Statement of

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Committee on Science and Technology
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Hearing on
"Building and Maintaining a Healthy and Strong NASA Workforce"

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Mr. Chairman, Ranking Minority Member, and committee members: I appreciate the opportunity to testify before you today. My name is David Black. I am President Emeritus of the Universities Space Research Association. I am also an Adjunct Professor in the Physics and Astronomy Department at Rice University. I appear today largely in my capacity as co-chair of the National Research Council (NRC)'s Committee on Issues Affecting the Future of the U.S. Space Science and Engineering Workforce. The NRC is the operating arm of the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine of the National Academies, chartered by Congress in 1863 to advise the government on matters of science and technology. The views expressed in my testimony today are primarily those expressed by the NRC Committee in its Final Report, as well as my own.[1] I shall do my best to make clear which views are mine and which are those of the Committee. The latter views are fully supported by my co-chair of the NRC study, Dr. Daniel Hastings, Dean for Undergraduate Education and Professor of Aeronautics and Astronautics and Engineering Systems at MIT.

Allow me to address the specific questions that you posed prior to this hearing. Your questions are indicated in bold type followed by my responses.

What was the scope of your recently released report on NASA's Workforce, and what are its major findings and recommendations?

The NRC Committee's charge from NASA is to explore long-range science and technology workforce needs to achieve the nation's long-term space exploration vision, identify obstacles to filling those needs, and explore solutions for consideration by government, academia, and industry. The specific tasks that we have been requested to undertake are the following:

1. Assess current and projected demographics of the U.S. aerospace engineering and space science workforce needed to accomplish the exploration vision;
2. Identify factors that impact the demographics of the affected workforces;
3. Assess NASA's list of the workforce skills that will be needed to implement the Vision for Space Exploration, both within the government and in industry;
4. Identify the skills needed to implement NASA's Vision for Space Exploration within the academic community;
5. Assess the current workforce against projected needs;
6. Identify workforce gaps and analyze obstacles to responding to the workforce needs, and in particular, analyze the proper role of academia and the obstacles to achieving this proper role; and
7. Develop recommendations for specific actions by the federal government, industry, and academia to address those needs, including considerations such as organizational changes, recruiting and hiring practices, student programs, and existing workforce training and improvement.

[1] *Issues Affecting the Future of the U.S. Space Science and Engineering Workforce-- Interim Report,* The National Academies Press, Washington, D.C., 2006

The NRC Committee has drawn upon input from a workshop and meetings, documents provided by NASA, and our own experiences to arrive at the following findings and associated recommendations:

Finding 1: NASA has undertaken a commendable top-down (i.e., headquarters-directed) analysis of current agency needs and the skill levels of its current workforce that the committee believes is an excellent first step. But although NASA has considered workforce needs for the agency as a whole, it has not yet projected its requirements for future hiring in terms of (1) the numbers and specific skill sets of workers expected to be needed by each NASA center over time and (2) the timeframes for hiring based on anticipated retirements of the present workforce. The committee believes that understanding future hiring requirements will depend on an accurate, detailed assessment of the skills, Vision for Space Exploration-related development capabilities, and expected attrition of the workforce for each center.

Recommendation 1: Collect detailed data on NASA workforce requirements.
The committee recommends that NASA collect detailed data on and develop accurate assessments of the capabilities possessed by the current workforce and required for the future S&T workforce. The issue here is not simply "more data", but data that are more to the point in terms of understanding the workforce issue. Examples of the type of data are cited below.

- Because each NASA center has unique mission requirements and the mobility of personnel between centers is limited, NASA should complete a center-developed, bottom-up assessment of the current skills, experience levels, and projected attrition of the workforce for each individual NASA center.
- NASA should use the data obtained from such assessments to develop a model for projecting future NASA priorities for Vision for Space Exploration skill development and hiring by competencies, experience levels, and centers, as well as a model for the best mix of skill development conducted within NASA versus within industry.
- NASA should translate identified workforce needs from competencies and experience levels into specific positions to be implemented at individual centers at specific points in time.
- NASA should assess whether the skill levels of in-house scientists at each field center are appropriate to fulfilling that center's scientific leadership and service responsibilities and should ensure that appropriate efforts are made to maintain the scientific competency and currency of each center's scientific workforce.
- NASA should ensure that hiring constraints such as pay levels, personnel ceilings, and ability to recruit suitable candidates guide make-or-buy decisions about how staffing needs will be met.
- NASA should ensure that appropriate workforce strategies including providing training for staff (e.g., through the NASA Academy of Program/Project and Engineering Leadership program), contracting out work to industry and academia, facilitating exchange programs, and hiring temporary contract and term employees are applied at each center.

The committee believes that it is premature to recommend a particular mix of strategies for obtaining the desired worker skill mix until NASA fully defines its staffing needs. NASA is moving to collect the data necessary to help them make these capability assessments. Since NASA is in the Vision for Space Exploration for the long term, NASA will need to establish a

systematic process for monitoring and updating its workforce needs.

Finding 2: In the short term, NASA has too few program and project managers and systems engineers with the requisite experience in human spaceflight systems development to successfully oversee Vision for Space Exploration projects. Given the lack of detailed data on NASA's near-term workforce skills and needs as well as uncertainties over NASA's budget, the committee did not attempt to assess the likely success of NASA's planned steps to address near-term workforce problems.

Recommendation 2: Hire and retain younger workers within NASA.
The committee recommends that NASA implement a long-term strategy for hiring a steady supply of younger workers and subsequently retaining those workers as they rise to senior management positions so that a balanced distribution of age and skill is maintained throughout the agency's entire workforce.

- NASA should take full advantage of the NASA Flexibility Act of 2004, which was passed to facilitate the agency's recruitment of employees from industry. NASA has already utilized the act to a considerable extent, and the committee encourages the agency to continue to do so, as well as to inform Congress of any additional hiring flexibility that is required.
- NASA, working with Congress and the executive branch, should develop solutions to legal problems that limit the flow of senior and highly skilled employees from industry to NASA even when such employees are willing to accept lower salaries. Issues regarding share holding, pensions, and perceived or actual conflicts of interest severely hamper personnel exchanges between industry and NASA. These problems stem from policy issues that cannot be resolved by NASA alone but instead require action by Congress and the executive branch working in concert with NASA.

Finding 3: NASA's workforce requirements and challenges cannot be considered in isolation from those of other government and industry organizations. NASA is part of an aerospace workforce ecosystem in which the health and needs of one organization or sector can affect another. Thus, NASA's workforce issues require the intervention and assistance of higher-level government organizations such as the Office of Science and Technology Policy in the Executive Office of the President.

Recommendation 3: Ensure a coordinated national strategy for aerospace workforce development among relevant institutions.
The committee recommends that representatives from relevant government agencies, the aerospace industry, including the emerging private sector, and the academic community work together to develop a coordinated national strategy to ensure an effective aerospace workforce ecosystem. When NASA is using only approximately 10% of the workers in the aerospace workforce, it must think about its needs in the context of agencies and actors who have much larger needs.

Finding 4: There is a longstanding, widely recognized requirement for more highly skilled program and project managers and systems engineers who have acquired substantial experience in space systems development. Although the need exists across all of NASA and the aerospace

industry, it seems particularly acute for human spaceflight systems because of the long periods between initiation of new programs (i.e., the Space Shuttle program in the 1970s and the Constellation program 30 years later). NASA training programs are addressing some of the agency's requirements in this experience base, but the current requirement for a strong base of highly skilled program and project management and systems engineering personnel, and limited opportunities for junior specialists to gain hands-on space project experience, remain impediments to NASA's ability to successfully carry out Vision for Space Exploration programs and projects.

Recommendation 4: Provide hands-on training opportunities for NASA workers.
The committee recommends that NASA place a high priority on recruiting, training, and retaining skilled program and project managers and systems engineers and that it provide the hands-on training and development opportunities for younger and junior personnel required to establish and maintain the necessary capabilities in these disciplines. Specific and immediate actions to be taken by NASA and other parts of the federal government include the following:

- In establishing its strategy for meeting Vision for Space Exploration systems engineering needs, NASA should determine the right balance between in-house and out-of-house work and contractor roles and responsibilities, including the use of support service contractors.
- NASA should continue and also expand its current employee training programs such as those being conducted by the Academy of Program/Project and Engineering Leadership (APPEL). To facilitate the development of key systems engineering and project management skills, NASA should increase the number of opportunities for entry-level employees to be involved in hands-on flight and end-to-end development programs. A variety of programs—including those involving balloons, sounding rockets, aircraft-based research, small satellites, and so on—can be used to give these employees critical experience relatively early in their careers and allow them to contribute as systems engineers and program managers more quickly.

System Engineering is a discipline and skill that can be partially taught and also has an important component of learning from experiences. It is much easier to learn on small projects where mistakes can be made and recovery is possible than from large projects where recovery might not be possible.

Finding 5: NASA relies on a highly trained technical workforce to achieve its goals and has long accepted a responsibility for supporting the training of those who are potential employees. In recent years, however, training for students has been less well supported by NASA. A robust and stable commitment to creating opportunities at the university level for experience in hands-on flight mission development, graduate research fellowships for science and engineering students, and research is essential for recruiting and developing the long-term supply of competent workers necessary to implement NASA's future programs.

- Faculty research not only is fundamental to student training but also leads to the development of new technology and tools for future applications in space. Programs supporting critical scientific and technological expertise are highly desirable.
- Hands-on experience for students is provided by suborbital programs, Explorer and other small spacecraft missions, and design competitions, all of which rely on continuing NASA support.
- The Graduate Student Researchers Program supports the education and training of

prospective NASA employees and deserves augmented support.
• Undergraduate and graduate co-op student programs are particularly effective in giving students early hands-on experience and in exposing students and NASA to each other to help enable sound career choices and hiring decisions.

Recommendation 5: Support university programs and provide hands-on opportunities at the college level.
The committee recommends that NASA make workforce-related programs such as the Graduate Student Researchers Program and co-op programs a high priority within its education budget. NASA should also invest in the future workforce by partnering with universities to provide hands-on experiences for students and opportunities for fundamental scientific and engineering research specific to NASA's needs. These experiences should include significant numbers of opportunities to participate in all aspects of suborbital and Explorer-class flight programs and in research fellowships and co-op student assignments.

Finding 6: Although NASA's primary role is not education or outreach, improved support of the higher education community and of young professionals is critical to maintaining a sufficiently talented workforce. Involvement in providing development and educational opportunities, especially hands-on flight and vehicle development opportunities, will pay future dividends not only by encouraging larger numbers of talented students to enter the field, but also by improving the abilities of incoming employees. Indeed, a failure to invest in today's students and young professionals will ultimately lead to a crisis when that generation is expected to assume the mantle of leadership within the U.S. aerospace community.

Recommendation 6: Support involvement in suborbital programs and nontraditional approaches to developing skills.
The committee recommends that NASA increase its investment in proven programs such as sounding rocket launches, aircraft-based research, and high-altitude balloon campaigns, which provide ample opportunities for hands-on flight development experience at a relatively low cost of failure. Rather than viewing sounding rockets, aircraft-based research, and balloon programs simply as low-cost, competed, scientific missions, NASA should also recognize as an equal factor in the criteria for their selection their ability to provide valuable hands-on experience for its younger workers and should investigate the possibility of funding such programs through its education budget. In addition, NASA should take advantage of nontraditional institutions and approaches both to inspire and to train potential future employees. Investment in programs such as Centennial Challenge prizes and other innovative methods has the potential to pay benefits many times greater than their cost, by simultaneously increasing NASA's public visibility, training a new generation of workers, and pushing the technology envelope.

Strategic planning for workforce issues is difficult because budget and program decisions often have major impacts on the workforce that make strategic planning irrelevant. The committee heard from industry representatives who stated that NASA's ability to attract junior-level personnel and retain senior personnel would be heavily influenced by perceptions about how compelling and stably funded the Vision for Space Exploration is. The committee thus believes that NASA must adopt policies that, while relatively inexpensive, can have a longer-term impact on its ability to obtain the highest-quality personnel. The development of the right people is as

important as the development of the right hardware. NASA policies must recognize and reflect this attention.

Which issues, according to the report, present the most serious challenges to building and maintaining a healthy and strong NASA workforce?

The major challenges identified by the Committee are a) conducting programs on timescales that are better matched to those of the emerging labor market and for the near future, up to roughly five years from the present, and b) finding ways to tap the broad and deep experience base in key job areas that currently exist outside of the agency. Allow me to expand on both of these points.

The Committee received input from university professors who observed that people in today's young to middle-age labor market are more focused on short term success and are more mobile than were their counterparts of the Apollo era. They are attracted to careers where measurable progress of both a personal and professional nature takes place over five to ten years, as contrasted with decades. The vast majority of current and recent large scale and therefore highly visible NASA programs, be they robotic or human space flight, are of the latter variety. For example, it took nearly three decades of planning, replanning and redesigning before the remarkably successful Spitzer telescope was launched. It has been over 23 years since President Reagan charged NASA with building and operating a space station, and the end of that journey remains far in the future. These examples are typical of current NASA programs. Perhaps just as telling is that this trend appears to be true also for the Vision. The projected availability of the two key hardware components of the Vision is slipping for a number of reasons.

The Committee's discussions with members of the academic community revealed that most are unwilling to urge their best students to pursue a career with NASA or NASA-related programs. Moreover, given the propensity of younger members of the aerospace workforce to seek shorter term gratification, they are looking to other professions such as bio-related fields, or economics, as their first choice rather than the nation's space program. This represents rational choices given the potential returns and the perceptions of involvement in programs that might take a long time to come to fruition.

The Committee found that pay scales for entry to mid-range professionals at NASA are generally comparable, or even better, than in competing job sectors. This is generally not the case for the more senior members of the aerospace workforce. The drawn out nature of NASA's current programs, coupled with the pay discrepancy, is a major cause for the drain of experienced workers from the agency. Additional barriers in bringing experienced people back to NASA are found in conflict of interest issues and the need for these individuals to divest themselves of the financial returns that took them to industry in the first place. This tends to make these opportunities most attractive to people who are retiring from industry.

How well does NASA's Workforce Strategy address the findings and recommendations contained in your report?

The Committee applauds NASA's early efforts at developing a strategy for workforce development, but feels that it needs substantial work on several fronts. This strategy is based

fundamentally on the notion of maintaining ten healthy centers. While such an approach is understandable from a purely political perspective, I am concerned that it runs great risk that it becomes essentially a jobs program with work being sent to centers that are not necessarily staffed to do the jobs. If there were complete mobility in the civil service workforce, NASA might be able to make this approach viable, but that mobility does not exist.

The NASA Workforce Strategy does recognize many of the key challenges that NASA faces, but the Committee is concerned that the NASA strategy views its workforce issues in isolation of what the Committee has dubbed the "aerospace workforce ecosystem." The workforce problems that NASA faces are a microcosm of a broader national problem, one that faces academia, industry and other government entities, and it is the view of the Committee that all parties would be best served by seeking a national solution to these problems. This approach would yield a more stable long-term solution for NASA and the nation's aerospace workforce as a whole. This may take a cultural shift on the part of NASA and its centers. Data provided to the Committee by NSF from 2003 reveals that fully 75% of the workforce with a degree in aeronautics and space science-related fields does not currently work in those fields (Figure 1). The workforce is potentially available, but needs revectoring.

Given that NASA is a multi-mission agency, how de we ensure that core competencies are maintained in each of NASA's core missions?

The fundamental issue facing NASA in its efforts to maintain core competency in the short term is its shortage of qualified experienced personnel in key areas such as systems engineers and project managers. The Committee feels that training or retraining of existing staff cannot meet this shortage in the near term. There are too few opportunities to gain the needed experience, particularly in the human space flight regime to provide the number of needed experienced staff. Viewed from a longer-term perspective, say the time frame from 2012 and beyond, a well conceived and implemented set of training programs and opportunities could provide the necessary core of skilled workforce. This may mean looking to the full aerospace workforce ecosystem as a means to provide adequate hands-on training opportunities, not just NASA missions.

NASA is a relatively small player in the aerospace workforce ecosystem from a pure numbers perspective. For this reason, and others, the Committee encourages NASA to look for opportunities to leverage its efforts with those of the DoD, industry, and the academic community to identify existing programs that could provide opportunities, as well as work in a coordinated manner to develop new programs to accomplish this vital training.

Which of the recommendations do you believe NASA could readily adopt (i.e., that do not require significant resources or disruption in business processes), and which do you think will be the most difficult to implement?

A strong finding from the Committee's work is that meaningful opportunities for hands-on training, an end-to-end involvement in doing space projects, has been a declining element of NASA's portfolio for several years (see Figure 2). The programs that are most effective in

providing the experience that is needed are the low cost suborbital programs, such as sounding rockets and balloon programs. Relatively low cost space missions such as the small end of the Explorer line are also of value here, but they do not provide the opportunity to reach as many students as do the sub-orbital programs. Reaching students and workers when they are younger, and potentially more open to career paths is important.

Increasing efforts in the suborbital programs, particularly if paired with other entities with a vested interest in seeing skilled workers developed, would cost relatively little and could begin to show dividends on a timescale that is short compared to other similar training opportunities. The Committee feels that use of NASA educational funding, along with joint funding from other entities, could be brought to bear in this area. Emphasizing workforce development as a major factor in proposal competition for such programs, as distinct from a focus purely on the scientific return is also encouraged by the Committee. This would bring an explicitly strategic view to the funding of these opportunities.

Which issues related to NASA's workforce are least well understood and what recommendations does your report offer for addressing those uncertainties?

An oft-used exemplar for NASA's workforce is a plot of the age distribution. Two aspects of this distribution are usually mentioned; that the age of the peak has been steadily increasing over the past several years, and that those members at the upper end of the distribution will soon be retirement eligible. While it is the case that there has been an aging of the workforce distribution, a comparison with the other aerospace workforce sectors shows that NASA's workforce is not significantly different than the aerospace workforce generally (Figure 3).

The Committee would emphasize several points regarding this characterization of the NASA workforce. It does not capture a key aspect of the workforce, viz., the experience associated with the bodies that are represented in the data, and as the Committee has emphasized it is the lack of experienced personnel that lies at the heart of NASA's workforce issues. Moreover, the Committee was unable to find evidence that NASA, or anyone else for that matter, was able to say what the "right" distribution should be for an employer with NASA's needs and challenges. A key element here is how one can model this distribution so as to understand the "sources and sinks" that alter the distribution, understand the timescales over which those sources and sinks operate and hence alter the distribution. The Committee feels that any strategic plan that NASA develops for workforce development must include an effort to model and ultimately understand the dynamics of its workforce age distribution. The Committee was not able to conduct an extensive search for people or organizations that do, or could do, this type of analysis, but it seems clear that it lies outside of NASA, most probably in the academic community. We would strongly encourage studies in this area. We would also encourage NASA to periodically reevaluate its model and update its data both for the results and as a way of keeping focus on these critical workforce concerns.

In closing my prepared remarks Mr. Chairman, I would reiterate that the NRC Committee feels strongly that NASA needs to look outside of itself in assessing the nature, scope, and possible solutions for its skill mix. NASA has historically been a "can-do" agency, but also one afflicted to some extent with the "not invented here" syndrome. The issues NASA faces in terms of

workforce are national in character; they reverberate through other government agencies involved in space-related work, as well as the private sector including universities. NASA should not, in our Committee's view, try to structure a solution in isolation from consultation with the broader set of communities noted above. I believe I can speak for many people in saying that the nation's space programs would benefit if the issue of workforce is addressed by involving the representatives of the workforce ecosystem in both the assessment of the problem and the range of possible solutions.

Thank you again for the opportunity to share with your committee the perspectives on this important issue that the NRC Committee has developed over the past year.

I would be happy to expand on my remarks or address additional questions should you wish.

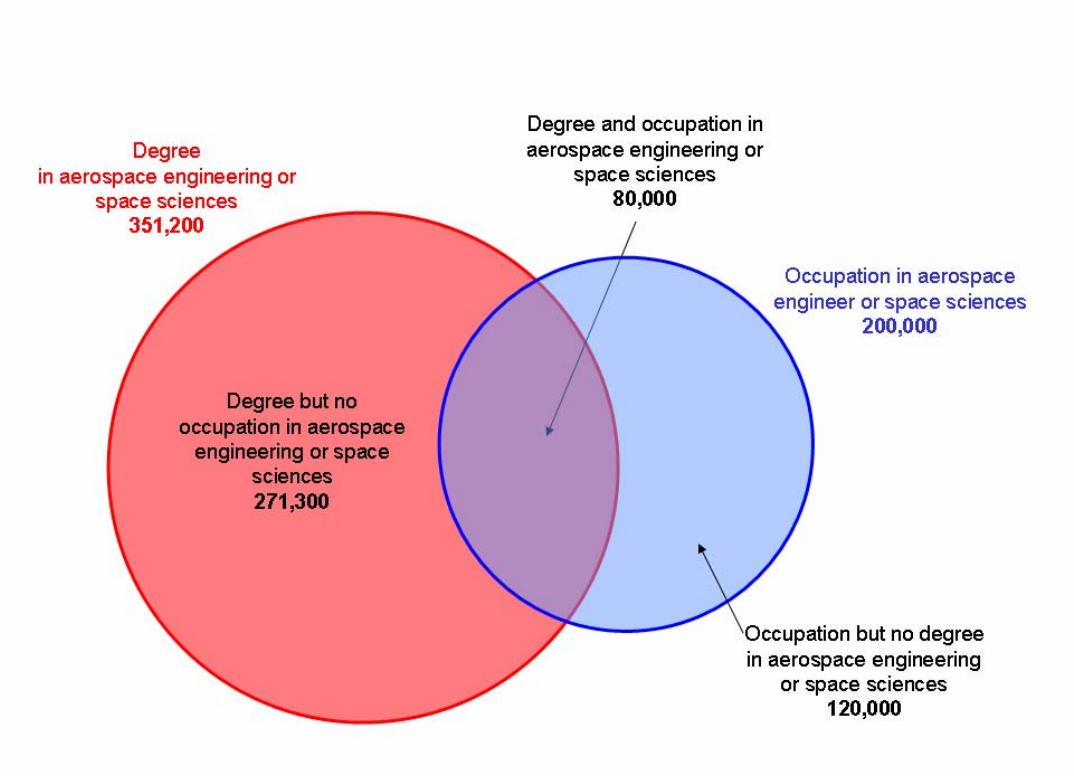

FIGURE 1: Degrees versus occupations in 2003, illustrating that people with specific degrees often work outside their areas. NOTE: Space sciences here include atmospheric sciences, physics, and astronomy. SOURCE: National Science Foundation/Division of Science Resources Statistics, Scientists and Engineers Statistical Data System.

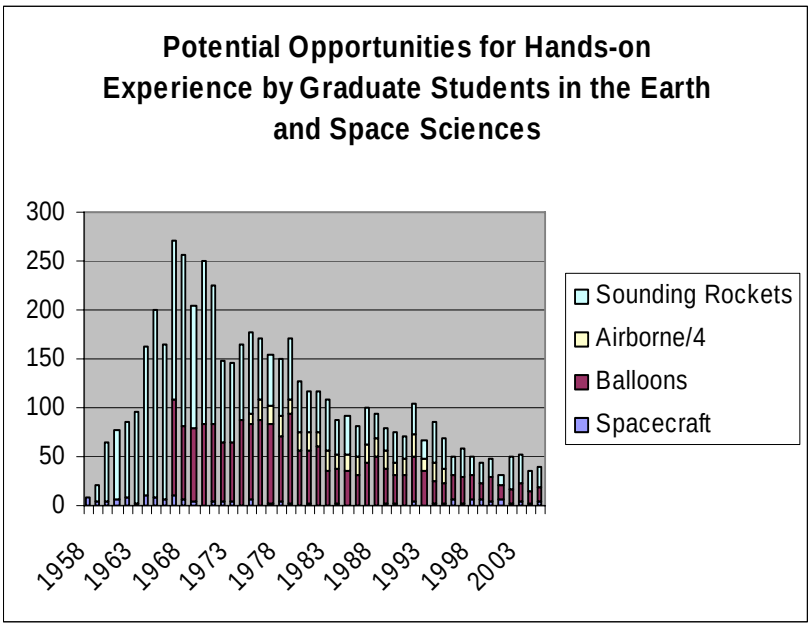

FIGURE 2: NASA's suborbital programs by year, from 1959 to 2005. These hands-on flight programs can provide critical experience to students and entry-level employees.

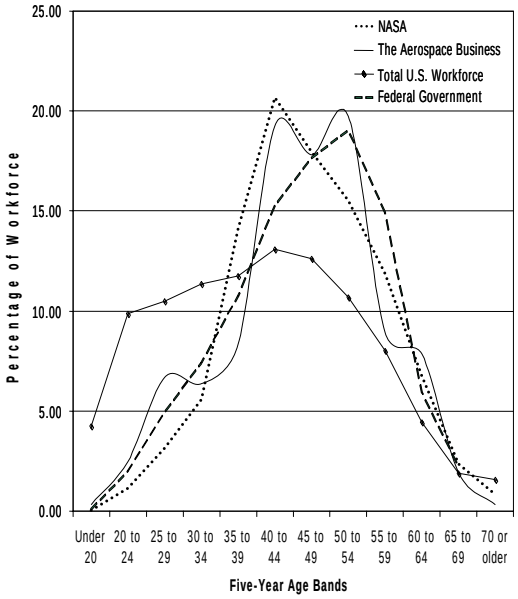

FIGURE 3: The age distribution of NASA's current workforce compared to the age distributions for the aerospace sector, the federal government, and the total U.S. workforce. NOTE: The line for aerospace business is based on very imprecise data. SOURCE: Garth Henning and Richard Leshner, NASA, presentation to the Committee on Meeting the Workforce Needs for the National Vision for Space Exploration, February 22, 2005.

DAVID C. BLACK, is President Emeritus of the Universities Space Research Association (USRA), a consortium of 97 different colleges and universities having graduate programs in space science or engineering. He is also adjunct professor of space physics and astronomy at Rice University. Between 1970 and 1975 Dr. Black served in various capacities at NASA's Ames Research Center, including chief of the Theoretical Studies Branch and deputy chief of the Space Science Division, and he was the first chair of the Ames Basic Research Council. Dr. Black was selected as the first chief scientist for the space station program at NASA Headquarters in 1985. He returned to NASA Ames in 1987 as the chief scientist for space research. He spent an academic year as a visiting professor at the University of London (1974-1975). Dr. Black is an internationally recognized researcher in theoretical astrophysics and planetary science, specializing in studies of star and planetary system formation. He has also done pioneering experimental research involving the isotopic composition of noble gases in meteorites, was the first to discover and correctly identify evidence for non-solar material in solar system matter, and was the first to show that the isotopic composition of solar flare noble gases differs from that of solar wind noble gases. He is a leader in the current effort to search for and study other planetary systems. He is past chair of the Solar System Exploration Subcommittee and the Origins Subcommittee of NASA's Space Science Advisory Committee. Dr. Black also served as a member of the NRC Planetary and Lunar Exploration Task Group (1984-1988) and the Working Group on Search for Extraterrestrial Intelligence (1979-1983).

Dr. Black served as co-chair with Dr. Daniel Hastings of the National Research Council (NRC)'s Committee on Issues Affecting the Future of the U.S. Space Science and Engineering Workforce. Dr. Hastings is a professor of aeronautics and astronautics and engineering systems and dean for undergraduate education at the Massachusetts Institute of Technology (MIT). The other committee members were:

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