BPA News

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New Survey of Astronomy and Astrophysics Released

Christopher F. McKee and Joseph H. Taylor, Jr.

In 1997, in discussions with the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) during a meeting of the Committee on Astronomy and Astrophysics (CAA), it became apparent that a new survey of astronomy and astrophysics would soon be needed. Later that year, BPA member Tony Readhead and Board Director Don Shapero organized a special session during the November meeting of the Board. The group concluded that a new survey was indeed called for, and they recommended to the Board that a new Astronomy and Astrophysics Survey Committee (AASC) be formed to carry out the survey.

We convened the AASC and began the study in 1998 with support from the National Aeronautics and Space Administration and the National Science Foundation. When the full magnitude of our task became apparent, we went to the Keck Foundation for additional funding, which they generously provided . We established nine panels to articulate the scientific goals of the various branches of astronomy. NASA asked us to accelerate the work to provide input in time for their strategic planning process. So the committee and panels redoudbled their efforts. The draft manuscript was submitted to the NRC for a review, which was successfully passed, and the draft was publicly released on May 19 at the Academies' headquarters in Washington, DC. We are now working on editing the manuscript and the panel reports and preparing them for publication with the help of BPA staff members Robert L. "Roc" Riemer and Joel R. Parriott, who have provided invaluable support throughout the study.

During the review process, the value of preparing a booklet that would summarize our vision for the future of astronomy for a broad audience became apparent. In parallel with preparing the report for publication, we are writing and designing that booklet. We hope to have these publications available in the fall of this year. Meanwhile, the unedited prepublication draft is available on the web at http://national-academies.org/bpa/reports . While the prose will be refined in the final book, the draft contains the final recommendations.

The present article is drawn from the executive summary of the prepublication draft. It is necessarily highly abbreviated, and we encourage the reader to refer to the full draft.

1. Introduction

In the first decade of the new millennium, humanity is poised to take a giant step forward in understanding the universe and our place within it. The decade of the 1990s saw an enormous number of

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In this issue:

The Impact of Selling the Federal Helium Reserve

Ray Beebe and John Reppy

We cochaired a committee that was charged with assessing the impact on users of helium of selling the contents of the federal helium reserve. The committee's report was released in May, and this article is based on the executive summary contained in the report. A link to a web version of the report may be found at http://national-academies.org/bpa/reports .

Background

The Helium Privatization Act of 1996 (P.L. 104-273) directs the Department of the Interior to begin liquidating the U.S. Federal Helium Reserve by 2005 in a manner consistent with "minimum market disruption" and at a price given by a formula specified in the act. It also mandates that the Department of the Interior "enter into appropriate arrangements with the National Academy of Sciences to study and report on whether such disposal of helium reserves will have a substantial adverse effect on U.S. scientific, technical, biomedical, or national security interests."

The Impact of Selling the Federal Helium Reserve is the product of that mandate. To provide context, the committee has examined the helium market and the helium industry as a whole to determine how helium users would be affected under various scenarios for selling the reserve within the act's constraints.

The Federal Helium Reserve, the Bush Dome reservoir, and the Cliffside facility are mentioned throughout this report. It is important to recognize that they are distinct entities. The Federal Helium Reserve is the federally owned crude helium gas that currently resides in the Bush Dome reservoir. The Cliffside facility includes the storage facility on the Bush Dome reservoir and the associated buildings and pipeline.

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exciting discoveries. For example, for centuries humanity has speculated about the possible existence of planets around other stars. This speculation ended in the past decade with the discovery of extrasolar planets, and the number of planets known continues to grow. Astronomers peered far back in time, to only a few hundred thousand years after the Big Bang, and found the seeds of out of which all galaxies, such as our own Milky Way, were formed. At the end of the decade came evidence for a new form of energy that may pervade the Universe. Nearby galaxies were found to harbor extremely massive black holes in their centers. Distant galaxies were discovered near the edge of the visible universe. In our own solar system, the discovery of Kuiper Belt Objects—some of which lie beyond the orbit of Pluto—opens a new window on the history of the solar system. This report presents a comprehensive and prioritized plan for the coming decade that builds upon these and other discoveries to pursue the goal of understanding the universe, a goal that unites astronomers and astrophysicists with scientists from many other disciplines.

The Astronomy and Astrophysics Survey Committee was charged with surveying both ground- and space-based astronomy and recommending priorities for new initiatives in the decade 2000 to 2010. In addition, the committee was asked to consider the effective implementation of both the proposed initiatives and the existing programs. The committee's charge excludes *in situ* studies of the Earth and planets, which are covered in other reports by the National Research Council. To carry out its mandate, the committee established nine panels with over 100 distinguished members of the astronomical community. Broad input was sought through the panels, through forums held by the American Astronomical Society, and through meetings with representatives of the international astronomical community. The committee's recommendations build upon those of four previous decade surveys, in particular the report of the previous survey, *The Decade of Discovery*, known as the Bahcall report, published in 1991.

The fundamental goal of astronomy and astrophysics is to understand how the universe and its constituent galaxies, stars, and planets formed, how they evolved, and what their destiny will be. To achieve this goal, we must survey the universe and its constituents, including galaxies as they evolve through cosmic time, stars and planets as they form out of collapsing interstellar clouds in the Galaxy, interstellar and intergalactic gas as it accumulates the elements created in stars and supernovae, and the mysterious dark matter and perhaps dark energy that so strongly influence the large-scale structure and dynamics of the universe. We must use the universe as a laboratory—a unique laboratory—for probing the laws of physics in regimes not accessible on Earth, such as the very early universe or near the event horizon of a black hole. We must search for life beyond the Earth, and if it is found, determine its nature and its distribution. And finally, we must develop a conceptual framework that accounts for all that we have observed.

The committee identified several key problems that are particularly ripe for advances in the coming decade. These problems are:

- Determining the large scale properties of the universe: the amount and distribution of its matter and energy, its age, and the history of its expansion.
- Studying the dawn of the modern universe, when the first stars and galaxies formed.
- Understanding the formation and evolution of black holes of all sizes.
- Studying the formation of stars and their planetary systems, and the birth and evolution of giant and terrestrial planets.
- Understanding how the astronomical environment affects Earth.

These scientific themes, all of which appear particularly promising for progress now, are only part of the much

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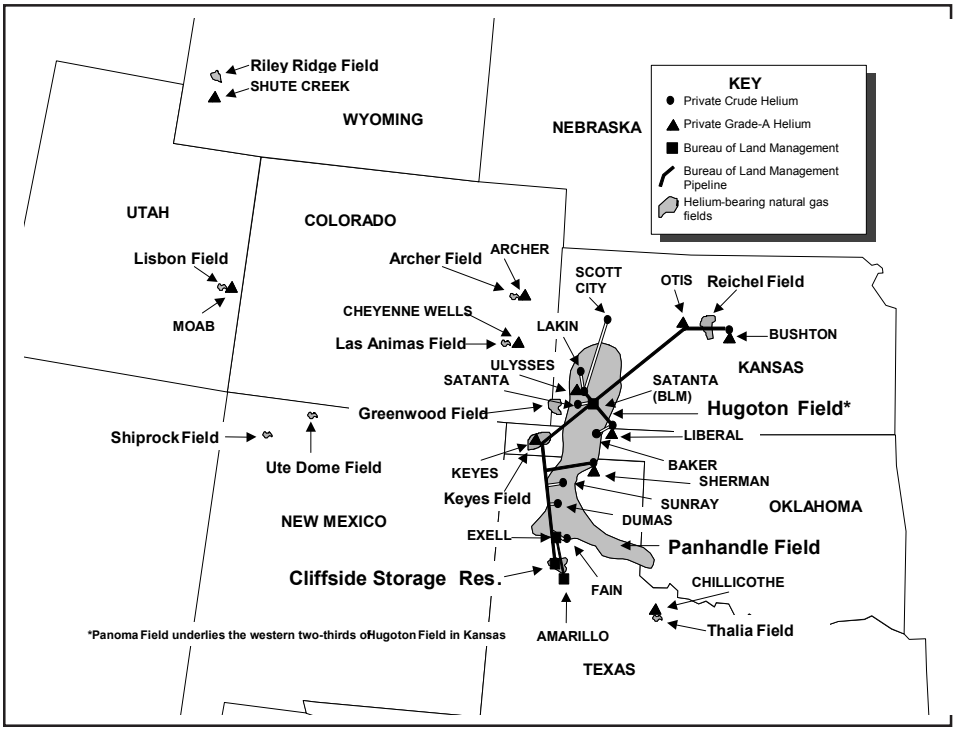
Impact of the Legislation

The helium community is currently enjoying an extended period of stability. Since the mid-1980s, there have been no drastic increases in the price of helium and no shortages of supply. The industry has consistently been emphasizing conservation. All the companies on the Bureau of Land Management (BLM) pipeline store their excess crude helium in the Bush Dome reservoir, and their net storage has led to the accumulation of a private stockpile of approximately 4 billion standard cubic feet (scf), equivalent to 110 million standard cubic meters (scm).

The price of helium will probably remain stable through at least 2010. The price established by the Helium Privatization Act for sales from the Federal Helium Reserve is approximately 25 percent above the current commercial price for crude helium. For this reason and because all helium refiners on the BLM pipeline have long-term take-or-pay contracts with producers of crude helium, it is highly unlikely that the refining industry will buy and use gas from the Federal Helium Reserve rather than from private stockpiles or cheaper commercial suppliers.

Once the private reserves are exhausted, however, refiners will have no realistic option other than to begin purchasing the crude available from the Federal Helium Reserve. (The only other source is more production, and production is driven by the demand for natural gas, not the demand for helium.) Nevertheless, under various plausible supply-demand scenarios, private industry will not need to purchase the entire Federal Helium Reserve to meet demand through 2020.



Based on the information assembled for this report, the committee concluded

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As the Hugoton-Panhandle gas fields are depleted and the Reserve is exploited, the price of crude helium will increase. However, because transportation and purification costs account for a large portion of the price of refined helium, an increase of 25 percent in the price of crude helium would probably increase the price of pure helium by only 8 to 10 percent.

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larger tapestry that is modern astronomy and astrophysics. For example, we cannot hope to understand the formation of black holes without understanding the late stages of stellar evolution, and the full significance of observations of the galaxies in the very early universe will not be clear until we understand how these galaxies have evolved since that time. Although the new initiatives recommended by the committee will advance our knowledge in many other areas as well, they have been selected explicitly to address one or more of the important themes listed above.

Astronomical discoveries have captured the imagination of scientists and laymen alike. The committee believes that in the coming decade astronomers can contribute to education by

- Using astronomy as a gateway to improve public science literacy and as a catalyst in interdisciplinary training of the technical work force.

2. Optimizing the Return on the Nation's Investment in Astronomy and Astrophysics

The United States has been generous in its support of astronomy and astrophysics, and as a result the U.S. enjoys a leading role in almost all areas of astronomy and astrophysics. The committee makes several recommendations to optimize the system of support for astronomical research so as to obtain maximum scientific return on the nation's investment. These recommendations are discussed in detail in the report. Here we provide a highly-abbreviated outline.

In setting priorities for new initiatives, a balance with the ongoing program must be sought. The committee reaffirmed the recommendations of *The Decade of Discovery*. It made a number of suggestions for participation in international projects and for continuation of activities and programs in progress now. It stressed the need to provide funding for operation of facilities and for support of associated data analysis and theory. And it reiterated the importance of unrestricted grants, which support research at the forefront of astronomy.

The committee had several suggestions to ensure the best scientific returns on the investment in astronomical research. The committee urged NASA to continue to develop a range of missions from small to large. It also pointed out that theoretical research provides much of the motivation for initiatives as well as the framework for interpreting the results and recommended the inclusion of theory challenges in the programs for most moderate and new initiatives.

Cooperation with our borders as well as with international partners can also provide leverage for obtaining the biggest returns on the investment in research in astronomy. U.S. agencies, including NASA, NSF, and DOE, should explore the possibility of cooperation when it makes sense for a given project. International collaboration can enable a project to go forward that would be too costly for any one nation. And it can bring together stronger and more diverse scientific teams. In particular, international collaboration plays a crucial role in the top priority of the committee for large projects.

Table I. Prioritized Equipment Initiatives (Combined Ground and Space) for the Decade 2000-2010.

Major Initiatives
- Next Generation Space Telescope (NGST)
- Giant Segmented-Mirror Telescope (GSMT)
- Constellation-X Observatory
- Expanded Very Large Array (EVLA)
- Large-aperture Synoptic Survey Telescope (LSST)
- Terrestrial Planet Finder (TPF)[f]
- Single-Aperture Far InfraRed (SAFIR) Observatory

Moderate Initiatives
- Telescope System Instrumentation Program (TSIP)
- Gamma-ray Large Area Space Telescope (GLAST)
- Laser Interferometer Space Antenna (LISA)
- Advanced Solar Telescope (AST)
- Square Kilometer Array (SKA) Technology Development
- Solar Dynamics Observer (SDO)
- Combined Array for Research in Millimeter-wave Astronomy (CARMA)
- Energetic X-ray Imaging Survey Telescope (EXIST)
- Very Energetic Radiation Imaging Telescope Array System (VERITAS)
- Advanced Radio Interferometry between Space and Earth (ARISE)
- Frequency Agile Solar Radiotelescope (FASR)
- South Pole Submillimeter Telescope (SPST)

Small Initiatives
- National Virtual Observatory (NVO)
- Other small initiatives

3. New Investments in Astronomy and Astrophysics

There are many mysteries before us in our quest to understand our place in the universe. How did the universe begin? What is the nature of the dark matter and dark energy that pervade the universe? How did the first stars and galaxies form? We infer the existence of stellar mass black holes in our Galaxy and supermassive ones in the nuclei of galaxies; how did they form? The discovery of extrasolar planets has opened an entirely new chapter in astronomy, bringing a host of unsolved questions. How do planetary systems form and evolve? Are planetary systems like the Solar System common? Do any extrasolar planetary systems harbor life? Even a familiar object like the Sun poses many mysteries. What causes the small variations in the Sun's luminosity that can affect the Earth's climate? What is the origin of the eruptions on the solar surface that cause "space weather"?

To seek the answers to these questions and many others described in the report, the committee recommends a set of initiatives for the coming decade that will substantially advance the frontiers of human knowledge. Table 1 presents these initiatives, combined for both ground-

based and space-based astronomy, in order of priority. The committee set the priorities primarily on the basis of scientific merit, but it also considered technical readiness, cost effectiveness, impact on education and public outreach, and the relation to other projects. The full report also includes cost estimates.

3.1 Major Initiatives

The Next Generation Space Telescope (NGST), the committee's top recommendation, is designed to detect light from the first stars and to trace the evolution of galaxies from their formation to the present. It will revolutionize our understanding of how stars and planets form in the Galaxy today. NGST is an 8-m infrared space telescope with 100 times the sensitivity and 10 times the image sharpness of the Hubble Space Telescope in the infrared. Extending NGST's sensitivity to 30 mm from the 10 mm currently planned would significantly add to its scientific return. Technology development for this program is well under way. The European Space Agency and the Canadian Space Agency plan to make substantial contributions to the instrumentation for NGST.

The Giant Segmented Mirror Telescope (GSMT), the committee's top ground-based recommendation and second priority overall, is a 30-m class, ground-based telescope that will be a powerful complement to NGST in tracing the evolution of galaxies and the formation of stars and planets. It will have unique capabilities in studying the evolution of the intergalactic medium and the history of star formation in the Galaxy and its nearest neighbors. GSMT will use adaptive optics to achieve diffraction-limited imaging in the atmospheric windows between 1 and 25 μm and unprecedented light-gathering power between 0.3 and 1 μm. The committee recommends that the technology development for GSMT begin immediately and that construction begin within the decade. Half the total cost should come from private and/or international partners. Open access to the U.S. astronomical community should be directly proportional to the investment by the NSF.

The remaining major initiatives are described in the draft report.

3.2 Moderate Initiatives

Ground-based programs

The highest priority moderate initiative overall is the Telescope System Instrumentation Program (TSIP), which would substantially increase NSF funding for instrumentation at large telescopes owned by independent observatories and provide new observing opportunities for the entire U.S. astronomical community. The second priority among ground-based initiatives is the Advanced Solar Telescope (AST), which offers the prospect of revolutionizing our understanding of magnetic phenomena in the Sun and in the rest of the universe. Next, the committee recommends that a program be established to plan and develop technology for the Square Kilometer Array, an international centimeter-wave radio telescope for the second decade of the century. The Combined Array for Research in Millimeter-wave Astronomy (CARMA) will be a powerful millimeter-wave array in the Northern hemisphere. The study of very high energy gamma rays will take a major step forward with the construction of the Very Energetic Radiation Imaging Telescope Array System (VERITAS). The Frequency Agile Solar Radiotelescope (FASR) will apply modern technology to provide unique data on the Sun at radio wavelengths. The South Pole Submillimeter Telescope (SPST) will take advantage of the extremely low opacity of the Antarctic atmosphere to carry out surveys at submillimeter wavelengths that are possible nowhere else on Earth.

Space-based programs

The committee's top recommendation for a moderate space mission is the Gamma-ray Large Area Space Telescope (GLAST). This joint NASA-DOE mission will observe gamma rays from 10 MeV to 300 GeV with six times the effective area, six times the field of view, and substantially better angular resolution than the Energetic Gamma Ray Experiment aboard the Compton Gamma Ray Observatory. The committee's next recommended space program is the Laser Interferometer Space Antenna (LISA), which will be able to detect gravity waves from merging supermassive black holes throughout the visible universe and from close binary stars throughout the Galaxy. The committee has assumed that LISA's cost will be shared with the European Space Agency. The Solar Dynamics Observer (SDO), a successor to the pathbreaking SOHO mission, will study the outer convective zone of the Sun and the structure of the solar corona. The highly variable hard X-ray sky will be mapped by the Energetic X-ray Imaging Survey Telescope (EXIST), which will be attached to the International Space Station. The Advanced Radio Interferometry between Space and Earth (ARISE) mission is an orbiting antenna that will combine with the ground-based VLBA to provide an order-of-magnitude increase in resolution for studying the regions near supermassive black holes in active galactic nuclei.

3.3 Small Initiatives

Several small initiatives recommended by the committee span both ground and space. The first among them—the National Virtual Observatory (NVO)—is the committee's top priority among the small initiatives. The NVO will provide a "virtual sky" based on the enormous data sets being created now and the even larger ones proposed for the future. It will enable a new mode of research for professional astronomers and provide an unparalleled opportunity for education and discovery to the public.

The remaining recommendations for small initiatives are not prioritized. The committee recommends a number of special programs and small projects that are listed in the draft report.

Conclusion

The committee also recommended a strong technology development program in recognition of the role that technological innovation plays in enabling scientific advances. And it pointed out that astronomy has a unique role to play in education and public outreach.

We have left many important initiatives and considerations out of this brief note, but it should be clear even from this discussion that astronomy is on the verge of extending our reach to the very beginnings of the Universe using scientific instruments of daring scope and unprecedented power and ingenuity. We look forward to the next decade of astronomy and astrophysics with excitement and anticipation.■

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that the Helium Privatization Act of 1996 will not have a substantial impact on helium users.

Follow-on Activities and Recommendations

Although the committee does not believe the legislation will have a substantial impact over the next two decades, it recommends consideration of a number of research programs and follow-on studies. These will ensure that the legislation has no adverse long-term (beyond 2020) effects, and that sufficient supplies of helium will continue to be available after 2020 to satisfy the needs of known and potential users.

Reviews of the Helium Industry

First, the committee recommends that future reviews of the helium industry be commissioned by BLM either (1) in response to drastic increases or decreases in helium capacity or use or (2) regularly, every 5 or 10 years. The BLM should assist this review by improving its methods for tracking helium capacity and use. The following recommended improvements will help ensure the timely identification of important shifts in the industry:

· Develop and implement a consistent and credible taxonomy of helium uses.

· Develop and implement better methods for tracking the international helium market.

· Report helium reserves using the natural gas industry's classification scheme.

Study of the Depletion of the Reserve

Second, the committee recommends that the BLM study the adequacy of the Bush Dome reservoir as the reserves are depleted. Specific study tasks that should be considered include the following:

· Determine the optimal size of a federal stockpile of crude helium.

· Develop models of gas extraction at the Bush Dome reservoir to predict the helium content of future extracted gas.

· Determine whether the quantity of gas that remains in the Bush Dome reservoir will be adequate to meet future federal needs in the event of a temporary drop in private production.

· Reassess the pricing structure for the storage of helium at the Cliffside facility so that it more accurately reflects the value of the facility.

Research and Development

Finally, the committee recommends that the Department of the Interior conduct research and development to ensure the continued supply of helium into the future. Goals should include (1) new geological models and exploration technologies, (2) improved helium storage systems, and (3) enhanced technologies to conserve, recycle, and eventually replace helium. The following specific tasks should be considered:

· Determine the geological characteristics and processes that permit the formation of helium-rich gas fields and develop methodologies and databases to assist in the discovery of these fields.

· Identify potential sites for natural storage facilities to permit the establishment of new facilities near future major helium producers and to allow an increase in the storage and conservation capabilities of helium users.

· Develop economic models for the extraction and storage of joint-product, nonrenewable resources the production of one of which is dominated by supply and demand for the other

· Incrementally improve the efficiency of technologies that currently depend on helium and develop alternative technologies that do not require helium.

Conclusion

The committee concluded that if a few modest precautions are undertaken, the legislation will not have a strong impact and helium will remain available for the foreseeable future.■

Board on Physics and Astronomy Meets in Washington DC

The BPA held its spring meeting in conjunction with the annual meeting of the National Academy of Sciences in Washington DC. Meetings of the BPA generally feature a policy topic and a science topic. The policy topic for this meeting was "Research and the Department of Defense". The lead speaker was Robert Trew, Research Director, Defense Research and Engineering. The Directorate of Defense Research and Engineering is the Pentagon-level office that oversees research in the DoD. The science topic was "The Next Generation Space Telescope" featuring a presentation by Steven V. W. Beckwith, Director of the Space Telescope Science Institute (operated by Johns Hopkins University).

Research at the DoD

Dr. Trew began his talk by pointing out that economic history shows a series of periods of prosperity associated with technological innovations, ranging from the steam engine to electricity to the present widespread use of information technology and computers. Major technology pushes have occurred about every 50-60 years, which is about how long it takes for a new idea or theory to makes its way through the various development stages, including concept formation, proof of the concept, start of development, decision to implement, and innovation. But information technology has moved forward at a rapid pace. Widespread use of new technologies is occurring at a quickening pace. Radio took 38 years to reach 50 million users. But television only took 13, and the internet took only 4 years. Information technology is growing at twice the rate of economic growth. Internet traffic doubles every 100 days. Rapid change on these every-shortening timescales pose considerable challenges to the DoD.

Trew defined six challenges to DoD research planning:

•What are the emerging areas of interest to DoD?

•What is basic (6.1) and what is applied (6.2) research?

•How can DoD maintain a stable basic research funding profile?

•Determination of exit strategies. When has a concept matured?
•What is the role of partnerships, collaboration, and leveraging the research investment with other agencies and industry?

In FY00, the DoD research, development, test, and evaluation (RDT&E) budget (6.1 through 6.7) amounts to about $38.19B (appropriations budget). Basic research (6.1) accounts for $1.2B of this sum. Universities are the largest factor in use of 6.1 funds, receiving roughly $600M, followed by in-house laboratories (receiving about $300M), industry, and other institutions. DoD is a small but significant player in federally funded basic research, with about 6 percent of the federal total. The National Institutes of Health are by far the largest supporter of federally funded basic research, with 50 percent of the total. In some fields, the DoD is the dominant supporter of research–for example, electrical engineering and mechanical engineering. Up to the early 90s, the trend had been upwards in current dollars for engineering and computer science, but in recent years, the trend has been down. Past strong DoD support for basic research has paid off in terms of prizes and recognition. Between 1950 and 1997, 43 percent of all U.S. Nobel laureates in physics received some funding from the DoD for work related to the prizewinning research.

Despite the downward trend, the DoD still takes a long-range view in its planning for basic research. It supports basic science and engineering areas that are believed to have good potential for breakthroughs that will eventually be important for DoD applications. It avoids investing 6.1 funds in specific technologies with near-term objectives. There are twelve topical areas that are specifically targeted for support. Physics and materials science as well as atmospheric and space science are among them. Physics research accounts for about 8 percent of 6.1 funding, materials science for about 11 percent, and atmospheric and space science about 5 percent.

There is increasing emphasis on multidisciplinary activities. High priority areas include
•Biomimetics
•Nanoscience
•Intelligent Systems
•Smart Materials and Structures
•Information Technology
•Compact Power

Trew concluded his remarks by pointing some broad current trends in basic research support at the DoD:
•Stable basic research funding will continue to be a challenge
•Growth in "center-type" programs. New funds are generally directed toward an "initiative"
•Increased emphasis upon multidisciplinary activities and cross-disciplinary activities
•Cooperative programs with industry
•Growth in trans-agency programs (e.g., DoD-NSF)
•Emphasis upon determining "new" research areas
•Emphasis upon defining "quality" - driven by Government Performance and Results Act (GPRA)

Next Generation Space Telescope

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THE BPA Web site at **www.national-academies.org/bpa** provides news on recently released reports and other developments. Reports may be ordered at **www.nap.edu.**

New Reports:

- *Gravitational Physics: Exploring the Structure of Space and Time*
- *Materials in a New Era: Proceedings of the 1999 Solid State Sciences Committee Forum*
- *The Impact of Selling the Helium Reserve*
- *Astronomy and Astrophysics in the New Millennium* (prepublication version)

Coming Later in 2000:

- *Astronomy and Astrophysics in the New Millennium* (published version)
- *Physics in a New Era: An Overview*

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2101 Constitution Avenue, NW
Washington, DC 20418

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