AUTHENTICATED
U.S. GOVERNMENT
INFORMATION
GPO

DECISIONS ON THE FUTURE DIRECTION AND FUNDING FOR NASA: WHAT WILL THEY MEAN FOR THE U.S. AEROSPACE WORKFORCE AND INDUSTRIAL BASE?

HEARING

BEFORE THE

COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

DECEMBER 10, 2009

Serial No. 111–69

Printed for the use of the Committee on Science and Technology

Available via the World Wide Web: http://www.science.house.gov

U.S. GOVERNMENT PRINTING OFFICE

54–449PDF WASHINGTON : 2010

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
Fax: (202) 512–2104 Mail: Stop IDCC, Washington, DC 20402–0001

COMMITTEE ON SCIENCE AND TECHNOLOGY

HON. BART GORDON, Tennessee, *Chair*

JERRY F. COSTELLO, Illinois
EDDIE BERNICE JOHNSON, Texas
LYNN C. WOOLSEY, California
DAVID WU, Oregon
BRIAN BAIRD, Washington
BRAD MILLER, North Carolina
DANIEL LIPINSKI, Illinois
GABRIELLE GIFFORDS, Arizona
DONNA F. EDWARDS, Maryland
MARCIA L. FUDGE, Ohio
BEN R. LUJÁN, New Mexico
PAUL D. TONKO, New York
PARKER GRIFFITH, Alabama
JOHN GARAMENDI, California
STEVEN R. ROTHMAN, New Jersey
JIM MATHESON, Utah
LINCOLN DAVIS, Tennessee
BEN CHANDLER, Kentucky
RUSS CARNAHAN, Missouri
BARON P. HILL, Indiana
HARRY E. MITCHELL, Arizona
CHARLES A. WILSON, Ohio
KATHLEEN DAHLKEMPER, Pennsylvania
ALAN GRAYSON, Florida
SUZANNE M. KOSMAS, Florida
GARY C. PETERS, Michigan
VACANCY

RALPH M. HALL, Texas
F. JAMES SENSENBRENNER JR., Wisconsin
LAMAR S. SMITH, Texas
DANA ROHRABACHER, California
ROSCOE G. BARTLETT, Maryland
VERNON J. EHLERS, Michigan
FRANK D. LUCAS, Oklahoma
JUDY BIGGERT, Illinois
W. TODD AKIN, Missouri
RANDY NEUGEBAUER, Texas
BOB INGLIS, South Carolina
MICHAEL T. MCCAUL, Texas
MARIO DIAZ-BALART, Florida
BRIAN P. BILBRAY, California
ADRIAN SMITH, Nebraska
PAUL C. BROUN, Georgia
PETE OLSON, Texas

CONTENTS

December 10, 2009

	Page
Hearing Charter	2

Opening Statements

Statement by Representative Bart Gordon, Chairman, Committee on Science and Technology, U.S. House of Representatives	15
Statement by Representative Gabrielle Giffords, Chairwoman, Subcommittee on Space and Aeronautics, Committee on Science and Technology, U.S. House of Representatives	16
Written Statement	17
Statement by Representative Pete Olson, Ranking Minority Member, Subcommittee on Space and Aeronautics, Committee on Science and Technology, U.S. House of Representatives	19
Written Statement	20

Witnesses:

Mr. David Thompson, President, American Institute of Aeronautics and Astronautics	
Oral Statement	22
Written Statement	24
Ms. Marion C. Blakey, President and Chief Executive Officer, Aerospace Industries Association	
Oral Statement	26
Written Statement	28
Mr. A. Thomas Young, Executive Vice President (Ret.), Lockheed Martin Corporation	
Oral Statement	32
Written Statement	33
Dr. Richard Aubrecht, Vice Chairman of the Board, Vice President, Strategy and Technology, Moog, Inc.	
Oral Statement	35
Written Statement	37
Discussion	
Opinion of the Panel: Impact of Decision To Augment or Flat-Fund Human Spaceflight and Exploration Programs	39
Augustine Report: Budget and Funding Issues	39
Stimulus Funds and Human Spaceflight Funding for NASA	41
Cooperation with Foreign Nations	41
Effects of Post-Shuttle Gap of U.S. Access to Space on Maintaining Inspiration; and Gap in U.S. Industrial Production of Heavy Lift Vehicle	42
Inspiring the Next Generation for Space Exploration	44
The Metric System	45
Revitalizing and Improving the Aerospace Workforce	45
Education Programs in Elementary Schools/Advocating Math and Science	47
Aircraft Propulsion Systems	48
Educational Initiatives Focused on Math and Science Teachers	49
Effect of Delaying or Indecision on Constellation Project	51
Impact of Previous Decisions on Current Status of Human Spaceflight and Loss of Jobs	52
Importance of Science R&D and Education	54

Page

Appendix: Answers to Post-Hearing Questions

Mr. David Thompson, President, American Institute of Aeronautics and Astronautics 58
Ms. Marion C. Blakey, President and Chief Executive Officer, Aerospace Industries Association 65
Mr. A. Thomas Young, Executive Vice President (Ret.), Lockheed Martin Corporation 68
Dr. Richard Aubrecht, Vice Chairman of the Board, Vice President, Strategy and Technology, Moog, Inc. 71

DECISIONS ON THE FUTURE DIRECTION AND FUNDING FOR NASA: WHAT WILL THEY MEAN FOR THE U.S. AEROSPACE WORKFORCE AND INDUSTRIAL BASE?

THURSDAY, DECEMBER 10, 2009

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Committee met, pursuant to call, at 10:06 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Bart Gordon [Chairman of the Committee] presiding.

HEARING CHARTER

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

Decisions on the Future Direction and Funding for NASA: What Will They Mean for the U.S. Aerospace Workforce and Industrial Base?

THURSDAY, DECEMBER 10, 2009
10:00 A.M.—12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

I. Witnesses

Mr. David Thompson, President
American Institute of Aeronautics and Astronautics

Ms. Marion C. Blakey, President and Chief Executive Officer
Aerospace Industries Association

Mr. A. Thomas Young, Executive Vice President (ret.)
Lockheed Martin Corporation

Dr. Richard Aubrecht, Vice Chairman, Vice President, Strategy and Technology, Moog Inc.

II. Overview

A series of recent Committee and Space and Aeronautics Subcommittee hearings have examined key issues related to upcoming decisions on the future direction and funding for the National Aeronautics and Space Administration (NASA), particularly as they relate to human spaceflight. The subcommittee has examined the results of the Review of U.S. Human Spaceflight Plans Committee, the state of advanced technology development at NASA, the growth of global space capabilities and what they mean for our space program, and human spaceflight safety. This hearing, convened by the Science and Technology Committee, looks at the health of the U.S. aerospace workforce and industrial base and how decisions on NASA's direction and funding would affect them, including decisions on human spaceflight plans.

The aerospace workforce and the industrial base are at the core of the space enterprise, whether for NASA's programs and other civil space activities, commercial space, or national security space activities. The United States would not have achieved its leadership position in space without the dedication, expertise and skills resident in the aerospace workforce and industrial infrastructure that supports the nation's space program. As the nation looks forward, it will continue to depend on these talents and capabilities to support America's future goals and objectives for its space activities.

Jobs in the aerospace workforce are highly-skilled and command good salaries. For example, according, to a report of the Space Foundation, *The Space Report 2009*, "*in 2007, the average annual wage of a U.S. aerospace engineer was $92,700, an increase of nearly $3,500 compared to 2006*." *The Space Report* further states that "*For the first time on record, professionals in the federal space research and space vehicle manufacturing sectors earned an average salary above six figures . . . or 2.3 times that of the average U.S. private sector worker*." In addition the aerospace industry is a significant contributor to the nation's economy, and the industry invests in research and development. *Aerospace Facts & Figures 56th edition*, a 2009 report of the Aerospace Industries Association (AIA), notes that "*Total sales for the aerospace industry grew by 7.2 percent to $200.3 billion in 2007*." In his prepared statement for a Space and Aeronautics Subcommittee hearing on "External Perspectives on the FY 2010 NASA Budget Request and Related Issues" held on June 18, 2009, Mr. J.P. Stevens, Vice President, Space Systems of the Aerospace Industries Association (AIA) stated: "*Our member companies export 40 percent of their total output, and we routinely post the nation's largest manufacturing trade surplus, which was over $57 billion in 2008 . . . . The aerospace industry continues to look to the future, investing heavily in research and development, spending more than $100 billion over the last 15 years*."

According to a series of advisory reports, however, the U.S. aerospace workforce and space industrial base face growing challenges. In 2001, the Bush Administration chartered The Commission on the Future of the United States Aerospace Industry to "*study the issues associated with the future of the United States aerospace industry in the global economy, particularly in relationship to United States national security; and assess the future importance of the domestic aerospace industry for the economic and national security of the United States*." In its report, the Commission identified several critical issues including the aging of the aerospace workforce, consolidation in the industry, and "*the failure of the U.S. K–12 education system to properly equip U.S. students with the math, science, and technological skills needed to advance the U.S. aerospace industry*". Subsequent reports that are discussed in the sections that follow reiterate many of the pressing concerns that the Commission identified. Those concerns are particularly relevant during a period in which NASA is moving toward a planned retirement of the Space Shuttle, is developing the next human spaceflight system, will be relying on non-U.S. means of access to space during for a period of at least 5 years, and is preparing for key decisions about the space program and NASA's plans for human spaceflight in low-Earth orbit and beyond that will have significant implications for the aerospace workforce and industrial base.

Will the nation pursue the current, congressionally-authorized course to return humans to the Moon as a stepping-stone to other destinations using the Constellation architecture, or will the Administration propose an alternative path or architecture that Congress will need to examine? Will the Administration and Congress support the increased funding for NASA and its human space flight activities that the Augustine committee has said is needed to carry out any meaningful exploration program? Will the International Space Station (ISS) be extended to at least 2020? What will be the interplay of scientific robotic and human endeavors in space? How are the knowledge and expertise gathered through our experience with the first fifty years of space activities, including the ability to design, develop, and operate a human lunar program and a space transportation system, being passed on to the next generation of aerospace professionals? What are the critical skills that the nation will need to preserve if it is to undertake future space activities? How can the nation retain and apply the critical skills and experience developed through decades of Space Shuttle operations to the next human space transportation system? I-low will the space program contribute to meeting national needs and advancing international goals and objectives? The impact of potential decisions on these questions will affect the types of skills and capabilities that are required, the size and distribution of the workforce, and the geographical concentrations of the workforce and institutions (government, industry, and academic) that have grown up to support NASA's programs over the past decades will also need to be considered.

Some of these questions on NASA's future have come to the fore with the Presidentially-charged independent review of U.S. human spaceflight plans that was carried out by a committee led by Mr. Norman Augustine, former Chairman and Chief Executive Officer of Lockheed Martin Corporation. The Committee, in its report, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, reviewed current spaceflight plans and proposed potential alternatives. Other actions for the future of the space program have been recommended in such reports as the National Research Council's (NRC) *America's Future in Space: Aligning the Civil Space Program with National Needs*. These and other reports refer to the importance of a healthy aerospace workforce and industrial base for the future of the space program. As noted in the NRC report, "*A competent technical workforce—sufficient in size, talent, and experience to address difficult and pressing challenges*" is one of four foundational elements that are critical to the ability of America's space activities to contribute to key national objectives.

Several reports, including the National Academies report, *Rising Above the Gathering Storm*, refer to the urgent need to improve science, technology, engineering, and mathematics (STEM) education and promote careers in science and technology if the nation is to maintain its leadership in science and engineering. As the National Research Council's *America's Future in Space* report noted, "*Aerospace engineering requirements compete nationally for much of the same technically trained talent needed across the broad research and engineering sectors of our country*." Because expectations often weigh heavily on those pursuing careers in STEM fields, including aerospace, it will be important for Congress and the White House to understand the extent to which the future direction and stability of funding for NASA and the nation's space program will be a significant factor in building and maintaining the pipeline of talent and experience for the aerospace workforce of the future. It is clear from a variety of independent assessments that adequate funding and stability of funding are critical ingredients in attracting and maintaining the skilled

workforce needed to carry out NASA's missions, including especially its human space flight and exploration activities, which can require multi-decadal commitments.

III. Issues

- *How do the aerospace workforce and industrial base contribute to the nation's economic strength, technological capabilities, competitiveness, and capacity for innovation?*
- *What are the critical issues and trends related to the U.S. aerospace workforce and space industrial base that Congress and the White House need to understand as decisions are made on the future direction and funding for NASA?*
- *How important is the adequacy and stability of funding and stability of NASA's program to the health of the aerospace workforce and space industrial base?*
- *What does the "gap" in U.S. human spaceflight capability mean for the aerospace workforce and industrial base, and how would any lengthening or shortening of the gap affect the workforce and industrial base?*
- *What, if any, lessons learned from our experience with the gap between the end of the Apollo program and the first flight of the Space Shuttle, and its effects on the workforce and industrial base, have application to the current plans for retiring the Shuttle and transitioning to a new U.S. human spaceflight system?*
- *What are the critical workforce skills and industrial capabilities that need to be preserved as national assets, and what are the most effective ways to preserve those assets?*
- *What would any significant cutback or change in direction from the current Constellation Program mean for the aerospace workforce and space industrial base?*
- *What is the implication of continuing ISS operations and utilization through at least 2020 for the workforce and industrial base?*
- *What are the most significant impediments to ensuring the strength and capabilities of the aerospace workforce and industrial base, especially for human spaceflight?*
- *How do emerging space companies affect the aerospace workforce and industrial base and what is the outlook for the future?*

IV. Background

The U.S. Aerospace Workforce and Its Contribution to the Economy

The aerospace workforce includes NASA civil servants and its grantees and contractor space workforce; the broader aerospace workforce that support space, aviation, and defense programs; as well as a chain of suppliers, businesses and service organizations that also support the aerospace sector.

- *NASA Civil Servant and Contractor Space Workforce*

The President's FY 2010 budget request for NASA describes the estimated level of full-time equivalents for NASA, including headquarters and ten centers for FY 2010 as 17,900. The budget request states that: "*In order to ensure that the necessary skills are available to meet the work demand of current and future programs and projects, maintaining a total workforce level of 17,900 FTE, while reshaping the skills, is vitally important to meeting the challenges of NASA's current and future commitments*," although it does not indicate why or whether that workforce level, as opposed to higher or lower levels, is considered to be optimal.

The relevant workforce also includes tens of thousands of contractors working at or near NASA centers that support NASA's space and aeronautics activities. The main occupations for NASA's workforce are science and engineering professionals, technicians, program managers, administrative professionals, and clerical staff

- *Aerospace Industry Workforce*

According to testimony by Mr. J.P. Stevens, Vice President, Space Systems for the AIA, to the Space and Aeronautics Subcommittee in June 2009, AIA "*represents nearly 300 manufacturing companies with over 660,000 high-wage, highly skilled aerospace employees across the three sectors: civil aviation, space systems and national defense. This includes over 140,000 workers who make the satellites, space sen-*

sors, spacecraft, launch vehicles and ground support systems employed by NASA, DoD, [Department of Defense] *NOAA,* [National Oceanic and Atmospheric Administration] *NRO* [National Reconnaissance Office] *and other civil, military and intelligence space efforts . . . . Aerospace indirectly supports 2 million middle class jobs and 30,000 suppliers from all 50 states*."

The Space Report 2009, a report of the Space Foundation, used workforce data from six North American Industry Classification System codes and the U.S. Bureau of Labor Statistics to calculate that, during 2007, a total of 262,741 Americans worked in the following areas of the space industry—search, detection, and navigation instruments; guided missile and space vehicle manufacturing; guided missile and space vehicle propulsion unit and propulsion unit parts manufacturing; other guided missile and space vehicle parts and auxiliary equipment manufacturing; satellite telecommunications; space research and technology. [The space research and technology code is defined as including "*government establishments primarily engaged in the administration of operations of space flights, space research, and space exploration. Included in this industry are government establishments operating space flight centers*."]

In addition, there is an emerging commercial space industry that plans to offer various commercial space and launch services and one issue for the hearing is to understand the relevant aerospace workforce and industrial base issues for this segment of the space industry.

• *Space Industry Wages*

Space industry jobs are high paying jobs. According to the *Aerospace Facts & Figures*, a publication of the AIA, "*On average, the aerospace workforce is highly-skilled, specialized, and productive. Although aerospace workers comprised only 4.7 percent of the total manufacturing workforce, their compensation represented 7.1 percent of the total annual payroll for all manufacturing*."

The Space Report 2009 states that "*the combined average annual salary across the six core U.S. space industry sectors analyzed was $88,092 in 2007, nearly double the average salary of U.S. professionals in the average private sector overall. For the first time on record, professionals in the federal space research and space vehicle manufacturing sectors earned an average salary above six figures, more than $101,000, or 2.3 times that of the average U.S. private sector worker*."

In addition, The *Space Report 2009* notes "*Growth in space industry employment delivers a disproportionately large boost to the economy compared to economic growth in other sectors due to high wage levels in the space industry*." The report also state that, "*Not only are U.S. space industry salaries high, they are growing. In 2003, the average U.S. space industry salary, adjusted for inflation to 2007 dollars, was $81,991. In real terms, U.S. space professionals made nearly S7,000 more on average in 2007 than they had five years prior, a real wage increase of 7.4%*."

General Issues Related to the Aerospace Workforce

The overall U.S. aerospace workforce faces a number of challenges, as identified by several reports and analyses on the topic. Those issues include the aging of the aerospace workforce, the stability of space-related programs, the skills required for major programs, and the status of the pipeline for future workers.

According to the Commission on the Future of the United States Aerospace Industry's 2002 report, "*The contributions of aerospace to our global leadership have been so successful that it is assumed U.S. preeminence in aerospace remains assured. Yet the evidence would indicate this to be far from the case. The U.S. aerospace industry has consolidated to a handful of players from what was once over 70 suppliers in 1980 down to 5 prime contractors today. Only one U.S. commercial prime aircraft manufacturer remains. Not all of these surviving companies are in strong business health. The U.S. airlines that rely upon aerospace products find their very existence is threatened. They absorbed historical losses of over $7 billion in 2001 and potentially more this year.*

The industry is confronted with a graying workforce in science, engineering and manufacturing, with an estimated 26 percent available for retirement within the next five years. New entrants to the industry have dropped precipitously to historical lows as the number of layoffs in the industry mount. Compounding the workforce crisis is the failure of the U.S. K–12 education . . . ."

• *Aging Workforce and Pipeline*

The employee ranks within both NASA and the aerospace industry are aging and the number of employees eligible for retirement is increasing. According to the 2009 NRC report, *America's Future in Space: Aligning the Civil Space Program With National Needs*, "*As of February 2009, more than 60 percent of NASA's full-time perma-*

nent employees were at least 45 years old, and nearly one quarter of employees were above 55." According to the AIA, "*Only 15.7% of the aerospace workforce is composed of 25–34 year olds. Nearly 60% of the workforce is 45 years and older*." The 2009 NRC report also notes that "*the experienced aerospace workforce that pioneered the exploration of space and engineered notable past accomplishments is quickly retiring*". A 2007 NRC report, *Building a Better NASA Workforce: Meeting the Workforce Needs for the National Vision for Space Exploration*, states that "*NASA has determined that 12 percent of its engineers and 21 percent of its scientists are now eligible to retire, and it projects that in 2011, 28 percent of its engineers and 45 percent of its scientists will be eligible to retire*." As a result of low annual rates of attrition at NASA (3.5 percent overall, annually), according to the NRC report, the authoring committee did not foresee a sudden large exodus from the NASA ranks.

To address the aging workforce situation, NASA and the aerospace industry have taken concrete steps to encourage and create opportunities for students to pursue education and then careers in STEM fields and to gain experience on space projects. Even with these ongoing efforts, NASA and the industry face challenges in building the pipeline to replace retiring workers.

The *Aviation Week 2009 Workforce Study* raises the issue that among those that do enter the aerospace workforce, the attrition rate has increased for employees in the early stages of their careers: "*The voluntary attrition rate among young professionals (those with 0–5 years of experience) rose to 15.7% from 14% a year ago. This data point was added to the survey in 2008 so there is no further longitudinal analysis available. Also note a voluntary attrition rate of 19.4% for the manufacturing/production workforce within those first five years of service . . . .*"

• *Workforce Needs and Priority Skills*

Among the skills in highest demand for aerospace programs, both civil and national security, are engineering capabilities—in particular systems engineering—and program management. A 2008 report by the Center for Strategic and International Studies (CSIS), *Briefing of the Working Group on the Health of the U.S. Space Industrial Base and the Impact of Export Controls*, states "*The issue of program management and systems engineering skills shortages in government and industry have been well identified in numerous studies over the last five years*." At the same time, these skills are not easily acquired, as the study notes: "*it takes up to 10 years to 'grow' systems engineers and multiple program experiences are critical*", as described in the CSIS report.

The overall economic climate and the instability of the nation's aerospace activities appear to be factors affecting hiring projections for the aerospace workforce, even for the most sought-after capabilities. According to the *Aviation Week 2009 Workforce Study*, which was prepared in partnership with the Aerospace Industries Association, the American Institute of Aeronautics and Astronautics, and the National Defense Industries Association, "*Hiring for the top four skills* [systems engineering, aerospace engineering, mechanical engineering, program/software engineering] *is predicted by these same companies to plummet by 38–80% in 2010, while other categories hold relatively steady. Only the fifth skill noted in the rankings, program management, projects a hiring increase (4%) in 2010. The economic hangover, then, is expected to last through 2010 or until new programs/contracts develop*."

In addition, *The Space Report 2009* identified a complement of engineering occupations as well as various science occupations that, according to the report, form a set of diversified skills and human capital that are needed for future space activities. Those occupations are: Aerospace engineering and operations technicians; Aerospace engineers; Astronomers; Atmospheric and space scientists; Avionics technicians; Chemical engineers; Materials engineers; Materials scientists; and Postsecondary atmospheric, Earth, marine, and space sciences teachers.

• *Growth*

In terms of space industry employment, *The Space Report 2009* states that "*After declining slightly between 2001 and 2003 with the bursting of the telecommunications market bubble, U.S. space industry employment has rebounded to 2001 levels. Between 2003 and 2007, the most recent five-year period for which official data is available, the number of space industry jobs grew by 5.1%*." This growth occurred in every sector of the U.S. space industry, except satellite telecommunications.

The *Aviation Week 2009 Workforce Study*, which was issued in July 2009, reports that "*What began as a full court press to hire and bring specific skills into the A&D* [aerospace and defense] *industry a year ago adjusted downward as the year progressed and economic concerns grew worse. A year ago, the projection was that 2008 hiring would hold at 5%, reflecting the industry's overall growth. This year, that*

number falls to 3% job growth and layoffs among 50% [of] *the organizations responding to the survey*."

• *Science and Aeronautics Workforce*

NASA conducts a broad portfolio of aeronautics and space and Earth science programs that will require a workforce pipeline with the skills and capabilities to implement those programs. Several National Research Council reports and assessments focused on NASA's science and aeronautics programs have commented on the need for a skilled workforce related to those areas. A sample of the findings and recommendations of those reviews include:

- *"Recommendation: To ensure that the NASA aeronautics program has and will continue to have an adequate supply of trained employees, the Aeronautics Research Mission Directorate* [ARMD] *should develop a vision describing the role of its research staff as well as a comprehensive, centralized strategic plan for workforce integration and implementation specific to ARMD. The plan should be based on an ARMD-wide survey of staffing requirements by skill level, coupled with an availability analysis of NASA civil servants to support the NASA aeronautics program. The plan should identify specific gaps and the time frame in which they should be addressed."* NRC, *NASA Aeronautics Research: An Assessment,* 2008.
- *"A successful Earth information system should be planned and implemented around long-term strategies that encompass the life cycle from research to operations to applications. The strategy must include nurturing an effective workforce, informing the public, sharing in the development of a robust professional community, . . . and much more."* NRC, *Earth Science and Applications from Space,* 2007.
- Finding. *"Due to reductions in the scope of NASA's Radiation Protection Plan, the current pool of intellectual capital will shrink as researchers retire and are not replaced."*
  Recommendation: *"NASA should try, perhaps as part of an interagency effort, to attract and engage young researchers and the broader radiation community at a level sufficient to supply the demands for radiation protection of astronauts in lunar mission operations and martian mission planning."* NRC, *Managing Space Radiation Risk in the New Era of Space Exploration,* 2008.
- *"Recommendation. The Exploration Systems Mission Directorate should implement cooperative research programs that support the Exploration Technology Development Program (ETDP) mission with qualified university, industry, or national laboratory researchers, particularly in low-technology-readiness-level projects. These programs should both support the ETDP mission and develop a pipeline of qualified and inspired future NASA personnel to ensure the long-term sustainability of U.S. leadership in space exploration."* NRC, *A Constrained Space Exploration Technology Program,* 2008.

The strength of the scientific and technical base, including for space and Earth science, has also been recognized as a critical aspect of the nation's economic engine, and its competitiveness and innovation infrastructure.

> *"The visible products of research . . . are made possible by a large enterprise mostly hidden from public view—fundamental and applied research, an intensively trained workforce, and a national infrastructure that provides risk capital to support the nation's science and engineering innovation enterprise. All that activity, and its sustaining public support, fuels the steady flow of knowledge and provides the mechanism for converting information into the products and services that create jobs and improve the quality of modern life. Maintaining that vast and complex enterprise during an age of competition and globalization is challenging, but it is essential to the future of the United States."* The National Academies, *Rising Above the Gathering Storm,* 2007.

• *Diversity*

The number of women and under-represented minorities involved in the U.S. aerospace workforce is not changing, according to recent studies. The *Aviation Week 2009 Workforce Study* notes that "*As in past years and despite significant effort, there has been no measurable change in the participation of women and under-represented minorities in the technical workforce for A&D*." The report also states that "*Under-represented minorities are defined as non Anglo or Asian American, as self-*

identified by members of the workforce. Women continue to make up 12% of the engineering workforce and under-represented minorities 18% of the job function. There has been no change in either in the past three years, despite hiring and retention efforts by participating companies."

According to the *Report of the Interagency Aeropsace Revitalization Task Force*, February 2008, "*A 2007 Aviation Week survey notes that while women comprise 26 percent of the aerospace workforce, they only comprise 10 percent of engineers and 17 percent of program managers. Meanwhile, minorities comprise 25 percent of the aerospace workforce, but only constitute 18 percent of engineers and 10 percent of program managers*."

Workforce and Industrial Base Issues Related to Human Spaceflight

• *Workforce Issues and the Constellation Program*

The NASA Authorization Acts of 2005 and 2008 authorized a national human and robotic exploration initiative, including the development of a new human space transportation system and a return of Americans to the Moon as a stepping stone to the exploration of other destinations in the solar system.

In addition, NASA studied and analyzed various architectures, requirements, and implementation approaches based on the Vision for Space Exploration articulated by President Bush in 2004. In 2005 NASA issued the Final Report of NASA's Exploration Systems Architecture Study (ESAS) and recommended an architecture that is now being developed as NASA's Constellation Program. In terms of workforce, the ESAS report states that "*The Shuttle-derived approach provides a relatively smooth transition of existing facilities and workforce to ensure lower schedule, cost, and programmatic risk*." Thus, the implications for the workforce were considered at the outset of planning for a future human spaceflight system.

In addition to easing the transition of the current workforce from the Space Shuttle program to the development of the next human spaceflight system, NASA also needs to ensure that the necessary technical skills will be in place to support a long-term human spaceflight and exploration program. The NRC's *Building a Better NASA Workforce* report studied the workforce needs that would have to be met to implement the exploration initiative and found that "*the agency now has a relatively low number of younger workers to assume future leadership roles in NASA as older workers retire. If it does nothing to achieve a better age distribution across its overall internal workforce, NASA will suffer a gap not only in technical leadership, but also in overall technical experience, especially if the development dates for key VSE* [Vision for Space Exploration] *components slip and highly skilled workers with experience in the Space Shuttle program retire*."

The NRC report also found that "*There is a longstanding, widely recognized requirement for more highly skilled program/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).*

Finally, workforce challenges in the Constellation Program are exacerbated by the funding instability that the program has encountered. As Dr. Kenneth Ford, chair of the NASA Advisory Council, testified to the Space and Aeronautics Subcommittee on June 18th of this year:

> *"When a program such as Constellation has to re-plan, due to significant budget cuts, it means that schedules are shifted and contracts must be changed and renegotiated to a new baseline, inevitably at higher cost. The schedule delays also impact the ability to retain the highly skilled workforce currently working in support of the Shuttle and ISS systems. As the schedule slips, workers are first impacted in the hardware manufacturing facilities, and then as launch and orbit operations are delayed, workers are impacted in launch processing and operations. These workers have unique skills, and it is important to retain much of this workforce for the new systems. This unstable funding scenario is reminiscent of the instability in the Space Station Freedom yearly budgets in the late '80s and early '90s that resulted in annual re-planning, cost overruns, and delays. Largescale engineering development programs and the associated contracts cannot be stopped and started without the inefficiency of replanning, loss of critical skills, additional significant costs, and loss of schedule. I hope that this is a 'lesson learned,' and that it will not have to be* relearned *at great cost. The current budget environment is jeopardizing the future of U.S. human space*

flight at a time when NASA has made significant progress toward development of the new Space Transportation Architecture."

- *Workforce Issues and Transition from Shuttle to Constellation*

NASA's currently operating human space flight programs include the Space Shuttle and the International Space Station (ISS) programs. It should be noted that some of the Shuttle and ISS workforce also contribute to the Constellation Program, which includes the Ares I launch vehicle and the Orion crew exploration vehicle, among other development activities. NASA's estimates of the Shuttle and Constellation workforce are presented as a combined number in the NASA Space Shuttle Workforce Transition Strategy of July 2009, which NASA prepared and updates pursuant to the FY 2008 Consolidated Appropriations Act (P.L. 110–161).

NASA has taken several steps to prepare for the transition from the Space Shuttle to follow-on systems while also assessing the key skills needed for the human space flight program. The NASA Space Shuttle Workforce Transition Strategy also reports on actions that NASA has taken regarding the workforce transition. The March 2008 NASA Workforce Transition Strategy Initial Report, Space Shuttle and Constellation Workforce, states that "*NASA has made a concerted effort to share civil servant and contractor workforce across the programs (especially between Space Shuttle, ISS, and Constellation). This workforce synergy enables the Constellation Program to make steady progress towards its development and operational goals while ensuring the continuing availability of the critical skills necessary to safely and efficiently execute the remaining Space Shuttle Missions.*" In addition, as described in the July 2009 Transition Strategy update, NASA has worked with Federal, state, and local organizations, including in Florida, to share information related to retaining the technical workforce needed to implement the exploration initiative; established a Space Shuttle Transition Liaison Office; completed Phase III of a NASA Workforce Skills Mapping activity and awarded contracts for mission operations services that provide the workforce with opportunities following the retirement of the Shuttle; among other actions.

Some of the abovementioned NASA actions regarding workforce transition are also discussed in the Aerospace Skills Retention and Investment Reutilization Report, which was prepared pursuant to Section 614 of the NASA Authorization Act of 2008 (P.L. 110–422) and the Explanatory Statement accompanying FY 2009 Omnibus Appropriations Act (P.L. 111–8), and was transmitted in July 2009. According to the report, NASA is providing assistance to Shuttle workers with career development plans following the planned retirement of the Shuttle. The agency has conducted a series of workforce mapping processes "*to understand how people will migrate from Shuttle to Constellation and other NASA programs*" and is working with industry contractors on mapping of contractor workforce skills and levels. The Constellation workforce size and skills, the report notes, will depend on the program's requirements. "*NASA believes that the highly skilled, experienced, and dedicated human spaceflight workforce of the Space Shuttle and ISS programs will be employed by successful bidders for future Constellation development work, but the geographic distribution and quantity of each type of work continues to be determined as NASA competes and selects contractors to design and develop Constellation systems. As Constellation contractors further define their vehicles through successful design reviews, suppliers and vendors will be selected, and the opportunities for maintaining continuity of critical workforce experience will become clear.*" What the report does not discuss in detail, but what is critically important, is that the ability to transition the Shuttle workforce and ISS development workforce to the Constellation program is predicated on an adequately funded and sustained human space flight and exploration program.

In its Annual Report for 2008, the Congressionally-charted Aerospace Safety Advisory Panel (ASAP) refers to workforce development and sustainment in the transition from the Space Shuttle to Constellation program. Specifically, the report states:

> *"**1. Workforce Transition Planning**. NASA currently is managing the transition from the Space Shuttle program to the new flagship Constellation program as well as continuing the development of specific science missions. The ASAP has several observations.*
>
> - *The morale of Shuttle personnel is still high and represents a fundamental and professional dedication to crew safety and mission assurance.*
> - *The Constellation program is implementing a workforce strategy that includes an integrated design process, development of needed workforce skill sets, an inclusive team approach, and knowledge transfer from one generation of scientists, engineers, and managers to the next.*

- *NASA still must develop an Agency-wide personnel skills matrix to identify missing skill sets and to match needed skills with available personnel, including transferring or relocating Center and program personnel from declining-demand projects to new or expanding projects.*

2. Workforce Retention and Development*. Both the ASAP and the Agency recognize that the aging of the NASA workforce requires not only retention of experienced Shuttle engineers and leaders with Apollo expertise, but also the recruitment and task-specific training of the next generation.*

- ***Retention of Key Technical, Engineering, and Management Leaders****. ASAP concerns include (1) retention of experienced personnel for late-stage programs; (2) unique local workforce retention issues, such as post-Katrina housing expenses or a large influx of new Department of Defense Base Realignment and Closure (BRAC) positions (e.g., at Marshall Space Flight Center and the U.S. Army Redstone Arsenal); and (3) the need for the Office of Personnel Management to approve reemployment of retired Federal civil service annuitants without financial penalty to better enable NASA to retain needed expertise.*
- ***Educational Outreach****. The ASAP suggests that NASA continue focusing on its well developed Cooperative Education (Co-op) program, but expand its reach and also recruit experienced candidates from industry or academia."*

The Government Accountability Office (GAO) commented on the funding for Constellation and implications for the workforce. In its August 2009 report, *Constellation Program Cost and Schedule Will Remain Uncertain Until a Strong Business Case is Established*, GAO noted that, "*a poorly phased funding plan that runs the risk offending shortfalls in fiscal years 2009 through 2012, resulting in planned work not being completed to support schedules and milestones. This approach has limited NASA's ability to mitigate technical risks early in development and precludes the orderly ramp up of workforce and developmental activities*."

- *Impact of "the Gap" on the Workforce and Knowledge Base*

The nation previously experienced a gap in human spaceflight systems following the end of the Apollo program and when the Space Shuttle flew for the first time. One of the issues for the hearing is to understand how NASA addressed the Apollo-Shuttle gap and what can be learned from that experience.

One recurring theme regarding the Shuttle-Constellation gap is the issue of retaining knowledge and skills. The Review of U.S. Human Spaceflight Plans Committee's report noted that "*The Committee is concerned about the retention of critical knowledge and skills and the availability of that unique portion of the workforce necessary to conduct the next set of human spaceflight missions—which, as of now, cannot be expected until late in the next decade*."

As mentioned in National Research Council reports and by the Aerospace Commission, and the Review of U.S. Human Spaceflight Plans Committee, systems engineering is one of the critical skills that must be retained and developed in the pipeline. In its report, the Human Spaceflight Plans Committee comments that "*If NASA is to successfully execute the complex undertakings to which it aspires, it must maintain a world-class systems engineering capability, a capability that this and other reviews have deemed to be marginal in its current embodiment*."

- *Potential Alternative Human Spaceflight Architectures and Issues and Implications for the Aerospace Workforce and Industrial Base*

  - Testimony by Mr. Norman Augustine before the Senate Committee on Commerce, Science and Transportation Subcommittee on Science and Space, September 16, 2009

"And unless one makes a major shift in how one conducts business, the overall NASA employment should stay about the same. However, the mix of that employment will certainly change. We'll need different talents. For example, if we terminate the shuttle in 2010 or early 2011, the people who have been focusing on launching shuttles are very different people probably than some that will be needed to build an Ares or Ares I or an Ares V or whatever, a shuttle drive [derived] *vehicle. So there will be changes in skill . . . . The other we looked at are those critical skills that only people at NASA or in the industry are likely to have. Those we think it's very important to preserve. And we need to consciously go out and do that . . .. an example would be the large solid segmented solid rocket motors. It's an art as well as a science to build those things safely. And if we lose that capability it will very hard to get back. Ability to work with*

liquid hydrogen, liquid oxygen—we would like to see us learn how to do that in space as well as here on earth. So those special skills we have to find a way to preserve, for sure."

The Review of U.S. Human Spaceflight Plans Committee Statement of Task specifies that the evaluation parameters for the review should include, "*Implications for transition from current human space flight operations*" and "*Impact on the nation's industrial base and competitiveness internationally*", among several other parameters. To that end, the Committee's presentation of options for human spaceflight plans and architectures included discussion of the workforce. With the Committee's report, consideration of workforce issues is apparent in the analysis of options for potential heavy-lift launch vehicles.

- *Impact of Alternative Launch Vehicles on Workforce*
  - Shuttle Extension
    "Extending the Shuttle would have a beneficial impact on the near-term workforce issues. Some workforce reductions would be indicated by the reduced flight rate proposed, but there would be several years in which to manage these reductions. In 2015, when the Shuttle finally retires, no NASA crew launch system would be available for several more years, and then the problem of maintaining key workforce skills would resurface. If however, the commercial crew option were to be ready by 2016 or so, some national competence in crew launch would be nearly continuous."
  - Ares V (with Ares I) vs. Ares V Lite dual launch
    "Programmatically, the choice of the Ares V (together with Ares I) unquestionably has less impact on current workflow or contracts. However, the. Ares V Lite preserves some of the investment already made for Ares I, and would possibly allow some of the contract structure to stay in place."
  - NASA heritage vs EELV [Evolved Expendable Launch Vehicle]-heritage super-heavy vehicles
    "The EELV-heritage super heavy would represent a new way of doing business for NASA, which would have the benefit of potentially lowering development and operational costs . . . . However, this efficiency of operations would require significant near-term realignment of NASA. Substantial reductions in workforce, facilities closures, and mothballing would be required. When the Committee asked NASA to assess the cost of this process, the estimates ranged from $3 billion to $11 billion over five years . . . . The transition to this way of doing business would come at the cost of cutting deeply into a the internal NASA capability to develop and operate launchers, both in terms of skills and facilities."
  - Ares V versus Shuttle-derived family
    "The Committee viewed the decision between the Ares V family and the Shuttle-derived family as one driven by cost and capability. The development cost of the more Shuttle-derived system would be lower, but it would be less capable than the Ares V family and have higher recurring costs. There are potential workforce and skill advantages associated with the use of the more-directly Shuttle-derived system, but the long gap between when the Shuttle is retired in 2011, or even 2015, and when the Shuttle-derived heavy-lift launcher becomes available in the early to mid-2020s would diminish the potential value of the workforce continuity associated with Shuttle derivatives."

In the Subcommittee on Space and Aeronautics' September 15, 2009 hearing on *Options and Issues for NASA's Human Space Flight Program: Report of "Review of U.S. Human Space Flight Plans" Committee*, Dr. Edward Crawley, a member of the Committee, provided technical commentary in support of testimony by the Committee chair, Mr. Norman Augustine:

> *"And they are the problem is that the—the options—the differing of the options tend to do different things. So, for example, the ones that continue to use the solid rocket boosters like Ares 1 and Ares 5 preserve that aspect of our national capability and workforce skills. Some of the other options tend to preserve other aspects of workforce skills. The—the one piece of—that—that does come through, however, is the options that have some variant or another that—that preserve—that extend the shuttle, or shuttle heritage systems do tend to preserve the workforce capabilities preferentially."*

U.S. Space Industrial Base

The U.S. space industrial base is closely coupled to the aerospace workforce because the capabilities of the industrial base and the business opportunities pursued

by the aerospace industry must be coordinated with and supported by the skills and talent of the U.S. aerospace workforce.

The Aerospace Commission recognized the importance of these elements to U.S. leadership in space: "*Global U.S. aerospace leadership can only be achieved through investments in our future, including our industrial base, workforce, longterm research and national infrastructure*."

The space industrial base includes a diverse set of sectors. One accounting of the various sectors is provided in the *Report of the Interagency Aerospace Revitalization Task Force*, February 2008:

- *"Civil*
- *Air (e.g., air traffic management system, safety regulation, accident investigation, environmental permitting, noise and emission standards)*
- *Space (e.g., weather satellites, air and space-based Earth monitoring, International Space Station, Space Shuttle, Hubble Space Telescope, robotic missions to the planets*
- *Commercial*
- *Air (e.g., aircraft manufacturing, air carriers, general aviation, airport operations)*
- *Space (e.g., space launch, launch vehicles and satellite manufacturing, telecommunications, remote sensing)"*

In addition, a broader range of associated businesses and suppliers support the aerospace industry and also rely on its technical workforce and technologies. It is important to note that for every prime aerospace contractor, there are several subcontractors and suppliers that support aerospace programs.

- *Status of the U.S. Space Industrial Base*

The 2002 report of the Aerospace Commission concluded that "*aerospace capabilities and the supporting defense industrial base are fundamental to U.S. economic and national security. While the nation's defense industrial base is strong today, the nation is at risk in the future if the United States continues to proceed without a policy that supports essential aerospace capabilities*." The Commission recommended several elements of a policy, among them were some that related to the aerospace industrial base:

  - *"Removing barriers to international sales of defense products;*
  - *Sustaining critical technologies that are not likely to be sustained by the commercial sector, e.g. space launch, solid boosters, etc.; and*
  - *Stable funding for core capabilities, without which the best and brightest will not enter the defense industry."*

In 2008, the Center for Strategic and International Studies (CSIS) conducted a study that involved reviewing studies on export controls and the U.S. space industrial base, examining the results of a survey on the U.S. space industrial base that was performed by the Department of Commerce and analyzed by the Air Force Research Laboratory, and assessing the health of the space industrial base and whether export controls are having any adverse impacts, especially on lower-tier contractors. The report, *Briefing of the Working Group on the Health of the U.S. Space Industrial Base and the Impact of Export Controls*, found that:

1. *"Overall financial health of the top tier manufacturers in the space industrial base is "good", but there are areas of concern within the broader health of the industry"*
2. *"As earlier studies have documented, the ability of the government and industry to meet program execution commitments remains inadequate", and*
3. *"The space industrial base is largely dependent on U.S. defense/national security budgets".*

- *Critical Space Industrial Base Space Capabilities*

The Aerospace Commission comments on the need to "*maintain and enhance critical national infrastructure*." As stated in the Commission's report, "*The federal government must assume responsibility for sustaining, modernizing, and providing critical, often high-risk, defense related technologies and infrastructure when it is in the nation's interest. This includes critical design capabilities, solid rocket boosters, radiation hardening, space launch facilities, critical research, development, test and evaluation (RDT&E) infrastructure, Global Positioning System (GPS), and frequency spectrum*."

The report of the Review of U.S. Human Spaceflight Plans Committee also notes the importance of the industrial base and workforce for solid-rocket motors: "*Special attention needs to be devoted to assuring the vitality of those portions of the workforce that represent critical and perishable skills that are unique to the space program. One example is the design and manufacturing of very large, solid-propellant motors*."

The production of solid rocket motors has been a critical element of the space industrial base that supports the Space Shuttle program; however the Department of Defense has counted on that industrial base for its programs, such as the Navy's Trident D–5 missile program. One issue for the hearing is what are the full ramifications of decisions on human spaceflight for associated defense and national security programs that use the same industrial base? In addition, what are the implications for other Federal government users of that industrial base if NASA's human spaceflight plans no longer require the capabilities that have established elements of the space industrial base, and would other agencies be willing to carry that industrial base to support their programs?

• *Health of Lower-Tier Suppliers*

According to the CSIS report, the space industry over the last decade has been fraught with "*high volatility, high risk, market bubbles and financial losses*". The industry is recovering from that period, especially in the national security space sector, and although the space manufacturers are experiencing improved financial health, "*margins remain thin and below the average for the general aerospace/defense industry particularly the 2nd and 3rd tier*", according to the report. The 2nd and 3rd tier of the industry is also weak in depth. In some areas there might be "*only one domestic supplier*" or a "*financially weak supplier*". The health of these lower-tiers is important to monitor, because the 2nd and 3rd tier of the industry are an important source of innovation.

• *Dependence of Space Industrial Base on Defense*

Overall, the CSIS report states that the dependence of the U.S. space industrial base on the U.S. defense/national security budgets "*implies that the national security community 'owns' the U.S. space industrial base, and must either provide for the health of the industry ('arsenal strategy') or encourage it (and enable it) to participate more in the global market place to broaden its economic base*".

• *Export Controls*

The CSIS report discusses several factors that affect the health of the U.S. space industrial base, including the rapid pace of growing space capabilities in foreign nations and the ability of foreign companies to compete in the global marketplace, a situation that U.S. export control policies may have encouraged. The report found that "*Export controls are adversely affecting U.S. companies' ability to compete for foreign space business—particularly the 2nd and 3rd tier*."

A January 2009 Special Report of the Aerospace Industries Association, *The Role of Space in Addressing America's National Priorities*, echoes the CSIS findings, especially the influence of export control policies on the industrial base. In addition, the report states that: "*Many U.S. companies, particularly second- and third-tier suppliers, increasingly rely exclusively on sales to the U.S. government or are considering exiting the space business altogether. Absent a healthy, cutting edge, U.S. space industrial base, our government could be forced to rely on foreign suppliers for key components*."

• *Coordination for Space Industrial Base*

The importance of the industrial base for the nation's future in space was also raised in the NRC's 2009 report, *America's Future in Space: Aligning the Civil Space Program With National Needs*. The report recommends that the President task senior executive-branch officials to coordinate space-related budgetary, policy, infrastructure and other issues across Federal agencies, including "*responsibility and accountability for stimulating, nurturing, and sustaining a robust space industrial base, including the commercial space industry*."

• *Human Spaceflight*

The report of the Review of U.S. Human Spaceflight Plans Committee discussed potential alternatives for a human spaceflight architecture to transport humans to low-Earth orbit and to destinations beyond low-Earth orbit. In considering those potential alternatives, especially for a heavy-lift launch vehicle that would be needed for human exploration beyond low-Earth orbit, the Committee discussed some of the potential implications for the industrial base. A sample of those comments include:

- *"If a decision is made to human-rate the EELV systems and NASA were to abandon the Ares I system but retain the Ares V heavy-launch capability, the solid rocket motor industrial base would need to be sustained until the Ares V generated demand. The DoD may have to consider support to the solid rocket motor industrial base in recognition of both civil and NSS needs. If both the Ares I and Ares V programs were abandoned, a detailed civil and military analysis would need to be accomplished to ascertain the interdependence of technical and production capabilities between large solid rocket motors that are needed to support the nation's strategic strike arsenals and the large segmented solid-rocket motors supporting human-rated systems for NASA."*
- *"The Committee considered as an issue the commonality with the national space industrial base. The Ares V uses engines from the RS–68 family, with commonality in the industrial base with those used on the EELVs by National Security Space. Both the Ares V and the more-directly Shuttle-derived vehicle have commonality in the solid-rocket motors with vehicles used in National Security Space."*
- *"The Committee viewed the decision between the Ares V family and the Shuttle-derived family as one driven by cost and capability. The development cost of the more Shuttle-derived system would be lower, but it would be less capable than the Ares V family and have higher recurring costs. There are potential workforce and skill advantages associated with the use of the more-directly Shuttle-derived system, but the long gap between when the Shuttle is retired in 2011, or even 2015, and when the Shuttle-derived heavy-lift launcher becomes available in the early to mid-2020s would diminish the potential value of the workforce continuity associated with Shuttle derivatives."*

Chairman GORDON. Indulge us for about three or four minutes. We have some business to take care of.

On November the 19th, Mr. John Garamendi from California was appointed to fill the final vacancy on this Committee. Mr. Garamendi was most recently the Lieutenant Governor of California and I am sure will be a great contributor to the Committee as we move forward. So we all want to welcome him.

This past week, Mr. Lipinski and Ms. Edwards graciously resigned their seats on the Technology and Innovation and Energy and Environment Subcommittees to make room for Mr. Garamendi. Members should have an updated subcommittee roster in front of them reflecting the addition of Mr. Garamendi to those subcommittees.

And at this time, I would ask unanimous consent that the Committee approve the rosters. All in favor say aye. Opposed?

Before we conclude this, let me just give you a little overview of John Garamendi. He has really 34 years' public service before he comes to us in the House of Representatives. He started off not like me but like many of you in the state legislature. In 1974, he was elected to the Tennessee General Assembly, and in 1976, he was elected to the State Senate, later becoming the Senate Majority Leader and while there, among other things, he chaired the Joint Committee on Science Technology. And Ralph, I am afraid you and I are the only ones—this is sort of scary—but that person with the sweater on back there, Mr. George Brown, we are the only ones that remember him I am afraid, that are still members.

Mr. HALL. I remember Tiger T.

Chairman GORDON. Well, you remember Herbert Hoover, too. So interestingly, John served with George Brown in the California State Legislature on their Science and Technology Committee and worked together in a lot of areas. Later John was the State Insurance Commissioner from 1991 to 1995, and then in 1995, President Clinton appointed him to be the Undersecretary of Interior where he served in 1998. Then he went back to California, was reelected the Insurance Commissioner and most recently was Lieutenant Governor. As you can see, he has had a hard time holding onto a job, and we hope we will have him here a little bit longer.

But interestingly, he is not the only public servant in their family. He and his wife married and then went into the Peace Corps, and Mrs. Garamendi, for eight years, was in the Clinton Administration as the Assistant Director of the U.S. Peace Corps, and she continues her public service as the Deputy Secretary of California, Business, Transportation and Housing Agency, and is now the Assistant Manager at the California Exposition and State Fair. And as most all of us here know that serving in Congress is a team sport and that John, we are glad that you have a good teammate with you.

And so with that, we will now begin the hearing, and the Chair will yield to our very able Chair of the Aviation and Space Subcommittee. And let me thank you, Gabrielle, and your staff for really the good work that you have been doing reviewing NASA in so many ways here. So I will yield to you for an opening statement.

Ms. GIFFORDS. Thank you, Mr. Chairman, and to members of the Committee. First of all, I would like to——

Chairman GORDON. Gabrielle, I am sorry, if you don't mind. John, would you like to say anything before we yield to Gabrielle?

Mr. GARAMENDI. Yes. Thank you for the privilege of serving on the Committee, and I look forward to working with all of the members of this Committee on the issues that are terribly important to this entire Nation, and in fact, the entire earth on which we live. Thank you for the privilege.

Chairman GORDON. Gabrielle, I yield again.

Ms. GIFFORDS. Thank you, Mr. Chairman. And again, I would like to welcome our panelists for being here today. Thank you so much. I know that we have had 69 hearings so far this year. This is the last of our Subcommittee, and it is really a testament to the hard work of our staff for being able to make sure that we are able to provide such quality information to the United States Congress and to the American people.

This hearing is the latest in a series that the Committee and the Space and Aeronautics Subcommittee have convened over the past several months on the critical factors that both the Administration and the Congress will need to consider when we make our decisions on the future direction and funding for NASA and in particular for NASA's human space flight and exploration activities.

We decided to hold those hearings, including last week's hearing on human space flight safety, because it is so important for the White House and for Congress to understand truly what is at stake. I personally believe that a great deal is at stake, not just in the near term, but certainly for decades to come. And I believe that we need to keep the long-term perspective front and center when we look at the potential impact on the workforce and the space industrial base on pending decisions for NASA's future. Because it is not just a question of jobs, although each and every one of us who serves in the Congress and are responsive to our constituents, know that jobs are vitally important, but it is truly the quality of jobs that we need to be paying attention to as well.

As we will hear today, aerospace jobs are high-paying, they are high-quality jobs, jobs that will enable us to compete and to lead in the 21st century, using those skills that we know have been so critical and vital to building the robust economy that has produced the Nation as a true international leader. These are jobs that we would like to have more of, and they are certainly the kind of jobs that we don't want to see go away, and this is already happening across the country and I think we will hear that from our witnesses today.

Finally, these are the kinds of jobs that can excite and inspire our young people to pursue careers in science and engineering, something that this Nation needs to have happen. Yet if those jobs go away, even for awhile, it can be very, very difficult to get back these jobs. It is really the health of the workforce and of the space industrial base which is so important.

So let me just make sure all members know that contracts with the commercial sector account for more than 80 percent of NASA's budget. Those contracts encompass work done by large established aerospace firms, and we are going to hear from some of those folks today, but also work done by emerging companies that offer the promise of new capabilities to meet the agency's needs and prod-

ucts and services provided to NASA by non-aerospace companies both large and small. Given that, it is clear that support for NASA is also support for this commercial sector and for the jobs that the sector creates and the innovations that make it possible.

The President and this Congress thus have serious decisions to make in the coming weeks and the coming months. We need to decide whether we as a Nation are finally going to provide the resources NASA needs to carry out the important missions the Nation has given it or not. We need to decide whether we are going to maintain our commitment to a robust program of exploration involving humans and robots to use the words of the fiscal year 2010 NASA budget request, a program that successive Congresses have authorized and funded or not.

And if the President would recommend some manner of course change, we collectively would need to figure out how to make any such change in a way that protects the American taxpayers' dollars, preserves crew safety and maintains America's position as the world leader in space.

Make no mistake about it. The decisions we collectively make about the future of our space program will have a lasting impact on our workforce, our industrial base, and our standing in the world.

Several of our witnesses today are going to discuss the investments in our space program, or conversely, cutbacks in our space investments and the ripple effect that it will have on both large companies and small companies as well.

Mr. Chairman, I also serve on the Armed Services Committee where we have healthy discussions about what these workforce impacts will mean to the defense of our Nation, the protection of our country and of course, to our industrial base as well.

Just in closing, you know, oftentimes it is a little bit cliché I guess. We look at the quote behind you, the Proverb, "Where there is no vision, the people perish." This is profound, and it is something that we as Members of Congress know is very important but also for the President of the United States to have that clear vision of the future.

And with that, Mr. Chairman, I yield back.

[The prepared statement of Ms. Giffords follows:]

PREPARED STATEMENT OF CHAIRWOMAN GABRIELLE GIFFORDS

Thank you for yielding time to me, Mr. Chairman. I would like to start by welcoming our witnesses to this morning's hearing. This hearing is the latest in a series that the Committee and the Space and Aeronautics Subcommittee have convened over the past several months on the critical factors that the Administration and Congress will need to consider when we make our decisions on the future direction and funding for NASA, and in particular for NASA's human space flight and exploration activities.

We decided to hold those hearings, including last week's hearing on human space flight safety, because it is important for Congress—and the White House—to understand what is at stake. I personally believe that a great deal is at stake—not just in the near-term, but for decades to come. And I believe that we need to keep that long-term perspective front and center when we look at the potential impact on the workforce and the space industrial base of pending decisions on NASA's future. Because it's not just a question of the number of jobs, although our witnesses will testify that tens of thousands of jobs will be impacted by those decisions, it's also the quality of the jobs that should be a significant consideration.

As we will hear today, aerospace jobs are high-paying, high-skilled jobs—jobs that will enable us to compete . . . and lead . . . in the 21st century, not just in space

but back here on Earth too. They are the jobs that we would like to have more of, and they are certainly the kind of jobs that we don't want to see go away, as is already happening across the country. Finally, they are the jobs that can excite and inspire our young people to pursue careers in science and engineering, something that this nation needs to have happen. Yet if those jobs go away, even for awhile, it can be very difficult to get the best of those young people back. So the health of the workforce and of the space industrial base is important, because the commercial sector is critical to the success of NASA's missions.

Contracts with the commercial sector account for more than 80 percent of NASA's budget. Those contracts encompass work done by large established aerospace firms, work done by emerging companies that offer the promise of new capabilities to meet the agency's needs, and products and services provided to NASA by non-aerospace companies both large and small. Given that, it is clear that support for NASA is also support for the commercial sector and for the jobs that sector creates and the innovations that it makes possible.

The president and this Congress thus have serious decisions to make in the coming weeks and months. We need to decide whether we as a nation are finally going to provide the resources NASA needs to carry out the important missions the nation has given it . . . or not. We need to decide whether we are going to maintain our commitment to a "robust program of exploration involving humans and robots" to use the words of the FY 2010 NASA budget request—a program that successive Congresses have authorized and funded . . . or not.

And if the president would recommend some manner of course change, we collectively would need to figure out how to make any such change in way that protects the American taxpayers' money, preserves crew safety and maintains America's position as the world leader in space.

Make no mistake about it. The decisions we collectively make about the future of our space program will have a lasting impact on our workforce, our industrial base, and our standing in the world. As a result, I want our witnesses to give us their views on what we need to consider when making those decisions so that the outcome will inspire our best and brightest to pursue careers in aerospace—careers that will be vital to our future competitiveness, national security, and quality of life. And I hope that they will also share their views on which outcome is going to best help maintain and strengthen critical skills and capabilities this nation will need if it is to remain a leader in space activities. I ask because I worry that if we make the wrong decisions and waver in our commitment, we will not be keeping faith with that generation of young people we are seeking to inspire.

As today's hearing will make clear, the decisions we will be making will also have a profound impact on the future health of our space industrial base. Several of our witnesses will discuss the ways in which investments in our space program—or conversely, cutbacks in our space investments—have a ripple effect on the health of an array of businesses, both large and small, that are scattered across the nation. Those impacts extend beyond the business community focused on civil space to include impacts on the continued viability of suppliers of capabilities critical to our national security.

As someone who also serves on the Armed Services Committee, I am keenly sensitive to the need not to take actions with our civil space program that could have an adverse impact on the industrial base that also supports our national security.

I thus would like our witnesses to give us their views on the weight we should give to space industrial base concerns as we decide whether to support and fund a meaningful exploration program at NASA or not. You know, it's become almost a cliche to quote the saying carved on the wall behind us: "Where there is no vision, the people perish." However, we quote it because it contains a profound truth. Thus, as the president and Congress consider NASA's future, we need to see the potential impacts of our decisions as clearly as possible.

This hearing and the ones that have preceded it are all aimed at giving this Congress—and hopefully the Administration too—the clarity of vision that we will need to make informed choices about the future of America's space program and its human space flight activities. Each of you who are testifying here today has an important role to play in that effort, and I look forward to your testimony.

With that, I yield back the balance of my time.

Chairman GORDON. Thank you, Ms. Giffords. You know, I think just like Humpty Dumpty, if we lost this NASA workforce, it would be very difficult, if not impossible, to put back together. They have unique skills, unique institutional knowledge and so I compliment you on having this very important hearing.

I now recognize Mr. Hall for an opening statement.

Mr. HALL. Mr. Chairman, in the interest of time, I will waive my opening statement. If I run across one my group has prepared for me, I will send it to you. Thanks.

Chairman GORDON. Thank you, Mr. Hall. Your brevity is always appreciated.

If there are other members that would wish to make opening statements, your statements will be added to the record.

And at this time, I would like to yield the gavel to our gentlelady from Arizona to conduct her hearing.

Excuse me, Mr. Olson. If you have an opening statement, we would welcome that. Certainly being in the heart of the NASA workforce, I am sure that again you have unique knowledge there.

Mr. OLSON. Well, thank you, Mr. Chairman. I have a brief opening statement, and I appreciate your recognition, and thank you for calling this morning's hearing.

The decisions we make on the future direction and funding of NASA is a topic of tremendous importance to our Nation. The state of the economy and jobs have been at the forefront of this Congress since we convened in January. Attempts to stem the tide of rising double-digit unemployment have not worked, and against this backdrop, we are facing decisions about NASA which will have a profound affect not only on jobs but also on the critical knowledge, skills and production capabilities needed to maintain our aerospace and defense capabilities into the 21st century. This sector of our economy employs over 260,000 men and women and accounts for about 60 percent of our total exports.

I would like to thank our witnesses for appearing here today. I realize that each of you has spent a considerable time and effort preparing for this hearing, and I look forward to hearing from you so that our Subcommittee can have the value of your expertise.

Today we focus on the impact of NASA's funding levels on the current workforce which I am particularly interested in but also on the enormous scope of the challenge facing the aerospace industry as a whole. There are many issues: A workforce approaching retirement without the opportunity to teach the next generation of scientists, engineers, technicians and program managers; a highly skilled contractor force at risk of losing their jobs as a result of the human spaceflight gap; number three, decreased opportunities for future engineers and scientists which will reduce interest in the critical STEM education fields. In a perverse way, that could only come from Washington.

We are concerned about a shortage of engineers and scientists. We are concerned about attracting young, high-quality students to the aerospace field. We are concerned about America losing important strategic manufacturing capabilities, and yet, we are pursuing policies that in many ways may be exacerbating these very problems.

And the debate about job creation, the intent was to create high-quality jobs that paid good wages and reward important skills. Those are the very jobs that are the norm in the aerospace industry.

The automotive industry has been decimated. In last week's Aviation Week included an article about how the automotive indus-

try is looking toward aerospace for their displaced manufacturing technical workforce. We cannot, cannot, let a similar fate befall our aerospace industries, the industries we depend on for our national defense are simply too important to lose.

The decisions we are making in Washington have effects far beyond the obvious. I have stated repeatedly that we must continue to stay the course with the Constellation program and not just because of the significant job loss that would follow were we to cancel it. Stopping and starting a major program is not how you develop a technical workforce, attract workers, inspire engineers or stabilize a local or national economy.

Companies and communities are watching us, but so, too, are impressionable young students who may go into science and engineering fields. And if I may digress for just a minute, I would like to tell one story from the campaign trail, knocking on doors in the Clear Lake area where I grew up.

I knocked on the door, no one answered, left my literature, moved down the street, got a good two to three blocks down the street and a young man chased me down—it was pretty early in the morning—to talk. He is not very presentable, looks like he was in some boxer shorts, a robe, some flip-flops, but he was a young man who worked at Johnson Space Center and very concerned about the future of human space flight. And what I remember about him is, you know, this young engineer, he was actually taking care of his young daughter, very typical of the people we want to attract to the aerospace industry as employees. This young man had grown up wanting to be part of the next effort to put human beings back on the moon. He was inspired by what the aerospace industry, what NASA had done in the past. We can't forget that. If we aren't willing to commit to aerospace, why should he or why should someone like him?

I yield back my time, Madam Chairwoman.

[The prepared statement of Mr. Olson follows:]

PREPARED STATEMENT OF REPRESENTATIVE PETE OLSON

Madam Chairwoman, thank you for calling this morning's hearing. The decisions we make on the future direction and funding of NASA is a topic of tremendous importance to our nation. The state of the economy and jobs have been at the forefront of this Congress since we convened in January. Attempts to stem the tide of rising double digit unemployment have not worked. Against this backdrop of rising unemployment, we are facing decisions about NASA which will have a profound effect on not only jobs, but also on the critical knowledge, skills, and production capacities needed to maintain our Aerospace and Defense capabilities and compete in the 21st century. This sector of our economy employs over 262,000 men and women and accounts for about 60 percent of our total exports.

I'd like to thank our witnesses for their appearance today. I realize that each of you has spent considerable time and effort preparing for this hearing, and I look forward to hearing from you so that our subcommittee can benefit from your expertise.

Today we will focus on the impact of NASA's funding levels on the current workforce, which I am particularly interested in, but also on the enormous scope of the challenge facing the aerospace industry as a whole. There are many issues including: 1) a workforce approaching retirement without the opportunity to teach the next generational of scientists, engineers, technicians and program manager, the valuable lessons learned through years of experience, 2) a highly skilled contractor workforce at risk of losing their jobs as a result of the human space flight gap, 3) decreased opportunities for future engineers and scientists which by definition can and will reduce interest in the critical STEM education fields.

In a perverse way that could only come from Washington, we are concerned about a shortage of engineers and scientists. We are concerned about America losing important strategic manufacturing capabilities. We are concerned about attracting and retaining young, high quality students to the Aerospace field. Yet we are pursuing policies that in many ways may be exacerbating these very problems. In the debate about job creation, the intent was to create high quality jobs that pay good wages and that reward important skills. Those are the very jobs that are the norm in the aerospace industry. The automotive industry has been decimated. Last week's *Aviation Week* included an article about how the automotive industry is looking toward aerospace for their displaced manufacturing and technical workforce. We cannot let a similar fate befall our aerospace industries. The industries we depend on for our national defense are simply too important to lose.

The decisions we are making in Washington have affects far beyond the obvious. I have stated repeatedly that we must continue to stay the course with the Constellation program, and not just because of the significant job loss that would follow were we to cancel it. Stopping and starting a major program is not how you develop a technical workforce, attract workers, inspire future engineers, or stabilize a local and national economy.

Companies and communities are watching us, but so too are impressionable students who may go into science and engineering fields. If we aren't willing to commit to aerospace, why should they?

Thank you, Madam Chairwoman. I yield back by time.

Ms. GIFFORDS. [Presiding] Thank you, Mr. Olson.

We have a distinguished panel of witnesses appearing before us today, and I would like to introduce them at this time.

First up we have Mr. David Thompson who is President of the American Institute of Aeronautics and Astronautics. He will discuss key trends and issues in the aerospace workforce and the industrial base from the perspective of a major aerospace professional society, and he is also President and CEO of Orbital. Welcome, Mr. Thompson.

I am very pleased that today we have with us Ms. Marion Blakey who is President and Chief Executive Officer of the Aerospace Industries Association. She will provide the Subcommittee information on the industry perspective on key issues for the U.S. aerospace workforce and the industrial base, and we are very glad to have you this morning.

Mr. A. Thomas Young, who is Executive Vice President of Lockheed Martin Corporation. Mr. Young is retired now, but he will provide perspective based on his extensive industry and government experience in leading major space projects. Welcome, Mr. Young.

And finally, Mr. Richard Aubrecht who is Vice Chairman, Vice President of Strategy and Technology at Moog, Incorporated, and he will provide the Subcommittee his perspective of an aerospace supplier company.

Welcome all. As our witnesses should know, you will each have five minutes for your spoken testimony. Your written testimony will be included in the record for the hearing, and when you have completed your spoken testimony, we will begin with questions. And each member will have five minutes to answer and get responses to their questions, and we hope to have a healthy discussion today.

So I would like to begin the discussion with Mr. Thompson.

STATEMENT OF DAVID THOMPSON, PRESIDENT, AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

Mr. THOMPSON. Thank you. Chairwoman Giffords, Chairman Gordon, Ranking Member Hall, and distinguished members of the Committee and Subcommittee, I would like to thank you for the opportunity to address several topics of great importance to the U.S. aerospace sector and to the Nation as a whole.

As President of the American Institute of Aeronautics and Astronautics for the 2009–2010 year, I am proud to represent a constituency of more than 36,000 aerospace, engineers, scientists and other professionals as well as thousands of aerospace students from all 50 states and many overseas locations. Indeed, for nearly 80 years, AIAA has been the principal professional society for aerospace engineers and scientists in America and around the world.

On behalf of AIAA, I would like to express our appreciation to this Committee to its leadership and space and aeronautics policy and for its interest in the aerospace workforce and industrial base.

I am pleased to respond to the three questions that you have asked relating to the effects of NASA's direction and funding on the country's aerospace sector.

Your first question asked about most significant concerns regarding the aerospace workforce and industrial base. AIAA's response to this question is as follows.

Aerospace systems are of considerable importance to U.S. national security, economic prosperity, technological vitality, and global leadership. Aeronautical and space systems protect our citizens, armed forces, and allies abroad. They connect the fartherest corners of the world with safe and efficient air transportation and satellite communications, and they mentor the earth, explore the solar system and study the wider universe.

The U.S. aerospace sector also contributes in major ways to America's economic output and high technology employment. Aerospace research and development and manufacturing companies generated approximately $250 billion in sales in 2008 or nearly 1.75 percent of our country's Gross National Product. They currently employ about 650,000 people throughout our country. U.S. Government agencies and departments engaged in aerospace research and operations add another 125,000 employees to this sector's workforce, bringing the total to over 775,000 people. Included in this number are more than 200,000 engineers and scientists, one of the largest concentrations of technical brain power on earth.

However, the U.S. aerospace workforce is now facing the most serious demographic challenge in its 100-year history. Simply put, today, many more older, experienced professionals are retiring from or otherwise leaving our industrial and governmental aerospace workforce than early career professionals are entering it. This imbalance is expected to become even more severe over the next five years as the final members of the Apollo-era generation of engineers and scientists complete 40- or 45-year careers and transition to well-deserved retirements. In fact, around 50 percent of the current aerospace workforce will be eligible for retirement within just the next five years.

Meanwhile, the supply of younger aerospace engineers and scientists entering the industry is woefully insufficient to replace the

mounting wave of retirements and other departures that we see in the near future. In part, this is the result of broader technical career trends as engineering and science graduates from our country's universities continue, a multi-decade decline even as the demand for their knowledge and skills in aerospace and other industries keeps increasing.

Today only about 15 percent of U.S. students earn their first college degree in engineering or science, well behind the 40 or 50 percent levels seen in many European and Asian countries. Due to the dual-use nature of aerospace technology and the limited supply of visas available to highly qualified, non-U.S. citizens, our industry's ability to hire the best and brightest graduates from overseas is also severely constrained. As a result, unless effective action is taken to reverse current trends, the U.S. aerospace sector is expected to experience a dramatic decrease in its technical workforce over the next decade.

Your second question concerns the implications of a cutback in human spaceflight programs. AIAA's view on this is as follows.

While U.S. human spaceflight programs directly employ somewhat less than ten percent of our country's aerospace workers, its influence on attracting and motivating tomorrow's aerospace professionals is much greater than its immediate employment contribution. For more than 50 years, the excitement and challenge of human spaceflight have been tremendously important factors in the decisions of generations of young people to prepare for and to pursue careers in the aerospace sector. This remains true today as indicated by hundreds of testimonies AIAA members have recorded over the past two years, a few of which I will show in brief video interviews at the end of my statement.

Further evidence of the catalytic role of human space missions is found in a recent study conducted earlier this year by MIT which found that 40 percent of current aerospace engineering undergraduates cited human space programs as the main reason they chose this field of study.

Therefore, I think it can be predicted with high confidence that a major cutback in U.S. human space programs would be substantially detrimental to the future of the aerospace workforce. Such a cutback would put even greater stress on an already weakened strategic sector of our domestic, high-technology workforce.

Your final question centers on other issues that should be considered as decisions are made on funding and direction for NASA, particularly in the human spaceflight area.

In conclusion, AIAA offers the following suggestions in this regard. Beyond the previously noted critical influence on the future supply of aerospace professionals, Administration and Congressional leaders should also consider the collateral damage to the space industrial base if human space programs were substantially curtailed. Due to low annual production rates and highly specialized product requirements, the domestic supply chain for space systems is relatively fragile. Many second- and third-tier suppliers in particular operate at marginal volumes today, so even a small reduction in their business could force some critical suppliers to exit this sector. Human space programs represent around 20 percent of the $47 billion in total U.S. space and missile system sales from

2008. Accordingly, a major cutback in human space spending could have large and highly adverse ripple effects throughout commercial, defense and scientific space programs as well, potentially triggering a series of disruptive changes in the common industrial supply base that our entire space sector relies on.

Thank you for the opportunity to address these important questions this morning. I look forward to your additional questions. And now I would like to let you hear from several of my fellow AIAA members on this topic.

[Video]

[The prepared statement of Mr. Thompson follows:]

PREPARED STATEMENT OF DAVID W. THOMPSON

Chairman Gordon, Ranking Member Hall, and distinguished members of the Committee:

I want to thank you for the opportunity to address a subject of great importance to the aerospace sector and to the nation as a whole. At a time when our country is intensely focused on economic recovery and employment growth, it is especially relevant to underscore that aerospace engineering and manufacturing enterprises in America directly employed about 650,000 people in 2008 and generated total industry sales of $240 billion, or almost 2% of our GDP last year. Aerospace jobs are relatively high paying, with average manufacturing wages in the sector being some 50 percent higher than in the average industry. In addition, the sector employs nearly 200,000 engineers and scientists, one of the largest concentrations of technical brainpower on Earth. Moreover, the aerospace sector produces state-of-the-art products that are in high demand around the world, generating a record trade surplus of approximately $60 billion on total exports of almost $100 billion last year. This placed the sector at the top of all U.S. export industries, including agriculture. Altogether, factoring in its ancillary industries and multiplier effects, our domestic aerospace sector today supports approximately five million American jobs.

Behind all of these numbers, of course, are the actual men and women who work in the aerospace sector and whose creativity, expertise, and dedication propel it forward. As President of the American Institute of Aeronautics and Astronautics for the 2009–2010 year, I am proud to represent a constituency of more than 36,000 aerospace professionals and students who work in all 50 U.S. states. Indeed, for nearly 80 years, AIAA has been the principal professional society for aerospace engineers and scientists in America and around the world.

In the short videos that accompanied my oral testimony, we heard professionals discuss what inspired and motivated them to join the aerospace workforce in the first place. Now I would like to explore in a more systematic fashion the factors that attract and retain members of the nation's aerospace workforce, while highlighting the critical importance of a credible, long-term U.S. government commitment to human space flight that ensures that our country continues to benefit from a vibrant aerospace sector. I will address in order the three questions that the Committee has posed to me on today's hearing topic.

1. As the leader of a major aerospace professional society, what do you view as the most significant concerns and trends regarding the U.S. aerospace workforce—government and contractor—and industrial base?

The aerospace sector is steadily moving towards the edge of a steep demographic cliff. Aerospace workers are the foundation of the industry's current success, yet unique workforce demographics present unprecedented challenges for its future. Up to half of the current aerospace workforce will be eligible for retirement within five years; nearly 15% are eligible to retire immediately. Furthermore, the U.S. aerospace workforce composition does not match national demographic averages. Compared to the total U.S. workforce, America's aerospace industry and related government agencies have a disproportionately large percentage of workers aged 40–55, and a disproportionately small percentage of workers younger than 40. Within the U.S. workforce as a whole, the number of employees over age 50 amounts to less than 17% of the total; meanwhile, in the aerospace sector, that bracket accounts for 58% of the total. While current economic conditions have temporarily delayed many older aerospace professionals from exiting the workforce, the demographic challenges remain stark. If talented young engineers and scientists are not recruited, retained, and developed to replace the generation that is near retirement, then the

U.S. stands to lose the critical economic and national security benefits of the domestic aerospace industry.

Moreover, enrollment rates in our country's college engineering programs have been dropping. The U.S. ranks well behind other countries in the percentage of students earning their first university degree in engineering or science. In many leading European and Asian countries, the percentage of undergraduates receiving their initial degree in engineering or science is between 40 and 50%. In the United States, the corresponding figure is 15%.

At the advanced-degree level, the U.S. also is declining in the number of degrees earned by its citizens. The proportion of Ph.D. degrees earned by U.S. citizens is dropping as well: 34 percent of doctoral degrees in science and 56 percent of doctoral degrees in engineering in the United States are awarded to foreign-born students. To make matters worse, the U.S. ranks behind the European Union and China in Ph.D. degrees awarded in science and engineering. The European Union surpassed the U.S. nearly 20 years ago, and China will likely surpass us in 2010.

In terms of maintaining and strengthening the industrial base, R&D expenditures keep the aerospace sector strong and help maintain U.S. leadership in this area. In the early 1990s, after implementation of the R&D tax credit legislation, private expenditures on R&D rose. Yet even with this incentive, U.S. industry R&D funding is lagging. Perhaps as a result, American companies are lagging in patents. In 2005, only four American companies ranked among the top 10 corporate recipients of patents granted by the United States Patent and Trademark Office. And to further add to this disconcerting R&D situation, federal research funding is lagging as well. While AIAA enthusiastically applauds the Committee's efforts to fully fund the America COMPETES Act and to increase R&D funding more generally, at least until recently the amount invested annually by the federal government in research in the physical sciences, mathematics, and engineering combined has continued its long-term decline.

2. How important is a commitment to a robust human spaceflight program to the preservation of the workforce, professional skills and capabilities, and the industrial base? If a decision were made to cut back or otherwise change direction in human spaceflight programs, what would be the implications for the workforce and industrial base?

In terms of preserving and enhancing the specialized workforce that characterizes a vibrant aerospace sector able to contribute to both economic well-being and national security, a credible long-term commitment to human spaceflight on the part of the U.S. government is indispensable. As the Review of U.S. Human Space Flight Plans Committee (better known as the "Augustine Commission") recently noted, "human exploration of space can engage the public in new ways, inspiring the next generation of scientists and engineers, and contributing to the development of the future workforce in science, technology, engineering and mathematics (STEM)." Likewise, the Augustine Commission acknowledged the important role that space flight plays in promoting the nation's commercial interests and sustaining its aerospace industrial base.

When federal commitment to human space programs wavers, the adverse impact on the stock of human capital and related economic output can be highly disruptive. Those thousands of individuals and dozens of communities that experienced the termination of the Apollo program in the early 1970s can attest to this, as well as those who have been or will be adversely affected by the winding down of the Space Shuttle program. One danger in such a context—apart from the impact on individuals—is that the levels of human capital needed to sustain a robust national human space program will drop below critical mass. Another is that young Americans deciding on a career path will eschew space-related fields, as nominally appealing as these might be, due to a justifiably heightened perception of career uncertainty. In that regard, a stable, long-term commitment to human space flight by the U.S. government is necessary to ensure that space technology retains its allure as a career choice for today's students.

The concentration of aging R&D and manufacturing employees was significantly inspired by NASA's early Mercury, Gemini, and Apollo programs, and later was motivated and retained in part by the sustained effort behind the Space Shuttle and International Space Station programs. In other words, to attract individuals into joining and remaining part of the aerospace workforce, we need first to capture their imagination and later provide them with worthwhile, long-term projects to work on.

3. What issues regarding the workforce and industrial base do Congress and the White House need to consider as decisions are made on the

funding and future direction for NASA, particularly for human spaceflight and exploration?

Space and missile systems sales accounted for about $47 billion—or around 20%—of the U.S. aerospace industry's $240 billion in total revenues in 2008. Domestic space and missile direct employment generated nearly 80,000 high-technology jobs last year, representing work by hundreds of companies in all 50 states. While human spaceflight programs like the Space Shuttle and International Space Station represented only about 25% of space and missile sales, and a corresponding fraction of direct employment, their influence on the supply of future aerospace professionals is much greater.

By way of concluding my testimony, I commend for your consideration an illuminating result from the Survey of Aerospace Student Attitudes, a 2009 national study—led by Dr. Annalisa Weigel of MIT—of over 600 undergraduates in aerospace engineering departments from 23 schools across the country. Fully 40 percent of current aerospace engineering students cited human spaceflight specifically as the area that first sparked their interest in an aerospace career. This data provides a powerful reason for continuing our nation's human space program and funding it at adequate levels for a sustained period. Clearly, human space flight plays a critical role in ensuring that our country's young people persist in cultivating their STEM-related talents in order to pursue a career option that inspires them. In turn, their dedication and achievements will make our country a stronger, better place in which to live in the 21st century.

Thank you again for the opportunity to address you today.

Ms. GIFFORDS. Thank you, Mr. Thompson. I appreciate your testimony. Ms. Blakey, please.

STATEMENT OF MARION C. BLAKEY, PRESIDENT AND CHIEF EXECUTIVE OFFICER, AEROSPACE INDUSTRIES ASSOCIATION

Ms. BLAKEY. Good morning, Chairman Giffords, and I want to say thank you to you and to Ranking Member Hall and to all of those on the Committee for this opportunity. This really is an important opportunity to address the future direction and funding for NASA and what it will mean for the U.S. workforce, aerospace and our industrial base.

Our members are deeply concerned about these issues, so I am delighted that you are taking a serious review. Your decisions regarding NASA's programs will undoubtedly affect our current and future workforce and the industrial base. According to NASA, there are about 45,000 work-year equivalent contractors. AIA further estimates that NASA indirectly supports 151,000 contractors. Under current plans for the Shuttle's retirement and the transition to the Constellation program, the current number of contractors will drop by over 4,000 by the year 2013. The resulting impacts we believe have to be carefully considered.

Aerospace talent lost to other industries may be unrecoverable. New workers take years to train. Moreover, if we lose certain facilities that manufacture high-tech technologies, it may take years and additional resources to bring them back.

Another crucial relationship NASA has with the aerospace workforce is the agency's ability to attract and educate future workers. The state of education for our young people, I don't think I have to tell this Committee, is alarming. This is evidenced by poor preparation for science, technology, engineering and mathematics, known as the STEM fields; low graduation rates in those fields, especially when you compare it to other nations; and a lack of interest in STEM fields overall. The latest national test scores show that in math, fourth-graders are 62 percent below proficient, eighth-graders are 69 percent below proficient. In science, fourth-

graders are 68 percent below, and eighth-graders are 73 percent below proficient.

I thought this was interesting. In a study done by Raytheon, most middle-school students said they would rather do one of the following than do their math homework. Now get this, clean their room, eat their vegetables, go to the dentist, or take out the garbage than do their math homework. It tells us something.

By comparison, India and China respectively graduate 6 to 10 times more engineering students each year. If this continues, the United States runs a real risk of losing its educated engineering edge over other nations.

One of the reasons for the lack of interest in aerospace and defense could be the uncertainty surrounding funding for NASA programs. A commitment to a robust human spaceflight program we believe will help attract and retain such workers. A reduction of programs, consequently, would be highly detrimental, both for our aerospace community and for our national security.

Just as the recent Wall Street crisis turned young people away from financial careers, a lack of job security in aerospace will dim the light of attraction.

Young people seek out companies with exciting opportunities. For example, Lockheed-Martin was hiring for the Crew Exploration Vehicle, and they had 10 highly qualified resumes for each available job. Some of our other member companies are doing exciting work. SpaceX has gone into ISS commercial resupply service contracts, for example, and these kinds of contracts are going to be magnets for young people because they are inspiring.

To help spur enthusiasm for the aerospace industry, AIA itself is innovating. One of our exciting endeavors is the Team America Rocketry Challenge, or TARC, for middle- and high-school students. Participating in TARC is inspirational, and we have gathered more than a few stories about our young people who now work in aerospace as a result of their TARC experience.

While AIA and NASA are vigorously engaged in the supply side of the equation, it is the demand side that has to be addressed by Congress to provide resources needed for important aerospace projects. These projects provide young people exciting programs on which to work. A robust and sustainable space exploration program is key to building the workforce. Maintaining our workforce depends on continuing stable and robust funding for our Nation's space programs. Space programs don't just come off the shelf. They take years to develop and build. Fluctuating budgets and delayed programs adversely affect the schedule, production and maintenance of a skilled workforce. Budget shortfalls deeply impact agencies like NASA that have been asked to take on many important projects simultaneously.

Our space industrial base designs, develops, produces and supports our spacecraft, satellites, launch systems, support infrastructure. These systems are often produced in small or even single numbers. We need to keep the base healthy.

Therefore, in closing I want to say that we ask Congress to remain mindful that interruptions or cancellations negatively impact large companies, and they can be catastrophic to small firms who often are the only entities with the unique abilities to produce

small but critical components on which the larger infrastructure depends.

The United States has enjoyed preeminence in aerospace in great part due to our space program. That leadership is now in danger. While Congress considers the future of NASA's funding and direction, we must continue to assure our continuing leadership in space exploration by investing in our young people and providing cutting-edge programs to attract them. I believe the vitality of our Nation as a whole depends on a healthy renewable workforce.

Thank you very much.

[The prepared statement of Ms. Blakey follows:]

PREPARED STATEMENT OF MARION C. BLAKEY

Good morning Chairman Gordon, Ranking Member Hall and members of the Committee. I am grateful for the opportunity to testify before you today on the importance of the future direction and funding for NASA and what that will mean for the U.S. aerospace workforce and industrial base.

As the largest aerospace trade group in the United States, the Aerospace Industries Association (AIA) represents nearly 300 manufacturing companies with over 631,000 high-wage, highly skilled aerospace employees across the three sectors: civil aviation, space systems and national defense. This includes the thousands of workers who make the satellites, space sensors, spacecraft, launch vehicles and ground support systems employed by NASA, DoD, NOAA, NRO and other civil, military and intelligence space efforts. Our member companies export 40 percent of their total output, and we routinely post the nation's largest manufacturing trade surplus, which was over $57 billion in 2008. Aerospace indirectly supports 2 million middle class jobs and 30,000 suppliers from every state. The aerospace industry continues to look to the future, investing heavily in research and development and spending more than $100 billion since 1995.

Our members are deeply concerned with the issues of workforce and the industrial base, so I am delighted that you are undertaking a serious review. In our most recent "Member Needs Assessment," a lack of a trained technical workforce for the future was an extremely urgent industry issue for our membership.[1] As part of our response, AIA produced the report, "Launching the 21st Century American Aerospace Workforce," which documented the rising concerns over the future of our aerospace workforce, and detailed how our industry is addressing this issue, including recommendations on how to partner with government to improve our education system.

Last year, AIA also produced a seminal report entitled: "The Unseen Cost: Industrial Base Consequences of Defense Strategy Choices." This report provided analysis on how certain defense decisions made by policymakers could impact the future of our industrial base from a national security perspective. Among our conclusions: Government decisions directly impact the ability of our industry to mobilize and these decisions could either weaken—or preserve—the capacity to do so rapidly. Thus, policymakers need to be keenly aware of the long-term impact that policy can have on our industrial base.

Our nation's space endeavors are encountering this same challenge, which this hearing has been convened to examine today.

Much of our industry's success can be attributed to the growth of our nation's space program and we are proud of NASA and industry's many achievements. American astronauts have been aboard the International Space Station continuously since 2000; our probes are en route to, or have reached, all the planets of the solar system and have explored the surfaces of the moon, Venus and Mars. Our telescopes are looking deep into the cosmos and satellites gaze upon the Earth, monitoring climate change. NASA has led these achievements in partnership with our industry.

Now NASA is at a crossroads in deciding its future options for space exploration. The U.S. human space flight program is being debated by policymakers.

While this is an issue for the Administration and Congress to deliberate, your decisions regarding NASA's programs will undoubtedly affect our current and future aerospace workforce and industrial base.

[1] 2008 AIA "Member Needs Assessment" Report.

NASA and the Aerospace Workforce

Concerns over the Current Workforce and Industrial Base

NASA's programs play a critical role when it comes to the aerospace workforce, which supports everything from its launch vehicles to satellites.

According to NASA there are about 45,000 "work year equivalent" contractors. AIA further estimates that about 151,000 contractors are indirectly enabled by NASA.[2] And according to NASA's latest workforce transition strategy there are 4,600 civil servant "full-time equivalents" working on the current programs of record, Shuttle and Constellation, and as many as 21,200 contractor "work year equivalents" in 2009.[3]

Under current plans for the Shuttle's retirement and the transition to the Constellation program, NASA projects a drop of almost 7,000 contractor "work year equivalents" in the next two years and will recover only 1,200 the two years following. In other words, contractors will drop to 17,000 from 21,200 by 2013.[4]

Some regions will be hit hard by the transition. In Brevard County alone, Shuttle-related activity in Florida supports a workforce level of approximately 9,235 contract employees, (not including Federal workers). The total estimated shuttle-related annual payroll for this workforce is estimated at $600 million. Additionally, the shuttle program provides an estimated secondary economic contribution to the state, above salaries, of approximately $2 billion.[5]

I bring these points up to highlight the impact NASA's human space flight program has on the lives of so many Americans. Brevard County is but one example. As Congress and policymakers deliberate over the future of NASA, we should reflect on the unique skills of these men and women and the regions that benefit directly from these programs.

NASA is linked to the health of our industrial base. While the loss of a person's job is no small matter, especially in light of today's economic environment, we must also view these jobs as a national resource critical to our nation's technological capability and our national security.

Aerospace talent lost to other industries may be unrecoverable; new workers may take years to train. Additionally, if we lose certain facilities that manufacture high-tech technologies, it may take years and additional resources to bring them back.

Among the issues affecting the health of our industrial base that need to be considered by the White House and Congress are: How to maintain required skills for the duration of the shuttle's operation, how to maintain the workforce skills required for utilization of the ISS and how to transition the workforce to other current and new NASA programs.

Concerns over the Future Workforce

Another crucial relationship NASA has with the aerospace workforce is its ability to attract and educate future workers. In fact, the demographics of our industry reflect an influx of young workers who entered our industry during exciting times in our space program.

Developing the aerospace workforce of the future is a top issue for our industry. As the leader of the largest U.S. aerospace trade association, the most significant concerns and trends facing the U.S. aerospace workforce and industrial base at the present time include the impending retirements within the next decade. Today, 13 percent of our workforce is eligible to retire. By 2013, retirement eligibility for some job functions like R&D and program managers will be around 20 percent.[6]

The state of education for our young people is also in peril, including poor preparation for Science, Technology, Engineering and Mathematics, also known as STEM fields; low graduation rates of students in those fields, especially when compared to other nations, and a lack of interest in STEM fields overall.

Currently, the U.S. annually graduates just 74,000 engineers—covering all fields in the discipline. Further, many of these students are foreign nationals who return home shortly after graduating—which lowers the number of new domestically employable engineers under 60,000.[7] By comparison, India and China respectively

[2] 2008 AIA Facts & Figures.
[3] 2009 NASA Workforce Transition Strategy, 3rd edition.
[4] Ibid.
[5] 2007 Brevard County Development Board.
[6] 2009 Aviation Week Workforce Study.
[7] 2008 American Society for Engineering Education, "Engineering by the Numbers."

graduate six and ten times more engineering students each year.[8] If this continues, the U.S. runs a real risk of losing its skilled engineering edge over other nations.

The latest national test scores show that, in math, fourth graders are 62 percent below proficient and eighth graders are 69 percent below proficient. In science, fourth graders are 68 percent below proficient, while eighth graders are 73 percent below proficient.[9]

In a study done by Raytheon, most middle school students said they would rather do one of the following instead of their math homework: clean their room, eat their vegetables, go to the dentist or take out the garbage.

This lack of interest seeps into interest in aerospace. For example, in a recent survey 60 percent of students majoring in STEM found the aerospace and defense industry an unattractive place to work.[10]

One of the reasons for a lack of interest in aerospace and defense could be the uncertainty of NASA programs.[11] commitment to a robust human spaceflight program will help attract students and hold workers.

If a decision were made to reduce programs, the implications would be detrimental for our aerospace community and national security. Just as the recent Wall Street crisis turned young people away from financial careers, a lack of job security in aerospace will also hurt. Google has captured the magic to attract young people, while space, despite its history and potential, has lagged behind.

Young people want to work for companies with exciting opportunities. For example, when Lockheed Martin was hiring for the Crew Exploration Vehicle they had 25 high-qualified resumes for each job. There are other companies are doing exciting work; for example, the commercial resupply to the International Space Station service contracts at SpaceX. Young people are inspired by the projects they get to work on.

To help bring enthusiasm for the aerospace industry, AIA is being innovative. We run the Team America Rocketry Challenge, or TARC, for middle and high school students.

TARC starts off with a regional competition, with students teamed in many cases with real rocket scientists, with qualifiers coming to the Washington, D.C. region for the national competition. Their challenge requires them to achieve a designated flight time and altitude all while safely returning a raw egg payload. The winning team goes on an all-expense paid trip to the international competition for the "Trans-Atlantic Trophy." Last year our students were in Paris; a year before, in London. Plus, the top-scoring teams get invited by NASA to participate in a more demanding Student Launch Initiative.

The excitement of participating in TARC is inspirational; we have heard more than a few stories about young people who now work in our industry because of their TARC experience.

Since our first contest in 2003, one of the participants majored in aerospace engineering at the Naval Academy and is in the Navy in Florida flying helicopters. Another is a software engineer working on tanks, and a third is an aerospace engineer at an aviation company. And there are more success stories like these.

In a survey of participants we found that TARC has a strong impact. For example: 83 percent became more interested in science and math as a result of TARC. Almost 70 percent became more interested in a STEM career as a result of TARC and 81 percent gained a better understanding of how math, science, and technology are used to solve problems in the real world.

Many of AIA's members also have their own exciting STEM initiatives. Among these are Raytheon's "Math Moves U", Boeing's "Space Camp", Northrop Grumman's "Flights of Discovery" and Lockheed Martin's "Space Day." Our companies are literally investing millions of dollars to help inspire and attract the future aerospace workforce.

AIA CEOs have also publicly announced that this is an issue for our industry and have committed to actions to address STEM, as described in AIA's "Launch into Aerospace" report.[12] Such actions include: encouraging industry professionals to participate in mentoring and other volunteer activities; earmarking corporate grants for educational programs, and making government a partner in achieving the future technical workforce.

NASA's Office of Education is also very involved in STEM programs. In fact, the report I mentioned earlier: Launching the 21st Century American Aerospace Work-

---

[8] 2005 National Academies: Rising Above the Gathering Storm.
[9] 2007 National Assessment of Education Progress, U.S. Dept. of Ed.
[10] 2009 Experience Industry Survey.
[11] 2007 National Academies: Building a Better NASA Workforce.
[12] 2008. "Launch into Aerospace" (Report)

force, helped catalyze a joint industry-education forum last week at NASA to discuss ways in which we can collaborate on this important issue.

While AIA and NASA are vigorously engaged in the "supply" side of the equation, it's the "demand" side that also has to be worked on by Congress by providing the resources needed for important aerospace projects. These, in turn, provide young people with exciting programs to work on. A robust and sustainable space exploration program is key to building the workforce.

What can Congress do?

Most importantly, maintaining our workforce depends on continuing stable and robust funding for our nation's space programs. By their very nature, space programs take several years to develop, test and build. Fluctuating budgets and delayed programs adversely affect the schedule, production and maintenance of a skilled workforce. Budget shortfalls also deeply impact agencies like NASA that have been asked to take on many important projects simultaneously.

We need the Administration and Congressional leadership to conceive of and treat space as a "singular enterprise," for which the decisions and strategies of the many agencies using space are coordinated at a White House level. This will better leverage and align our nation's space endeavors.

Our space industrial base designs, develops, produces and supports our spacecraft, satellites, launch systems and supporting infrastructure. These systems are often produced in small, or even single, numbers. We need to keep this base healthy. We ask that Congress remains mindful that interruptions or cancellations negatively impact large companies and can be catastrophic to smaller firms—which often are the only entities with the unique abilities to produce small but critical components on which huge portions of our infrastructure and security depend.

To maintain and capitalize on our leadership in space exploration, the federal government needs to ensure support for U.S. space exploration, provide for maximum utilization of the International Space Station and support NASA's science and aeronautics programs.

Congress and the White House must also help instill an exciting direction for NASA's efforts that could include: a robust commercial space sector that provides cargo resupply to the International Space Station; exploration plans that go beyond low earth orbit; cutting-edge space and aeronautics designs; utilizing the national laboratory aboard the ISS for innovative research; U.S. leadership that promotes peaceful international cooperation in the pursuit of interests important to all of humanity, and earth observation programs to help study our planet and address important issues such as climate change.

While we want to have a young workforce looking out to space we also need to ensure we have the right skill set looking back at the Earth. Observing the Earth's environment takes a global perspective—a perspective space-borne systems supply. How can we draw young people toward this special skill set? I would suggest that one approach would be for our agencies that use space imagery, such as NASA, NOAA, USGS, the EPA and others, to work with companies that make this imagery widely available to the public. Let's find ways to make these services both exciting and educational to draw our next generation into Earth sciences, geology and even cartography.

Supply and demand

What can drive more engineering-minded students into the discipline of aerospace and aeronautics? I believe the opportunity to expand human spaceflight is the ideal type of project. An industry that can inspire them must remain vibrant and active.

Over decades, our space programs and workforce have helped fuel our economy and advance our technologies.

The United States has enjoyed preeminence in aerospace in great part due to our space program. That leadership is now in danger. The primary threat comes not from competitors' actions but from our own aging demographics and potential failure to act, both of which could be detrimental to our future aerospace and space programs.

The generation of aerospace talent that won the Moon Race and the Cold War is reaching retirement age, while our Shuttle workforce is also aging. Unfortunately, America is not producing the volume and quality of engineers, designers and technicians needed to even begin replacing those who have served so well for so long.

While Congress considers the future of NASA's funding and direction we must also continue as the world leader in space exploration by investing in our young people and providing cutting-edge programs for them work on. The vitality of our nation depends on a vital workforce.

Ms. GIFFORDS. Thank you, Ms. Blakey. Mr. Young?

STATEMENT OF A. THOMAS YOUNG, EXECUTIVE VICE PRESIDENT (RET.), LOCKHEED MARTIN CORPORATION

Mr. YOUNG. Chairwoman Giffords and Committee members, it is a privilege to present my views on the importance of our aerospace workforce to our country.

Spaceflight in general and specifically human spaceflight is one of the more challenging endeavors of our time. It is truly the domain of rocket scientists. However, successful spaceflight requires more than an expertise in rocket science. Intellectual capability is clearly necessary. However, without significant experience and continuity of participation, the intellectual capability is far from sufficient.

You might ask the question, why isn't intellectual expertise adequate and why is experience and continuity of participation so critical? Spaceflight is a one-strike-and-you-are-out business. Hundreds, and for large projects, thousands of people can do everything correctly and one individual can make one mistake that can be mission catastrophic. Now, while eliminating human error is a necessary aspect of successful spaceflight, we must recognize that human error cannot be totally eliminated and that human mistakes will occur.

There are not many endeavors that are characterized as one strike and you are out. For most activities a significant error can occur, it can be recognized and corrected without major consequences.

Some correlate spaceflight and commercial aircraft operations. I do not want to minimize the challenges of commercial aviation. However, airplanes land safely every day with significant problems, an option that is not available in the world of spaceflight.

Decades of experience and the dedication of extraordinary people who have made spaceflight their career has resulted in a way of doing business that greatly minimizes the probability of human error having a catastrophic result. It is the foundation of the extraordinary successes of the space program.

A safety net is required to prevent human error from becoming catastrophic. Testing, independent validation and inspection are elements of the safety net. If we test as we fly and fly as we tested, we will find and eliminate most problems. For some areas, such as software, a full test program is unrealistic requiring the use of an independent validation approach. In some special circumstances, such as the installation of a solid rocket motor, only inspection can provide the necessary safety net. It is the disciplined implementation of the safety net without compromise that is a foundation of missile success. A slight deviation from this disciplined approach can be the most damaging of human errors.

Unfortunately, failure reports are populated with deviations with names such as faster-better-cheaper, acquisition reform, we must take more risk, commercial practice, etc. Why do we accept these deviations which I will call miracle solutions? Many are the result of trying to put 10 pounds into a 5-pound bag. Others are in response to the criticism that we are too conservative and need to take more risk, and others are associated with the premise that

commercial practices are better. While there is some merit to each of these miracle solutions, and we should constantly be responsive to better ways of doing business, most have been toxic to a one strike and you are out enterprise.

I would like to offer a few examples. Mars '98 consisted of an orbiter, lander and two probes, all failed. Mars '98 was a faster-better-cheaper program with an inadequate budget. Risks were accepted in the absence of sufficient funding resulting in catastrophic failure.

A Titan IV with an important and expensive national security payload failed, because the failure was a human error in documenting a number, simply writing down the wrong number. This failure occurred in an era of acquisition reform where emphasis was shifted from mission success to cost. The cost focus resulted in eliminating aspects of the safety net that would have most likely caught the error and eliminated the failure.

In the 1990s, during the epoch of faster-better-cheaper, acquisition reform, take more risk, commercial practices, et cetera, the Aerospace Corporation documented $11 billion worth of failures.

My purpose has been to highlight the unforgiving nature of spaceflight, the need for uncompromising discipline and to recognize that it is a one-strike-and-you-are-out business. I have tried to emphasize that spaceflight is not a typical technological activity.

Because of the special characteristics of spaceflight, a workforce is required that has the culture and capabilities aligned with these characteristics, a workforce with the necessary intellectual strengths and possibly even more important, the experience and longevity to establish the sensitivity as to what is required for spaceflight success.

Today in government, universities and industry we have such a workforce. It has evolved over decades of extraordinary successes and tragic failures. Exceptional men and women have invested their professional careers, and the United States has invested significant resources to achieve the spaceflight workforce we have today. It is truly a national treasure. Without a challenging and meaningful space program, this national capability will atrophy. It can only be maintained by inspiring use. It has a limited shelf life.

As we debate the future of our space program, we must do so recognizing the importance of our spaceflight workforce and the role it will play in the success or failure of the space program of the future. Without proper attention and recognition of its importance, we could make changes that destroy what we have carefully built. I do not suggest change is to be avoided. I do suggest careful thought is necessary. A fundamental rule when debating change is do no harm. Thank you.

[The prepared statement of Mr. Young follows:]

PREPARED STATEMENT OF A. THOMAS YOUNG

Chairman Gordon and Mr. Hall,

It is a privilege to appear before this distinguished committee to present my views on the importance of our aerospace workforce to the United States.

Spaceflight in general and specifically human spaceflight is one of the more challenging endeavors of our time. It is truly the domain of rocket scientists. However, successful spaceflight requires much more than an expertise in rocket science. Intellectual capability is clearly necessary; however, without significant experience and continuity of participation, the intellectual capability is far from sufficient.

Why isn't intellectual expertise adequate? Why is experience and continuity of participation so critical? Spaceflight is a "one strike and you are out" business. Hundreds and for large projects, thousands of people can do everything correctly and one individual can make one mistake that can be mission catastrophic. While eliminating human error is a necessary aspect of successful spaceflight, we must recognize that human error cannot be totally eliminated and that human mistakes will occur.

There are not many endeavors that are characterized as "one strike and you are out." For most activities a significant error can occur, be recognized and corrected without major consequences. Some correlative spaceflight with commercial aircraft operations. I do not want to minimize the challenges of commercial aviation; however, airplanes land safely every day with significant problems. An option that is not available in the world of spaceflight.

Decades of experience and the dedication of extraordinary people who have made spaceflight their career has resulted in a way of doing business that greatly minimizes the probability of human error having a catastrophic result. It is the foundation. of the extraordinary successes of the space program.

A "safety net" is required to prevent human error from becoming catastrophic. Testing, independent validation and inspection are elements of the "safety net." If we test as we fly and fly as we tested, we will find and eliminate most problems. For some areas, such as software, a full test program is unrealistic requiring the use of an independent validation approach. In some special circumstances, such as the installation of a solid rocket motor, only inspection can provide the necessary "safety net." It is the disciplined implementation of the "safety net" without compromise that is a foundation of missile success. A slight deviation from this disciplined approach can be the most damaging of human errors.

Unfortunately, failure reports any populated with deviations with names such as faster-better-cheaper, acquisition reform, we must take more risk, commercial practice, etc. Why do we accept these deviations which I will call "miracle" solutions. Many are the result of trying to put ten pounds into a five pound bag. Others are in responses to the criticism that we are too conservative and need to take more risk and others are associated with the premise that commercial practices are better. While there is some merit to each of these "miracle" solutions and we should constantly be responsive to better ways of doing business, most have been toxic to a "one strike and you are out" enterprise.

I would like to offer a few examples. Mars '98 consisted of an orbiter, lander and two probes—all failed. Mars '98 was a faster-better-cheaper program with an inadequate budget. Risks were accepted in the absence of sufficient funding resulting in catastrophic failure.

A Titan IV with an important and expensive national security payload failed. Cause of the failure was a human error in documenting a number which resulted in failure. This failure occurred in an era of "acquisition reform" where emphasis was shifted from mission success to cost. The cost focus resulted in eliminating aspects of the "safety net" that would have most likely caught the error and eliminated the failure.

In the 1990's, during the epoch of faster-better-cheaper, acquisition reform, take more risk, commercial practices, etc., the Aerospace Corp. documented 11B$ of mission failures.

My purpose has been to highlight the unforgiving nature of spaceflight, the need for uncompromising discipline and to recognize that it is a "one strike and you are out" business. I have also tried to emphasize that spaceflight is not a typical technological activity. Because of the special characteristics of spaceflight, a workforce is required that has the culture and capabilities aligned with these characteristics. A workforce with the necessary intellectual strengths and possibly even more important, the experience and longevity to establish the sensitivity as to what is required for spaceflight success.

Today in government, universities and industry we have such a workforce. It has evolved over decades of extraordinary successes and tragic failures. Exceptional men and women have invested their professional careers and the United States has invested significant resources to achieve the spaceflight workforce we have today. It is truly a national treasure. Without a challenging and meaningful space program, this national capability will atrophy. It can only be maintained by inspiring use. It has a limited shelf life. As we debate the future of our space program, we must do so recognizing the importance of our spaceflight workforce and the role it will play in the success or failure of the space program of the future. Without proper attention and recognition of its importance, we could make changes that destroy what we have carefully built. I do not suggest change is to be avoided. I do suggest careful thought is necessary. A fundamental rule when debating change is "do no harm."

Ms. GIFFORDS. Thank you, Mr. Young. Dr. Aubrecht?

STATEMENT OF RICHARD AUBRECHT, VICE CHAIRMAN OF THE BOARD, VICE PRESIDENT, STRATEGY AND TECHNOLOGY, MOOG, INC.

Dr. AUBRECHT. Thank you for this opportunity to address the Committee. The thing I would like to do this morning is to illustrate with a very specific example the long-term effect of the NASA programs.

I am with Moog out of Buffalo, New York, and I have spent most of my 40-year career as an engineer and a technologist with Moog. We started doing NASA work in the late '50s, early '60s on programs like the Gemini, Apollo and later on on the Space Shuttle. We have a technical specialty referred to as precision motion control, and the places that it is applied primarily on the NASA launch vehicles is steering the rocket engines. So if you see the Shuttle when it is launched, you see it comes up and sort of rolls over, well, we are the guys at the back end that are moving the rocket engines to be able to steer it in a launch phase.

Similarly, when the Shuttle is landing, you have to move the flight control surfaces. Those are hydraulic actuators that move those. That is the specialty that we developed during that time period.

Based on that knowledge and heritage and experience that we had with that, we later then took that and evolved it for both commercial aircraft as well as military aircraft. So it is referred to today as fly by wire flight controls. Well, what does that mean? You have a computer that just connects with a wire to the actuators, and because of all of the concerns in terms of safety and reliability on these, these are very complicated, redundant systems. And our position with that all started with the work that we did with NASA in the 1960s.

In the last ten years, we have won all of the major contracts around the world on fly by wire flight controls. We are doing complete flight control system on the F–35 for the DoD. We won all of the contracts for the 787 at Boeing doing a complete flight control system there, and the one that I think is more significant as far as your consideration here is that we won the same contract on the A350 at Airbus. This is the first time that Airbus has gone outside of Europe for this kind of technology. Why is that? Because the very best fly by wire flight control technology is in Buffalo, New York, and it all stems back to the work we did with NASA in the 1960s.

We have had a similar experience on the unmanned NASA programs as well, starting all the way back with things like Viking and Voyager, all the deep-space probes, and more recently on the Mars science lab and the other Mars missions.

So we have been developing similar kinds of technology. So what do these do? When you have a satellite, you have to be able to position the antennas and the solar arrays, and as you see the animations of satellites when they are all—see the small thrusters that activate and position the satellite? That is what we do, supply all sort of precision motion control in those satellites. And again, this started with our work with NASA in the 1960s. Today we are the

world leading company for supplying those sorts of things to the DoD for all of their satellites, all the commercial satellites around the world. We are the supplier to the Europeans, to the Indians, to the Japanese for all that sort of hardware.

The same way that we have had the evolution of that from the NASA technology, we see the same thing going on today. What it does is it gives you the opportunity for the NASA programs to develop the core technologies and the core knowledge, and as a couple people have indicated already, knowledge is not the matter of drawings and documents and reports. That is not where the knowledge is. The knowledge is in the people who develop it, and they have the ability then to be able to say, well, okay. Here is this other problem coming in for a military vehicle. What are we going to do with all that? You all go back to the NASA technology we developed to begin with as the core for doing all of that. So that is how we have been able to develop this kind of position we have worldwide.

But it is not just us. We literally have hundreds of suppliers for the kind of hardware that we supply for NASA in the same way that NASA pushes us to find new technical boundaries and to push the envelope all the time. We do the same thing with our suppliers.

So the leverage that you get out of this is not just a couple of companies with this, it is literally hundreds of companies that advance the technologies. For many of our suppliers, their NASA work is only maybe 1 or two percent of their sales, but it accounts for—probably 80 percent of their technology advancement comes out of this sort of work that they do on these NASA programs.

And it is not just us. I can see upstream and downstream from where we are in these systems, and it is the suppliers of those sort of hardware because I follow their technologies as well. And they have seen the same kind of effect.

So I would suggest that our experience with the NASA programs is not a singularity. We see it all the way through the suppliers and all the other companies that are around.

The other point that I would make is that other people around the world understand this model of using space programs to lead the technology. The Europeans have clearly done it. When I first started with Moog in the 1960s, I worked in Europe, and this was right when Airbus was getting put together, you see. So why did the Europeans put Airbus together? They looked at it and they said, we really can't compete with the United States on manned space, given where they were at at that point in time. But they wanted to have a program to lead their companies to develop better technologies. So they chose to do it in commercial aircraft because they couldn't keep pace with the United States on the manned space program.

So you follow that whole history forward and look recently at what the Chinese are doing. Why do the Chinese have a manned space program? For exactly the same reason that the United States had a manned space program in the 1960s. They are looking for that to increase the quality and the competency of the companies in China. It is exactly the same sort of model.

So I would suggest that the Congress at this point in time is at a critical choice point. The Constellation program is clearly the

next chapter in our history in space, and you have a choice. You can either adequately fund it and consistently fund it so you can maintain the sort of base that we have to be able to not only do the work for NASA, to be able to take and to continuously leverage this and to maintain the U.S. leadership in space technologies and aerospace technologies applied to all kinds of aircraft, military, commercial, business jets, satellites, all of that. It all is going to come from the consistent funding of the Constellation program.

And a couple people have indicated, you can't have ups and downs in all of that. As a company, you have to maintain a consistent workforce if you are going to maintain this capability, and you can't have up one year, down the next year. It has to be a consistent funding stream really to make this work.

So as I say, you have a very critical set of decisions to make here in terms of are you going to consistently and adequately funds the Constellation program because I think if you do, we can maintain this sort of world leadership that we have. I can see it in our technologies. We won a very significant number of the contracts already on Constellation, and we hired a number of people already. We have increased our employment almost by 100 in Buffalo to support the Constellation program already. And these are the best, brightest people. You say, so why is that? A couple of people have talked about it in general terms. Specifically, I can see from my own experience in working with it and with my colleagues, NASA programs are really, really hard problems. Tom talked about that in terms of the fact that there is zero tolerance for failure on all of that. That is a really, really hard problem. What that does is attract the very best and the very brightest engineers, and bright engineers attract other bright engineers. And that is how we have built the company over the last 60 years.

So I am hoping that the Constellation program will get the adequate funding that it needs, and we will be able to continue the sort of technology evolution we have had in our company.

Thank you very much. I look forward to your questions.

[The prepared statement of Dr. Aubrecht follows:]

PREPARED STATEMENT OF RICHARD AUBRECHT

I am very pleased to have been invited to testify at the 10 December 2009 Congressional Hearings relative to NASA's programs and budget.

I have spent almost my entire 40-year career with Moog Inc. as an engineer and technologist. For the past 15 years, I have concentrated on developing Moog strategies and technology plans with our managers, engineers and technologists. Since Moog has had an over 40-year relationship with NASA as a supplier of control components and systems, a significant piece of our plans relate to our NASA work. These technology plans have enabled us to develop a very clear understanding of the relationship between the technologies we develop for NASA projects and the growth in Moog's other aerospace businesses.

Beginning with the Gemini Program in the 1960's, Moog has supplied the actuators to steer NASA's launch vehicles' rocket engines. Subsequently, we have supplied ever more sophisticated control components for the Apollo and then the Space Shuttle. For the Space Shuttle, we also supplied actuators for the flight control surfaces that guide the orbiter's flight path during the time it flies like an airplane. The technologies we developed and the experience our engineers gained provided the foundation, knowledge and heritage to begin developing similar control components for military and then commercial aircraft. Most recently, we have become the supplier of the complete flight control systems for the DOD's F–35, Boeing's 787, and Airbus' A350. Our experience on the Space Shuttle was clearly the essential starting point for Moog to have developed the technical experience and enabled us

to have been selected as the supplier for the flight control systems for these programs.

In addition, Moog has developed a variety of other control components and systems with NASA for other launch vehicles, and various deep space and orbiting satellites such as Mars Science Laboratory and DAWN. As with the rocket engine steering controls, these NASA programs have always been the most challenging and pushed the envelope. Moog's NASA experience on all these applications has enabled us to also provide the world's best technologies for similar applications on DOD and commercial launch vehicles, all types of satellites and various missile interceptors. NASA has a history of setting very ambitious goals that drive the need for new technologies, designs and capabilities that are beyond what the Commercial space projects are willing or able to undertake. Once the capability and reliability of the components are demonstrated on NASA projects, the Commercial space suppliers are then confident in using these components on their vehicles. Not only Moog's technologies benefit from these NASA projects. Our products incorporate technologies and components from several hundred companies. While some of these components are relatively standard, our innovative solutions for NASA require the majority of our vendors to push their designs to a higher level as well. So the benefit of the NASA programs becomes very widely spread. While I do not profess to be familiar with all aspects of the NASA vehicles, I am familiar with the technologies and components adjacent to our components. I can see the companies supplying these adjacent components have also similarly benefited from their NASA work.

It is no accident that the USA aerospace prime contractors and the hundreds of subcontractors have developed leadership positions on the vast majority of the relevant technologies. The NASA programs have clearly enabled USA companies to develop and maintain these leadership positions. A leadership position can be measured as a combination of performance, reliability, weight and cost. It is also clear that the Chinese, having watched NASA's successes, have embarked on a very ambitious manned space program. Their expectation is for their space program to provide Chinese aerospace companies with the experience to challenge the USA's leadership in commercial space and commercial aircraft.

NASA's Constellation Program is the next chapter. NASA's goals for the Constellation Program will again challenge all the suppliers to imagine, develop and create the next generation of space-related technologies.

The fundamental question Congress needs to address is:

> Does Congress want to continue to consistently fund NASA programs such as Constellation to maintain the USA's leadership position in aerospace technologies?

The key word in that question is "consistently". The relevant technologies are embodied in the engineers and technical staff who work on the NASA programs. Technologies are documented in drawings and reports. However, the application of the technical knowledge is totally dependent on the people who have developed the technology. Without consistent funding by NASA, companies are not able to keep the engineers and technical staff employed. If funding is inconsistent, technical capabilities wither as people move on to other programs or to other companies.

One of our major concerns relative to the Constellation Program is that having already been awarded a number of contracts for the Constellation Program, we have hired a large number of engineers and technical staff to support our contractually-obligated schedules set by NASA's current schedule. If the Constellation Program's funding is reduced and stretched out, we will have to lay-off a number of these people. We have a core group of people who have spent the past 20 or 30 years working on space-related programs. A number of these people will be retiring in the next several years. The new people we have hired to work on the Constellation Program are the next generation who need to learn from the senior people and then become the core group to apply their skills to the next generation of commercial space, military space, and other aerospace applications.

As with our experience on previous NASA programs, we continually grow by moving into adjacent technologies to our current core capabilities. The Constellation Program has provided us the opportunity to again expand our technical capabilities. We were surprised in several competitions that companies who had previously supplied specific technologies to NASA had either declined to bid, because they no longer have the ability to design the required components, or that they apparently submitted a weak technical proposal. This is an additional indication that consistent NASA funding is required if the USA is to maintain and advance its aerospace technology capabilities.

The Constellation Program is at a critical decision point for the country and specifically for the Congress. On one hand, you can decide to fully and consistently fund

the Constellation Program and the USA can maintain its leadership position in aerospace technology. On the other hand, you can decide to select one of several seemingly lower cost options. In which case, I strongly believe the USA will rapidly lose its leadership position, most likely to the Chinese.

Thank you for this opportunity to testify.

Ms. GIFFORDS. Thank you, Dr. Aubrecht and to all of our panelists for the very compelling testimony.

At this point, we are going to begin our first round of questions. The Chair will recognize herself for five minutes, but we have, I know, a variety of Members that want to speak. So let us really try to keep under the five minutes so we can move quickly.

OPINION OF THE PANEL: IMPACT OF DECISION TO AUGMENT OR FLAT-FUND HUMAN SPACEFLIGHT AND EXPLORATION PROGRAMS

I want to follow up on what Dr. Aubrecht presented to us and this decision that we are going to be making as Members of Congress, and of course the Administration will as well. We can either support a significant augmentation to NASA's budget to carry out a meaningful human space exploration program without having to gut other NASA initiatives, or we can keep NASA on a flat-funding profile and put our human spaceflight and exploration program frankly on hold for the unforeseeable future. What we eventually decide to do will have profound and very long-term effects. And so because of the consequences in front of us, we really need to get this right.

So I would like to ask each of our panelists to briefly just touch on the most significant potential impacts that Congress and the White House should be aware of as we prepare to make these decisions. And Dr. Aubrecht, I will go back to you, and we will work our way from right to left.

Dr. AUBRECHT. I think the critical thing is what I was just finishing on is the quality of the people that you have working on the Constellation program to begin with. If you are unable to maintain that base, you are going to lose it. People talked about the upcoming retirements. We are facing exactly that. The people that we had that did the Space Shuttle and did the Apollo program, they are about to retire, and the thing we are looking for the Constellation program to be is the transition to the next generation of people and to do the mentoring that you need for those people to get the maximum benefit out of the experience that we have had. It goes from person to person. It is not in the drawings.

So I think that is the critical factor, is this direct transition from one generation to the next. If you don't do it now, it won't happen.

Ms. GIFFORDS. Thank you. Mr. Young?

AUGUSTINE REPORT: BUDGET AND FUNDING ISSUES

Mr. YOUNG. The Augustine Report in my mind——

Ms. GIFFORDS. Mr. Young, can we have you push your microphone.

Mr. YOUNG. My apologies. Okay. The Augustine Report did some real service in an area that I think we knew, but it took something like that to make it happen and that is number one, that the cur-

rent NASA budget and the current NASA program is not executable in human spaceflight, not marginal.

The second thing I think that the report really highlighted was that there is no human exploration program at the current budget level. Now, I am defining human exploration as beyond going back and forth to the Space Station.

So I think we are faced with kind of a profound decision and that is I personally am a believer that great countries do great things, and I think human spaceflight, you know, falls in a category of one of those great things. I am also a fiscal conservative, I might say. But I strongly believe that if we do not approach this from what is in the best interest of the country as opposed to a budget issue, then I fear we are going to end up with the wrong answer. And as I said in my statement, this capability that we have built, and we should not underestimate how hard it was to build and how hard it will be to rebuild and how significant it is today, but if we don't use it in a bold and inspiring way, it is going to disappear on us.

So I think that we are really making a decision that is not a budget decision. We are not making a jobs decision. We are not even making a hardship on the people who might lose their job. We are making the decision as to what is in the best interest of the country, and how do we utilize this resource that we have developed with so much investment, both in human investment and dollar investment.

So I worry quite a lot as to whether or not as a country we are going to approach this issue in a manner that it deserves and the country deserves.

Ms. GIFFORDS. Thank you, Mr. Young. Ms. Blakey?

Ms. BLAKEY. I share the concerns of my fellow panelists, and so not to be redundant on that, I would mention a couple of other dimensions. This also has, this decision, has genuine impact on our national security because you must remember that some of these particularly smaller companies with unique capabilities and technologies such as Moog utilizes in fact also support that fragile national security supply chain, and when the programs are not there, they simply cannot maintain them and maintain any kind of integrity to their shareholders. So this is a significant issue.

Another issue that I think is important is that this country sees itself as a space-faring Nation. At the same time, we know, those of us who are following this closely, that it is very likely that the next boots on the moon will be Chinese. We know that we have very definite competition for the leadership in space from a number of countries, India as well as China, Russia. You know, this is very well-documented, and the resources are being applied there. But when you look back at it, our country does see itself that way, and that is important to our national psyche.

Back during the Apollo program, the numbers were around 50, 55 percent in terms of public support for the U.S. role in space. Those numbers in a recent poll—this was 2005 but not when we were trying to go beyond lower earth orbit—we at 77 percent.

So I simply would echo the thought that all these things matter, and budget should follow policy, not the other way around.

Ms. GIFFORDS. Thank you. Mr. Thompson?

Mr. THOMPSON. To preserve today's and to attract and retain tomorrow's specialized workforce which underpins all sectors of a vibrant aerospace industry, a robust, credible and long-term commitment by the United States Government to our future human spaceflight program is indispensable. As the Augustine Commission pointed out, human exploration of space will inspire the next generation of scientists and engineers and will in a very tangible way contribute to the broader development of the future workforce that our country needs in a variety of sectors, all supported by science, engineering and technology.

STIMULUS FUNDS AND HUMAN SPACEFLIGHT FUNDING FOR NASA

Ms. GIFFORDS. Thank you. Mr. Olson.

Mr. OLSON. Thank you, Madam Chairwoman. One thing we have been working very hard on in the Texas delegation is to identify viable sources of increased funding for NASA and one of those we think would be entirely appropriate given what was passed for is the economic stimulus plan that was passed back in the February timeframe. And this is a question for Mr. Thompson and Ms. Blakey. Has either the AIAA or the AIA taken a position about proposals to have stimulus funds used to help mitigate anticipated human spaceflight deficiencies and the resultant loss to aerospace workforce?

Ms. BLAKEY. We are very interested in and sympathetic to more flexible use of the TARP funding, stimulus funding. We do see that there is certainly an enormous support for some of the purposes of that money, to give the kind of support to our infrastructure, and infrastructure is a broad word, but space is certainly a vital part of our infrastructure. And we believe that those kinds of resources could be very appropriately applied.

Mr. THOMPSON. I agree, while AIAA has not yet taken a formal position on your question, I believe our individual and corporate members would be highly supportive of the actions that you suggest.

Mr. OLSON. Thank you very much. Just to echo Ms. Blakey's comments, these are exactly the jobs that that stimulus package was supposedly passed to produce, high-quality, high-tech jobs that stimulate and ensure America's future and in this case, ensure our dominance in human spaceflight which again we should never, ever relinquish.

COOPERATION WITH FOREIGN NATIONS

One other question and this is sort of about our indigenous capabilities. One thing the Augustine Commission talked about was more cooperation with foreign nations, and at yesterday's Aerospace and Women Luncheon, the NASA Administrator, Charlie Bolden, emphasized the Obama Administration would utilize space exploration for diplomatic purposes by encouraging greater cooperation with foreign nations.

Assuming this cooperation means utilizing the capabilities from other nations and have them play larger roles, larger mission roles,

supplying mission work, how would this be balanced with the Administration's priority to save and create jobs? That is for everyone.

Ms. BLAKEY. Well, I certainly would make the case that this is a case of growing our activities, and in the long run, the pie becomes larger, not smaller. It is not a question of dividing it up into little pieces. It really is a question of whether a shared mission is there. And we see the compelling work.

Let us just use the work at the International Space Station alone because there we are finding that after all the investment, multination investment and contributing to building, we are now beginning to see some of the fruits of that. And this is in the areas where cell cultural biology experiments that are going on are addressing problems that we share across the globe. Salmonella is one of them. You know, this is something that affects the globe as a whole. Staph infections. Now, you know the pharmaceutical companies will find that this is an area that they additionally will be happy to put resources into as we begin to see payoff.

So I do believe it is a question of additional jobs on multi levels that you can see from this kind of international cooperation.

Mr. OLSON. Any other comments? I just wanted to, Mr. Thompson, commend you for that video. That is exactly—that was the kid I was talking about walking the streets on the campaign trail. That is exactly that person, and we can't forget the power of human spaceflight to inspire you.

And with that, Madam Chairwoman, I yield back my time.

Ms. GIFFORDS. Thank you, Mr. Olson. The Chair will recognize Mr. Wu.

Mr. WU. Thank you, Madam Chair. At this time, I would like to yield my time to the gent lady from Florida who represents her congressional district and state's interest in space exploration so well, Ms. Kosmas.

EFFECTS OF POST-SHUTTLE GAP OF U.S. ACCESS TO SPACE ON MAINTAINING INSPIRATION; AND GAP IN U.S. INDUSTRIAL PRODUCTION OF HEAVY LIFT VEHICLE

Ms. KOSMAS. Thank you very much, Mr. Wu, and also Madam Chairman. I am happy to be here today. I represent the Kennedy Space Center in Florida, and obviously the workforce issue is huge for us in this current economically stressed time but in the big picture that you all have described, important to us as a Nation I believe.

I wanted to ask, I was at the Kennedy Space Center Monday of this week and addressed 700 sixth-graders, along with some former astronauts, to encourage them in the STEM fields and also attended earlier this week a forum that was put together including the Space Foundation and DoD where there was an effort to—Norm Augustine was the keynote speaker and also emphasized the need for education in these areas in order to keep these things moving forward, as well as the shared information between manned space exploration and our Department of Defense and national security issues. So much of what you all have said is very familiar to us, and as Committee members, I think it has been made clear to us that both a sustained commitment to human spaceflight and a sustained commitment to the funding necessary

to make it happen are required ingredients for what Ms. Blakey described as U.S. preeminence, and we all agree I believe on this Committee that it is necessary for us to do that for a lot of obvious reasons.

My concern is that the gap if the Shuttle, if the manifest is completed in 2010 or even early 2011 that we will have as much as perhaps a five-year gap before we can pick up again on human space exploration, and during that time period we will be relying on the Russian Soyuz, how seriously do you see this gap as with regard to the inspiration that we have described as being necessary to attract the next generation but also at the same time, that gap with regard to the industrial base and the potential loss of opportunities for the industries that help us to make not only the manned space exploration but as you described the commercial and DoD infrastructure necessary to be successful at it? So any one of you may answer the question. Number one is the gap and the Russians flying our astronauts to the International Space Station, and number two is the gap with regard to the industrial production.

Mr. YOUNG. I guess somebody has to volunteer. The gap is unfortunate. The gap will not inspire, but the gap is in reality I think is a legitimate question of, you know, new folks entering it and how could those of us who were stewards of the program allow the gap to happen. And it is a legitimate question.

I think it fundamentally happened because we were not willing to fund the program at a level necessary to safely finish out the Shuttle program and in parallel develop the necessary resources to not have a gap. In other words, we chose a relay race where rather than smoothly handing off the baton, we heaved it up ahead, hoping there was somebody there to catch it in the process. So I think unfortunate but you know a reality.

Why don't I stop at that point? Somebody else may want to add.

Dr. AUBRECHT. In our case, because we have the Constellation contracts already started, we have transitioned a lot of the people who were supporting the Shuttle program are now working on the Constellation program. So for us, it is not that much of a problem, provided the Constellation is funded.

But I would worry, your other point about the Russians supplying that, I mean, if you think about it, so you are totally dependent on the Russians at this point in time to keep the Space Station. As you may be aware, you just can't leave the Space Station up there. You have to continuously bring fuel up there. Gravity and solar drag is pulling the Space Station down. So if there is an interruption in the fuel going up to the Space Station, it is coming down one way or another. And so you are totally dependent on the Russians for doing that. I would worry about that.

Mr. YOUNG. If I could come back and just add to Dick's point and your second part of your question dealing with, you know, what do we do now so to speak, I made a point in my statement which I strongly believe, this workforce capability that we have has a limited shelf life. And it is not something we can put on the shelf, you know, waiting for the next system. And we will only get through this so-called gap era in a reasonably positive fashion is if we have the kind of work that Dick is talking about for these people to do. In other words, if we really can employ them, all the skills won't

match but many will. But it is critical to have the challenging work that will assure that that capability doesn't, as I said earlier, atrophy.

INSPIRING THE NEXT GENERATION FOR SPACE EXPLORATION

Ms. KOSMAS. I guess my question—that answered a part of a workforce and industrial-based question, but my question, the big one is, if we have a five-year gap, how do we inspire? What is the best way that we can inspire the next generation to be engaged in space exploration if in fact we have handed off our delivery of our astronauts to the Space Station to the Russians? How do we say to the next generation the kind of inspiration that we saw Mr. Thompson among your folks? How do we get that to happen during this gap?

Ms. BLAKEY. I think it does depend very much on our continuing activities on ISS. Again, we are seeing results up there. That is a very exciting thing, and people want to be a part of that. They want to be a part of exciting launches, like the Ares I–X this fall. I mean, you know, everyone said, yes. You know, we had a very successful launches early stage on our new program. At the same time, there is very exciting work that is being done commercially as well. SpaceX, Orbital, they are doing some excellent work that I think people understand gives a commercial opportunity to resupply the Space Station.

So there is a lot that could happen in the gap, and I hope that we don't focus entirely on the fact that it is a Russian seat that is getting our astronauts up there at, by the way, $50 million a pop. So it is not free, either.

Ms. GIFFORDS. Ms. Kosmas?

Ms. KOSMAS. Yes? Is my time up?

Ms. GIFFORDS. Your time is up.

Ms. KOSMAS. Thank you.

Ms. GIFFORDS. Thank you. Also, it is important that everyone recognizes that we have had a gap in the past. I personally believe that we will get through the gap as long as we have a strong, committed vision and a program for the future.

Now the Chair will recognize the very distinguished Mr. Ehlers.

Mr. EHLERS. Thank you, Madam Chair. I have a deep interest in this subject, having devoted something like 50 years of my life to trying to teach STEM ed to future elementary school teachers. My colleagues who love to teach the advanced courses thought I was crazy because I also would have loved to teach the advanced course, but I felt an obligation to try to educate young kids. If you don't get them excited about math, science, engineering in the elementary school, they are not likely to pursue it in high school. They will take the minimum requirement but that is it. If they do that and then go to the university and say, well, you know, I would like to be an engineer, they suddenly find they have to spend an extra year or two at the university and they are likely to decide not to. So a very important factor this is, making certain that all of our elementary and secondary schools are dead serious about good math, science and engineering instruction, and I hope all of you in your professions will keep emphasizing that as well.

THE METRIC SYSTEM

I was interested in the comments of—I think it was Mr. Young made the comments about the importance of getting things right, and I recall when we lost a $159 million satellite on a trip to Mars because NASA used the metric system and the engineering contractor used the English system of units. I immediately introduced a bill to require that all NASA contractors had to use the metric system. The NASA administrator came to me and begged me, literally begged me, to drop the bill and forget about it because he would take care of it administratively, which he did not do. I think that is something that we should do. That I think is one of the stupidest errors that ever occurred in spaceflight, and it is so elementary.

So I would hope that you would encourage the Congress to get over their phobia about the metric system and at least set an example in NASA of how to do it right, and hopefully the rest of the country—it is happening by itself with the international trade we have. But that is a very slow, torturous way to do it. And the biggest mistake people take, by the way, is trying to teach people how to convert from one system to another. That is not the way to learn. The way to learn is simply to use it, and very shortly you will have it.

REVITALIZING AND IMPROVING THE AEROSPACE WORKFORCE

I would appreciate any comments on that, but I do have a specific question for Ms. Blakey. Some years ago I sponsored the resolution establishing an interagency aerospace revitalization task force which did fine work and reported on it. Ms. Blakey, I know you were involved in that. Can you give me a summary and perhaps others could as well of what impact this has had if any on trying to develop a better workforce and more numerous engineers graduating? Is there any follow-up to that?

Ms. BLAKEY. I think that task force was spot-on in the impetus to have the agencies pull together and begin combining resources as well as combining programmatically so that it was greater than the sum of the parts, if you will.

We feel very strongly that the time has again come, Congressman Ehlers, to have an interagency group that really should function on the highest level. We believe the White House should coordinate this, and it should be for all those agencies that have responsibility for space programs that they come together, and you really do begin to look at the impact that they are having and the ways that redundancies as well as synergies can develop. And it will have a huge impact, we think, on STEM issues because again, there are a lot of resources out there, but they all need to be pulling in the same direction.

Mr. EHLERS. Well, we do have a President who is interested in science and has made some very good appointments in the areas of science. So perhaps with your help and my help we can try to bring this to the forefront again. I think that would be very, very helpful.

One last thing. I want to compliment you, Ms. Blakey, on your comment that budgets should follow policy. That doesn't happen

very often around the Congress, but it is a very important statement and we should all keep that in mind and really, really work hard on developing a policy so that the budgets will in fact follow the policy.

With that, thank you very much, and I will yield back.

Ms. GIFFORDS. Thank you, Mr. Ehlers. The Chair will now recognize Ms. Edwards.

Ms. EDWARDS. Thank you, Madam Chairwoman, and thank you to our witnesses today. This is something that at least in the time that I have served on this Committee we have been deeply concerned about. Where are the next generation of engineers, scientists and leaders for whom NASA is actually a platform, really, for other kinds of technology and research. And so that is really where the investment really pays off throughout our industrial base and not just specifically focused in the space program.

In September of this year I hosted a gathering actually in this room of women and minority businesses, entrepreneurs, really invested and interested in the commercial space industry and their role in it, many of them young who had just come out of undergraduate and graduate school and were starting their own businesses. The space program is what led them to their creativity and innovation. Back in the back of the room in the last few rows were young people, African-American and Latino students in our local schools, girls and boys, who sat. You could see the inspiration happening in their eyes as they listened to business leaders, as they listened to researchers, as they saw and took photographs with astronauts.

So I think that we have a great opportunity right now to in some ways reinvent our space and space exploration for this latest generation. And so I am interested to hear from you where you think there are opportunities both for the agency to reach out to communities and schools and inspire this next generation and opportunities for the private sector to do the same thing because my experience in the county that is the home to the Goddard Space Flight Center is sort of like it is getting better but Goddard is kind of over there and the rest of us are outside, and we need to bring those two things together. We need to bring it together through the private sector but also through the agency itself. And so I wonder if any of you have any comments about that, at least from a policy perspective, how we can help make that leap.

Mr. THOMPSON. Perhaps I could provide part of the perspective there from an AIAA point of view. We have advocated for some years now that the Administration, with the support of the Congress, adopt policies that would be specifically focused on increasing the country's scientific and engineering workforce at several levels. One of those levels would center on providing incentives for colleges and their students to expand their educational programs in the relevant technical fields.

The second recommendation was more focused on companies, particularly those that work under government aeronautics and space contracts to provide incentives for workforce development so that we can reduce the attrition. Once a young engineer or scientist comes into our industry, that today results in about half of those

entry-level technical professionals not staying in the industry for the majority of their career.

And finally, despite our best efforts to increase the domestic supply of well-qualified aerospace engineers and scientists, it is AIAA's view that that alone will not be sufficient to fully address the problem that our country is going to face over the next decade or so. And so we further advocate a reexamination of immigration laws and visa levels so that we can more effectively attract from around the world the best and brightest young people that want to come to our country and build their lives and careers here to strengthen our aerospace sector and the Nation as a whole.

In addition, within this general framework, AIAA and a number of other engineering societies across a variety of fields have advocated the pursuit of policy specifically focused on emphasizing the two middle initials in the STEM acronym, namely technology and engineering. I think we are further behind in those areas or we risk falling further behind in those areas than we perhaps do in the bracketing letters of science and math. All are important, but as we look out over the next decade, the challenges in engineering and technology may even be worse, more severe, than the challenges in the basic sciences and math.

Thank you, and I am sure we could go on, but my time is expired, Madam Chairwoman.

Ms. GIFFORDS. Dr. Aubrecht, did you want to add something real quick?

Dr. AUBRECHT. Yes, just to come back to the point that you made there in terms of immigration policy. We employ about 9,000 people in 26 countries around the world. We are headquartered in Buffalo, and that is where the center of our aerospace business is, but we have taken this technology into all kinds of other fields. And a number of cases where we would like to bring people in from outside the United States, and we just simply have a terrible time trying to get visas for these people to come in.

So I don't think we are going to be able to meet the needs from a technological staffing standpoint unless you open up the immigration. People from all over the world would just love to come to the United States and work on these programs. This is where it is happening, but they just can't get the visas.

Ms. GIFFORDS. Thank you, Dr. Aubrecht. The Chair recognizes Mrs. Fudge.

Ms. FUDGE. Thank you very much, Madam Chair, and thank you, all of you.

EDUCATION PROGRAMS IN ELEMENTARY SCHOOLS/ ADVOCATING MATH AND SCIENCE

Let me just preface my brief comments by first saying that I happen to represent NASA Glenn, and certainly we have a critical stake in human exploration, aeronautics research and space research and technology.

But I do have a couple of questions. The first one really is probably more a comment. Ms. Blakey, you cited that 69 percent of eighth-graders are below the proficient level in mathematics. The Department of Education just came out with numbers that indicate in my district, in the City of Cleveland, that number is 92 percent.

Ninety-two percent of eighth-graders are below the proficient level in mathematics.

I hear often, because we have a lot of high-tech businesses in our area and we talk about immigration, we talk about a number of things. But I just have to say, not necessarily for a response, but that if this country knows we have those kinds of problems, we know what needs to be done. We just need to have the will to get it done because I believe every child well-taught can learn.

So I don't think that we need to focus all of our attention on trying to bring somebody in here to take care of the short term but to teach young people coming up through the system so that we have our own base to do the kinds of things that need to be done.

I am going to go to just a couple questions I have. Ms. Blakey, again, to you. You mentioned that one of your outreach programs, the Team America Rocketry Challenge, you said that this challenge starts with a regional competition in which students are teamed with real rocket scientists. How are the schools that participate in this challenge selected?

Ms. BLAKEY. We encourage every school in the country to be a part of it. We put out information, CDs, we send a great deal out to all of the schools, and we also as the National Association of Rocketry, which literally, these are rocket scientists, to reach out to folks in their own communities because they are employed in both government as well as our company facilities around the country and go to the school and say, look, I would like to work as a mentor on this program.

That is the way it starts. It has a very low-entry cost to get involved. These are small rockets. They are not hard to build in theory, but to understand the physics and the engineering and all of that, that is the trick.

So there is not a great barrier to entry. We are trying to get schools all over the country. We bring 100 of them here in May out to the plains on a Saturday to shoot off their rockets to compete against each other, and frankly, the fact that we have also begun to get other countries. England and France are now competing against us in the international rocketry contest, also gets kids really juiced about this because they know, look, you know, we do really well. We get an opportunity to go to the big air show in London this year.

So there is a lot to it in addition to a lot of prizes. We are trying very hard to have this permeate schools everywhere. If there are some in your district that might participate, I would love to talk to you about it.

Ms. FUDGE. I would love to talk with you about it as well.

AIRCRAFT PROPULSION SYSTEMS

My next question is for any member of the panel. Aircraft propulsion systems have major environmental and fuel consumption implications, and specialized skills are needed to assure low emissions, reduced noise and increase the performance of aircraft engines. What policy and funding decisions are needed to make certain that the future workforce of NASA, of industry and universities can provide the needed advances for engines with low emissions, low fuel consumption and utilization of alternative fuels?

Mr. THOMPSON. AIAA has adopted as one of our three strategic imperatives for at least the next half-decade the advancement of technology specifically focused on improving aircraft propulsive efficiency and reducing related harmful emissions. As part of this initiative, which we believe is critical to the future growth and prosperity of the world's air transportation network, we advocate that the Administration and Congress not lose sight of the important work that NASA does in aeronautics, keeping in mind the first A in NASA continues to be highly relevant to the industrial sector in the United States that must compete worldwide for new orders in the aircraft sector and which serves an industry which this past year, even during times of economic downturn, moved about 6 million people every day, along with something like 135 tons of cargo during every 24-hour period, generating roughly $.5 trillion in worldwide revenue.

So this is a very vital part of NASA's research program, one that AIAA commends to the Congress to ensure that its funding remains at a robust level.

Ms. FUDGE. Thank you, Madam Chair.

Ms. GIFFORDS. Thank you, Ms. Fudge. The Chair recognizes Mr. Luján.

EDUCATIONAL INITIATIVES FOCUSED ON MATH AND SCIENCE TEACHERS

Mr. LUJÁN. Madam Chair, thank you very much. And I am glad to hear the emphasis in and around education as well. To build upon what a few of my colleagues have discussed today, when we had some of the national leadership here before the Committee back in May, I asked a lot about a program called MUST, Mentoring Underserved in Science and Technology, a program that I feared during the budget discussions that would not get the support that it should. We talked about the importance of retaining and building the workforce, exposing young people that are in these STEM fields in college to getting these scholarship opportunities and getting involved in NASA programs, to provide for further job opportunities down the road. And I would certainly hope that that is a program that we would be able to advocate together for the importance of this for fully funding and expanding this program specifically to see what we can do to try to attract more individuals into these fields.

Are there any programs that you are working on or that you have within the structures of your organizations to mentor teachers, to bring teachers in, to teach them science, technology, engineering, mathematics, to take those experiences during summer months back to school districts and traditional school districts where they have three months off in the summer, where there may be employment opportunities or educational opportunities to take that back into the classroom so we can address some of what Ms. Fudge was addressing with targeting these young students especially, where I share the same sentiments as Ms. Fudge. We give kids a chance and we teach them. They will learn, they will grasp it, and they will do phenomenal things. You are all examples of that.

How can we get more people involved?

Mr. YOUNG. If I could comment just a little bit? Thinking about my personal case, I grew up in a very rural area. I sit here because of two or three math and science teachers who I had in high school. That is the only reason I am here today.

Second comment is that in my corporate life, we wrestle—corporations have modest amount of funds that they can employ in helping, so to speak, and we wrestled with how to best do that, and obviously corporations can't be a Department of Education. But our conclusion was that we could both leverage what modest funds we had with supporting math and science teachers. And we established summer academy, actually I guess we called it, for math and science teachers at various locations where we had operations and invited teachers there, the objective being to enhance their—being proficient and up to date as to what was going on. And I participated in a lot of those programs, and I was extraordinarily impressed at how, with modest investment, you can, you know, leverage through math and science teachers an enormous capability.

I have got one last comment that is only slightly there but, you know, there are other ways to motivate, and we were talking about and I go back. One of the things I did in my life, I was mission director on a program called Viking. We landed a couple spacecraft on Mars, and a couple folks on the program, project scientist named Jerry Soffin and a scientist named Carl Sagan, got the idea, why didn't we have a summer intern program on the program and invite young, you know, kids who were interested and invite them to work, you know, come out and work hand in hand, you know, in such a program.

It is kind of interesting. One of those was David Thompson. Without that program, he might today be testifying to the banking committee.

Mr. LUJÁN. Madam Chair, just quickly before I run out of time, one thing that I would be interested in visiting more about so we can get more individuals like Mr. Thompson here before us, maybe we can get some young people involved to follow in your footsteps. An interesting program is under way at Los Alamos National Laboratories where Ph.D.s, physicists, engineers, professionals of all types, with a modest investment are giving some of their time to be able to bring these teachers in during these summer months in school districts that we saw serious problems with underperformance, especially in mathematics, where these kids are turning around and have some of the highest math scores in the state now. Almost 100 percent turnaround. And it is because we brought these teachers in to show them what they could show these kids and to show these kids that they could go to the moon, that they could design the next, most fuel efficient vehicle, whatever it may be. And so to see what more we can do in each of these areas where we can have these public/private collaborations and make sure that we are making these investments in our kids such that you have the workforce that you need to continue to build upon the programs and successes that you have brought forward.

So I appreciate your earnest attention to these areas and look forward to working closely with you, Madam Chair in each of these areas. Thank you.

Ms. GIFFORDS. Thank you, Mr. Luján. The Chair will now recognize Mr. Griffith.

EFFECT OF DELAYING OR INDECISION ON CONSTELLATION PROJECT

Mr. GRIFFITH. Thank you, Madam Chair. I appreciate the effort in the educational community. It has been a discussion going on for I think three decades. The space program however will be either successful or unsuccessful within the next 16 months. The verbal expression of commitment to the space program is basically inadequate without national commitment of money and tangible enthusiasm from the executive branch. We will send a message of confusion and indecision to our scientific community. Mr. Augustine said it best when he said, get in or get out. It is unfair to the astronauts, it is unfair to the scientific community, and it is unfair to those children who have an interest in science that we are trying to attract into this absolutely vital, vital part of not only our economy but the development of science for science's sake.

I appreciate the concept that maybe we could use this as a diplomatic effort, and I would love to see this as a sideline. But basically, this is research and development. America represents five percent of the world's population. Ninety-five percent live somewhere else. We have seen the benefits of NASA, human spaceflight. It has been proven to us over and over again that this has to be a national commitment, and leadership has got to come out of the executive branch. We are in fact in a space race to the moon with the Chinese, and we have not decided to put a team on the court yet.

What better opportunity than a successful launch of Ares I–X to segue into a national announcement that we are now committed to the moon in 2020, 2019, 2018? What better opportunity have we had to say to America's children, science and math is cool? What better opportunity? Imagine had we spent the time that we have spent on cap-and-trade, stimulus, healthcare, had we spent that on science education and the development of our human spaceflight program. We would be sitting here today feeling very good. Today, we are very, very anxious.

I must tell you that my district is Marshall Space Flight Center. I am an oncologist. I took care of many of the pioneers, and I have seen firsthand in medicine all of the things that NASA has done, the development of these unusually specific and special little instruments that we are now able to not only save lives but reduce morbidity and increase early diagnosis.

So there is no question that the scientific community has benefited the rest of America and the rest of the world greatly. We can no longer discuss this. This needs to be a commitment from the executive branch and the leadership of Congress. If we delay it, we are playing into the hands of our competitors, and we, as America, want to win. We are winners.

I might ask this one question. If we delay this Constellation Project, if we—you know, no decision and indecision is in fact is in fact a decision. So if we are making a decision to either delay or not make a decision, what is the effect of this on our community

and the culture that we have developed in human spaceflight in America over the last four decades?

Anybody can——

Dr. AUBRECHT. Let met take that. A very specific example, they said we are right in the middle of starting to execute the contracts that we have on the Constellation program. We have hired about 100 new engineers and technicians in Buffalo to support this program. If there is a break in the program, we are going to have to lay off the substantial majority of those people. So what message does that pass? It passes the message along is that we are not serious about doing this, and trying to hire other people on later on, people would not be interested.

So I think as I said at the end of my testimony, you are at a very, very critical decision point, probably more critical than it has been in the last 15 or 20 years because the decisions that have been made in the last 15 or 20 years have been, we kind of work on it a little and we delay it. We work on it a little more and we delay it, and you have come to the end with the Space Shuttle in terms of what you can safely fly. So it is now or never. This is the time.

Mr. GRIFFITH. Thank you. Thank you, Madam Chair.

Ms. GIFFORDS. Thank you, Mr. Griffith. Next we will hear from Mr. Grayson.

IMPACT OF PREVIOUS DECISIONS ON CURRENT STATUS OF HUMAN SPACEFLIGHT AND LOSS OF JOBS

Mr. GRAYSON. Thank you, Madam Chairman. We seem to have reached something resembling a dead end in the space program right now, and it is going to take us years to figure out how to go in a different direction. I think the Augustine Report is an effort to try to simply figure out what direction that ought to be. And I am wondering how we reach this point. Sometimes the best way to figure out how to go forward is to take a look back. So I am going to ask each of you this question. The question is, what should we have been doing for the last 35 years in the space program that would have led us to a better position than we are in right now, a position where we are looking at the loss of thousands of jobs in Central Florida and the loss of important skills that will be difficult to replace? Mr. Thompson?

Mr. THOMPSON. That is a very tough question. I would point out that despite the challenges that we face today, the path that the country has followed over the last several decades in the human spaceflight are a has led to a much broader space industry than existed in the 1960s and the 1970s, so much so that today, using financial and employment metrics as a means of comparison, NASA can be congratulated for having spawned a commercial and national security space sector which collectively are much larger than our civil space sector.

So while the programs of the past with the benefit of today's hindsight may not have been ideal, they were effective at developing the applications of space technology originally pioneered by NASA during the 1960s such that space today influences the everyday lives of virtually every American, whether it takes the form of the timing signals on an automatic teller machine when we go to

the bank or credit card verifications at the gas station or directions navigating us through traffic from satellites, much of the underlying technology in these devices that we now take for granted traces its origins back to investments made several decades ago by government space programs. And so while the path perhaps hasn't been ideal, it has produced unexpected benefits for the economy and for the everyday lives of virtually all Americans.

Mr. GRAYSON. Dr. Aubrecht?

Dr. AUBRECHT. Yeah. The Space Shuttle was only supposed to fly for about ten years. If you will go back and look at the original program of the Space Shuttle, it was only to fly for ten years. It was then to be replaced by a next generation manned space vehicle, and that should have happened by 1990. We participated in the study programs and the design of the preliminary design of those vehicles. It came along to a certain point and then again, the decision was made in the Congress that, well, the Shuttle is still flyable, NASA can get on with it. We don't have to fund this new program because it was going to be a very large incremental funding in order to be able to do this next generation vehicle. And the same thing happened again in the mid- to late-'90s. There was another study program that went on and again, the same decision. We are going to walk away from it.

So in terms of looking, your question, looking at the past, I would suggest that both of those were just gigantic mistakes. The Shuttle is 1960s technology. You look at any of the things that is in there, and it is incredible that it has had as few a problems that it has had. It should have been replaced a long time ago. That was the fundamental error that was made with just not replacing it at the ten-year cycle when it was originally slated for.

Mr. GRAYSON. Mr. Young?

Mr. YOUNG. Yeah, I will make three comments. One is when we look back, we should not under-recognize there have been some enormous successes, and you know, things are flying throughout the solar system right now that are mind-boggling.

But more relevant to your question, I think there are really two areas in which we have dropped the ball. One is we transitioned from one system to another system. It is true in national security. Every one of our national security programs is facing a gap. It is true in our weather satellites. We are facing gaps. And it is true here. So why have we done that? And I think it is fundamentally, you know, driven by inadequate budgets and trying to get 10 pounds to 5-pound bag. Fundamentally, a whole new business or enterprise has developed called gap-fillers, and you know, there are programs that you hear about every day, a gap-filler for communications, a gap-filler for this, a gap-filler for the other. So I think that is it.

The third item I would add is we really have fallen back as I try to mention on miracle solutions. And my biggest worry is that we are going to latch onto another miracle solution to solve this problem as we go forward.

Mr. GRAYSON. Thank you. My time is up.

Ms. GIFFORDS. Thank you, Mr. Grayson. We have time for one final question. Ms. Johnson.

IMPORTANCE OF SCIENCE R&D AND EDUCATION

Ms. JOHNSON. Thank you very much. As I sit here and listen to the same information every year, this is my 17th year, I am increasingly concerned about how we do look after our scientific research for the future. We are a Nation that is beginning to spend less than developing nations on it, and yet, space exploration has offered us more than any other type of scientific research that we have in the world. With all of the products and the healthcare products, I do get concerned about the plan for the future because we know that we cannot do this. We cannot do it without good minds, and my concern is I have sat here and listened. In my State of Texas we have the nucleus of space exploration, and a lot of aerospace industry, and I see the involvement with some of the students. You must know that in Texas the majority of the college-age students are minorities. And many of the programs that I have seen does not have that diversity. And that continues to concern me because that means that is going to be the brain power for the future. It is going to be the brain power, so we might as well let them in and do more for the embracement of their education. We are going to require really highly skilled workforce. And I have said this so much until I think everybody is probably tired of listening to it. But it is so essential. No nation will ever progress or remain free without this research.

And so we have just really got to do it. If I had a choice today between food stamps and science, I would go with science because in the future, it will offer us so much that we might not even need food stamps. But I know each of you, and I know your passion and your interest, and I just want to pledge to you that I am going to do everything I can. I have seen right here in this room on this Committee people that don't have the appreciation because they don't know what it does. As a matter of fact, when I first came here, the person who fought NASA and space exploration is now the Chairman of this Committee.

And so we have got a long ways to go inside, and I hope we can get there. Sometimes I feel like I have to preach this sermon, but our education must start with K through 12 in order to have a good background. And they have to be nurtured and monitored and encouraged to keep on their course. We have got to improve the talents of our teachers, and America COMPETES has some capacity to do that. I would like to see it in action because we certainly need it for our future.

Thank you. I don't have any questions of this panel. And I ask unanimous consent to put my statement in the record.

Ms. GIFFORDS. Thank you so much, Ms. Johnson. As we have heard, votes have been called, and so I would like to thank again our panelists for coming and testifying today. Today's hearing is not going to be the last time that we look at these issues, but it is an important time. It is the last time for the members of the Full Committee and the Subcommittee to really get a better feel of what you all are facing out there on the front lines of this national decision, and frankly, I believe it is a national crisis.

We have had a chance to pick your brains. We have had a chance for you to provide us information. I would like to state that the

record will remain open for two weeks for additional statements from members, also for any answers of questions that the Committee may ask of witnesses. But I also understand some of the panelists will have additional information that they would like to provide to the Committee, and we would welcome that information as well.

With that, the witnesses are now excused, and the hearing is adjourned. Thank you very much.

[Whereupon, at 12:00 p.m., the Committee was adjourned.]

Appendix:

Answers to Post-Hearing Questions

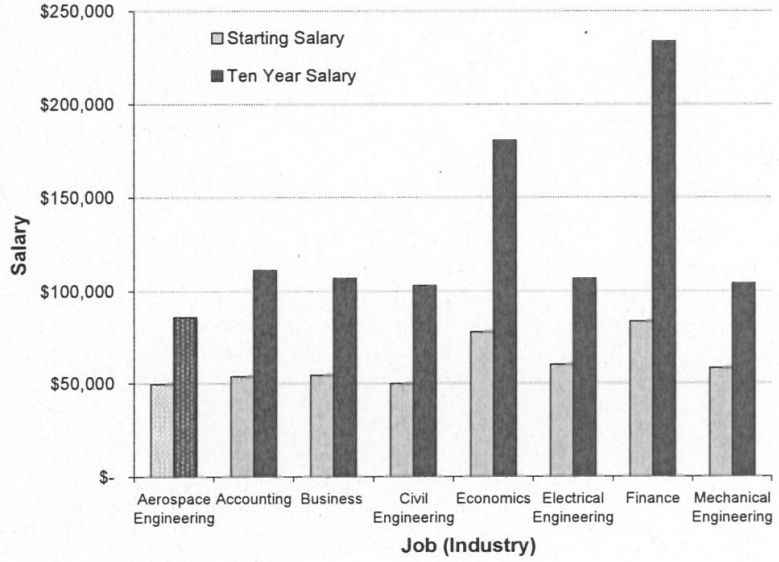
ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. David Thompson, President, American Institute of Aeronautics and Astronautics

Questions submitted by Chairman Bart Gordon

Q1. How would you characterize aerospace jobs in terms of skill levels, pay, and turnover as compared to jobs in other high-technology and research institutions? What are the key drivers for job growth or reductions in the aerospace workforce?

A1. Historically, many young people with an aptitude for technical subjects have been directly inspired by human spaceflight to pursue challenging engineering careers (as was demonstrated by the responses to the AIAA "When did you know?" campaign). Their imaginations were captured by the space exploration enterprise, providing a sustaining motivation for their career choices. A significant number of individuals so inspired became the aerospace professionals who enabled our nation to achieve its global technical lead in aerospace, which provided many international trade and security benefits to our nation. Other professions offer the opportunity for greater compensation than engineering. Human spaceflight provides evidence to many bright students that by being engineers, they can contribute to long-term goals that they may deem of such great importance that the opportunity to contribute to the achievement of those goals is more important than following a path that may offer greater personal wealth. In the long term, removal of the basis for such inspiration will reduce the number of young engineers entering the aerospace profession, who are needed to replace the current aging workforce. This will thereby impact critical national capabilities.



Turnover industry-wide in the first five years of employment is about 20%. Skill levels are relatively high and require constant updating as new technologies are developed.

The level of government spending is the key driver to aerospace job growth or shrinkage—in the human spaceflight area and across the board. Nearly three in five aerospace jobs are dependent on the federal government, through government spending on research and development, or through the government's role as a consumer of aerospace and aerospace-related systems and components.

Q2. The nation's space program and the aerospace workforce and industrial base that support it are critical elements of the nation's science and technology infra-

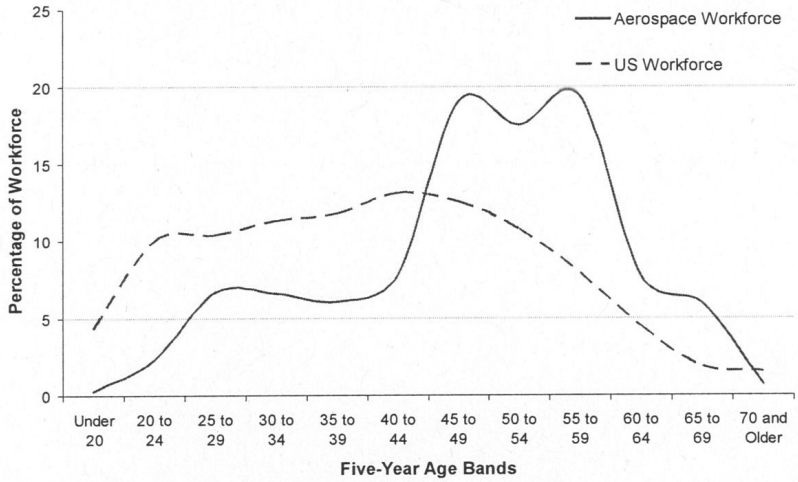
structure. How important is the work that your companies and professionals perform on NASA projects as opposed to other projects to our national competitiveness and our capacity for innovation?

A2. First, NASA's projects tend to be highly visible and inspirational in nature. The ripple effects for American leadership by virtue of being first to put a human on the Moon are still being felt internationally. The Apollo-Soyuz mission also highlighted the potential of space in foreign affairs and tangibly eased tensions during a critical juncture of the Cold War. Skylab expanded the limits and capabilities of astronauts in space, as it conducted 2,000 hours of scientific and medical experiments, including eight solar experiments. The Viking missions to Mars awed a generation of schoolchildren and led them to wonder about the planets. Without question, many astronomers today can trace some of their initial professional impetus to the images beamed back from the Red Planet. Not much later, the debut of the Space Shuttle became the focal point of inspiration and aspiration for a generation of students and professionals. As our country seeks to attract more students into the "STEM" fields of science, technology, engineering, and mathematics, the type of headline projects that NASA historically has undertaken are indispensable.

Second, since 1958 NASA's activities have produced countless technological transfers and commercial spinoffs that have boosted our standard of living. These have occurred in seven main areas: Health and Medicine (e.g., new polymer coats for implantable medical devices); Transportation (e.g., lithium battery power); Public Safety (e.g., space suit technologies that protect deep sea divers); Consumer, Home and Recreation (e.g., panoramic photography); Environmental and Agricultural Resources (e.g., web-based mapping); Computer Technology (e.g., integrated circuit chips to improve network efficiency); and Industrial Productivity (e.g., new technology to improve the welding process). NASA's activities in space almost inevitably contribute to our quality of life on Earth.

Q3. What makes NASA's human spaceflight programs different from other NASA programs or other federally-sponsored research programs with respect to the workforce and industrial base that support it?

A3. It has been widely publicized that fewer American college students study engineering than in China or India, both in relative and absolute terms. The focus and inspiration that human spaceflight creates, as noted above, helps to ensure that more students at least consider a career in the STEM fields than would otherwise. Indeed, for over 50 years, NASA's manned flight programs have provided a locus for the burgeoning scientific interest of America's youth. With 75% of NASA's workforce now at least 40 years old, it is important for the Agency to retain a powerful allure for younger scholars and professionals if it hopes to perpetuate a vibrant culture of innovation and achievement. Without a workforce of sufficient talent and size, other countries will find it increasingly easy to surpass the United States in space-related technology. Our country would lose a critical edge in both foreign affairs and the global economy.



Q4. The aerospace workforce is described as a highly-skilled and highly-trained workforce. I'd like to get your insights, as leaders of this community, on what it means to develop this highly-skilled workforce? What is entailed in fostering a critical skill in this field? And, if decisions are made that disrupt the need for those skills and capabilities, how easy or difficult is it to bring those skilled workers back online?

A4. A successful career in aerospace engineering requires core competency in math and science, demands insight into the nuances of a broad range of technologies, benefits from an aptitude for problem solving, and needs frequent insights in how to overcome system integration challenges. Training for the personal mental discipline to develop these skills must begin at an early age (no later than middle school) and must be accompanied by goals tied to an external source of inspiration that can motivate the personal sacrifice associated with mastering those disciplines. Pre-college preparation, a suitable, specialized college education, and often additional graduate studies are needed to fully develop the knowledge and professional skills required of aerospace engineers. The full formulation of the applicable engineering skills during college and graduate studies must also include opportunities to tackle and solve relevant system design, test, and demonstration challenge problems, which necessitate access to suitable laboratories and sponsoring research initiatives.

At all preparatory education levels, and especially at the start of an aerospace career, aspiring engineers need mentors that have already tackled and mastered design challenges. The mentors transfer the unique knowledge of practical experience, processes, and lessons learned from prior successes, and maybe more importantly, from prior failures. The young engineers then need the opportunity to apply themselves in programs where their full range of newly acquired skills can be tested and honed. Lengthy gaps in support of specific technical areas result in loss of painstakingly acquired knowledge and capabilities, and finite resources and time are subsequently needed to re-learn past lessons and to resurrect what was already done.

There are several dimensions to that skilled aerospace workforce that one must consider; scientist/engineer is one level, technician is another.

Technician—the workers who process launch vehicles, and work on the production floors for satellites and rockets, have unique skills that take either specialized training or on-the-job experience. An error in soldering or welding or fastening connectors can lead to a failure on launch or on orbit, so having qualified people in this part of the workforce is very important. There are certification programs available at several community colleges near aerospace facilities, and every company maintains a substantial training program. Because these are skilled, disciplined workers, they are often attractive to employers outside aerospace. In an area such as Florida, where there's the potential for the loss of thousands of jobs as the Shuttle is retired, it's likely to be difficult to attract these workers back if we need them for a program that starts flying 5–10 years in the future.

Engineer—the people who design, develop, and oversee the production of aerospace systems, as has been mentioned, take far longer to achieve the skills necessary to be a productive worker. Virtually all have undergraduate degrees in a technical field, and many have some graduate education. For that to happen generally requires some emphasis on math and science in high school, so the "pipeline" to enter the profession is often at least 8–10 years. The evolution from an entry-level engineer who is qualified to work on specific issues (structures, guidance, propulsion, etc.) to one who is capable of providing technical oversight for a major project, a satellite or launch vehicle, is a decades-long process. From one perspective, there are too few scientists and engineers entering the aerospace workforce to ensure the necessary population will be there 10 and 20 years in the future. However, because the number of programs has declined significantly across almost all areas of aerospace, there are enough scientists and engineers to fill current needs. The problem is that as some of those entering now leave for other jobs or other reasons, there is substantial risk that there will be a shortage of experienced engineers in the future. That's a problem that will be very difficult to solve because of the long time it takes to train and "mature" that part of the workforce.

These are not simple programs that can start and stop without significant costs both in investment and in institutional knowledge. As you lose the existing workforce in any given program, it is very difficult to attract competent, willing professionals to pick up the pieces. There is then a lag time as those professionals have to piece back together the previous program and determine the best approach for moving forward. Without some certainty in this programs and this field, it is very difficult to maintain—much less grow—the pipeline of competent, competitive professionals to support this sector.

Another facet to consider is that a relationship has existed between the aerospace industry and the auto industry that has provided a stopgap during program reductions and changes in vision. Between these two sectors, as one industry faced stagnation and reduction, the existing workforce had some ability to move into the other sector. This relationship has served to keep competent experienced individuals employed and increasing their skill sets, and often broadening their approach to overcoming engineering challenges within each discipline. However, with the current uncertainties in the short- and long-term health of the auto industry, there is not an apparent safety net for those aerospace professionals if there is a long- or even short-term reduction of existing programs and platforms to support.

Questions submitted by Chairwoman Gabrielle Giffords

Q1. Mr. Thompson, you noted that "one danger . . . is that the levels of human capital needed to sustain a robust national human space program will drop below critical mass." How do we know when we've reached that critical point? How serious is this issue for what our nation can or cannot do in future human spaceflight and exploration?

A1. There are a number of specific technical disciplines needed to develop and integrate subsystems and systems associated with human spaceflight (encompassing launch vehicles, spacecraft, and the supporting research and operational infrastructure). Furthermore, there are the disciplines that are needed to support significant technical advances in human spaceflight, such as life sciences and microgravity research. Given this array of disciplines, an assessment can be made of the number of active professionals and managers with applicable skills at each of the major organizations involved with associated system developments (including both government and industry organizations). If these organizations have identifiable skill gaps that are not easily filled, or they have insufficient staff in any specific skill area that cannot be easily remediated to cover the projected program needs, then a critical mass does not exist to do the job, and the success of these development programs is at risk. In addition, the demographics of this workforce matters. If the available workforce to develop these systems is skewed toward too many who can retire soon, then the workforce critical mass is at risk of being lost soon. Furthermore, if the flow of students who are U.S. citizens into applicable college and graduate school curricula is insufficient to provide a pool of prospective capable replacements for impending retirees from the profession, then that is another indicator of impending loss of critical mass.

Once the workforce critical mass is lost, programs either fail, or cannot go forward, which exacerbates the problem by pushing more experienced professionals out of the field, often permanently. Subsequently, trying to reestablish the workforce critical mass will be exorbitantly costly, will take years to accomplish, and will reduce our national capabilities in the field. This in turn may enable other nations to assume the role of the new aerospace and human spaceflight leaders.

Much of the knowledge for engineering human spaceflight and exploration missions is experiential knowledge. When those professionals who have the experience leave the business, those years of important operational knowledge disappear as well. It would be very costly and take a long time to grow that operational knowledge in a new workforce, thus limiting what can be done with finite national resources for exploration.

Q2. Aerospace organizations compete with other high-technology institutions for talented workers with education and experience in STEM fields. How easy or difficult is it to attract talent to aerospace positions?

A2. Almost no one comes into aerospace "casually." The coursework at college is demanding, the compensation is generally below that of comparably educated, technical workers entering the job market, and there are more persons graduating with degrees in aerospace engineering than there are available entry-level positions. Therefore, the students in aerospace are usually there because they have a passion for it. Aerospace also attracts graduates from other disciplines that are critical to building aerospace systems—mechanical engineering, electrical engineering, computer science, physics, mathematics, chemistry, etc. Again, they enter aerospace because of the excitement of the area, and the downturn in new programs can't help but have a negative effect on our ability to attract the best and the brightest.

The ability to capture the imagination and to inspire is countered by the lack of consistency in programs and the marketplace. Many of the high-tech fields, especially those in automation, computer sciences, and information technology, offer the excitement of entrepreneurial opportunities and quick success. That is the also part

of the promise of the growth of commercial space. It offers that additional element that attracts this latest generation of STEM professionals.

Cultural issues remain, however. Many from this new generation of STEM professionals list two specific facets as motivation: the desire to be an integral part of or to lead a research program, and the opportunity to work on something that is going to have a significant impact on the human condition. On that first point, aerospace is very challenging because as a mature technology sector there are generations of professionals who have earned leadership roles through experience, expertise, and achievement. On the second point, the green technology sector is capturing a lot of that exuberance on the edge of technology. The aerospace sector is likely to play an increasingly important role in this area, but it has yet to gain the necessary visibility to attract more of young professionals into aerospace.

Q3. How are the knowledge and expertise gathered through our experience with the first fifty years of space activities, including the ability to design, develop, and operate a human lunar program and space transportation system, being passed on to the next generation of aerospace professionals? How perishable is this knowledge and expertise?

A3. Many of the young professionals who worked on the Apollo, Gemini, and Saturn programs are now in the waning years of their careers. However, if there is a silver lining to the current economic downturn, it is that many of these professionals are postponing retirement, providing an opportunity to capture their experiences and institutional knowledge to retain that knowledge base.

That being said, within 10 years many of those remaining professionals will retire, and unless we seize this moment, that opportunity will be lost, and future aerospace professionals will not be able to gain from those experiences and lessons from those early programs.

It has been decades since a vehicle such as the Shuttle was built, or propulsion systems of the size and complexity of the Space Shuttle Main Engine or the large Saturn V engines. On the other hand, new engines were developed for the Delta IV and the SpaceX Falcon series. Satellites far more complex than anything flown in the first 20 years of the space are "routine" products today. The people that designed, built, and operated the Mercury/Gemini/Apollo systems, or the early military or intelligence systems, had far less accumulated experience and available information than those who will design the next generation system. No question that it is important that we capture the experience of the past, but this is an ongoing process, done within every aerospace company and, I hope, within the government. In one sense, the worst thing we can do in terms of moving forward is to rely too heavily on those who built the systems 20, 30 and 40 years ago. We need to have them help guide the current generation of professionals, while allowing these extremely bright and innovative young people substantial freedom to try things, experiment, and occasionally fail, fix, and recover.

Q4. Your organization represents over 36,000 aerospace professionals and students, as you note in your prepared statement. Given that AIAA membership includes students, early-career, mid-career, and senior-level aerospace professionals, what issues are most important to each of those segments of the workforce and how can the needs of the different groups be balanced?

A4. Though there are differences among needs at different stages of professional development, what is similar among the groups is that they all draw inspiration to continue to achieve and continue to invest their talents from the continuation of an exciting set of spaceflight programs.

Questions submitted by Representative Pete Olson

Q1. In your testimony you talk about the gap that existed between the end of the Apollo program and the beginning of the Shuttle program. You said NASA's early Mercury, Gemini, and Apollo programs attracted young individuals into the aerospace workforce, and some of those who remained in the workforce formed the core expertise behind the development of the Space Shuttle and later the International Space Station programs. As a result, today's aerospace workforce is generally older than the Apollo workforce was in the 1970's, and a significant percentage is eligible to retire over the next ten years. How does this older workforce make today's situation more problematic and complicated than in the 1970's? What should be done to minimize the loss of critical skills?

A1. As you point out, in the Apollo era we were starting the development of a skill set of doing lunar missions from square one. At that time, we had a comparatively

large resource base to invest in the endeavor, and could afford the building up of a skill set starting from scratch. What's different today is that we indeed do have the people currently in the workforce who have the experiential knowledge to help us go back to the Moon and we need to retain the investment in them that this country has already made. In addition, we do not find ourselves in an era of large budgets for space exploration, as was the case in Apollo. We cannot afford to spend additional money re-learning the lessons of Apollo that could instead be retained simply by keeping the current knowledge base employed.

Today's aging aerospace workforce poses at least two problems: 1) There is a need to replace these workers with younger engineers, and to capture and transfer the experienced engineers' knowledge and lessons learned for use by those younger engineers; 2) The fresh perspective and thinking provided by young engineers that helps to find novel solutions to the problems at hand is less prevalent when the workforce demographics and/or hiring gaps limit the number of young engineers involved in the profession. To mitigate those problems, programs are needed that justify and motivate hiring young engineers combined with incentives to retain the older engineers in organized mentoring and knowledge capture activities. In parallel, programs are also needed to better prepare students for analytical thinking and technical careers at all educational levels. From an engineering workforce perspective, the gap between Apollo and the Shuttle is very different than the gap that will likely exist between the Shuttle and the next generation transportation system, or capability. The important "gap" between Apollo and Shuttle was between the development times. The first Saturn I rocket was launched in 1961. The first Apollo-capable Saturn V was launched in 1967.

The first Shuttle launch was in 1981, fourteen years later. It is now almost thirty years since the first Shuttle launch, and we are still many years away from the first launch of a Saturn or Shuttle-class heavy lift vehicle.

Not only can we not rely on the Apollo/Shuttle era workforce to produce the next generation systems, it would be foolish to do so. Space transportation needs to work toward the same kind of incredible advancements that we've seen in the satellites that the rockets carry to space. In 1963 a Delta rocket placed a communications satellite in geosynchronous orbit. In 2003 a Delta II—an upgraded version of essentially the same rocket with solid rocket boosters—launched the now famous Mars Rovers. In December last year, the same rocket launched NASA's Wide field Infrared Survey Explorer. A Delta engineer, seeing the three rockets, would have known exactly what they were and how they would perform. An engineer from the SYNCOM-era would find the Mars Rovers to be almost inconceivably complex and capable. The same would be true if he or she saw any of the communications satellites that are flowing down our production line today. It is time to turn the clock forward, not backwards, on space transportation. We need to do the basic research and development so that in 20 or 30 years the United States is once again building and operating the finest space transportation vehicles in the world. To do that, we need to get young people engaged in exciting, new work. If we have that kind of challenge to put in front of them, they will come—just as they did for Mercury and Gemini and Apollo. It is not something that industry is able to do on its own—we are too constrained by short- and mid-term finances. Industry can do a great job delivering the payloads of the next decade or two, using vehicles that are flying now, or based on technology that is well in hand. But, that commitment to the future, to once again being the best in the world, is exactly the kind of thing that only the government was able to do in those earlier days, and that it can and should be doing again today.

Q2. Norm Augustine suggested that his panel did not adequately address the erosion of the Industrial Base in their report. In your view, is this issue getting the appropriate level of attention from the Administration's decision-makers? What recommendations do you have for Congress to ensure that impacts to the industrial base are properly evaluated and addressed in the current process?

A2. When addressing the issue of a declining industrial base, there are many facets that one must consider beyond the ability to support the human spaceflight program. There are two specific topics that have been discussed at length before this committee in recent years that are having a tremendous effect upon the national aerospace industrial base. The first is inspiring, educating, and retaining a highly competent professional workforce that excels in an ever more competitive global marketplace. A second issue that has been identified by this committee is the impact that our current export control regime, and specifically the International Traffic in Arms Regulations, has had on our industrial base, while inadvertently helping create and assist the growth of industry competitors abroad.

The Congress needs to continue to seek and invest resources into programs that encourage more young people to enter the STEM fields, equipping them with ample classroom and laboratory learning and training opportunities to foster interest and develop core competencies. This country currently lacks sufficient homegrown talent with the requisite proficiency to retain our competitive edge. It wasn't so long ago that the U.S. was able to attract the best and brightest students from around the world. However, many of those same students now have opportunities at home, and are finding a greater global marketplace to sell their talents. To bridge that growing gap of talent lost to global competitors, we must commit ourselves to developing our youth to support the needs of the next generation workforce.

After several years of moving towards tightening and retaining export controls, there appears to be some recognition of the harmful effect that over-regulation is having on our industrial base, and thus on our national and economic security. The aerospace industry has already seen a dramatic decline in secondary and tertiary subcontractors. Both in Congress and in the Administration, we have begun to see a willingness to examine our current policies and consider changes that will help increase our competitiveness while retaining technological advantages critical to our national security. I believe it is going to require substantial leadership in this area if we are to see any meaningful changes. I see this as a major challenge to shoring up and hopefully growing our industrial base in the long term.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Ms. Marion C. Blakey, President and Chief Executive Officer, Aerospace Industries Association

Questions submitted by Chairman Bart Gordon

Q1. The nation's space program and the aerospace workforce and industrial base that support it are critical elements of the nation's science and technology infrastructure. How important is the work that your companies and professionals perform on NASA projects, as opposed to other projects, to our national competitiveness and our capacity for innovation?

A1. The work on NASA projects is very important to our companies, large and small alike. For some of our larger companies, entire facilities are dedicated to developing space programs; for some smaller companies, NASA space programs are their main livelihood. As a result, cancelling NASA programs can affect the workforce of entire regions. In addition to economic impact, NASA programs are also valued by companies because they help drive innovation. The unique knowledge gained by working on space programs has contributed positively to companies' work in other areas and other industries, such as health and medicine. Research that provides cross-cutting benefits like NASA programs sustains our national competitiveness and capacity for innovation.

Q2. How would you characterize aerospace jobs in terms of skill levels, pay, and turnover as compared to jobs in other high technology and research institutions? What are the key drivers for job growth or reductions in the aerospace workforce?

A2. As listed by the Bureau for Labor and Statistics, aerospace jobs are high-paying compared to other industries. For example, engineers in aerospace product and parts manufacturing earn $44.27 per hour compared to $42.58 in other industries. Mechanical engineers earn $39.01 per hour compared to $36.02 in other industries. Inspectors, testers, sorters, samplers and weighers earn $22.10 per hour compared to $15.02 in other industries. Machinists in aerospace earn $19.49 compared to $17.41 in other industries.

The proportion of workers with education beyond high school is larger in the aerospace industry than the average for all industries. In addition to training requirements and high skill-level, workers in defense-related aerospace companies often need to be able to obtain a security clearance. Aerospace jobs at the entry level for professional occupations primarily require a bachelor's degree in a specialized field such as engineering. At the "production-level" it typically requires a high school diploma and additional vocational training at community colleges and technical schools.

AIA is in the process now of collaborating with other industry associations to compare data including turnover rates. Within our industry, the highest turnover for aerospace employees are those with 0 to 5 year experience. Anecdotally, it is speculated that these employees are likely going to other industries such as IT.

Q3. What makes NASA's human spaceflight programs different from other NASA programs or federally-sponsored research programs with respect to the workforce and industrial base that support it? What capabilities are most critical to retain in the aerospace workforce and industrial base to ensure we continue to maximize our odds of successful and safe human spaceflight?

A3. Making spaceflight programs safe for humans adds an additional, necessary component to human spaceflight programs. As we move towards retirement of the shuttle and development of a new vehicle it is critical that we have a workforce that is experienced in the development and systems integration of human-rated space vehicles. Workers with this type of skill set were most utilized during the Apollo era and development of the shuttle in the 70s. In recent times, the major activity at the agency has shifted from the development of human-rated vehicles to robotic vehicles. Given this focus, project managers and systems engineers with experience in developing human vehicles are rare and their numbers will continue to decrease. Utilizing this group's knowledge to develop our next vehicles and train new professionals in this skill set is necessary now.

Additionally, the need to maintain our mission operations workforce is also critical. As we move towards a new human-rated vehicle, experienced mission operations personnel working on the shuttle could likely transfer their skill set to the

new vehicle, but if there is a large gap between the retirement of the shuttle and the launch of this new vehicle there is a risk of losing these skilled individuals.

Q4. In your written testimony, you note that "when Lockheed Martin was hiring for CEV they had 10 high-qualified resumes for each job." That suggests that aerospace can attract high-quality talent. Once you get that talent, what is needed to keep them involved in aerospace as opposed to having them go off to other high-technology fields?

A4. AIA is currently coordinating with Aviation Week and NASA on a survey of young aerospace professionals and college students to address this question. The catalyst for this survey was a finding by Aviation Week that young professionals with 0 to 5 years of experience have the highest voluntary attrition rate (almost 16%) in the industry. We have anecdotal evidence that the key to retaining these young professionals is their feelings that they are: 1) doing exciting work, 2) feeling engaged and involved, and 3) contributing to work that will make a positive societal impact.

At previous AIA & AIAA sponsored conferences, dedicated panels of young professionals have discussed programs at their workplace that have kept them involved. These programs involved teamwork, mentoring programs and working on projects where they are active participants and where they can see the results (e.g., an operationally responsive space project that requires a fast turnaround).

Q5. The aerospace workforce is described as a highly-skilled and highly-trained workforce. I'd like to get your insights, as leaders of this community, on what it means to develop this highly-skilled workforce? What is entailed in fostering a critical skill in this field? And, if decisions are made that disrupt the need for those skills and capabilities, how easy or difficult is it to bring those skilled workers back online?

A5. Keeping an experienced incumbent workforce continuously engaged is critical especially in regards to human spaceflight safety (see also #3 above). A gap in mission operations could lead to a decrease in practice of these valuable skills, which could jeopardize the safety of future missions. The current gap in development of human-rated vehicles (the last program was between Apollo and the space shuttle in the 70s) has already lead to a shortage of project managers and systems engineers who have experience with this type of work.

Development of the future workforce is a concern because it takes several years for an aerospace professional to develop, whether they are a technician that requires additional vocational training after high school or an engineer that requires at least a bachelor's degree. Consequently, disruptions to inspirational projects could have a negative effect on the numbers of young people that pursue these types of careers. Additionally, the number of schools that offer training in these fields may decrease if enrollment in those programs falls.

If decisions are made that disrupt the need for those skills and capabilities, it's not only a question of how easy it is to bring those skilled workers back online—it's very difficult—but also *how long*. The process of inspiring and training workers is decades-long.

Questions submitted by Chairwoman Gabrielle Giffords

Q1. To what extend do agencies such as the DoD count on the industrial base that supports NASA activities for defense-related programs? What are the implications for the DoD and national security actives if NASA's human spaceflight plans would no longer require certain industrial base capabilities?

A1. Our space efforts are deeply intertwined between commercial ventures, civil programs and national security space programs. Many of the same companies support all three ventures, sometimes with the same equipment. For example, the GPS program is administered by the Department of Defense, yet countless civilian and commercial applications render the system indispensable. Similarly, commercial, civil and national security payloads are often placed in orbit by the same types of launchers. Therefore, when one program is canceled or delayed, the impact can easily spread across our space industrial base.

Reducing our civil space R&D effectively reduces the overall investment to our space industrial and technology base. Even though the space industry has the ability to move talent between programs, and to share resources (such as components for satellites, launchers or the solid fuel for launch systems which is provided by a single company for commercial, civil and national security projects), a reduction in any one aspect of R&D ultimately affects the entire resource pool.

NASA's R&D is largely driven by developing or improving human-rated systems. A reduction in human exploration R&D would significantly reduce the overall pool of space R&D that benefits the nation.

Q2. Your written statement talks about the importance of a space program that inspires younger people and attracts them to the aerospace workforce, especially as increasing numbers of that workforce become eligible to retire. How serious is this issue for what our nation can or cannot do in the future of human spaceflight and exploration? What economic impact on the aerospace industry if the required technical workforce is not there when you need it?

A2. The issue of a retiring workforce and attracting the future workforce is serious. According to the latest Aviation Week survey, 17.3% of the engineering workforce will be eligible to retire by 2013. In research and development retirement eligibility will be 24.8%. Among engineering technicians, 22.1% will be retirement eligible. In touch labor, 19.5%. This equates to thousands of the aerospace workforce becoming eligible to retire in the next 3 years.

As this workforce retires, attracting and retaining the future workforce is critical. The replacement costs for lost workers are extremely high. For example, replacing a young professional in an engineering or technical profession costs approximately 300% of that individual's base salary. Keeping a robust human spaceflight and exploration agenda will not only help retain critical skills in industry, but also help the private sector avoid having to replace workers at a high price.

Q3. How are the knowledge and expertise gathered through our experience with the first fifty years of space activities, including the ability to design, develop, and operate a human lunar program and a space transportations system, being passed on to the next generation of aerospace professionals? How perishable is this knowledge and expertise?

A3. Knowledge management practices are critical for the industry due to complex nature of aerospace and defense programs. In Aviation Week's survey it was found that 70 percent of the industry uses "Intranet Portals" for knowledge management, followed by 65 percent who use a "Knowledge/Content management system" and about 50 percent who utilize an "apprenticeship" model featuring subject matter experts who mentor young professionals. While a computer may be useful for maintaining knowledge, the hands-on learning that comes from an apprenticeship is paramount, especially in regards to spaceflight missions that require human safety. As mentors with these abilities disappear over the years, their knowledge and expertise perish with them.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. A. Thomas Young, Executive Vice President (Ret.), Lockheed Martin Corporation

Questions submitted by Chairman Bart Gordon

Q1. Having co-chaired a study on the space industrial base, are there finding from that assessment and should be brought to bear on the decisions being made on NASA's future and funding?

A1. The Space Industrial Base study was conducted in 2007. At that time, the space industrial base was considered healthy with some areas of concern being associated with second and third tier suppliers. International competition was cited as rapidly growing with U.S. preeminence in space under challenge in many areas.

The space industrial base will continue to be healthy only if it is used to implement challenging programs. A gap in development challenges will result in significant loss in expertise that will take decades to recover at a very high cost. Decisions on NASA's future and funding must consider the impact upon the industrial base. While jobs are important the expertise of the base should be of primary consideration.

Q2. To what extent do agencies such as the Department of Defense count on the industrial base that supports NASA activities for defense-related programs? What are the implications for the DOD and national security activities if NASA's human spaceflight plans would no longer require certain industrial base capabilities?

A2. The DOD and NASA utilize and depend upon the same space industrial base. A change in direction in the programs of one organization can have significant adverse impacts on the other organization. When making major decisions on direction of the DOD or NASA space program, the impact on both organizations must be understood and considered. To assume proper coordination between national security and civil space programs, the U.S. needs a national space strategy and a Space Council to oversee the strategy's implementation.

Q3. The nation previously experienced a gap in U.S-provided access to space between the end of the Apollo program and the first flight of the Space Shuttle. What did we do right and what did we do wrong with respect to the workforce and industrial base during that time? What lessons learned are most applicable to the current situation and the decisions on NASA's funding and human spaceflight plans that Congress and the White House must make?

A3. A significant difference exists between the end of Apollo gap and the end of the Space Shuttle gap. There was no operational requirement for space transportation as current exist with the space station. This will result in significant resources being used to acquire transportation to and from low earth orbit from Russia. Resources that will not be available to support the U.S. industrial base.

There are also significant similarities in the respective gaps. Namely, both represent the end of a major program heavily involved in operations and the beginning of a development program. The result was and is the loss of technical operating jobs. A lesson learned is that critical expertise can be maintained if there is no significant technical gap. That is, the following program is initiated in parallel with the program which is being concluded. That is the course we were on with the Constellation program. While technical operating jobs would be lost, critical technical expertise would be maintained in NASA and industry.

A significant gap in utilizing this technical expertise in program development will have a devastating effect on the space workforce.

Questions submitted by Chairwoman Gabrielle Giffords

Q1. In your prepared statement, you state that "A detailed exploration plan with destinations, dates and implementation plans is needed." What, in your view, is involved in developing such a good plan?

a. What can be held up as a model?

b. What would you recommend Congress do in the absence of such a plan from NASA?

A1. There are many examples of NASA programs with excellent plans. Apollo and the Mars robotic programs are two superb models. Most successful programs are

characterized by detailed plans that focus the efforts of diverse organizations required to work together to accomplish a defined objective. A primary responsibility of leadership is to establish a detailed implementation plan with all the definition needed to provide program direction. Destinations, dates, etc. and required elements of the plan.

Failure to provide a detailed implementation plan is a failure of leadership and will result in a failed or highly inefficient program.

A budget without a detailed implement plan is an oxymoron. Congress should refuse to approve a budget without first having and approving a detailed implementation plan.

Q2. As a seasoned aerospace professional who has led and overseen the development of many complex, expensive military and civilian spacecraft, what, from your perspective, are the most significant challenges in implementing NASA's proposed plan for purchasing commercial crew services for access to low-Earth orbit?

a. Does the administration's estimated price tag of $6 billion and estimated 5-year time horizon to establish commercial crew capabilities across multiple commercial providers make sense?

b. What further information would you want to see in order to develop confidence in the proposed timeline and budget for this type of development project?

A2. Space projects are hard. Even with the application of our best capabilities all are not successful. We have developed a methodology that maximizes the probability of success. This methodology utilizes NASA's extraordinary leadership and continuity of human spaceflight expertise and the implementation capability of industry which is second to none. This partnership is a model that is tested, proven and continuously improved. Why would anyone make a drastic, unproven change to this methodology? Risk of such a change are enormous and involve mission, schedule, cost, workforce and space program risks.

I do not believe the $6B cost or 5 year schedule are realistic or supported by experience. I have seen no analysis that support these budget and schedule numbers.

I would not approve commercial crew without extensive proof of capabilities with flight performance. Commercial cargo can be a first step followed by non-NASA commercial crew demonstrations. I do not believe this can be accomplished on a schedule that will allow repetitive commercial crew flights to space stations prior to 2020.

Q3. The FY2011 request proposes $3.1 billion over five years for research in heavy-lift and propulsion technology. One of the areas this budget line is to emphasize is development of a first stage engine, and in particular, a hydrocarbon engine that would be used for a future heavy-lift vehicle. The congressional budget justification also indicates the projected level of funding is anticipated to lead to an operational engine by the end of the decade.

a. How important is the development of a new first stage engine, and in particular a hydrocarbon engine to development of a future heavy-lift vehicle?

b. Does the proposed budget and timeline make sense, in your view?

A3. The budget and timeline do not make sense to me. I am a strong supporter of technology development and I believe a human spaceflight technology program with mission focus is needed. However, I believe we have the capability to start heavy-lift today. Heavy-lift is dependent upon funding authority not a 5 year technology program. The $3.1B would be better utilized to start the heavy-lift development.

Q4. How will the absence of a specific exploration goal, timeline, and mission affect the advanced technology programs that the Administration is proposing?

a. Are there any lessons learned from previous technology programs that Congress should consider?

b. In your statement, you noted that "NASA, with appropriate outside support, should define the required technology program." What type of outside support would be involved and from what institutions?

A4. A technology program without mission focus often results in an inefficient, "hobby shop" approach. The technology developed in such an environment results in technology that satisfies the technologist but not the mission need.

The Mars robotic program has been a highly effective and focused technology endeavor. Rover, atmospheric entry, landing, electronics, etc., technology development have all supported a highly successful program.

I believe the best source of outside support is the National Academies. The Academies National Research Council (NRC) has the capability to make available extraordinary individuals to conduct reviews of NASA's technology program. Emphasis should be given to individuals with space project experience to assure the focus factor is not lost. I should note, I am a member of the National Academy of Engineering and the NRC Space Studies Board.

Questions submitted by Representative Pete Olson

Q1. You have noted that today's aerospace workforce is generally older than the Apollo workforce was at the time of the last major gap between the Apollo and Shuttle programs in the 1970's, and a significant percentage of the current workforce will be eligible to retire over the next ten years. How does this older workforce make today's situation more problematic and complicated than in the 1970's? What should be done to minimize the loss of critical skills?

A1. A healthy workforce requires the contemporary intellectual capability, exuberance and the belief that the impossible is achievable of youth and the experience, wisdom and appropriate respect for risk, represented by maturity. Today the aerospace workforce is somewhat unbalanced in the direction of maturity. While retirements will result in the loss of critical skills, this is reality and must be compensated for by attracting the "best and brightest" young professionals to the workforce. This can only be accomplished by having challenging and interesting work, the opportunity to work with and learn from extraordinary leaders and the privilege to work on projects of sufficiently short duration to allow individuals to see the impact of their contributions. If leadership will establish a program with the cited characteristics, the workforce challenges will solve themselves.

Q2. Our subcommittee has received testimony that the funding instability in the Constellation program has complicated the challenges of managing workforce retentions, transitions, etc Dr. Ken Ford, chair of the NASA Advisory Council said, "The current budget environment is jeopardizing the future of U.S. human space flight at a time when NASA has made significant progress toward development of the new Space Transportation Architecture." Assuming the President does not take an active leadership role in the issues facing NASA's human space flight program, with the likely result that OMB continues to starve NASA of funds in an effort to contain a runaway federal budget, how will a no-growth budget environment affect the industry, the workforce and the Aerospace and Defense industrial base? How would the aerospace and defense supplier base be affected if the Ares 1 program were terminated?

A2. I have had the privilege to work at several levels in the public and private sector. This has included being Director of NASA's Goddard space Flight Center and President/COO of Martin Marietta.

A common observation in each of these experience, is that the budget/financial entities are critically important to the success of the organization, but should not be the source of strategy or priorities. When the budget organization establishes strategy either by design or absence of leadership, mediocrity is typically the result.

Leadership of organizations, the President, Corporate Executives, NASA Executives, etc. are responsible to define strategy. Budget entities such as OMB are responsible for funding the established strategy and performance monitoring.

Impact of Ares I termination on the Aerospace and Defense supplier base depends upon the potential replacement program. If there is no replacement or a replacement is scheduled many years in the future, the termination will have a major adverse impact on our national capabilities.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Richard Aubrecht, Vice Chairman of the Board, Vice President, Strategy and Technology, Moog, Inc.

Questions submitted by Chairman Bart Gordon

Q1. The aerospace workforce is described as a highly-skilled and highly-trained workforce. What does it mean to develop this highly-skilled workforce? What is entailed in fostering a critical skill in this field? And, if decisions are made that disrupt the need for those skills and capabilities, how easy or difficult is it to bring those skilled workers back online?

A1. The vast majority of the aerospace workforce is engaged in highly specialized activities that require years of training and experience to be really effective and productive. There must be a zero tolerance for errors and so one needs an orientation and mind set not required to the same degree in producing other products.

The skill set and culture is built over a period of years. If there is an interruption in an organization's involvement in a particular technology or activity, the skill is lost. The difference in the aerospace business is that it consists of thousands of relatively small elements, each of which is critical.

Q2. What is your perspective on critical skills at the second tier levels of industry that should be high national priorities to retain?

A2. The first tier, prime contractors, are primarily responsible for the system designs and integration. They are supported by thousands of second and third-tier suppliers who have technical specialties. In many cases, there are only two-or-three really qualified suppliers of these technical specialties.

Q3. How are the knowledge and expertise gathered through our experience with the first fifty years of space activities, including the ability to design, develop, and operate a human lunar program and a space transportation system, being passed on to the next generation of aerospace professionals? How perishable is this knowledge and expertise?

A3. The knowledge and expertise related to manned space is passed on through a mentoring process. The drawings, reports and test records provide the data, but data is not knowledge. The knowledge comes through a mentoring, experimental learning process. This knowledge is very perishable.

Q4. In your testimony, you state "Once the capability and reliability of the components are demonstrated on NASA projects, the commercial space suppliers are then confident in using these components on their vehicles." Isn't NASA in effect a force multiplier? What would be the impact on the commercial sector if NASA project work opportunities are reduced?

A4. NASA is a knowledge and technology multiplier, and a pioneer of new technologies. Much of the progress in the commercial aerospace sector would slow dramatically if the NASA projects were to be reduced. NASA projects push boundaries so new technologies must be developed to meet these challenges. The commercial aerospace companies cannot take the financial risk to push the boundaries.

Q5. Congress and the Members of this Committee have been clear about the mismatch between NASA's programs and the funding requested to carryout those programs. What, if anything, does this mismatch mean for the 2nd and 3rd tier of the aerospace industry?

A5. The mismatch has a similar effect on Tier 1, 2 and 3 companies. It is very difficult to maintain the skill sets and knowledge base when funding is inconsistent. If funding is consistent, but not adequate, the programs are stretched out and eventually costs increase. There is a body of work that needs to be accomplished for any program and a pace at which the work can be efficiently done. Stretching out a program many times leads to very inefficient progress since people are often waiting around for someone else to complete a task or make a decision.

Questions submitted by Chairwoman Gabrielle Giffords

Q1. In your testimony, you said you were surprised that in several competitions, companies who had previously supplied specific technologies to NASA had either declined to bid because they no longer had the ability to design the required components, or had apparently submitted a weak technical proposal. You saw

this as an indication that consistent NASA funding is required if the nation is to maintain and advance its aerospace technology capabilities. In your opinion, are these isolated examples or representative of what will be going on in the industry if consistent NASA funding is not provided?

A1. I do not believe our experience is an isolated example. Many of the NASA programs require unique technologies. It is expensive to maintain these technical capabilities. If NASA does continuously pursue programs and consistently fund the programs, companies cannot maintain the required capabilities. NASA must provide a consistent flow of projects if they want the suppliers to maintain the capabilities.

Q2. In your prepared statement, you comment that your company's "technology plans have enabled us to develop a very clear understanding of the relationship between the technologies we develop for NASA projects and the growth in Moog's other aerospace business." Is there a way to quantify the growth that your company has leveraged from its NASA work in terms of the number of jobs created and percentage of new business that is generated?

A2. Currently, the sectors of Moog that produce NASA-related technologies are about $800 million of our sales. Of the $800 million, at least one-half is derived from our NASA experience. This $400 million in sales needs about 2,000 employees in our facilities and I would estimate about another 2,000 at our suppliers.

Q3. Your written statement talks about the importance of a space program that inspires younger people and attracts them to the aerospace workforce, especially as increasing numbers of that workforce become eligible to retire. How serious is this issue for what our nation can or cannot do in future human spaceflight and exploration?

A3. Attracting the best and brightest younger engineers is absolutely necessary for us and all the NASA suppliers to maintain our aerospace capabilities. NASA projects, especially the manned space projects, are really hard technical problems. To execute these at all, we all need the best and brightest talent. With experience on NASA programs, these engineers can then apply their knowledge and skills to commercial projects, but this talent pool needs to be constantly renewed.

Q4. In your prepared remarks, you make a striking statement, "On the one hand, you can decide to fully and consistently fund the Constellation Program and the USA can maintain its leadership position in aerospace technology. On the other hand, you can decide to select one of several seemingly lower cost options" and lose leadership. What is it about the Constellation Program, as opposed to alternative options for human spaceflight, that you believe is so critical to America's leadership in aerospace technology?

A4. Over the past 50 years, NASA has created the culture, knowledge and experience to execute successful human space flight programs. Human space flight requires extreme attention to thousands of details and a zero tolerance for error. Tom Young gave some very illuminating examples of what has happened when NASA attempted to run a human space flight and other programs with a money-saving mentality. There were some very expensive and unnecessary failures and NASA ultimately spent at least the same amount of money as it would have spent if it had adequately funded the program from the beginning.

At this point, some want to believe that commercial entities can be a lower-cost option for some of the human space flight requirements. I do not believe the commercial entities have the same orientation relative to risk and loss of life that NASA has. From what I have seen, the cost-saving decisions made by the commercial entities have led to failures of their launches. So far, these have been test vehicles and some satellites, and not human space flight vehicles. The culture in the commercial entities is willing to trade-off the potential loss of life against cost. This value set is likely to lead to expensive failures and ultimately higher costs than if NASA were to run the program.

Questions submitted by Representative Pete Olson

Q1. Our subcommittee has received testimony that the funding instability in the Constellation program has complicated the challenges of managing workforce retentions, transitions, etc. Dr. Ken Ford, chair of the NASA Advisory Council said, "The current budget environment is jeopardizing the future of U.S. human space flight at a time when NASA has made significant progress toward development of the new Space Transportation Architecture." Assuming the President does not take an active leadership role in the issues facing NASA's human space

flight program, with the likely result that OMB continues to starve NASA of funds in an effort to contain a runaway federal budget, how will a no-growth budget environment affect the industry, the workforce and the Aerospace and Defense industrial base?

A1. If the Administration "continues to starve NASA of funds", it will not be possible to make adequate progress on the "new Space Transportation Architecture". Any Space Transportation Architecture will be a very complex system of interacting subsystems and components, all of which need to be developed in a parallel set of design and development activities. Without adequate funding to achieve a critical mass of NASA engineers, prime contractors and several levels of subcontractors, the likely result will be the same as what happened in the past NASA efforts to develop a Shuttle replacement. That is, there will be several years of paper designs, a minimal amount of hardware built and tested, after which the program will be cancelled.

As was stated by all the panel members in the hearing, the funding needs to be sized to the needs of the program; not the other way around.

Q2. The NASA Administrator has emphasized that the Administration would utilize space exploration for diplomatic purposes by encouraging greater cooperation with foreign nations. Assuming this cooperation means utilizing the technical and industrial capabilities from other nations and having them play larger roles in supplying hardware and services, what potential negative consequences could this policy have America's capabilities and workforce? What recommendations do you have for Congress to ensure that policies designed to increase foreign cooperation do not have adverse consequences for American industry?

A2. Involving foreign nations in the space program can be beneficial. With the Space Station, foreign nations developed high-level modules that had relatively few and well-defined interfaces to the Station. These modules could be developed mostly with their own in country technologies. Therefore, there was not a significant amount of leading-edge USA-based technologies needing to be transferred.

This model is not likely to be applicable to the Constellation Program because it is a highly integrated system. In this case, there would have to be a very significant amount of technology transfer to the foreign suppliers for them to design their modules and components. With the current export control regulations, processes, and resources, the program delays would be intolerable.

○