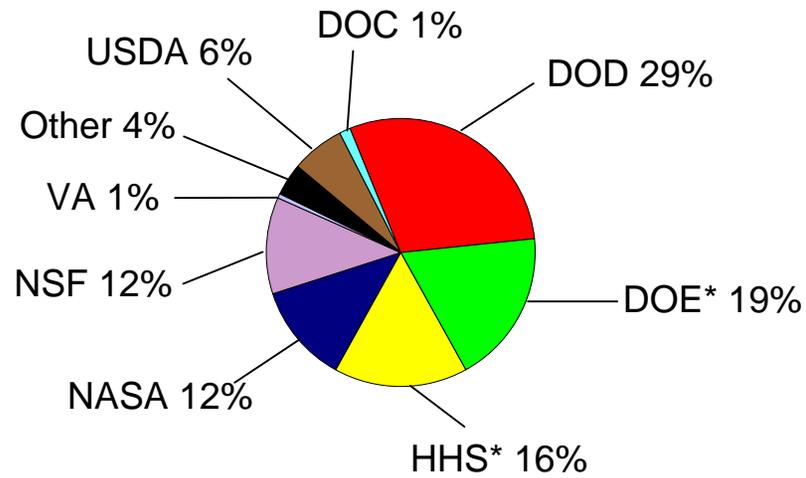
* Includes Predecessor Agencies

1958 - TOTAL Basic Research \$1.64 Billion Constant FY 2000 Dollars



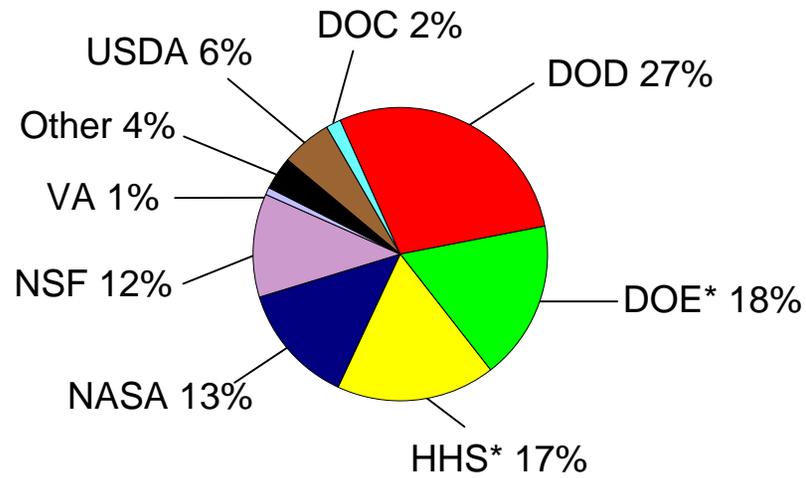
* Includes Predecessor Agencies

1959 - TOTAL Basic Research \$2.25 Billion Constant FY 2000 Dollars



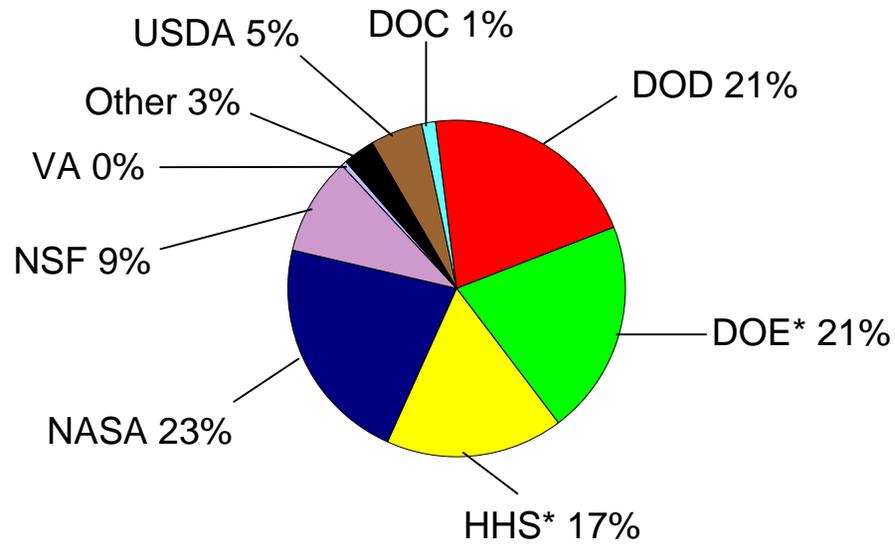
* Includes Predecessor Agencies

1960 - TOTAL Basic Research \$2.81 Billion Constant FY 2000 Dollars



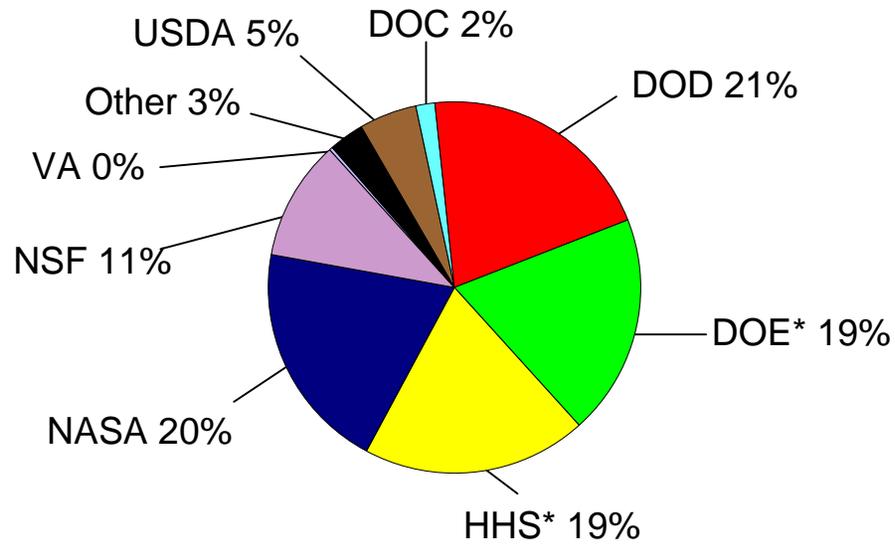
* Includes Predecessor Agencies

1961 - TOTAL Basic Research \$3.82 Billion Constant FY 2000 Dollars



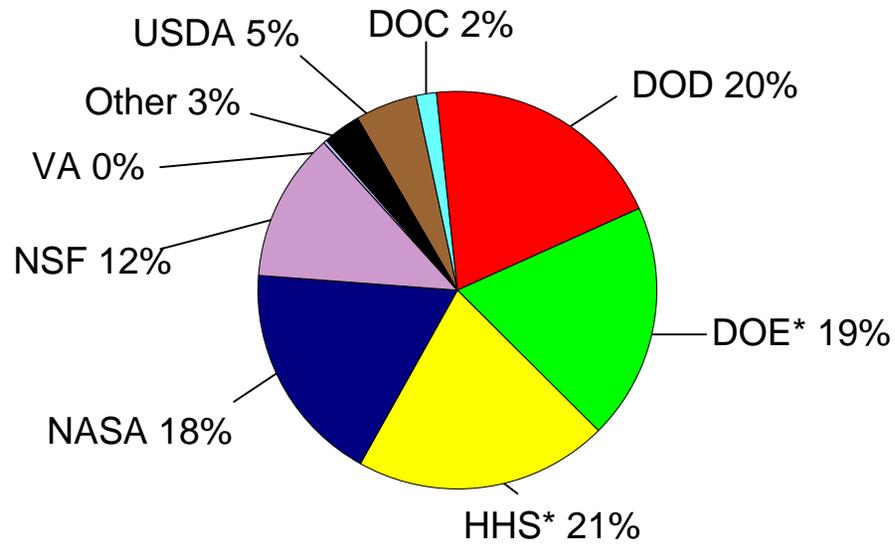
* Includes Predecessor Agencies

1962 - TOTAL Basic Research \$4.58 Billion Constant FY 2000 Dollars



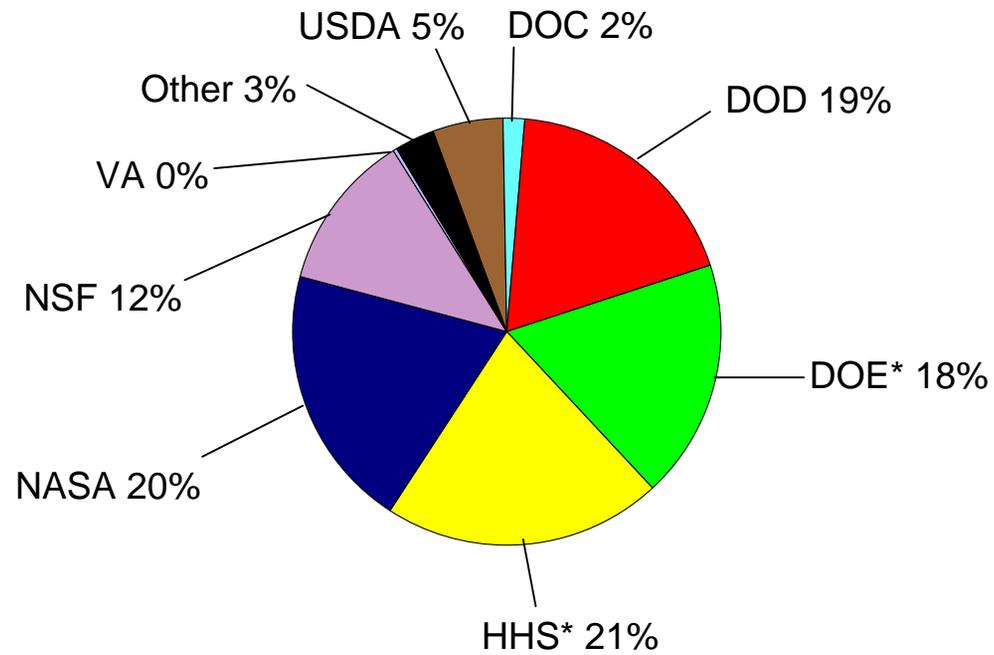
* Includes Predecessor Agencies

1963 - TOTAL Basic Research \$5.28 Billion Constant FY 2000 Dollars



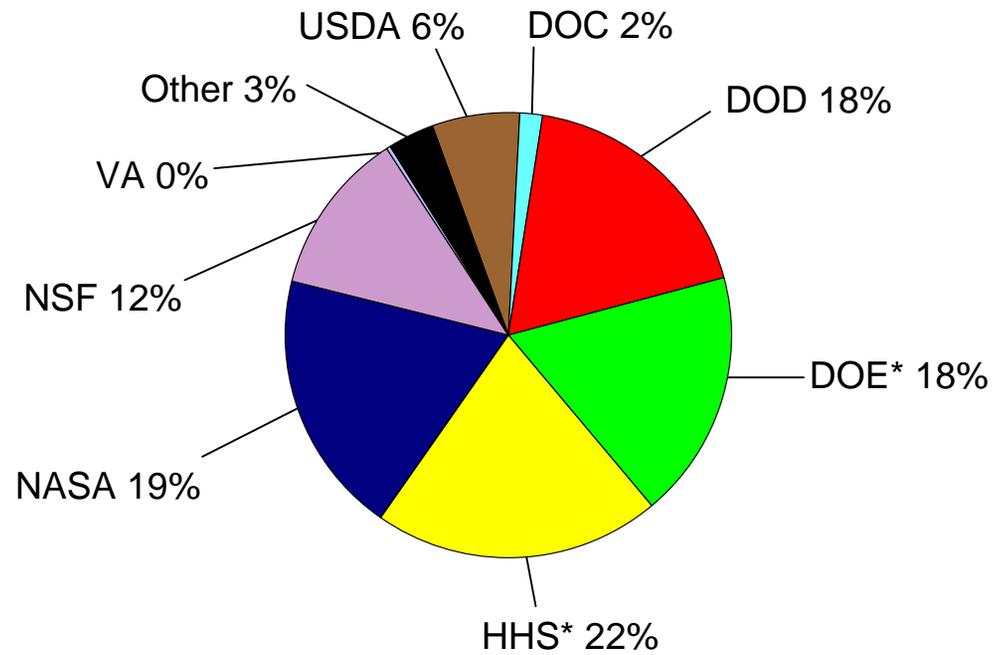
* Includes Predecessor Agencies

1964 - TOTAL Basic Research \$5.90 Billion Constant FY 2000 Dollars



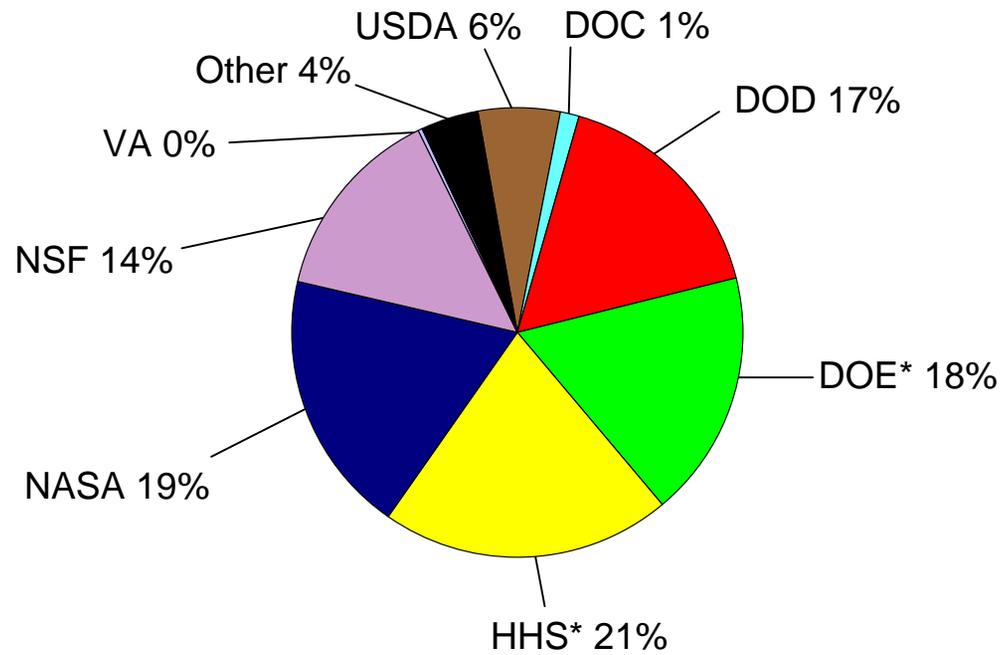
* Includes Predecessor Agencies

1965 - TOTAL Basic Research \$6.39 Billion Constant FY 2000 Dollars



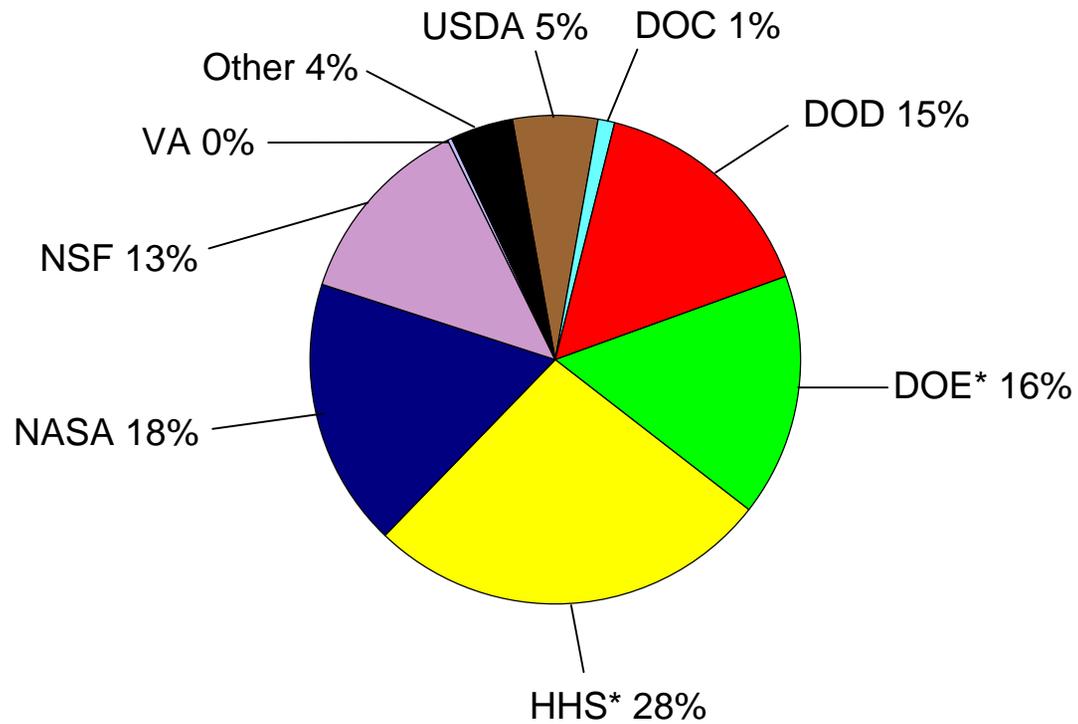
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1966 - TOTAL Basic Research \$6.89 Billion Constant FY 2000 Dollars



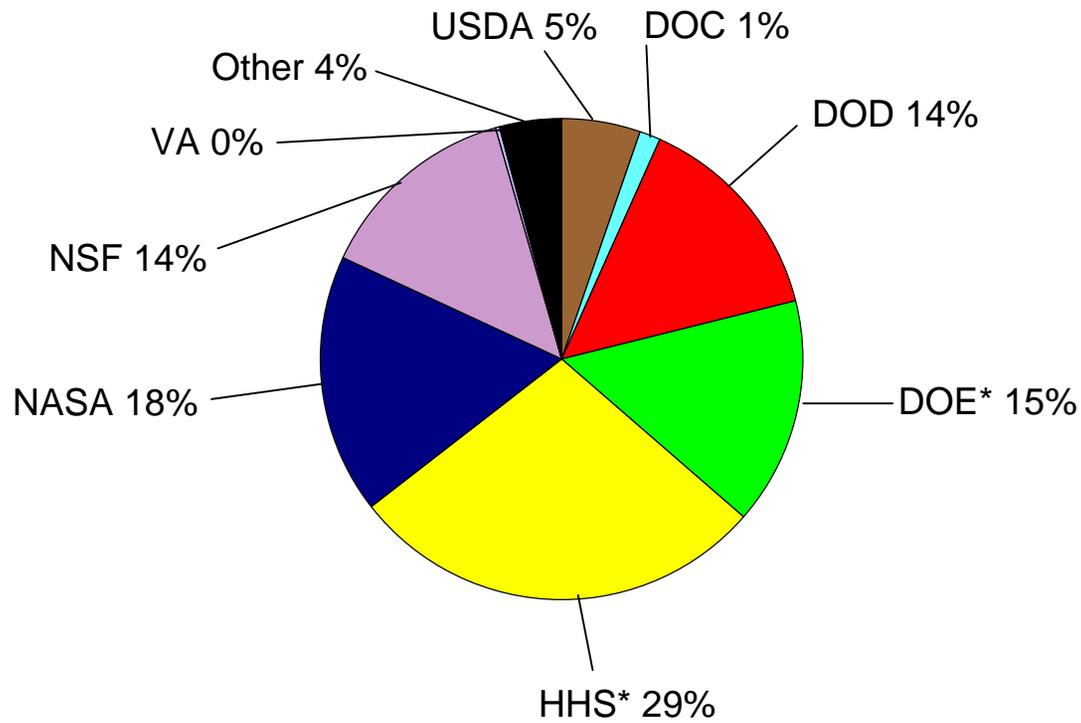
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1967 - TOTAL Basic Research \$7.80 Billion Constant FY 2000 Dollars



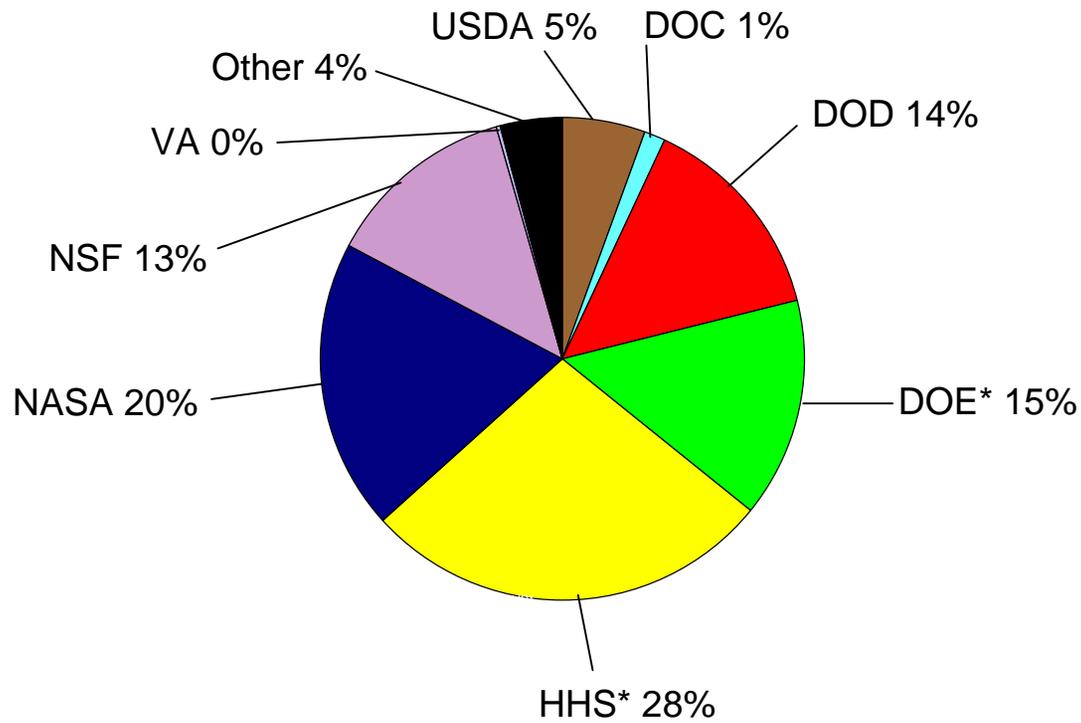
* Includes Predecessor Agencies

1968 - TOTAL Basic Research \$7.51 Billion Constant FY 2000 Dollars



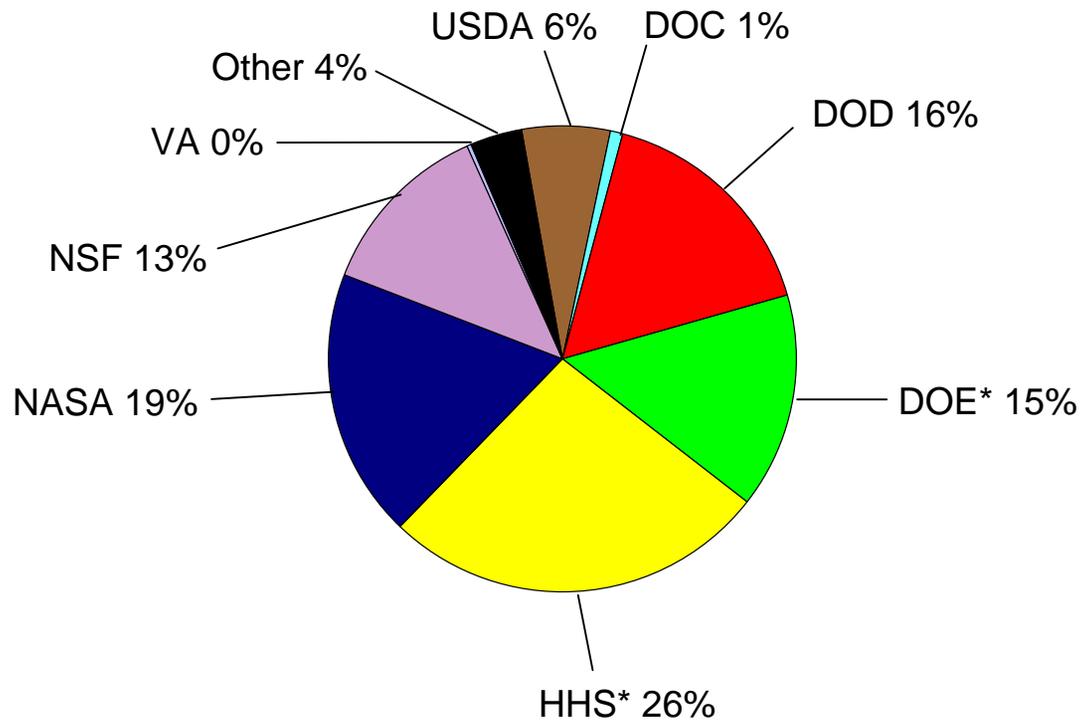
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1969 - TOTAL Basic Research \$7.59 Billion Constant FY 2000 Dollars



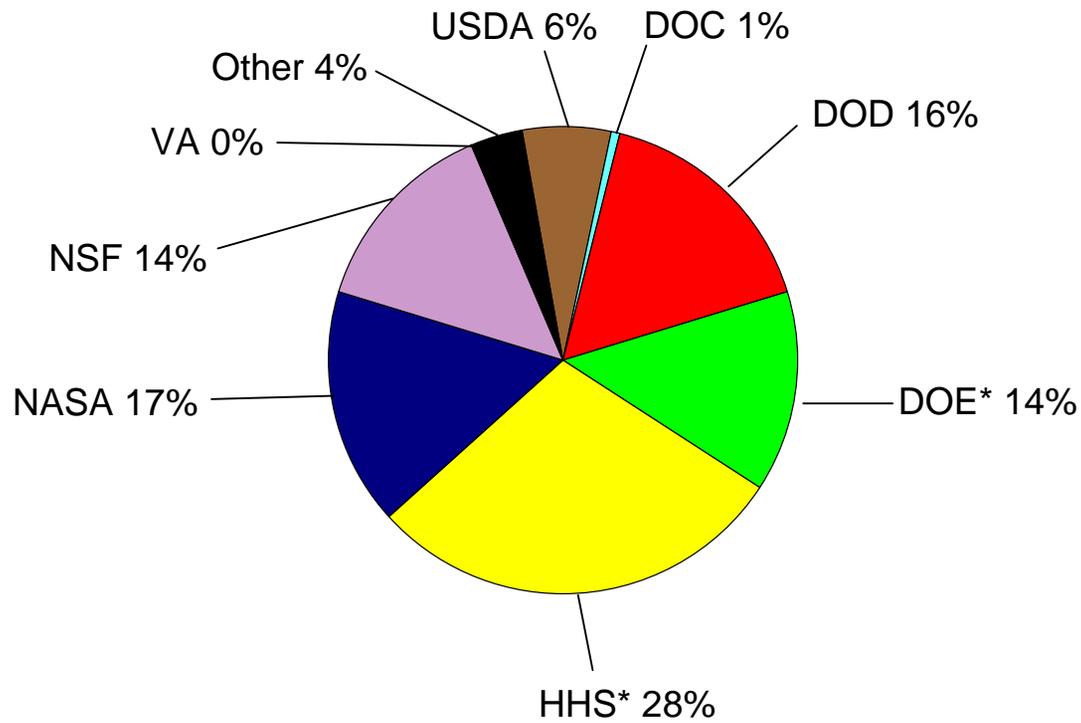
* Includes Predecessor Agencies

1970 - TOTAL Basic Research \$7.13 Billion Constant FY 2000 Dollars



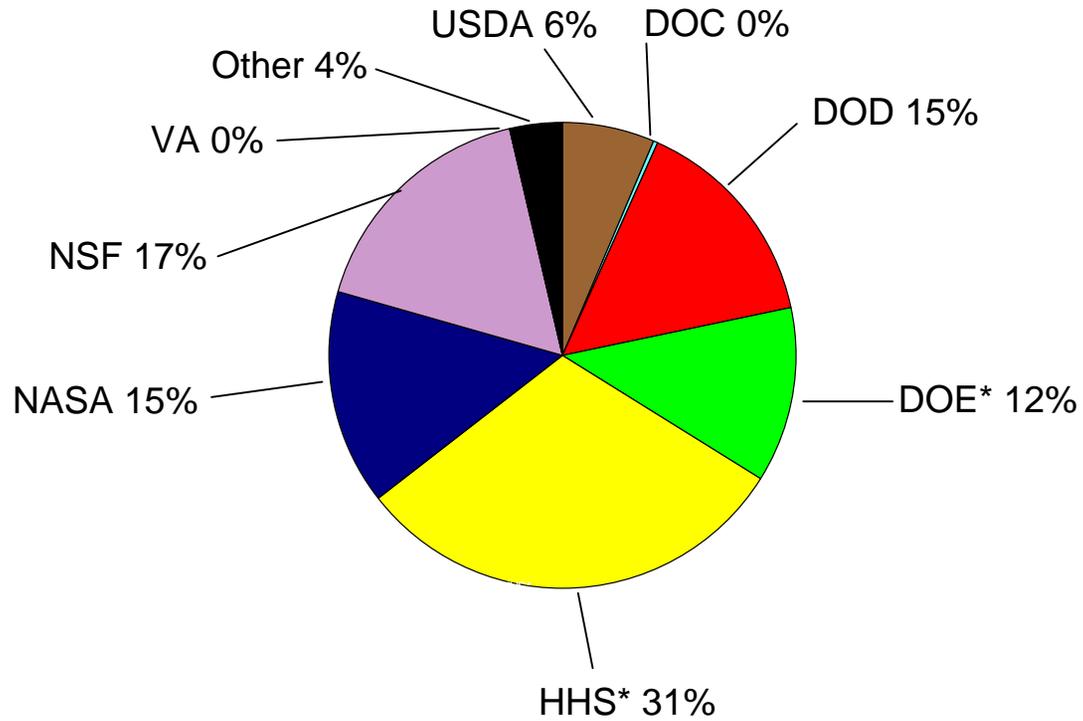
* Includes Predecessor Agencies

1971 - TOTAL Basic Research \$6.98 Billion Constant FY 2000 Dollars



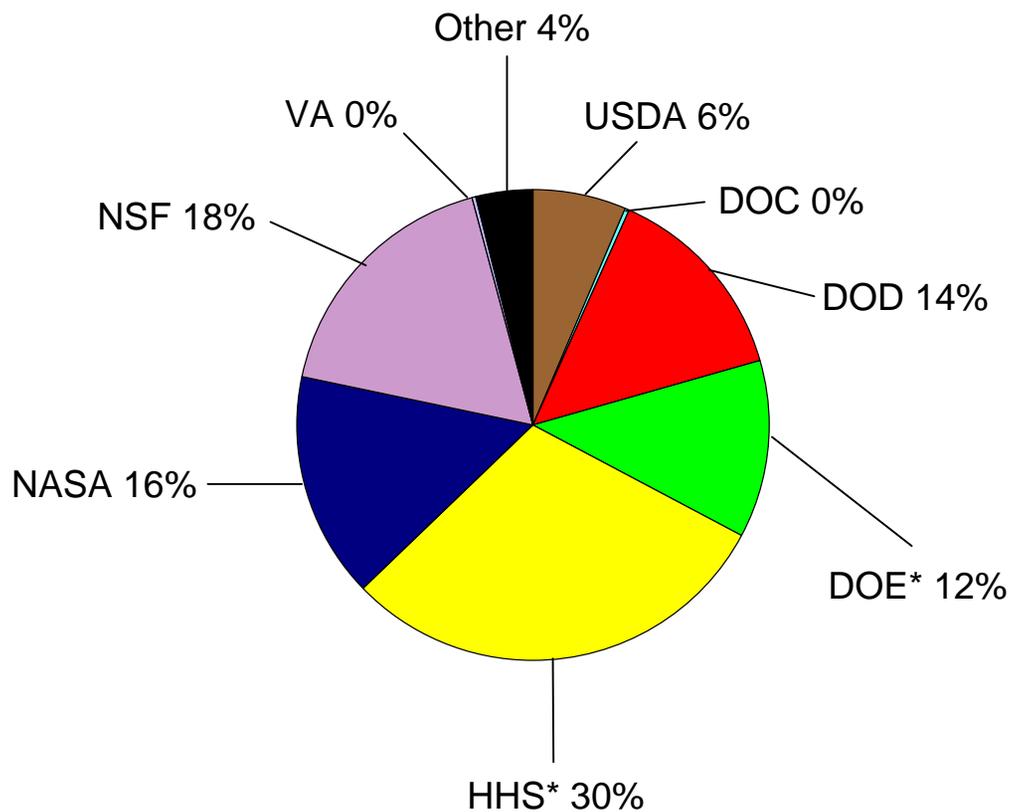
* Includes Predecessor Agencies

1972 - TOTAL Basic Research \$7.36 Billion Constant FY 2000 Dollars



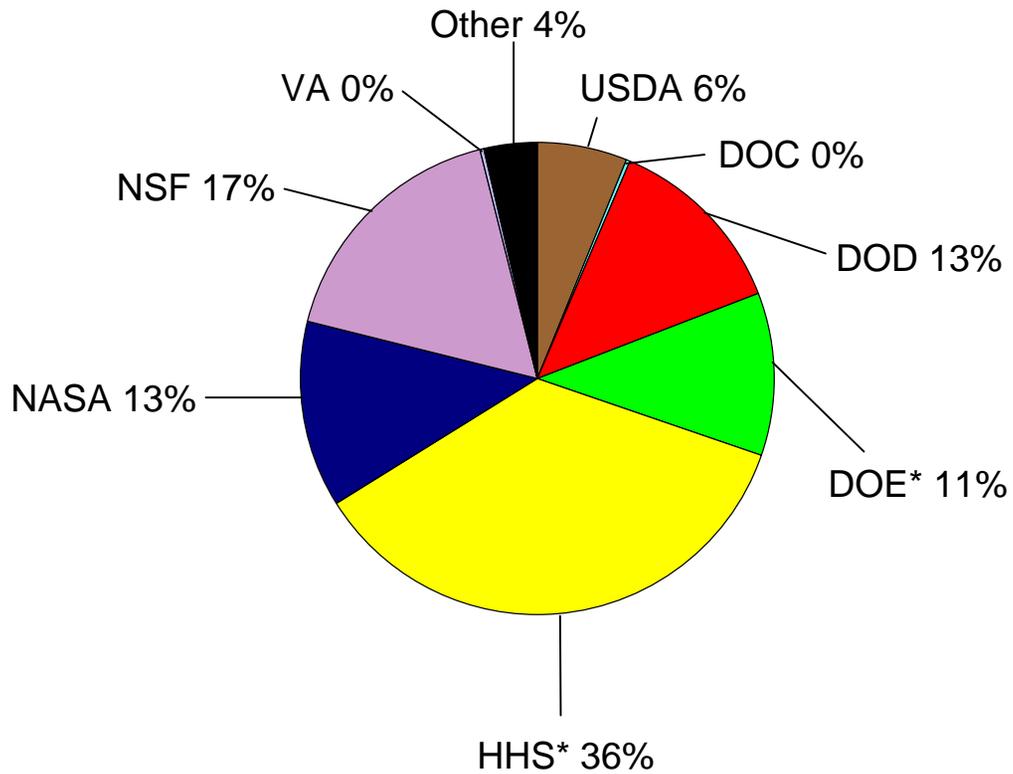
* Includes Predecessor Agencies

1973 - TOTAL Basic Research \$7.19 Billion Constant FY 2000 Dollars



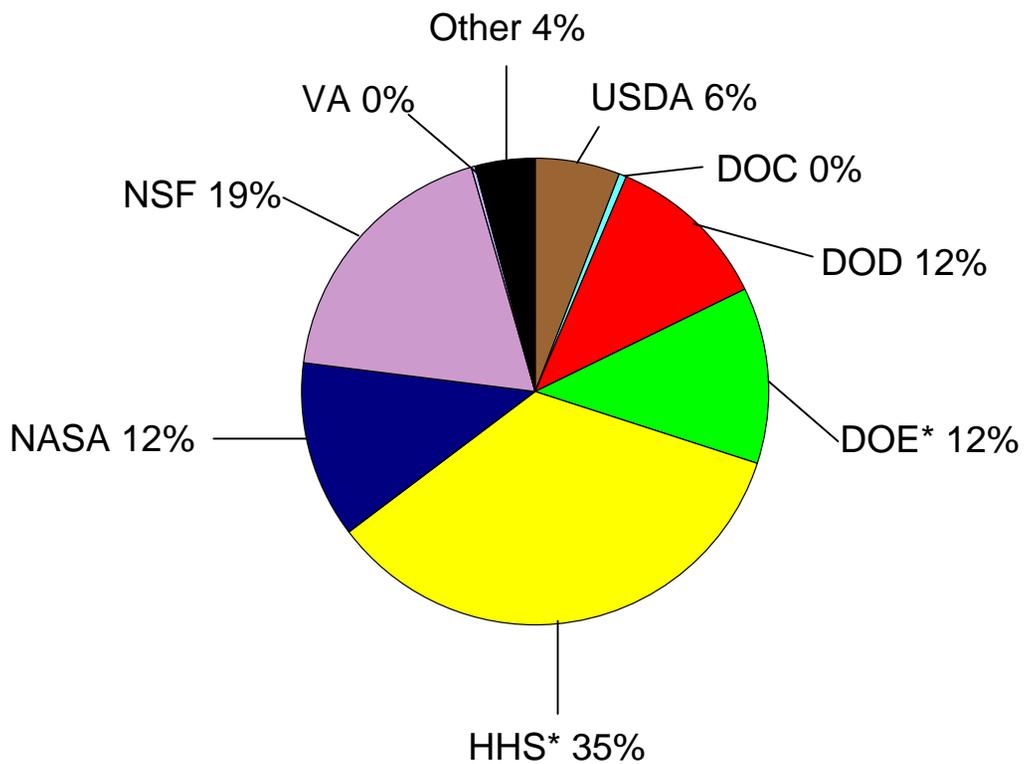
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1974 - TOTAL Basic Research \$7.18 Billion Constant FY 2000 Dollars



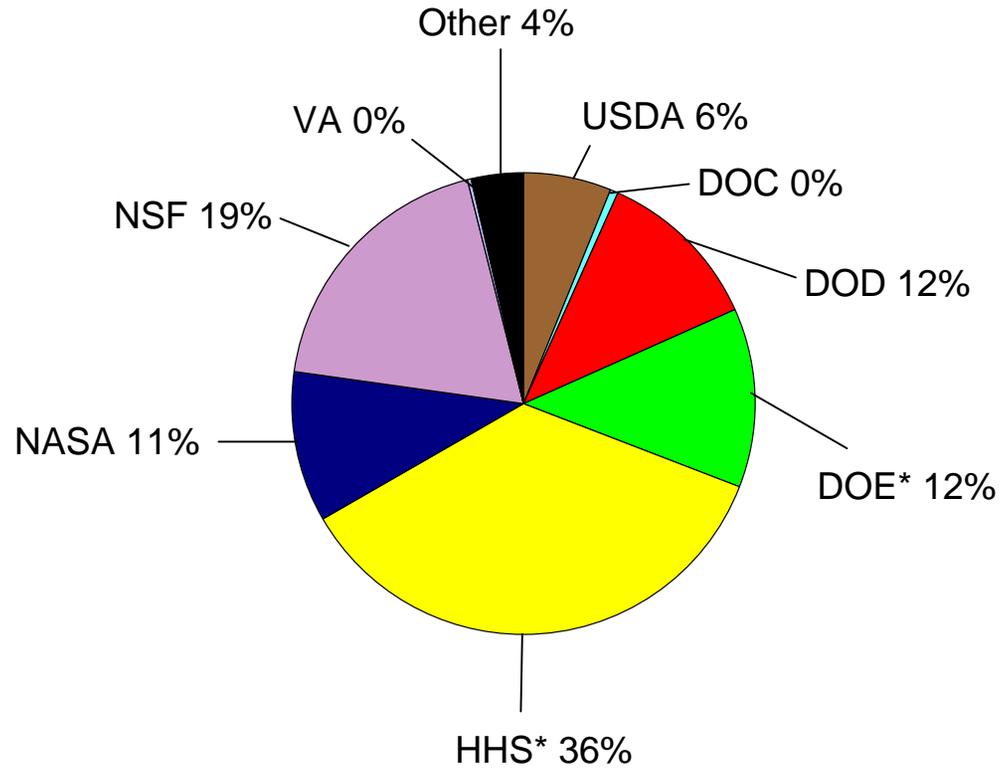
* Includes Predecessor Agencies

1975 - TOTAL Basic Research \$7.05 Billion Constant FY 2000 Dollars



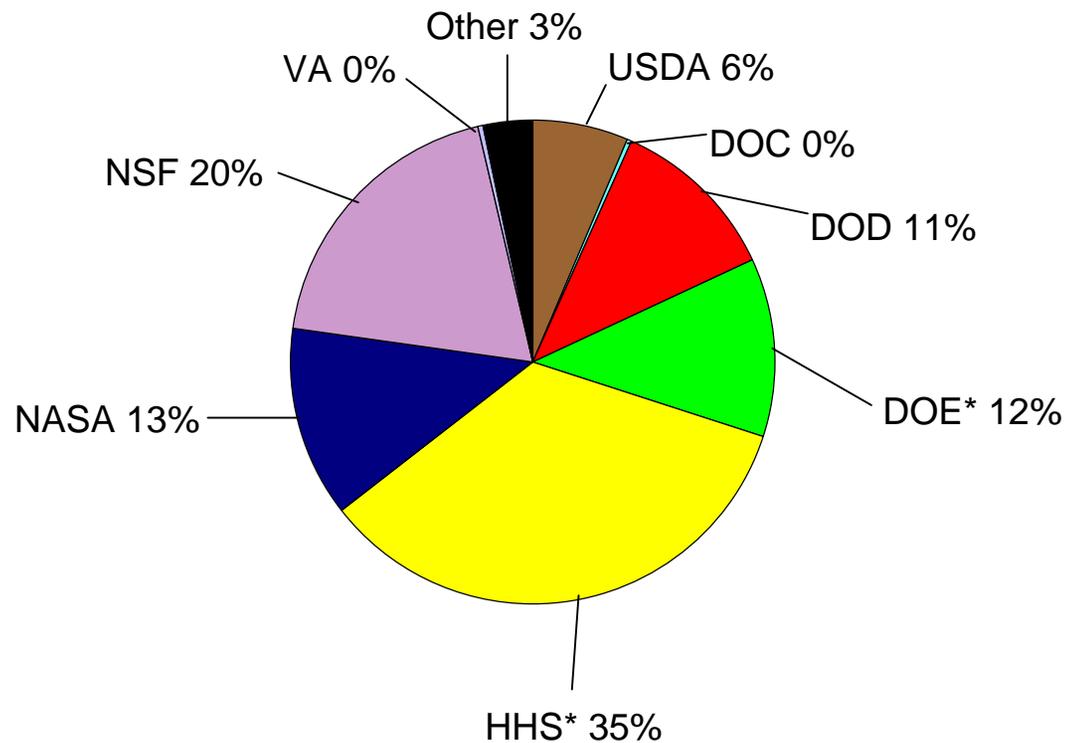
* Includes Predecessor Agencies

1976 - TOTAL Basic Research \$7.03 Billion Constant FY 2000 Dollars



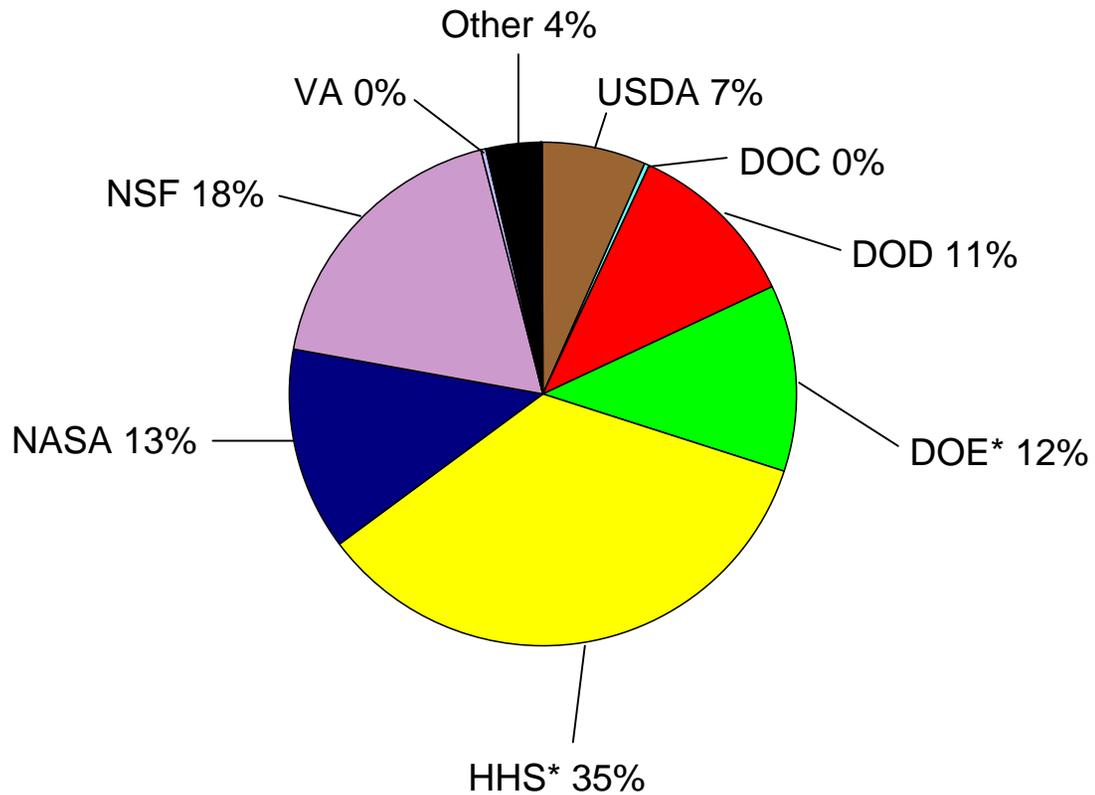
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1977 - TOTAL Basic Research \$7.70 Billion Constant FY 2000 Dollars



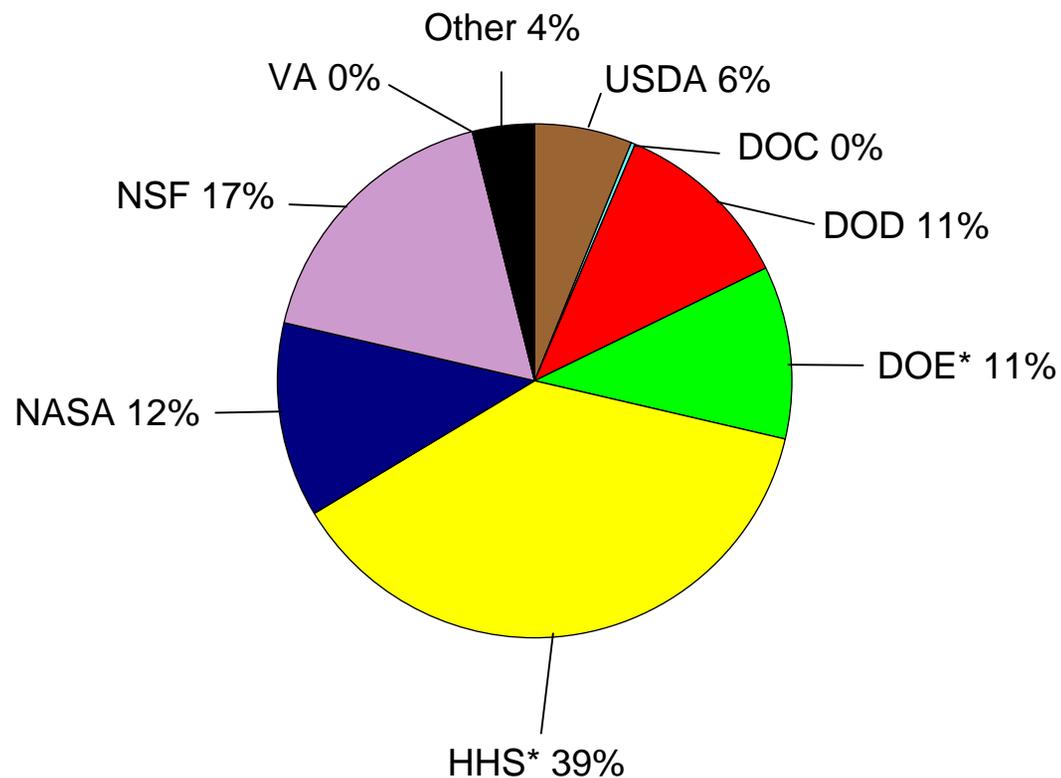
* Includes Predecessor Agencies

1978 - TOTAL Basic Research \$8.19 Billion Constant FY 2000 Dollars



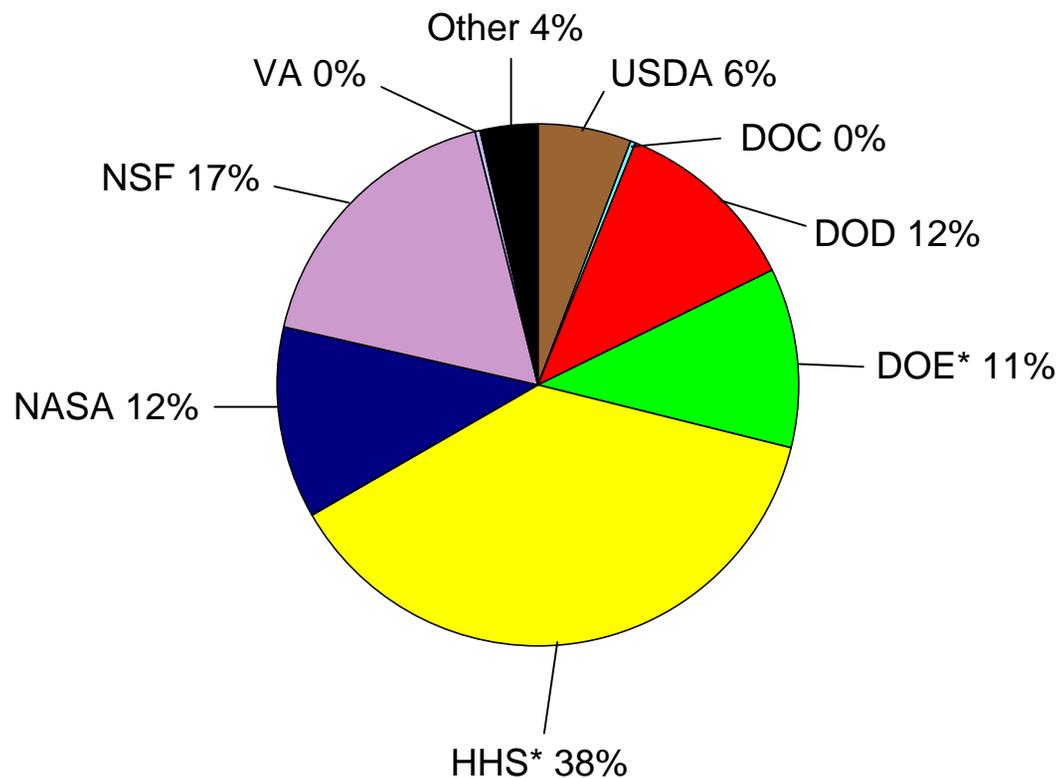
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1979 - TOTAL Basic Research \$8.59 Billion Constant FY 2000 Dollars



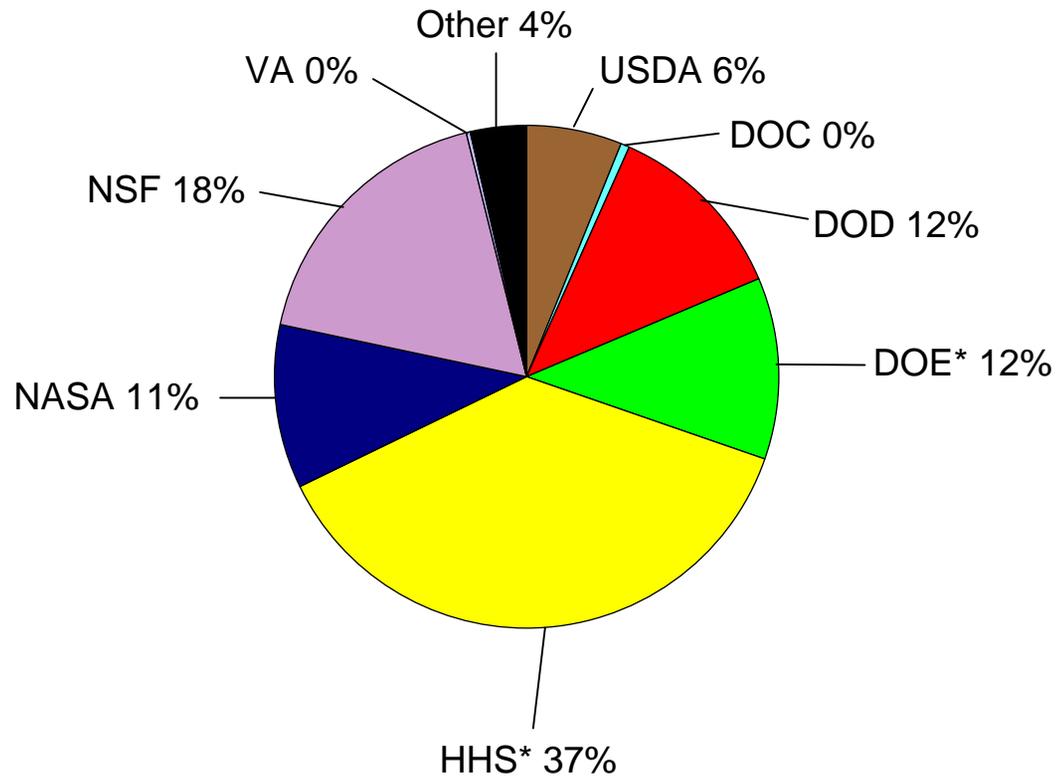
* Includes Predecessor Agencies

1980 - TOTAL Basic Research \$8.80 Billion Constant FY 2000 Dollars



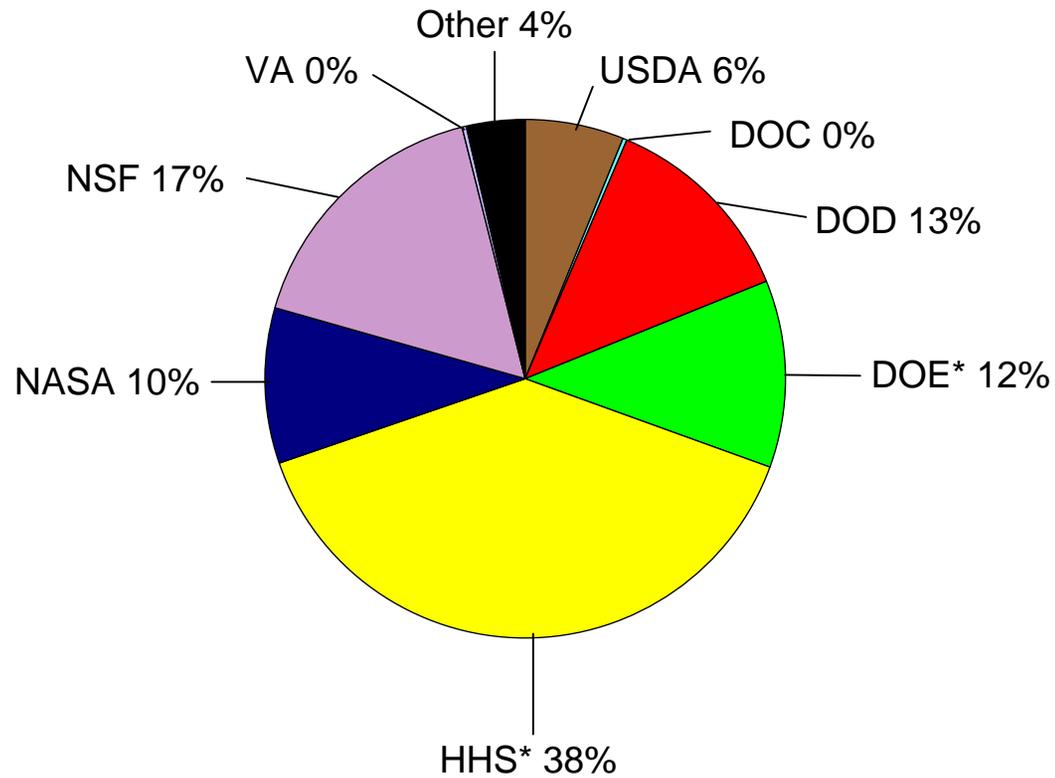
* Includes Predecessor Agencies

1981 - TOTAL Basic Research \$8.65 Billion Constant FY 2000 Dollars



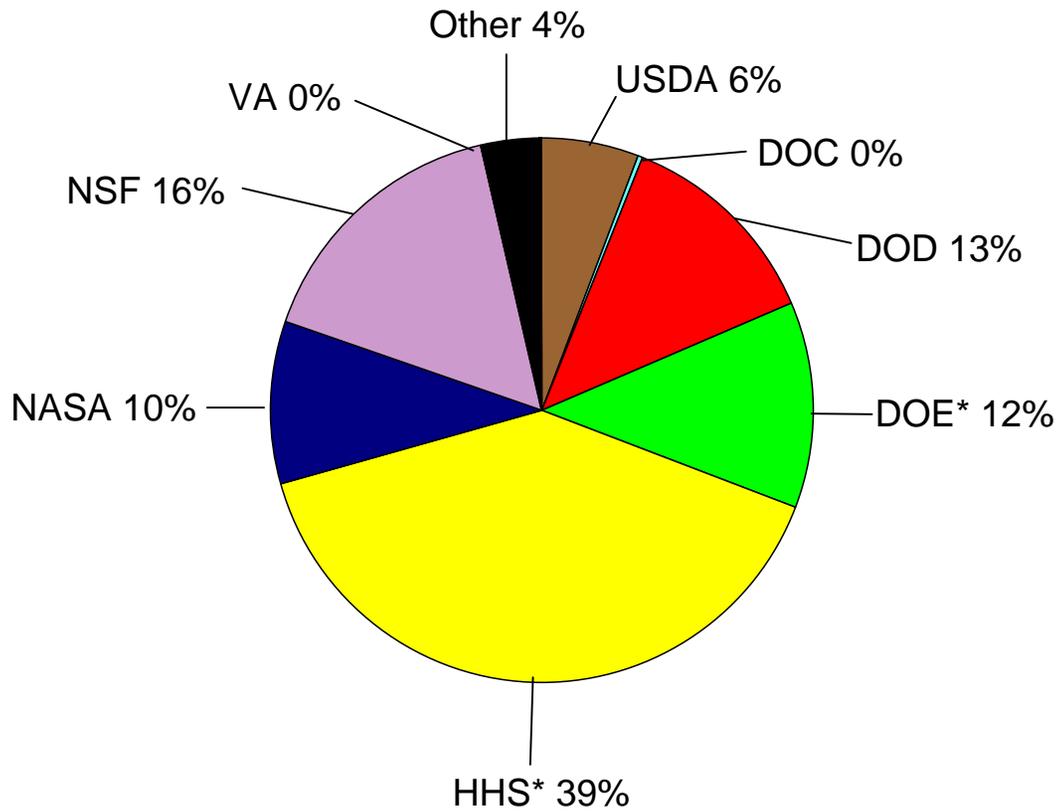
* Includes Predecessor Agencies

1982 - TOTAL Basic Research \$8.80 Billion Constant FY 2000 Dollars



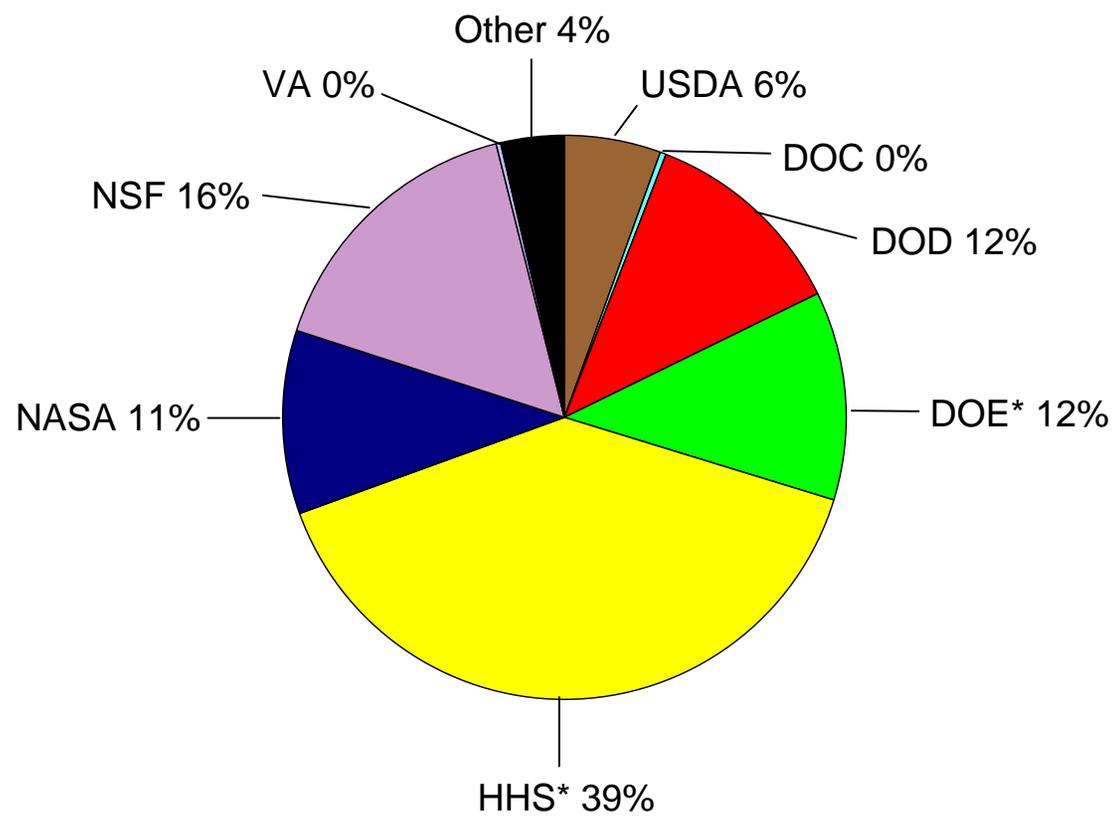
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1983 - TOTAL Basic Research \$9.63 Billion Constant FY 2000 Dollars



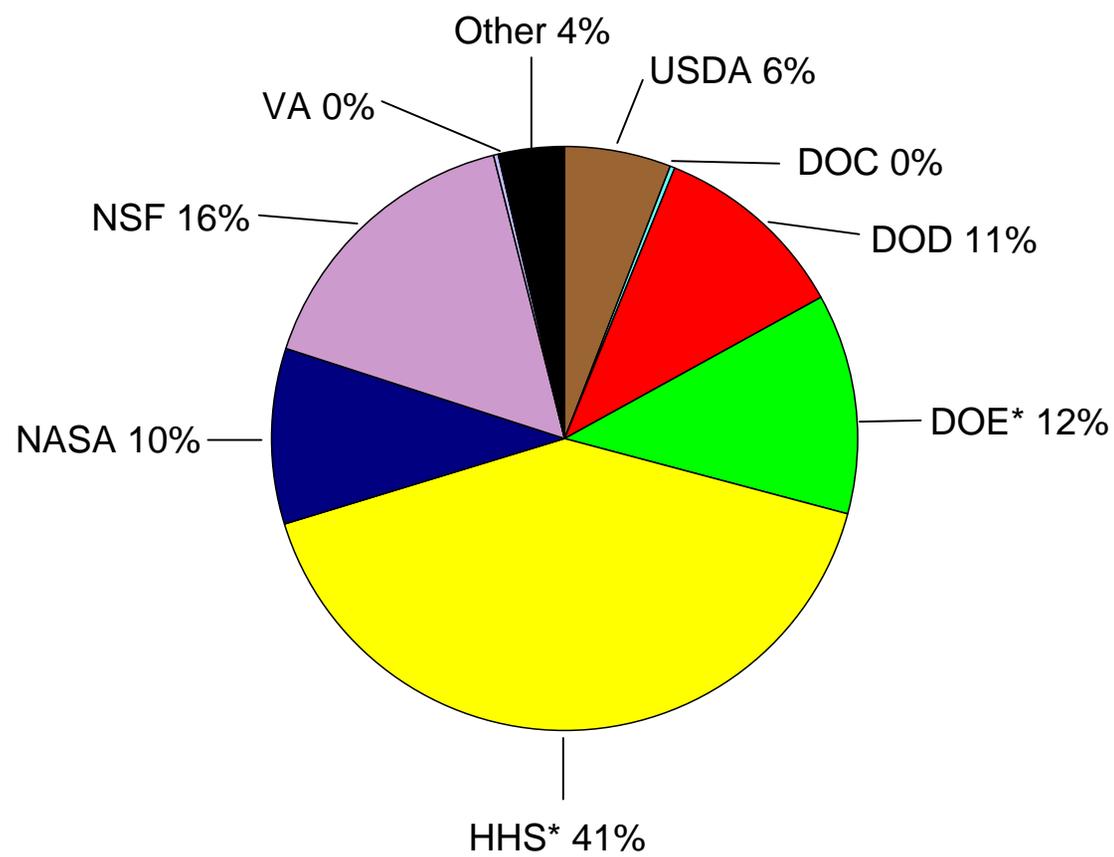
* Includes Predecessor Agencies

1984 - TOTAL Basic Research \$10.48 Billion Constant FY 2000 Dollars



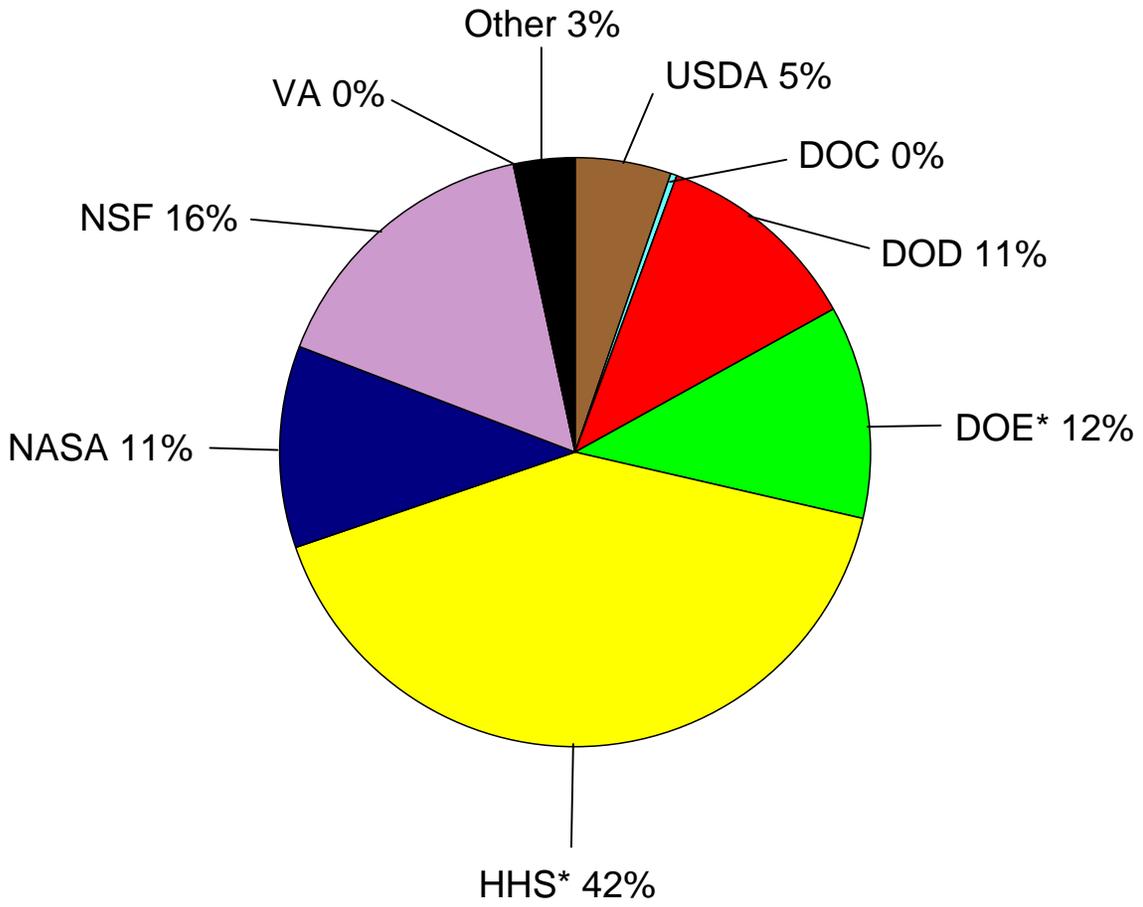
* Includes Predecessor Agencies

1985 - TOTAL Basic Research \$11.23 Billion Constant FY 2000 Dollars



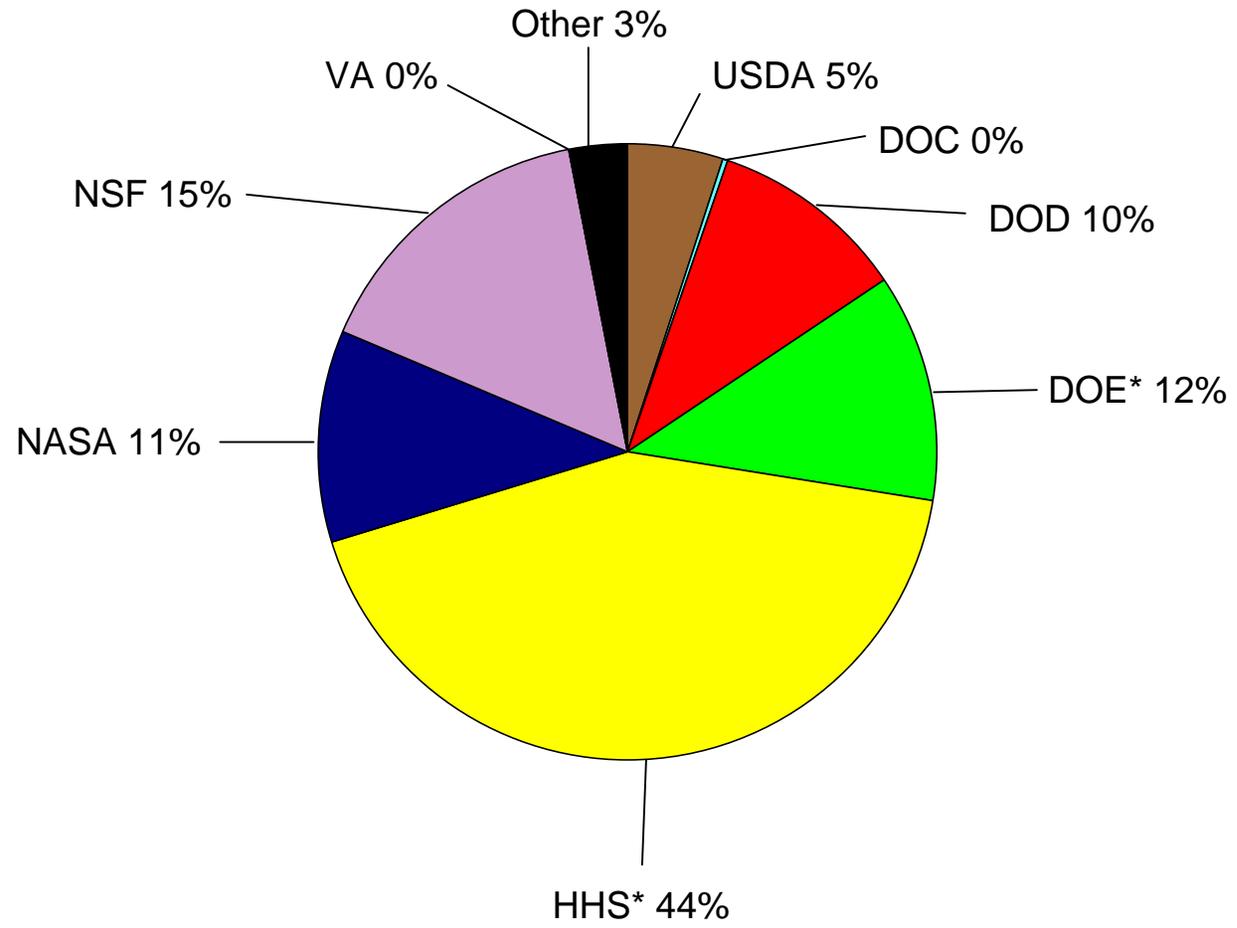
* Includes Predecessor Agencies

1986 - TOTAL Basic Research \$11.44 Billion Constant FY 2000 Dollars



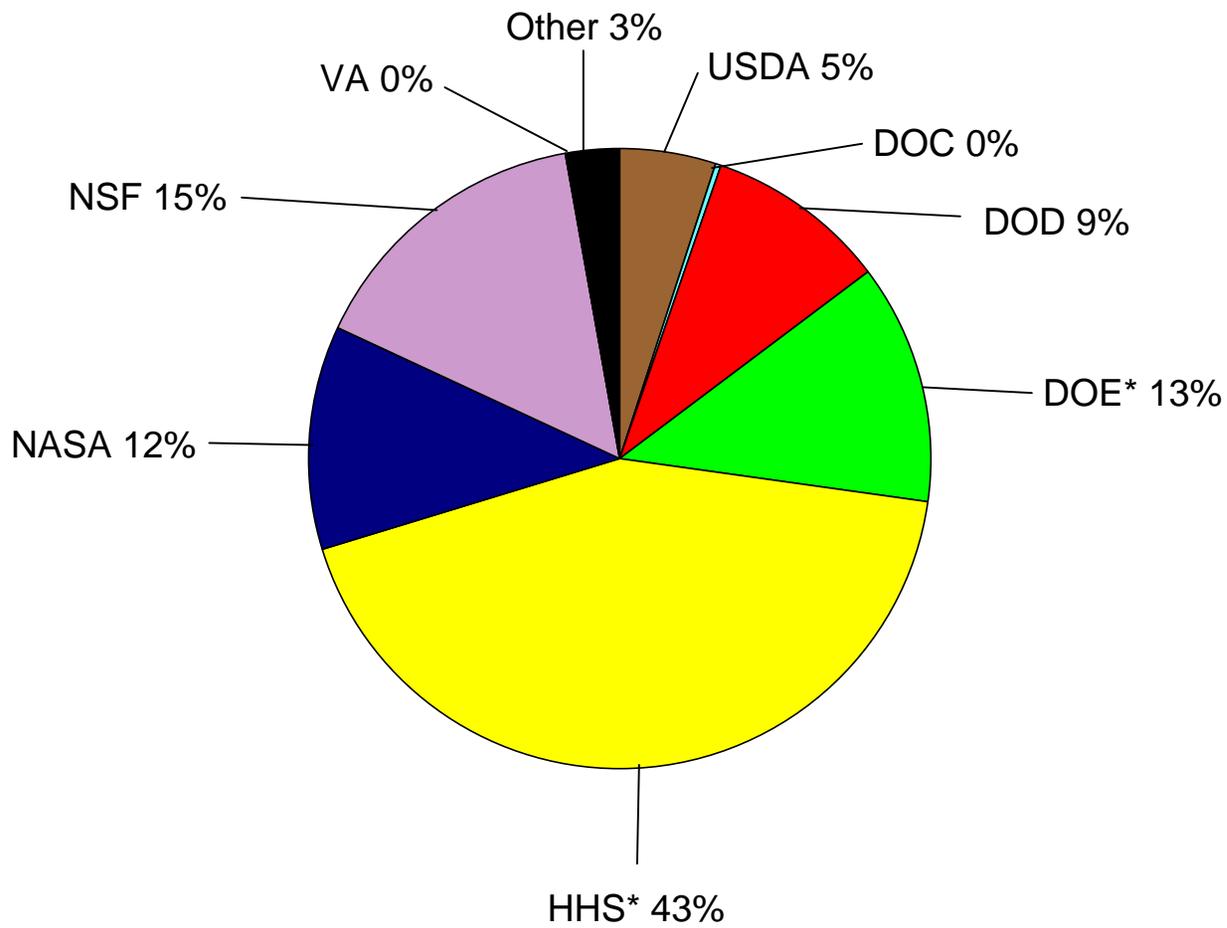
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1987 - TOTAL Basic Research \$12.23 Billion Constant FY 2000 Dollars



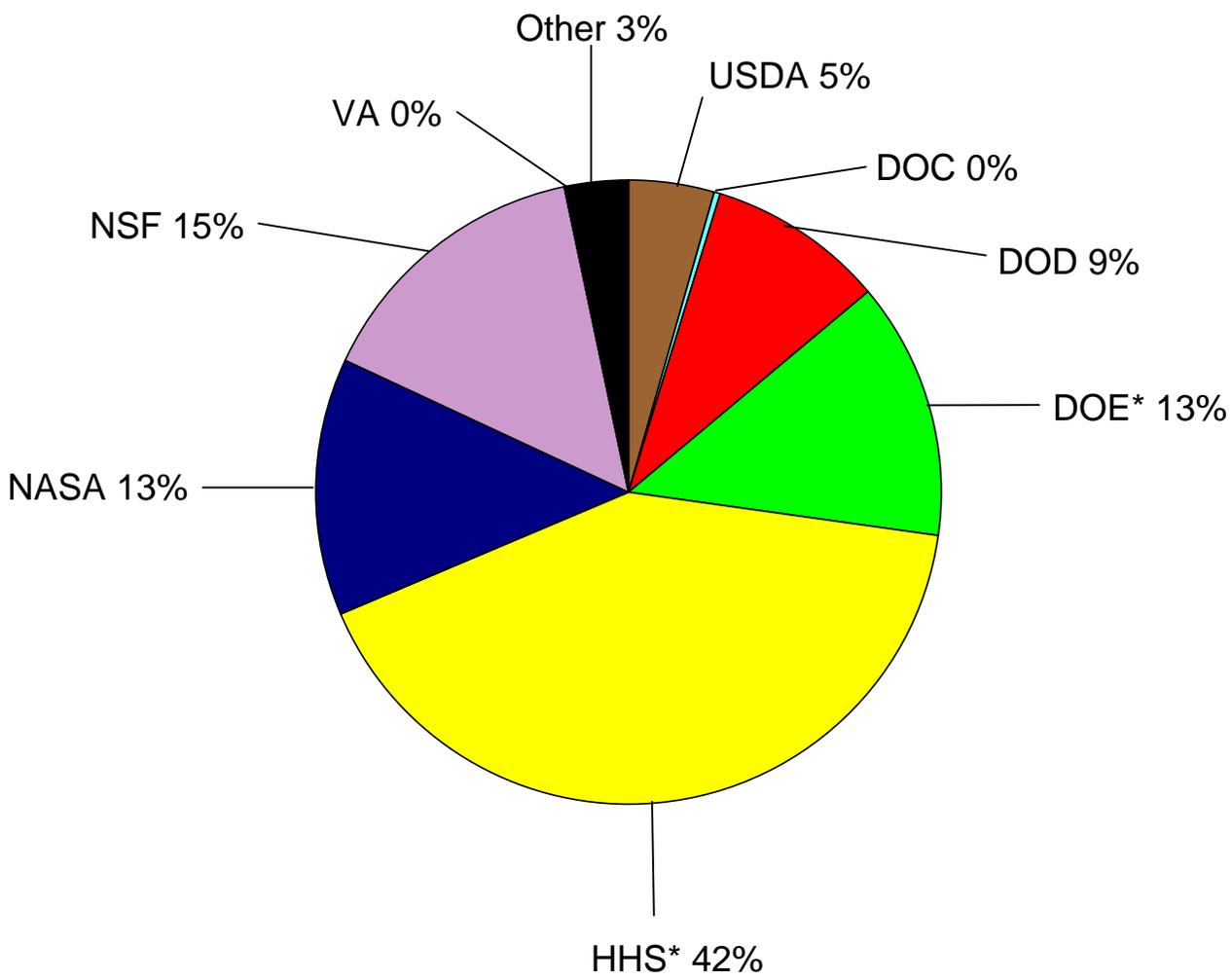
* Includes Predecessor Agencies

1988 - TOTAL Basic Research \$12.56 Billion Constant FY 2000 Dollars



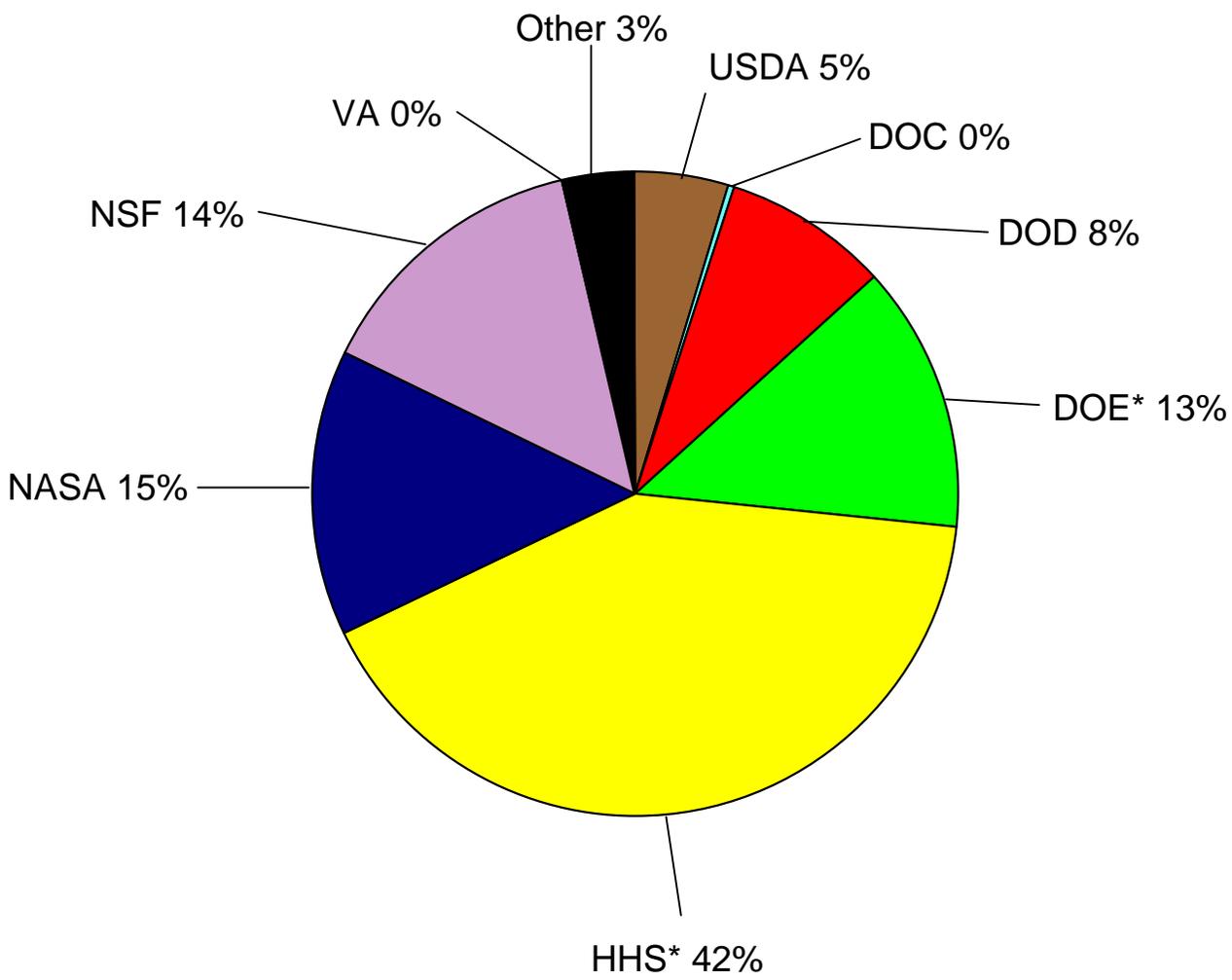
* Includes Predecessor Agencies

1989 - TOTAL Basic Research \$13.53 Billion Constant FY 2000 Dollars



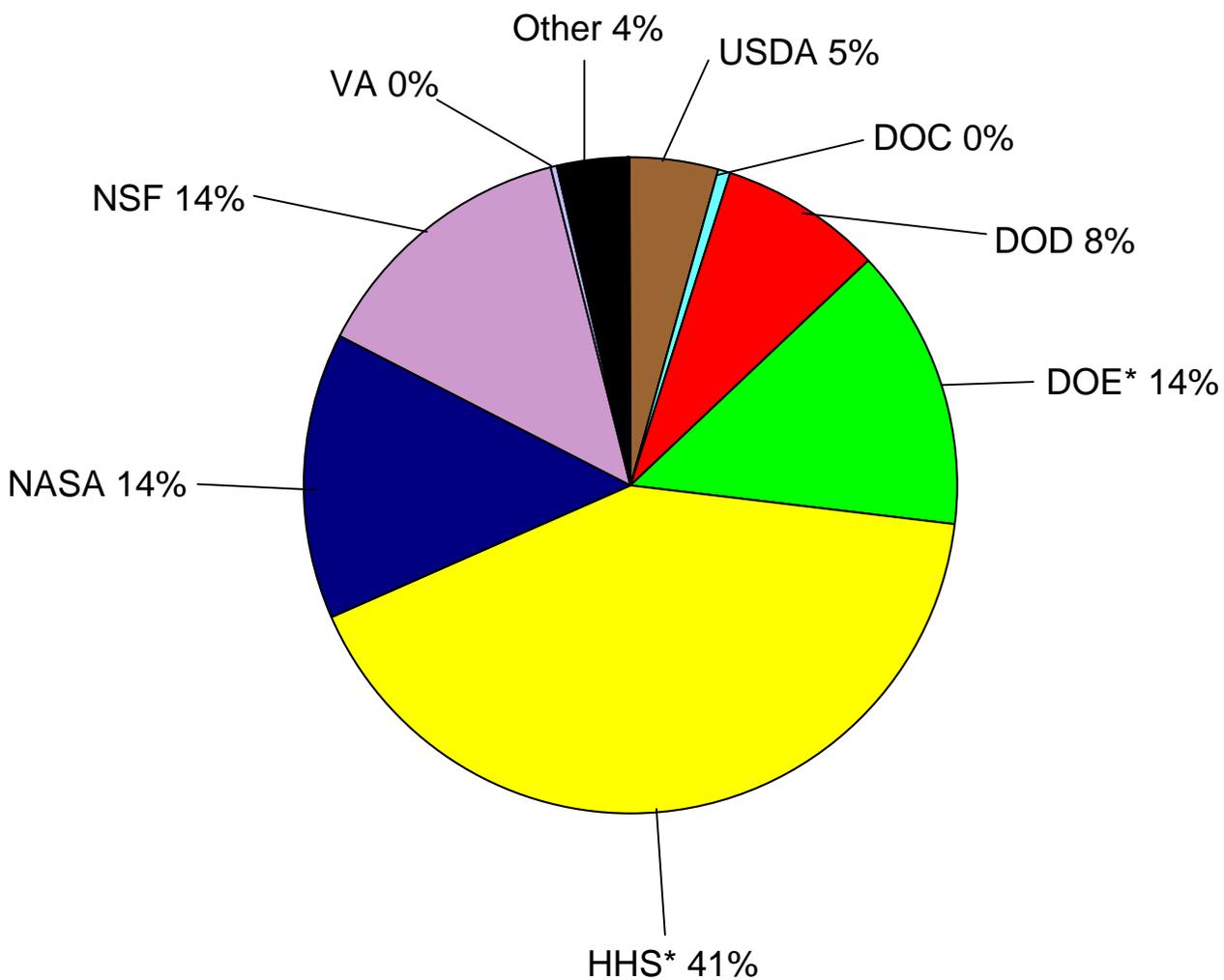
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1990 - TOTAL Basic Research \$13.89 Billion Constant FY 2000 Dollars



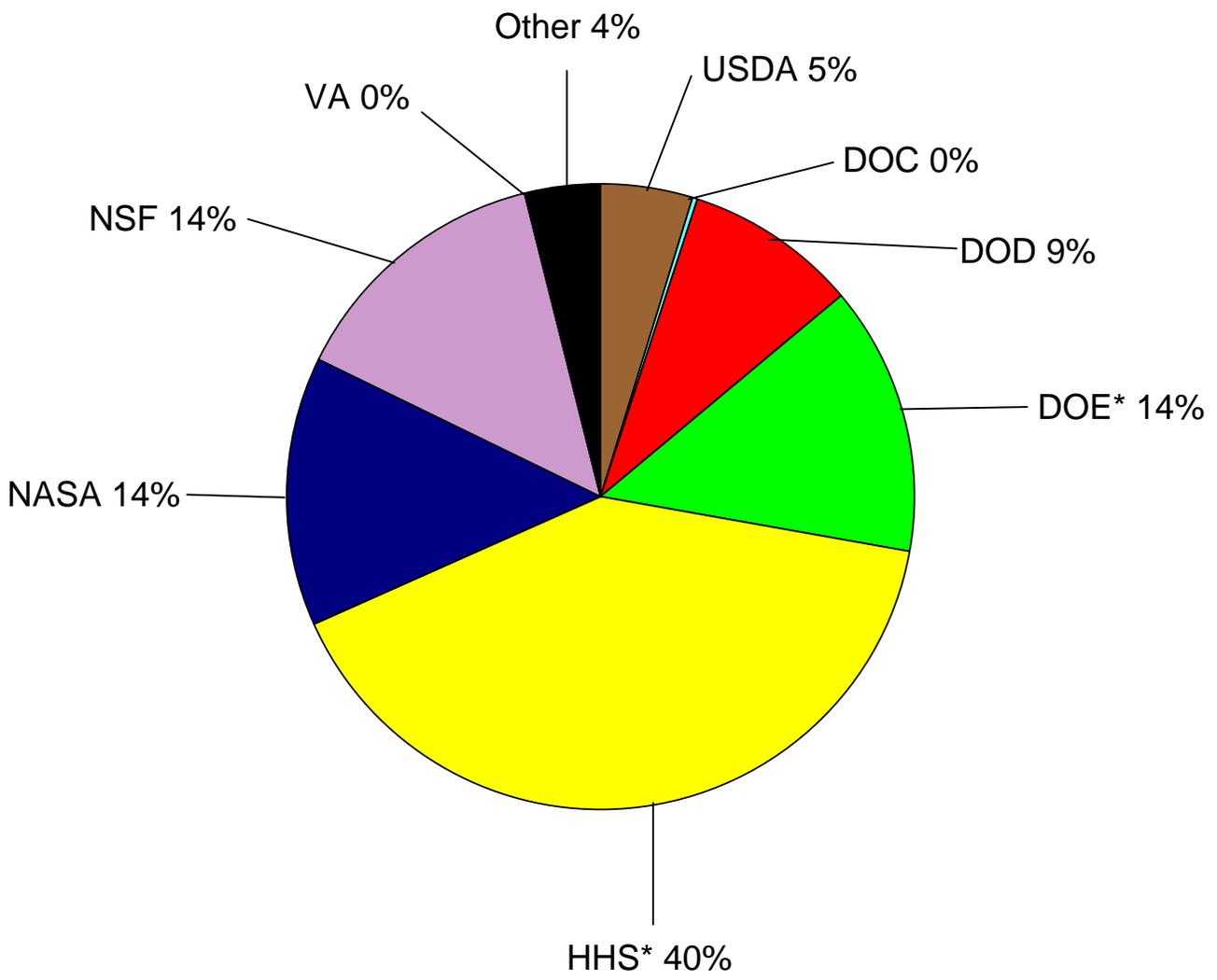
* Includes Predecessor Agencies

1991 - TOTAL Basic Research \$14.44 Billion Constant FY 2000 Dollars



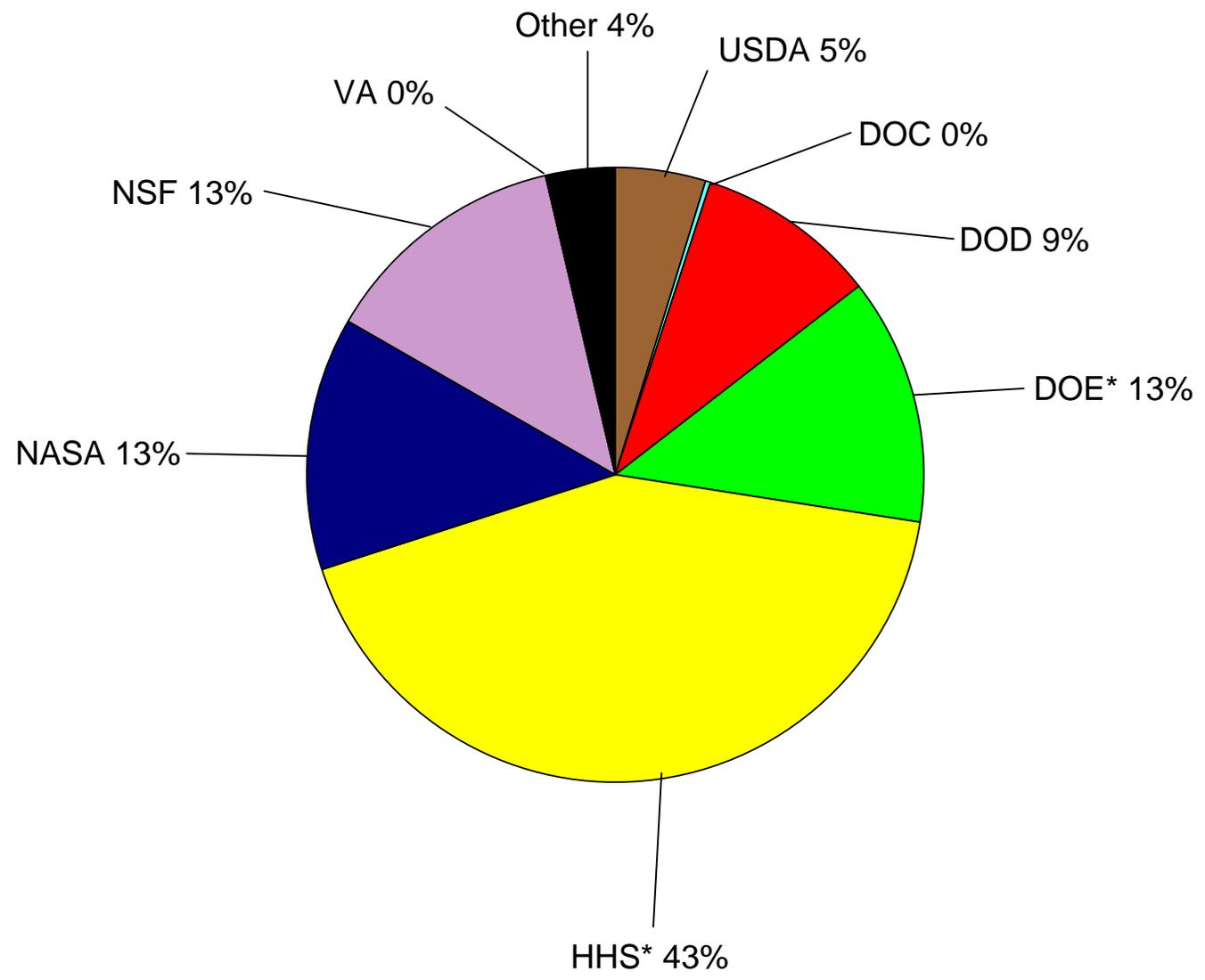
* Includes Predecessor Agencies

1992 - TOTAL Basic Research \$14.45 Billion Constant FY 2000 Dollars



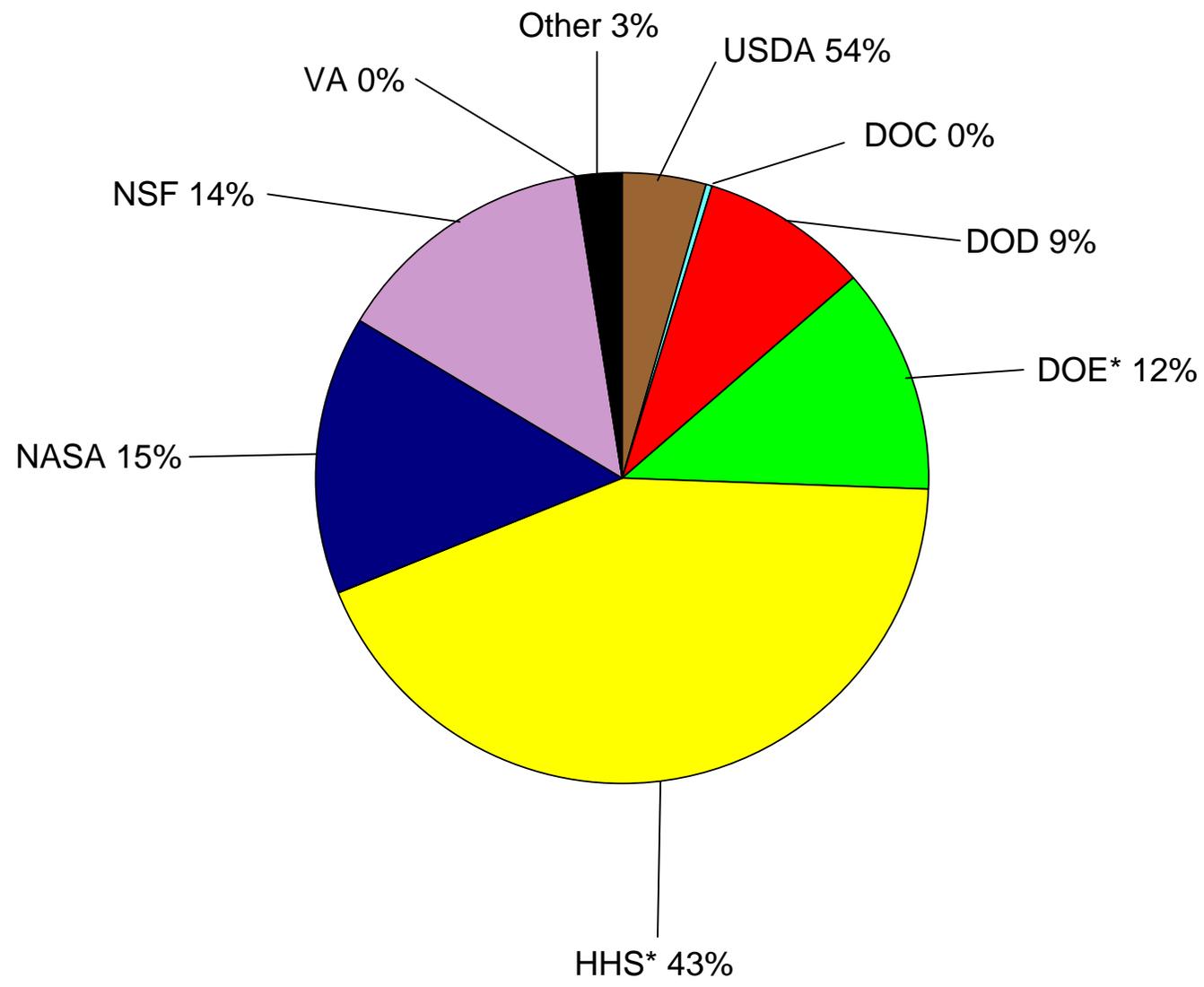
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1993 - TOTAL Basic Research \$15.16 Billion Constant FY 2000 Dollars



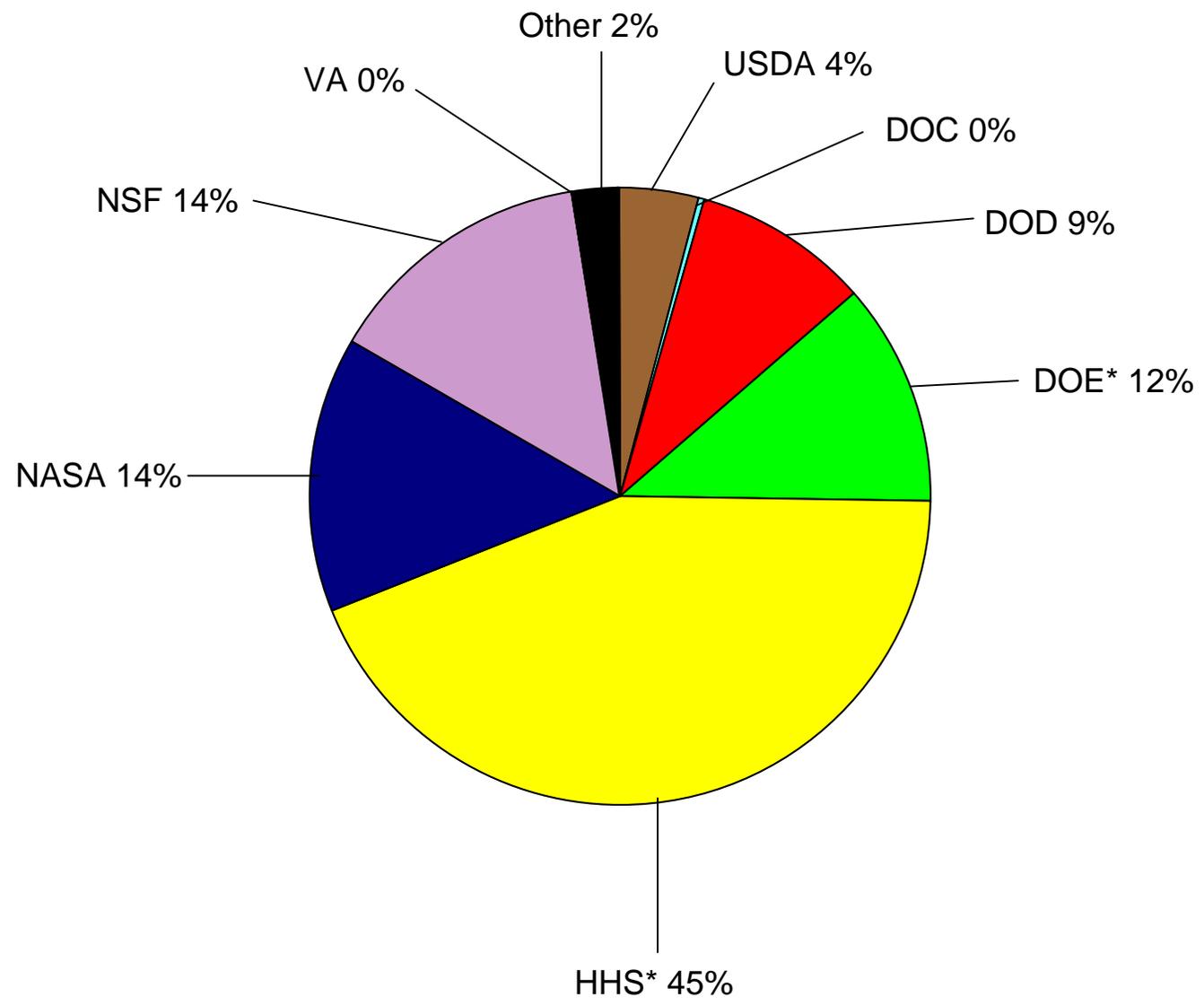
* Includes Predecessor Agencies

1994 - TOTAL Basic Research \$14.98 Billion Constant FY 2000 Dollars



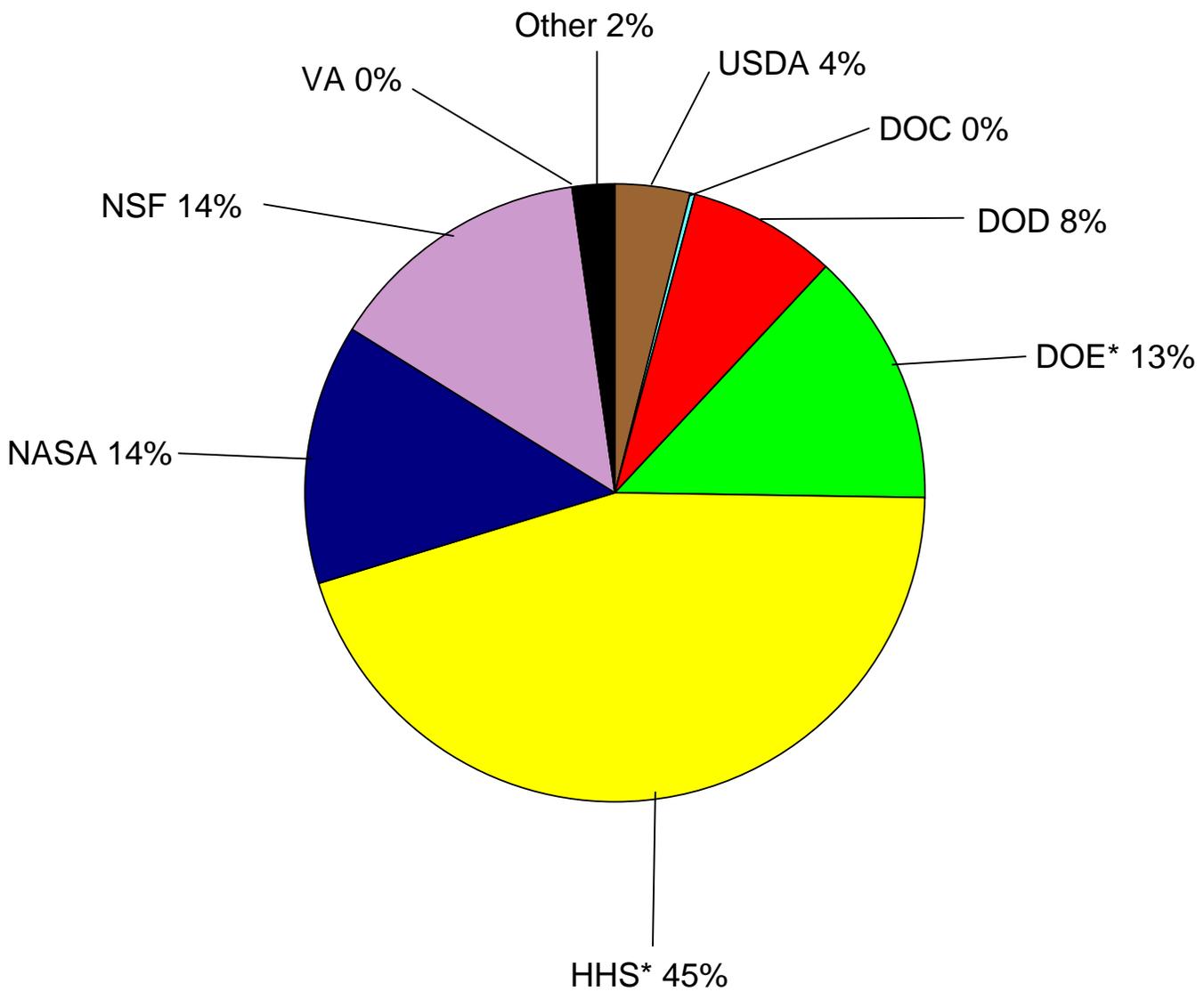
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1995 - TOTAL Basic Research \$15.05 Billion Constant FY 2000 Dollars



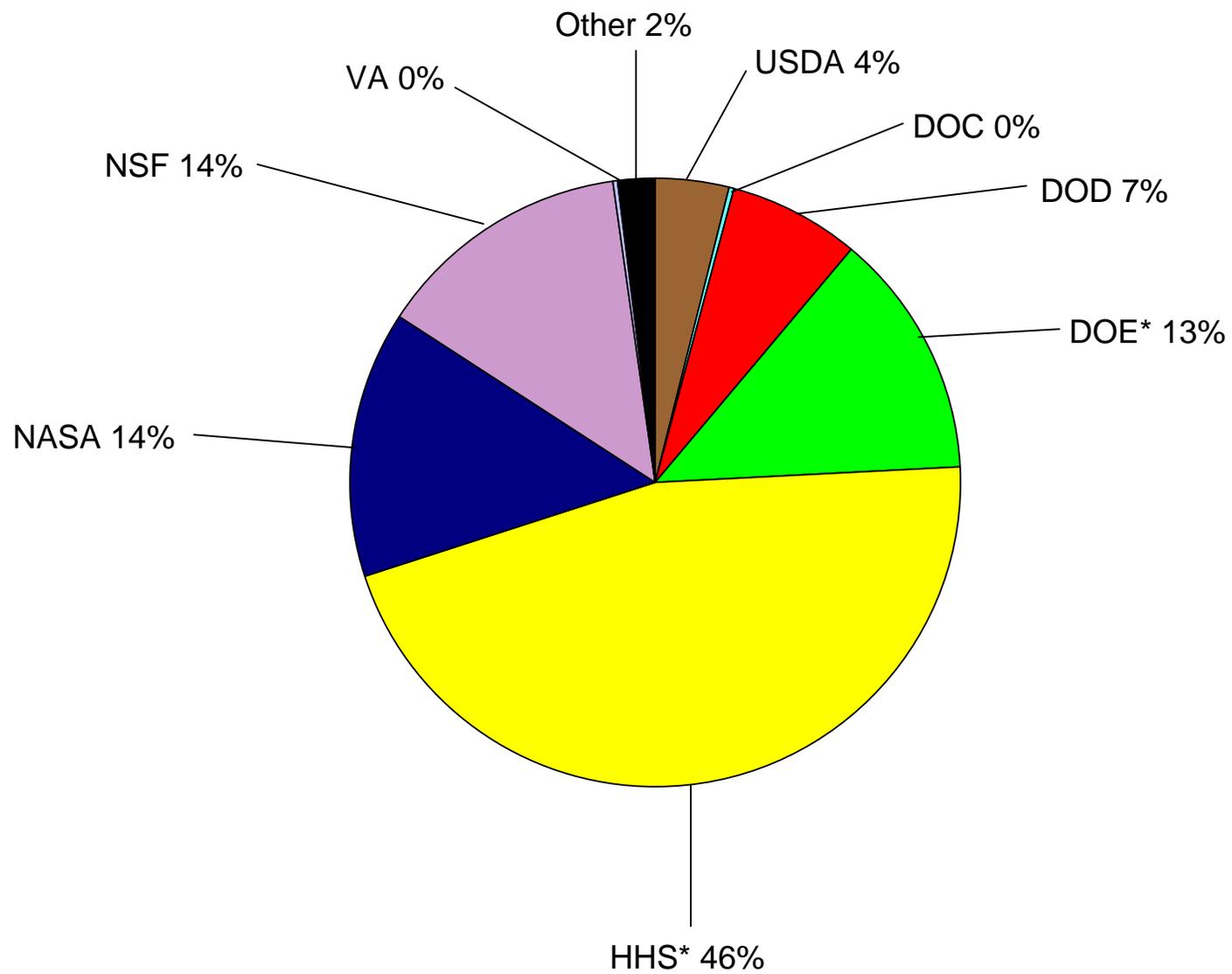
* Includes Predecessor Agencies

1996 - TOTAL Basic Research \$15.40 Billion Constant FY 2000 Dollars



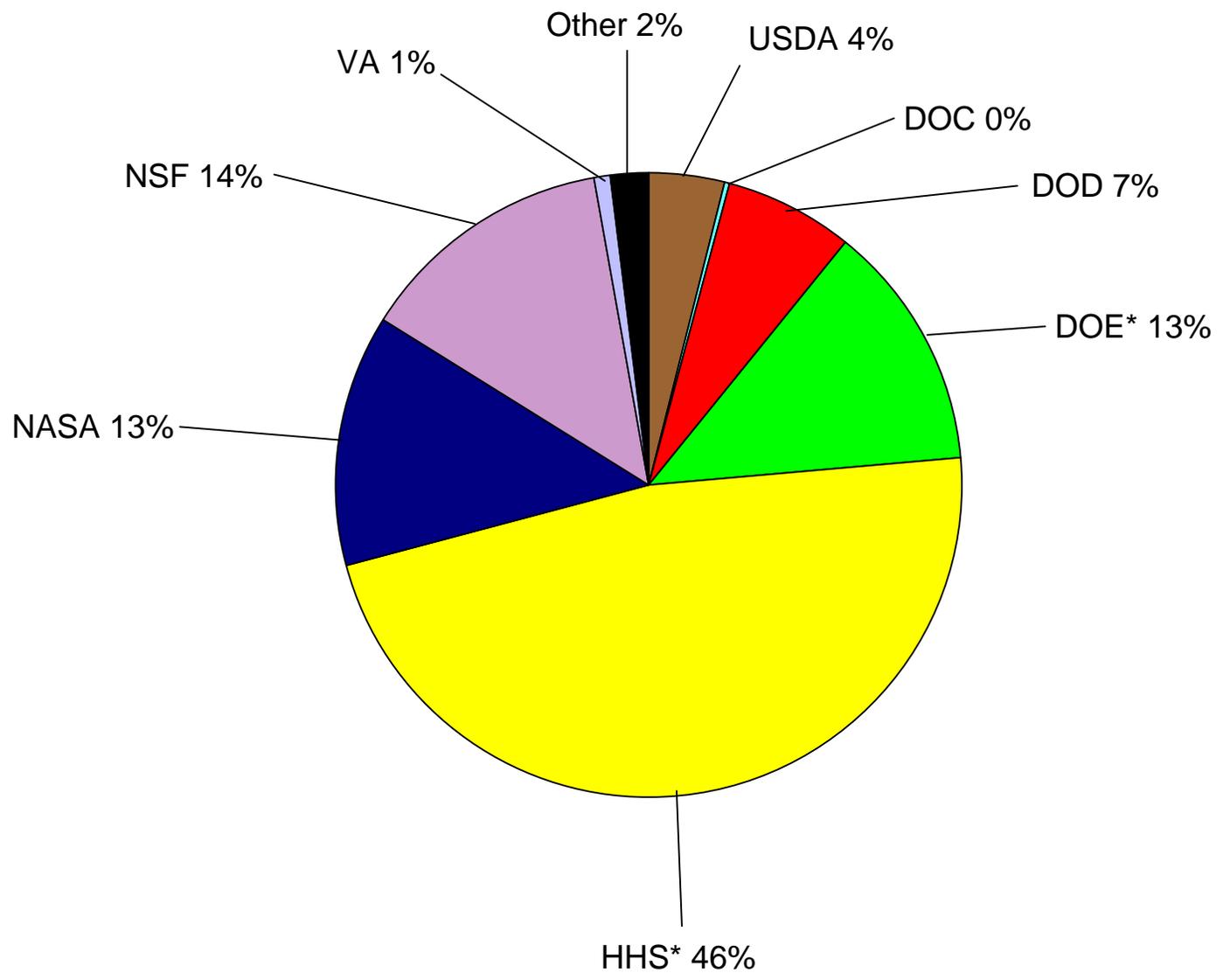
* Includes Predecessor Agencies

1997 - TOTAL Basic Research \$15.63 Billion Constant FY 2000 Dollars



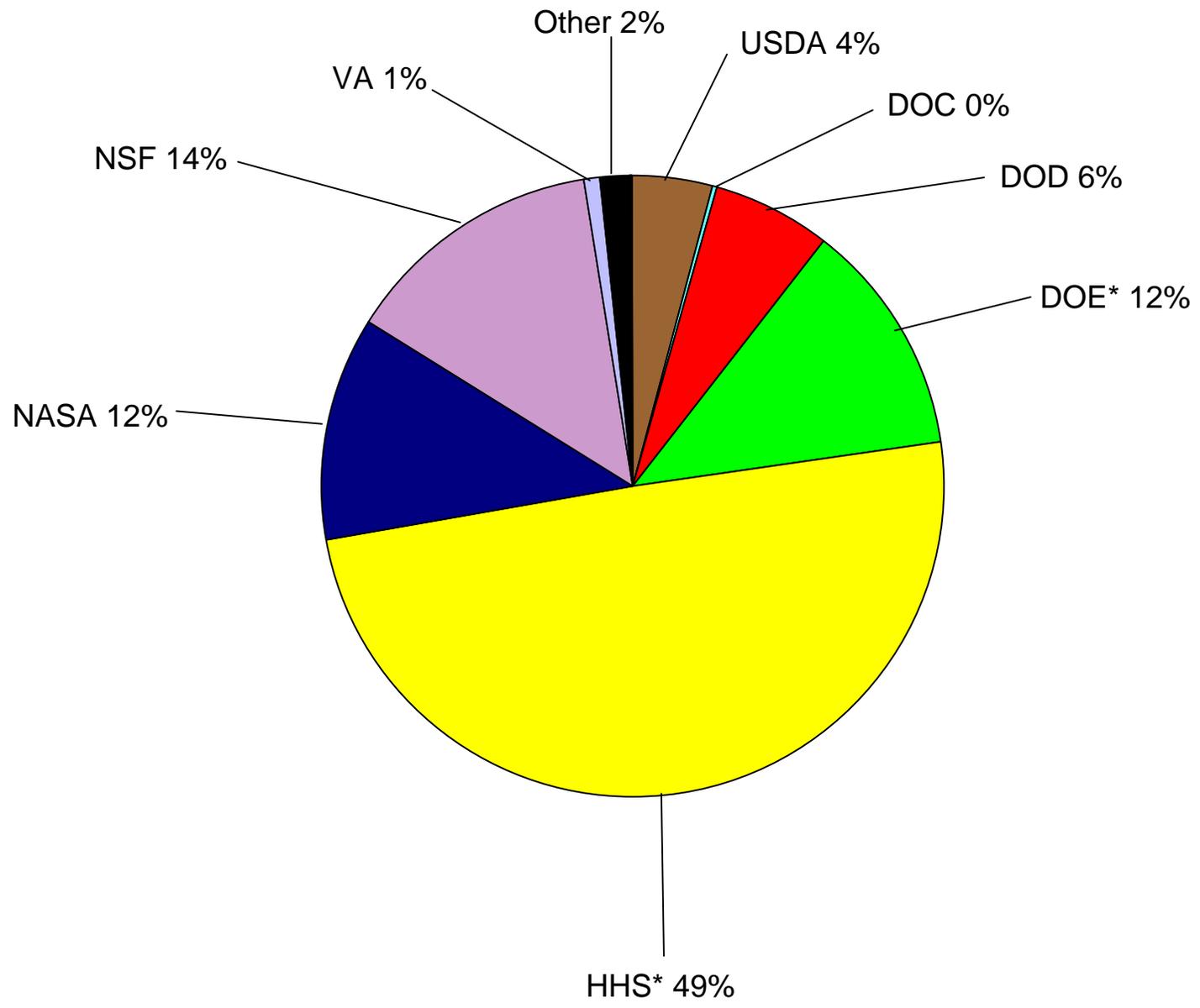
* Includes Predecessor Agencies

1998 - TOTAL Basic Research \$16.14 Billion Constant FY 2000 Dollars



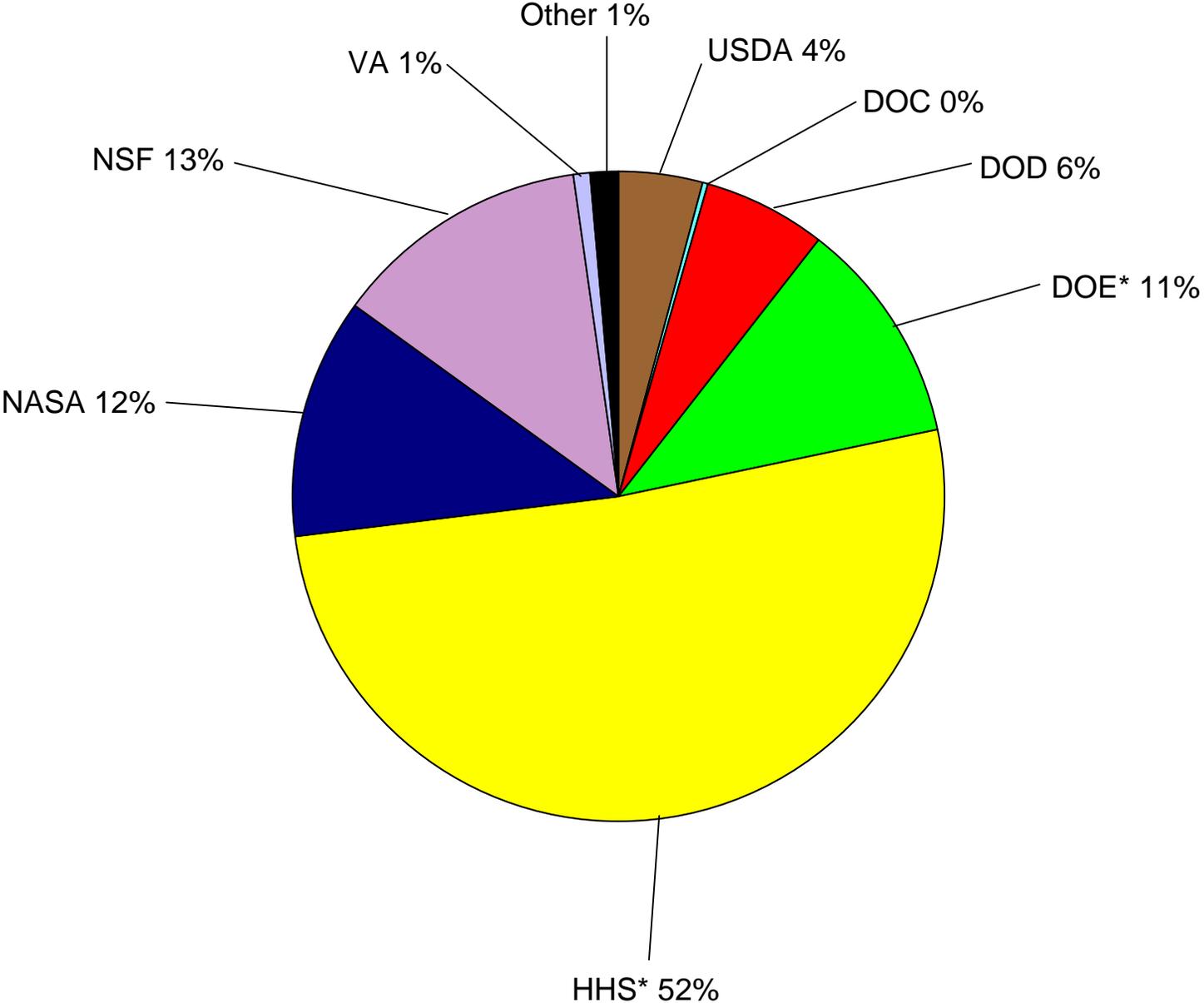
* Includes Predecessor Agencies

1999 - TOTAL Basic Research \$17.80 Billion Constant FY 2000 Dollars



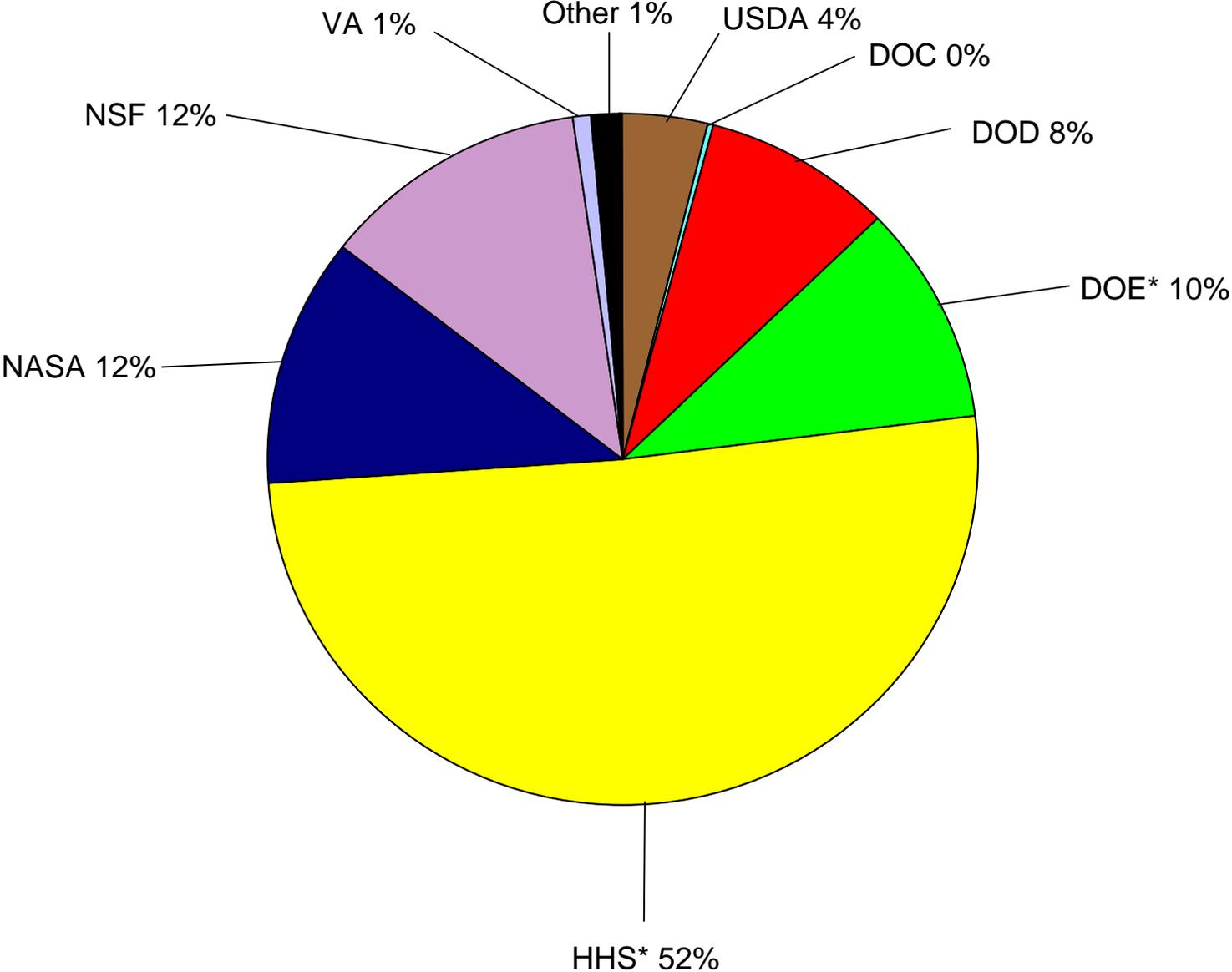
* Includes Predecessor Agencies

2000 - TOTAL Basic Research \$19.57 Billion Constant FY 2000 Dollars



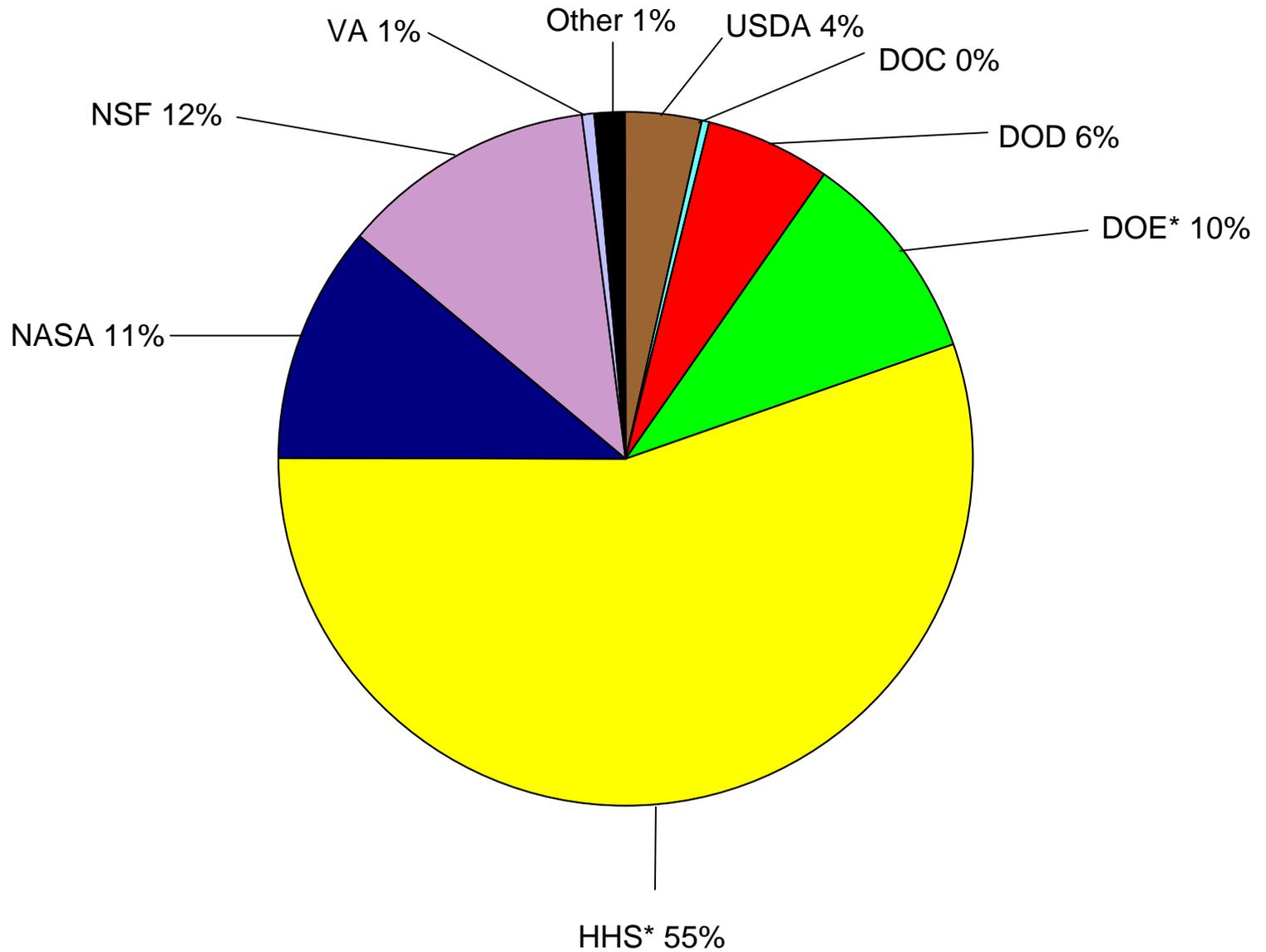
* Includes Predecessor Agencies

2001 - TOTAL Basic Research \$22.19 Billion Constant FY 2000 Dollars



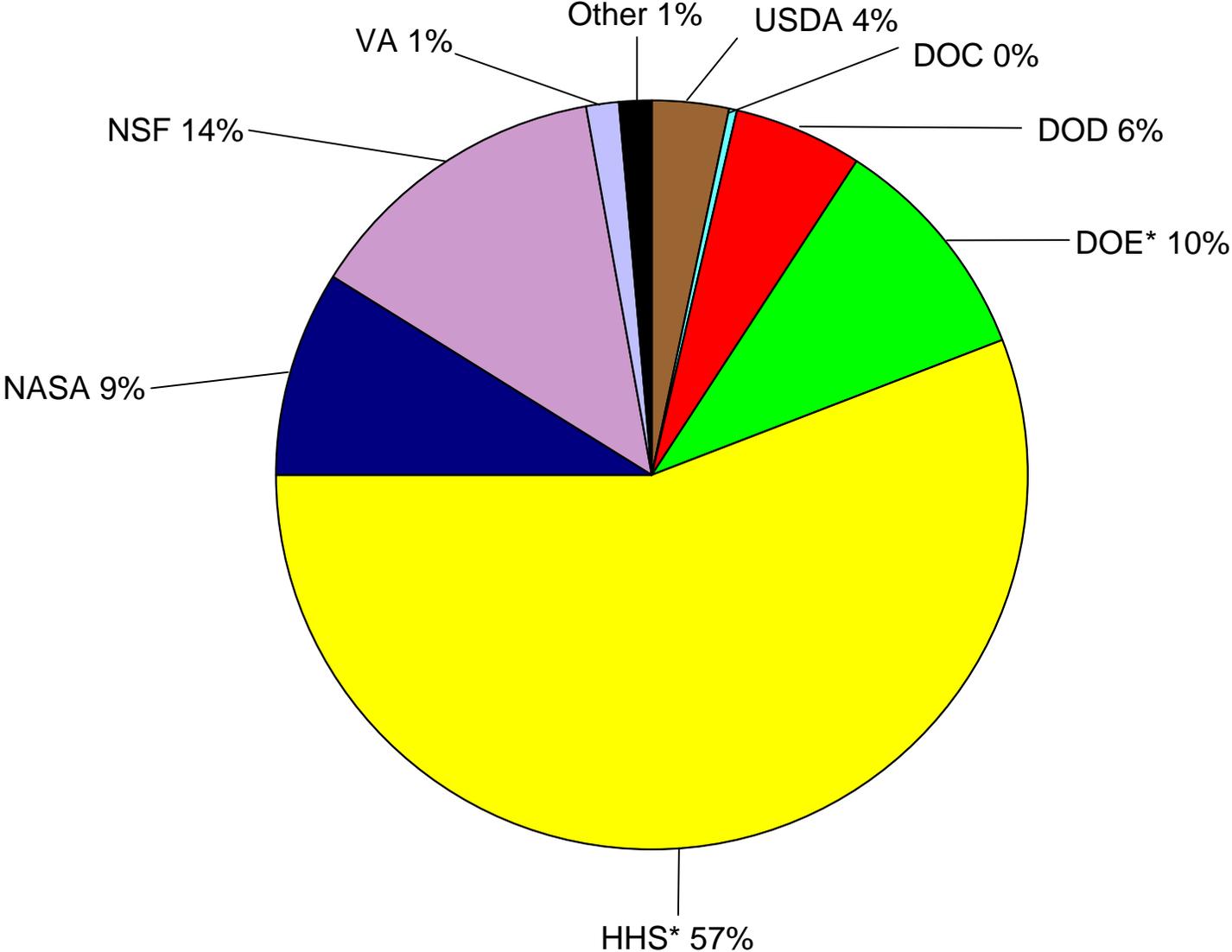
* Includes Predecessor Agencies

2002 - TOTAL Basic Research \$22.47 Billion Constant FY 2000 Dollars



* Includes Predecessor Agencies

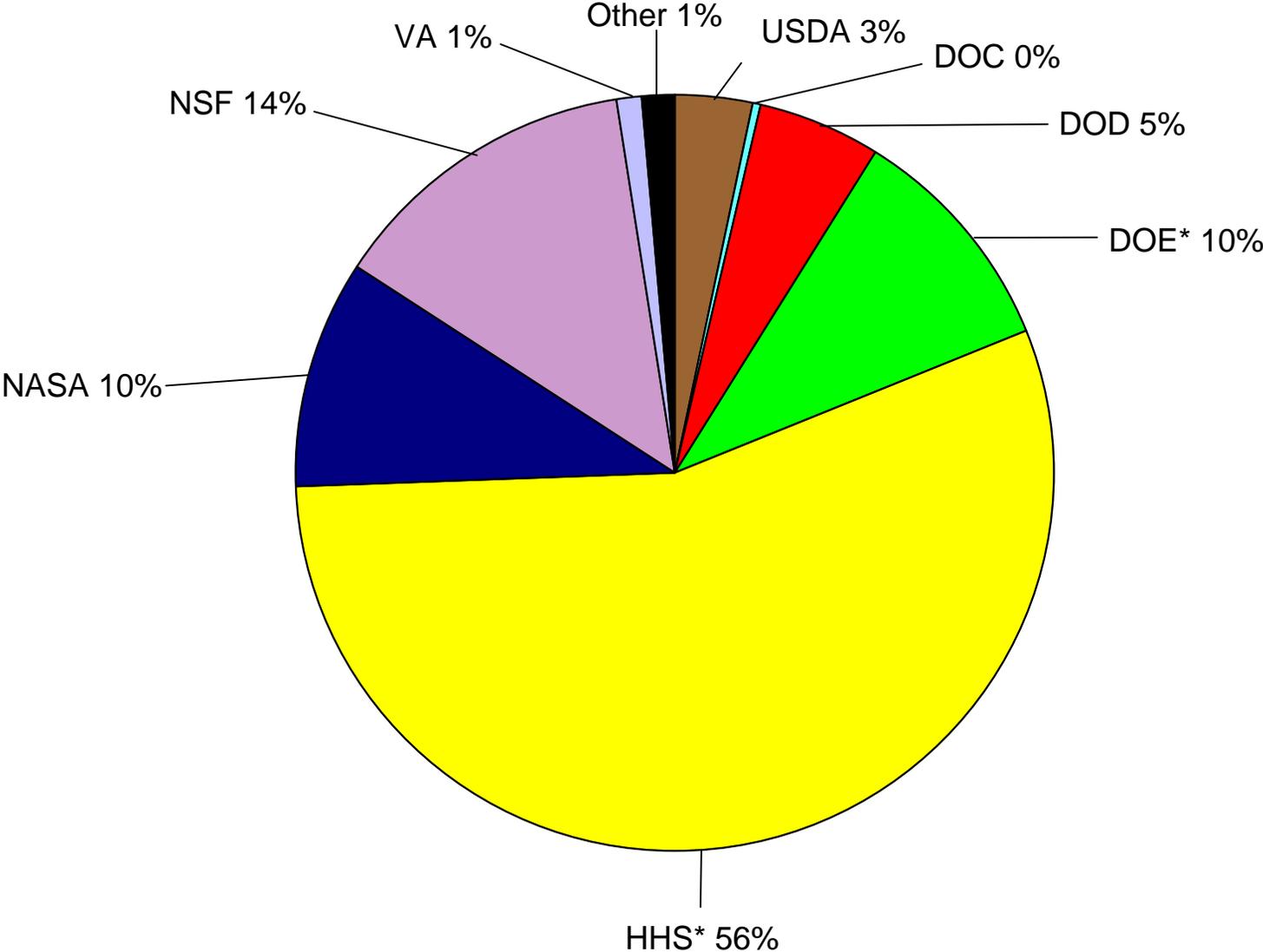
2003 - TOTAL Basic Research \$23.92 Billion Constant FY 2000 Dollars



* Includes Predecessor Agencies

Source: AAAS R&D in Fed Budget

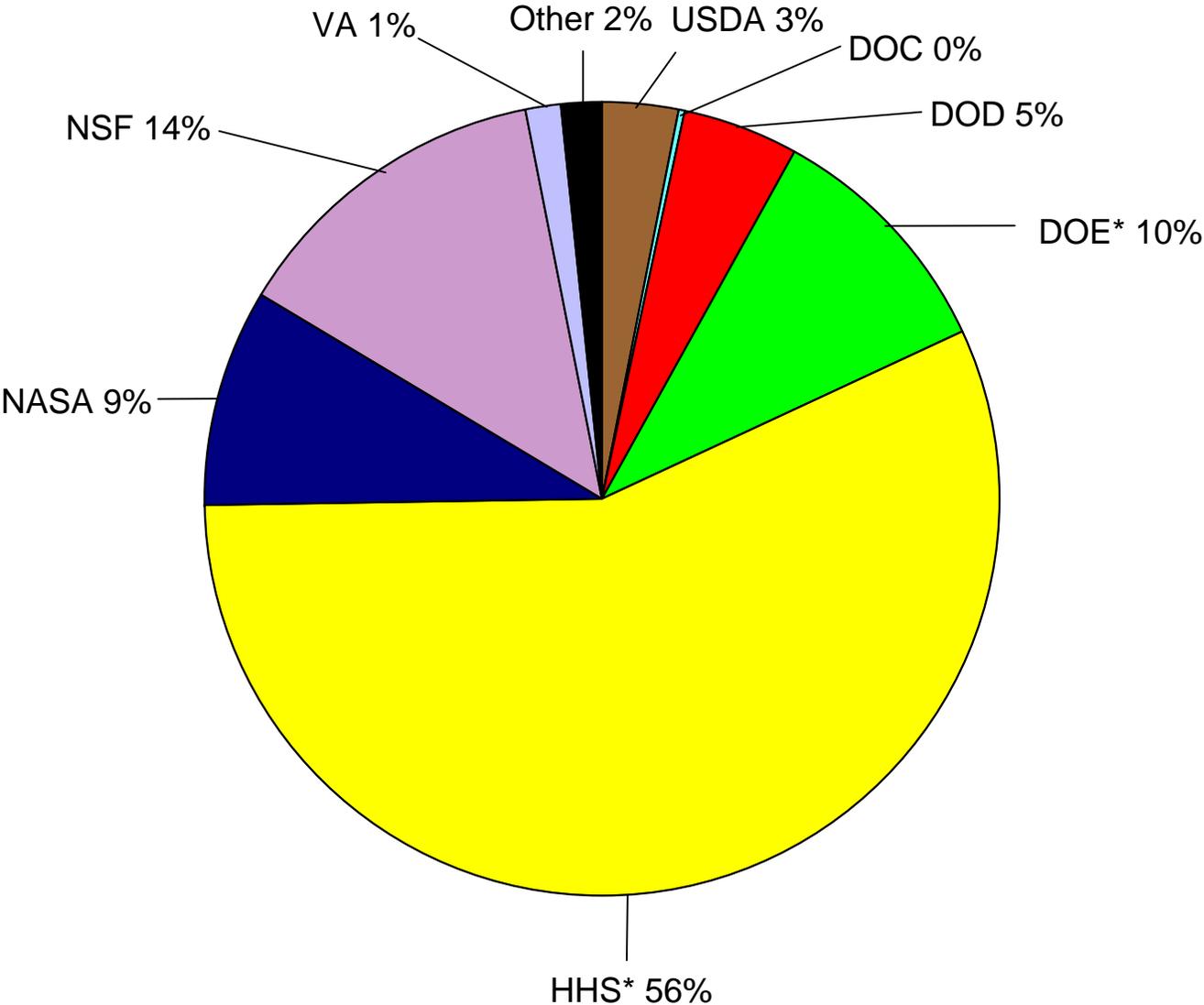
2004 - TOTAL Basic Research \$24.76 Billion Constant FY 2000 Dollars



* Includes Predecessor Agencies

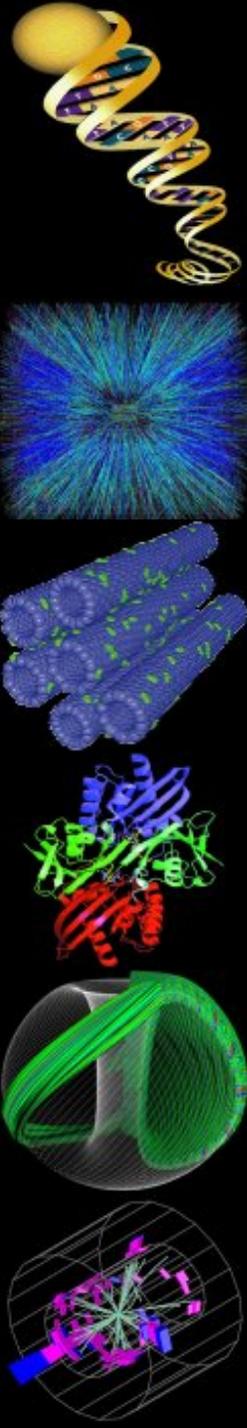
Source: AAAS R&D in Fed Budget

2005 - TOTAL Basic Research \$24.69 Billion Constant FY 2000 Dollars



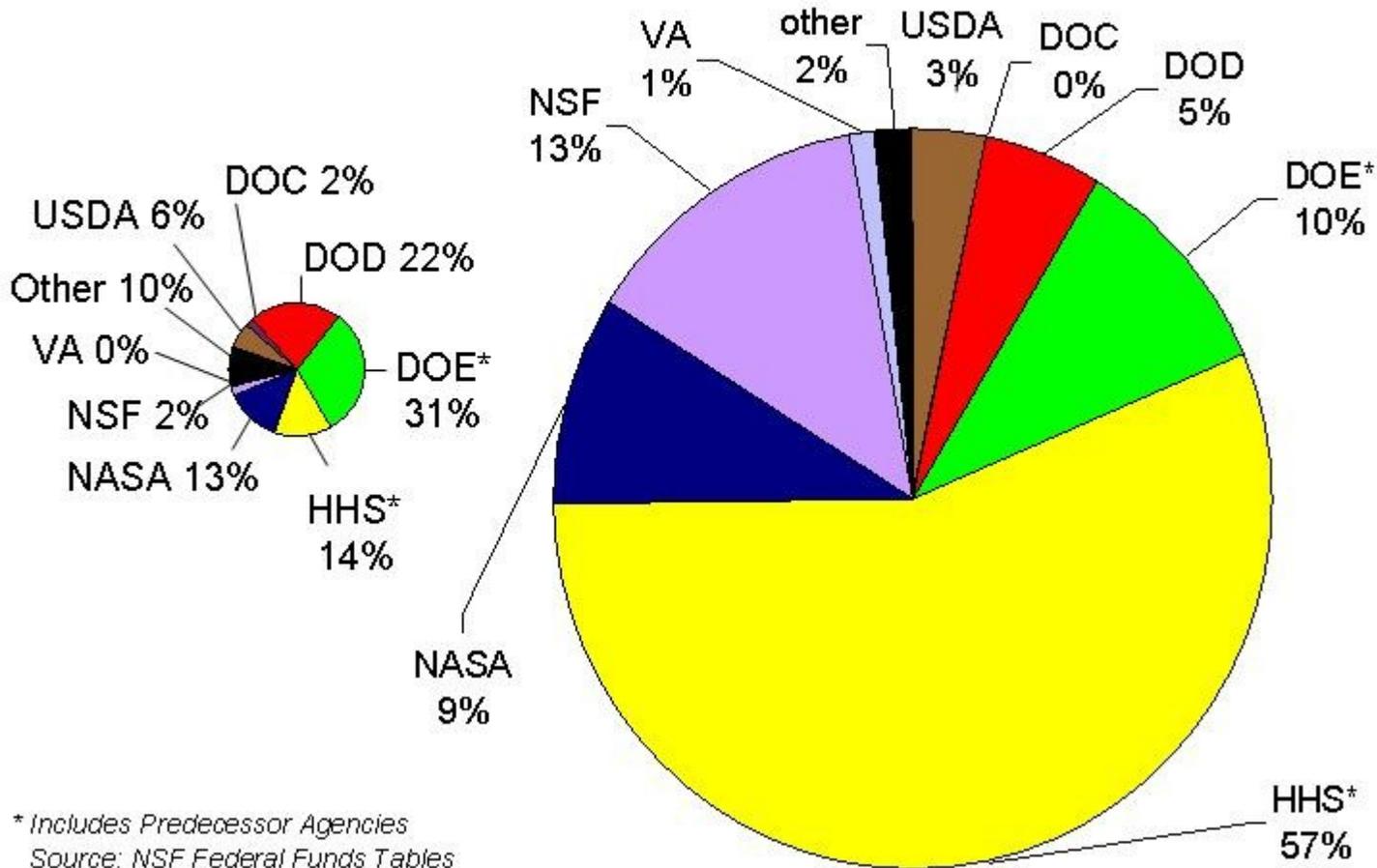
* Includes Predecessor Agencies

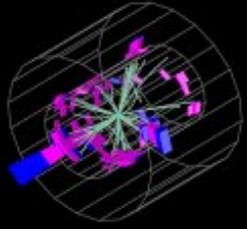
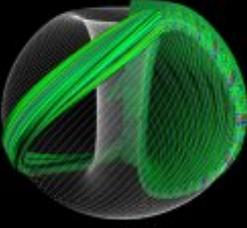
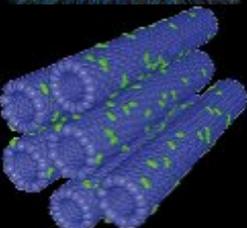
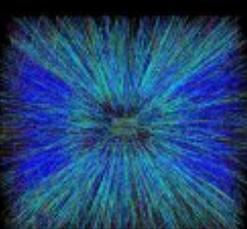
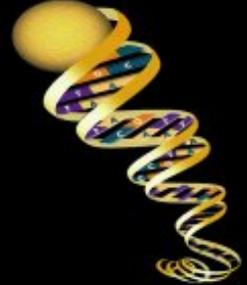
Source: AAAS R&D in Fed Budget



**1952-1954 – Average TOTAL
Basic Research \$0.64 Billion
Constant FY 2000 Dollars**

**2003-2005 – Average TOTAL
Basic Research \$24.46 Billion
Constant FY 2000 Dollars**





Office of Science

U.S. Department of Energy

“The NIH does a magnificent job, but it does not hold all the keys to success. The work of several science agencies is required for advances in medical sciences, and the health of some of those agencies is suffering....”

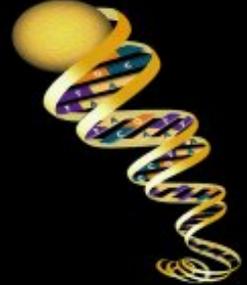
“Medical science can visualize the inner workings of the body at far higher resolution with techniques that sound dazzlingly sophisticated: ultrasound, positron-emission tomography and computer-assisted tomography. These techniques are the workhorses of medical diagnostics. And not a single one of them could have been developed without the contributions of scientists, such as mathematicians, physicists and chemists supported by the agencies currently at risk....”

“Medical advances may seem like wizardry. But pull back the curtain, and sitting at the lever is a high-energy physicist, a combinational chemist or an engineer. Magnetic resonance imaging is an excellent example. Perhaps the last century’s greatest advance in diagnosis, MRI is the product of atomic, nuclear and high-energy physics, quantum chemistry, computer science, cryogenics, solid state physics and applied medicine....”

“In other words, the various sciences together constitute the vanguard of medical research. And it is time for Congress to treat them that way....”

“Scientists can wage an effective war on disease only if we--as a nation and as a scientific community--harness the energies of many disciplines, not just biology and medicine. The allies must include mathematicians, physicists, engineers and computer and behavioral scientists....[I]t is essential to provide adequate budgets for the agencies that traditionally fund such work and train its practitioners. Moreover, this will encourage the interagency collaboration that fuels interdisciplinary science. Only in this way will medical research be optimally poised to continue its dazzling progress.”

- Dr. Harold Varmus, former Director of NIH



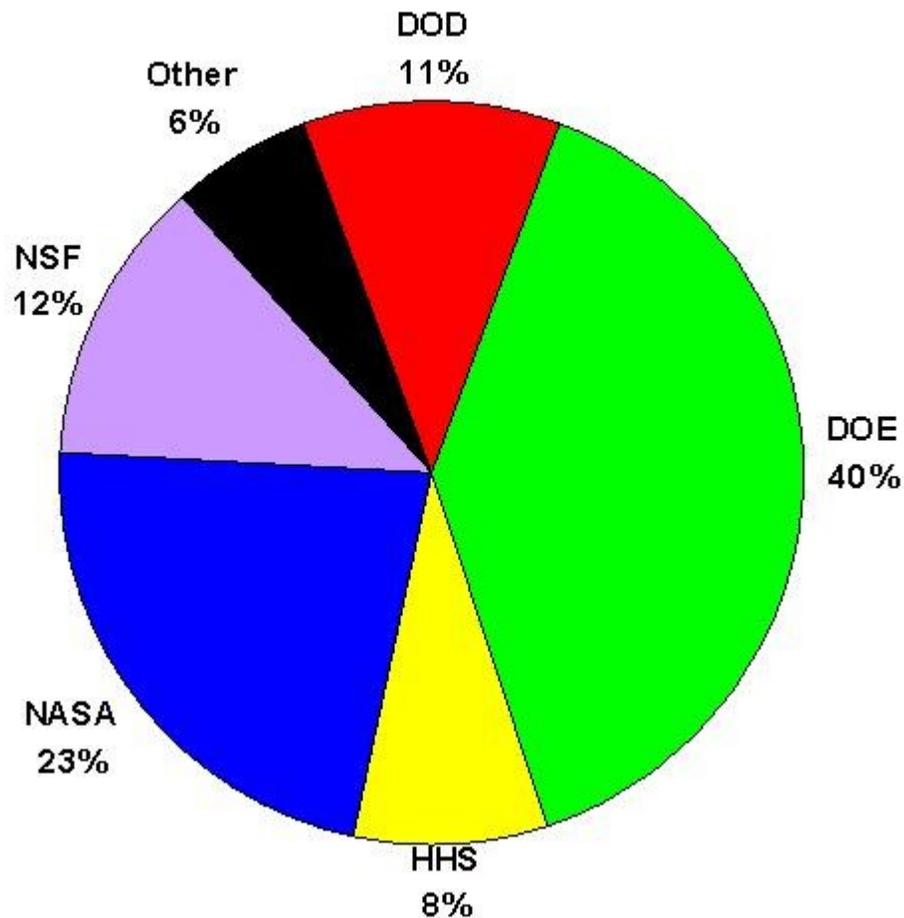
Office of Science

U.S. Department of Energy

The President's Council of Advisors on Science and Technology echoes this call for balance in their report titled *Assessing the U.S. R&D Investment*, October 16, 2002:

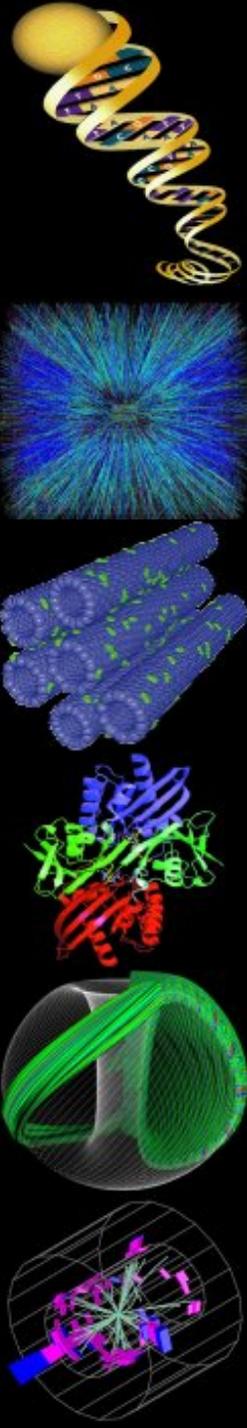
“Recommendation 1. All evidence points to a need to improve funding levels for physical sciences and engineering. Continuation of present patterns will lead to an inability to sustain our nation's technical and scientific leadership. We recommend that beginning with the FY04 budget and carrying through the next four fiscal years, funding for physical sciences and engineering across the relevant agencies be adjusted upward to bring them collectively to parity with the life sciences.”

FY 2003 Federal Obligations for Basic Research in the Physical Sciences



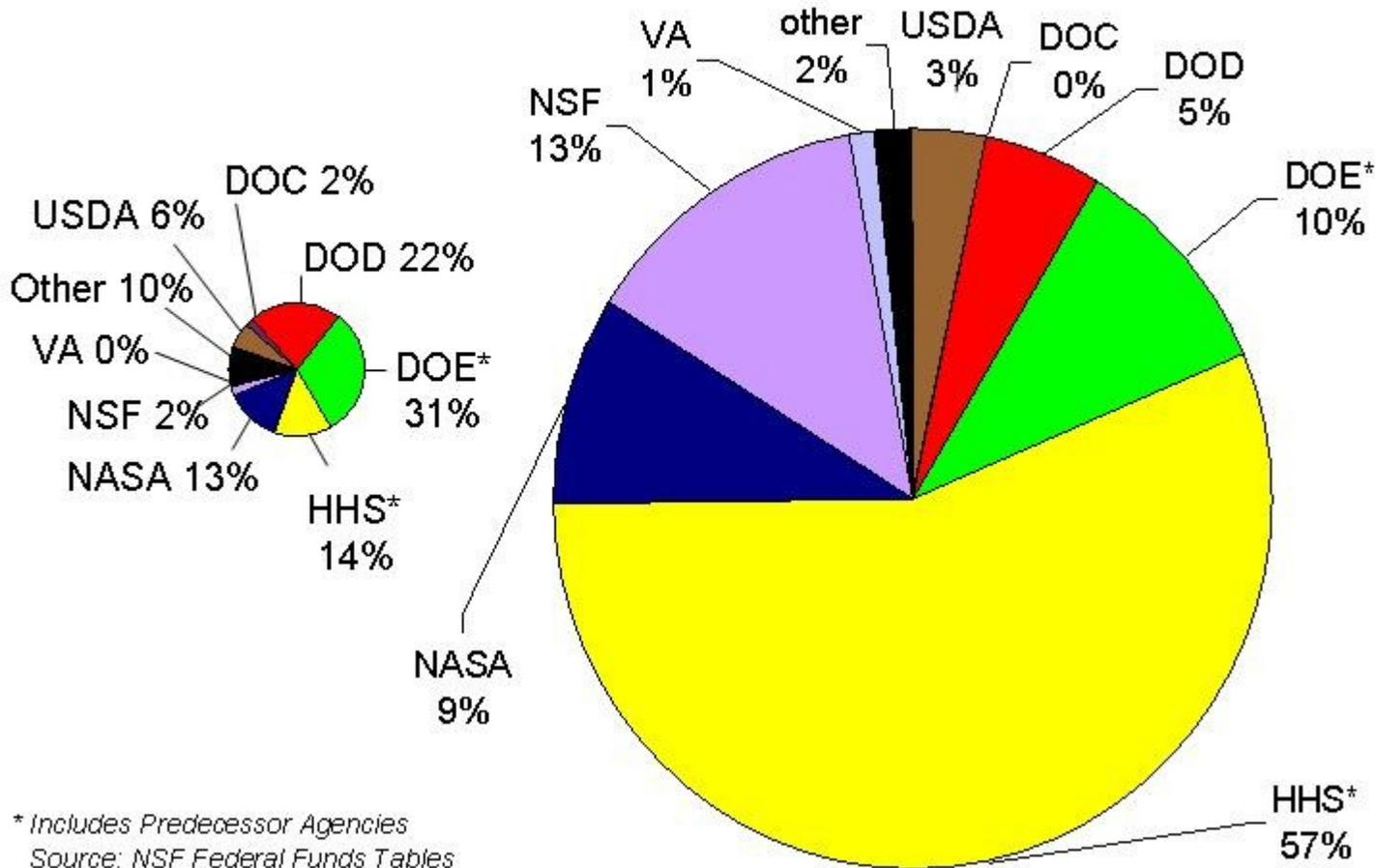
The share of the pie for basic research in the mission-driven agencies DOD, DOE, NADA, and USDA have sharply declined.

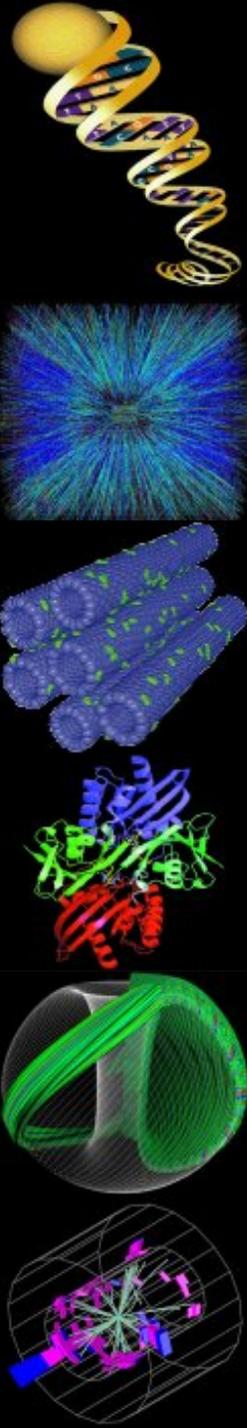




**1952-1954 – Average TOTAL
Basic Research \$0.64 Billion
Constant FY 2000 Dollars**

**2003-2005 – Average TOTAL
Basic Research \$24.46 Billion
Constant FY 2000 Dollars**





Summary and Conclusion

In summary, these three factors--

- Lack of long-term investment in basic research by industry
- Pressures to “simplify support of basic research into a single government agency
- Changes in funding patterns amongst federal agencies

--are the dangers that threaten U.S. scientific preeminence, a historic and magnificent strength. Restoration within science of Madison’s multiplicity of interests is essential to achieve Jefferson’s aspiration: the advancement of knowledge and the freedom and happiness of man.