AUTHENTICATED
U.S. GOVERNMENT
INFORMATION
GPO

# OPTIONS AND ISSUES FOR NASA'S HUMAN SPACE FLIGHT PROGRAM: REPORT OF THE "REVIEW OF U.S. HUMAN SPACE FLIGHT PLANS" COMMITTEE

## HEARING

BEFORE THE

## COMMITTEE ON SCIENCE AND TECHNOLOGY
## HOUSE OF REPRESENTATIVES

ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

SEPTEMBER 15, 2009

**Serial No. 111–51**

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
51–928PDF 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
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

**September 15, 2009**


| | Page |
|---|---|
| Witness List | 2 |
| Hearing Charter | 3 |

**Opening Statements**

| | |
|---|---|
| Statement by Representative Bart Gordon, Chairman, Committee on Science and Technology, U.S. House of Representatives | 29 |
| Written Statement | 30 |
| Statement by Representative Ralph M. Hall, Minority Ranking Member, Committee on Science and Technology, U.S. House of Representatives | 31 |
| Written Statement | 33 |
| Prepared Statement by Representative Jerry F. Costello, Member, Committee on Science and Technology, U.S. House of Representatives | 34 |
| Prepared Statement by Representative Eddie Bernice Johnson, Member, Committee on Science and Technology, U.S. House of Representatives | 35 |
| Prepared Statement by Representative Gabrielle Giffords, Chairwoman, Subcommittee on Space and Aeronautics, Committee on Science and Technology, U.S. House of Representatives | 35 |
| Prepared Statement by Representative Harry E. Mitchell, Member, Committee on Science and Technology, U.S. House of Representatives | 37 |

**Panel I:**

| | |
|---|---|
| Mr. Norman R. Augustine, Chair, Review of U.S. Human Space Flight Plans Committee | |
| Oral Statement | 37 |
| Written Statement | 39 |
| Biography | 42 |
| Discussion | |
| Constellation Program Status | 43 |
| Future Options for NASA | 45 |
| Closing the Shuttle/Ares Gap | 45 |
| Evaluating Crew Safety | 46 |
| Viability of the Commercial Sector to Support NASA Human Space Flight | 48 |
| Importance of Funding Human Space Flight | 50 |
| Should the Columbia Accident Investigation Board Findings Apply to All Human Space Flight? | 50 |
| Concerns About Commission's Findings | 52 |
| Finding Extra $3 Billion for NASA | 54 |
| Implications of Canceling Ares I | 56 |
| Consequences of Not Increasing NASA's Budget | 56 |
| ISS and Mars | 57 |
| Comments on Commission's Findings | 59 |
| Determining the $3 Billion Increase | 60 |
| Risks of Commercial Ventures | 61 |
| NASA Skills and R&D | 62 |
| Workforce Sustainability | 64 |
| Space Shuttle Recertification | 65 |
| Possibilities Without $3B Increase | 66 |
| Inspiring Students With NASA's Current Budget | 66 |
| Serving President Kennedy's Vision for the Space Program | 67 |

Page

Has NASA Ever Been Fully Funded? ..... 69
International Cooperation for Human Space Flight ..... 70
American Leadership in Space ..... 71
Current State of NASA ..... 72

**Panel II:**

Vice Admiral Joseph W. Dyer, USN (Ret.), Chair, Aerospace Safety Advisory Panel, NASA; President, Government & Industrial Robots Division, iRobot Corporation
Oral Statement ..... 74
Written Statement ..... 76
Biography ..... 79

Dr. Michael D. Griffin, Eminent Scholar and Professor, Mechanical and Aerospace Engineering, University of Alabama, Huntsville
Oral Statement ..... 79
Written Statement ..... 81

Discussion
Shuttle Extension ..... 87
Constellation Program With Budget Augmentation ..... 87
Effect of NASA Budget Cuts ..... 88
Commercial Transportation to the ISS ..... 90
Transforming NASA Expertise to Private Industry ..... 92
Continuation of Constellation Development ..... 93
Budget Limitations and Miscalculation ..... 94
Methodology of Cost Assessments ..... 96
Completion Dates for Constellation ..... 96

**Appendix 1: Answers to Post-Hearing Questions**

Mr. Norman R. Augustine, Chair, Review of U.S. Human Space Flight Plans Committee 100

Vice Admiral Joseph W. Dyer, USN (Ret.), Chair, Aerospace Safety Advisory Panel, NASA; President, Government & Industrial Robots Division, iRobot Corporation 110

Dr. Michael D. Griffin, Eminent Scholar and Professor, Mechanical and Aerospace Engineering, University of Alabama, Huntsville 113

**Appendix 2: Additional Material for the Record**

Letter to The Honorable Gabrielle Giffords from Gary P. Pulliam, Vice President, The Aerospace Corporation, dated March 19, 2010 119

# OPTIONS AND ISSUES FOR NASA'S HUMAN SPACE FLIGHT PROGRAM: REPORT OF THE "REVIEW OF U.S. HUMAN SPACE FLIGHT PLANS" COMMITTEE

---

**TUESDAY, SEPTEMBER 15, 2009**

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

The Committee met, pursuant to call, at 2:00 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Bart Gordon [Chairman of the Committee] presiding.

**COMMITTEE ON SCIENCE AND TECHNOLOGY**
**U.S. HOUSE OF REPRESENTATIVES**
**WASHINGTON, DC 20515**

**Hearing on**

# *Options and Issues for NASA's Human Space Flight Program: Report of "Review of U.S. Human Space Flight Plans" Committee*

September 15, 2009
2:00 p.m. – 4:00 p.m.
2318 Rayburn House Office Building

**WITNESS LIST**

**Panel I**

**Mr. Norman R. Augustine**
Chair
Review of U.S. Human Space Flight Plans

**Panel II**

**Vice Admiral Joseph W. Dyer USN (Ret.)**
Chair
Aerospace Safety Advisory Panel
NASA

**Dr. Michael D. Griffin**
Eminent Scholar and Professor
Mechanical and Aerospace Engineering
University of Alabama in Huntsville

Section 210 of the Congressional Accountability Act of 1995 applies the rights and protections covered under the Americans with Disabilities Act of 1990 to the United States Congress. Accordingly, the Committee on Science & Technology strives to accommodate/meet the needs of those requiring special assistance. If you need special accommodation, please contact the Committee on Science & Technology in advance of the scheduled event (3 days requested) at (202) 225-6375 or FAX (202) 225-3895.

HEARING CHARTER

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

# Options and Issues for NASA's Human Space Flight Program: Report of the "Review of U.S. Human Space Flight Plans" Committee

TUESDAY, SEPTEMBER 15, 2009
2:00 P.M.—4:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

### I. Purpose

To examine the summary report of the Review of U.S. Human Space Flight Plans Committee that was established by the National Aeronautics and Space Administration (NASA) under the direction of the Office of Science and Technology Policy, and to consider implications and related issues for NASA.

### II. Witnesses

*Panel I*

**Mr. Norman Augustine,** *Chair, Review of U.S. Human Space Flight Plans Committee*

*Panel II*

**Vice Admiral Joe Dyer USN (Ret.),** *Chair, Aerospace Safety Advisory Panel, NASA*

**Dr. Michael Griffin,** *Eminent Scholar and Professor, Mechanical and Aerospace Engineering, University of Alabama in Huntsville*

### III. Key Issues for the Hearing

- *How was the review committee able to compare options that differ significantly in terms of technical and programmatic maturity, understanding of risk, and fidelity of cost estimates? What are the limitations of the review committee's approach, and how should Congress and the Administration assess the options in light of those limitations?*
- *Given the differing degrees of technical, programmatic, and cost estimation maturity of the various options, what level of confidence can Congress and the Administration have that any of the alternative options can actually fit into the enhanced funding envelope proposed by the review committee in its summary report?*
- *Since the Constellation program is the program for which funds have been authorized and appropriated over the last four years and for which design, development, and test activities have been underway over that same period, did the review committee attempt to develop an option that would maintain the Constellation program development path but that would fit into the enhanced funding envelope proposed by the Committee by rephasing of milestones, initial exploration destinations, etc.? If so, why was it not included in the final set of options contained in the summary report?*
- *The same historical cost risk factor [1.51] appears to have been applied by the review committee to all of the options regardless of their level of technical and programmatic maturity. Does it make sense to apply the same risk factor to a program that has completed design reviews and hardware testing activities that is applied to options for which no comparable milestones have yet been achieved and for which the fidelity of the original cost estimate is correspondingly low?*

- *How can Congress and the Administration meaningfully compare the safety implications of the Constellation program of record and the other options in light of the review committee's decision not to attempt to distinguish between the levels of safety of the various options?*
- *What was the review committee's assessment of the technical maturity, program management, and cost control of the Constellation program? Did it find it to be a well executed program within the resources available or a flawed program?*
- *How high should the threshold be for a decision to scrap the existing Constellation program that has been under development for four-plus years? What circumstances would justify abandoning the program at this point in its development?*
- *If the Administration and Congress were to maintain the outyear budget plan that accompanied the FY 2010 NASA budget request and not provide enhanced funding, how should those funds be allocated?*
- *To what extent do the options presented by the review committee address the goals and objections for exploration that Congress has authorized in the* NASA Authorization Acts *of 2005 and 2008?*
- *How would the review committee rank the various options each other and against the Constellation program?*
- *What driving assumptions (e.g., cost, programmatic, risk) steered the review committee in determining its final options? How, if at all, are the assumptions that guided the conclusions in the Summary Report different from those discussed during the review committee's last meeting on August 12, 2009?*
- *How did the review committee develop measures and criteria by which to evaluate the options and their ability to meet the direction set by the Office of Science and Technology Policy for the review?*
- *How does the sustainability of the workforce and expertise needed to pursue the review committee's human space flight options differ under each of the options proposed?*
- *How should the review committee's finding that "interim reliance on international crew services" is "acceptable," be interpreted in terms of the gap in the Nation's ability to launch humans into space? What, if any, strategic implications of the gap did the review committee consider? How, if at all, does the gap affect implementation of any of the options presented by the review committee?*
- *When making a decision on an option, how do Congress and the Administration reconcile the review committee's statements that it treated human safety as a "sine qua non" while also stating that it was "unconvinced that enough is known about any of the potential high-reliability launcher-plus-capsule systems to distinguish their levels of safety in a meaningful way"?*
- *What are the implications of the recommended options on NASA's ability to sustain a balanced portfolio of science, aeronautics, human space flight and exploration?*
- *How, if at all, do the options presented by the review committee contribute to the development and evolution of international collaboration for human exploration over the long-term? How do the options compare in that regard? How did the review committee assess the international capabilities that could be potentially leveraged for each option?*
- *To what extent do the integrated options require technologies and operational techniques or other research and development that can only be conducted on the International Space Station? How did the review committee assess the time needed to achieve such R&D into its estimates of the timeline for each of the proposed options?*
- *What is the basis for the review committee's estimate that commercially provided crew service could be available a year earlier than the currently planned Ares/Orion program?*
- *Stimulating a "vigorous and competitive commercial space industry" as the review committee suggests would seem to depend on a robust government-sponsored exploration program. What did the review committee assume about the existence of a commercial market that would allow the government to be a marginal user of commercial services?*
- *To what extent do the options recommended require major technology developments, breakthroughs, or demonstrations of advanced technologies? For exam-*

*ple, how critical is the capability to provide in-space refueling to enable the implementation of the options presented by the review committee? Are the vehicles and pathways for achieving technology advancements in place? What level of programmatic risk is introduced if an option is dependent on achieving such advancements in advance?*

- *How did the review committee assess the extent to which each option could engage the public and the younger generations on whom the Nation will depend to carry out human exploration plans into the future?*
- *What is the basis of the $3 billion increase above the FY 2010 budget profile for exploration that the review committee concluded was needed to support a meaningful human space flight program? What does that $3 billion include and what is the increase each year that the review committee thought was needed to reach that level of investment?*

## IV. Overview of Review of U.S. Human Space Flight Plans

On May 7, 2009, the Office of Science and Technology Policy, Executive Office of the President, announced the *"launch of an independent review of planned U.S. human space flight activities with the goal of ensuring that the Nation is on a vigorous and sustainable path to achieving its boldest aspirations in space."* According to the press release, John P. Holdren, Assistant to the President for Science and Technology and Director of the Office of Science and Technology Policy stated: *"President Obama recognizes the important role that NASA's human space flight programs play in advancing scientific discovery, technological innovation, economic strength and international leadership."* He went on to say that *"The President's goal is to ensure that these programs remain on a strong and stable footing well into the 21st Century, and this review will be crucial to meeting this goal."*

### Charter and Scope of the Review of U.S. Human Space Flight Plans Committee

The National Aeronautics and Space Administration chartered the "Review of U.S. Human Space Flight Plans Committee" as a *Federal Advisory Committee Act* (FACA) committee, which requires that meetings and information presented to the review committee be accessible to the public.

The Charter for the review committee states the following Scope and Objectives:

> *"The Committee shall conduct an independent review of ongoing U.S. human space flight plans and programs, as well as alternatives, to ensure the Nation is pursuing the best trajectory for the future of human space flight-one that is safe, innovative, affordable, and sustainable. The review committee should aim to identify and characterize a range of options that spans the reasonable possibilities for continuation of U.S. human space flight activities beyond retirement of the Space Shuttle. The identification and characterization of these options should address the following objectives: a) expediting a new U.S. capability to support utilization of the International Space Station (ISS); b) supporting missions to the Moon and other destinations beyond low Earth orbit (LEO); c) stimulating commercial space flight capability; and d) fitting within the current budget profile for NASA exploration activities."*
>
> *"In addition to the objectives described above, the review should examine the appropriate amount of research and development and complementary robotic activities needed to make human space flight activities most productive and affordable over the long-term, as well as appropriate opportunities for international collaboration. It should also evaluate what capabilities would be enabled by each of the potential architectures considered. It should evaluate options for extending ISS operations beyond 2016."*

The review committee reports to the NASA Administrator and the Director of the Office of Science and Technology Policy (OSTP), Executive Office of the President. The review committee was given 120 days, following the date of its first meeting, to submit a report.

*Members of the Review Committee*

The review committee is comprised of nine members, including the Chair, with background and expertise in launch and aerospace systems, engineering, space science, human space flight, and management. The review committee is chaired by Mr. Norman Augustine, Chairman and CEO, Lockheed Martin Corporation (retired). Mr. Augustine is also a former member of the President's Council of Advisors on Science and Technology under Presidents Clinton and George W. Bush and chaired

the National Academies study, *Rising Above the Gathering Storm.* The full list of review committee members, as presented in a NASA Press Release dated June 1, 2009, is provided in Attachment D.

*Review Committee Meetings and Materials*

The review committee held six public meetings, beginning with its first meeting held on June 17, 2009 in Washington, D.C. and near NASA Centers involved in human space flight, held fact finding meetings, and conducted site visits to NASA facilities that support the human space flight and exploration programs. The material presented to the review committee, including statements from Members of Congress and analyses and syntheses prepared by the review committee members, are available to the public at the Review of Human Space Flight Plans committee web site *<http://www.nasa.gov/offices/hsf/home/index.html>*

**Results and Options Presented by the Review Committee (Excerpts from the Summary Report)**

A summary report of the Review of U.S. Human Space Flight Plans Committee was released publicly on September 8, 2009. The review committee is preparing a final report.

In its Summary Report, the review committee stated that *"The U.S. human space flight program appears to be on an unsustainable trajectory. It is perpetuating the perilous practice of pursuing goals that do not match allocated resources. Space operations are among the most complex and unforgiving pursuits ever undertaken by humans. It really is rocket science. Space operations become all the more difficult when means do not match aspirations. Such is the case today."*

In its direction from OSTP, the review committee was tasked to fit the options for a U.S. human space flight program into the existing budget profile for NASA's exploration activities. With respect to that direction, the review committee *"found two executable options that comply with the FY 2010 budget. However, neither allows for a viable exploration program. In fact, the Committee finds that no plan compatible with the FY 2010 budget profile permits human exploration to continue in any meaningful way."*

The review committee also received approval from OSTP to present options that exceed the FY 2010 budget profile for NASA's exploration activities. In that regard, the review committee stated that *"The Committee further finds that it is possible to conduct a viable exploration program with a budget rising to about $3 billion annually above the FY 2010 budget profile. At this budget level, both the Moon First strategy and the Flexible Path strategies begin human exploration on a reasonable, though hardly aggressive, timetable. The Committee believes an exploration program that will be a source of pride for the Nation requires resources at such a level."*

The review committee's key findings are as follows:

*Summary of Key Findings*

*"The Committee summarizes its key findings below. Additional findings are included in the body of the report.*

**The right mission and the right size:** *NASA's budget should match its mission and goals. Further, NASA should be given the ability to shape its organization and infrastructure accordingly, while maintaining facilities deemed to be of national importance.*

**International partnerships:** *The U.S. can lead a bold new international effort in the human exploration of space. If international partners are actively engaged, including on the "critical path" to success, there could be substantial benefits to foreign relations, and more resources overall could become available.*

**Short-term Space Shuttle planning:** *The current Shuttle manifest should be flown in a safe and prudent manner. The current manifest will likely extend to the second quarter of FY 2011. It is important to budget for this likelihood.*

**The human space flight gap:** *Under current conditions, the gap in U.S. ability to launch astronauts into space will stretch to at least seven years. The Committee did not identify any credible approach employing new capabilities that could shorten the gap to less than six years. The only way to significantly close the gap is to extend the life of the Shuttle Program.*

**Extending the International Space Station:** *The return on investment to both the United States and our international partners would be significantly enhanced by an extension of ISS life. Not to extend its operation would significantly impair U.S. ability to develop and lead future international space flight partnerships.*

**Heavy-lift:** *A heavy-lift launch capability to low Earth orbit, combined with the ability to inject heavy payloads away from the Earth, is beneficial to exploration, and it also will be useful to the national security space and scientific communities. The Committee reviewed: the Ares family of launchers; more directly Shuttle-derived vehicles; and launchers derived from the EELV* [Evolved Expendable Launch Vehicle] *family. Each approach has advantages and disadvantages, trading capability, life cycle costs, operational complexity and the "way of doing business" within the program and NASA.*

**Commercial crew launch to low Earth orbit:** *Commercial services to deliver crew to low Earth orbit are within reach. While this presents some risk, it could provide an earlier capability at lower initial and life cycle costs than government could achieve. A new competition with adequate incentives should be open to all U.S. aerospace companies. This would allow NASA to focus on more challenging roles, including human exploration beyond low Earth orbit, based on the continued development of the current or modified Orion spacecraft.*

**Technology development for exploration and commercial space:** *Investment in a well-designed and adequately funded space technology program is critical to enable progress in exploration. Exploration strategies can proceed more readily and economically if the requisite technology has been developed in advance. This investment will also benefit robotic exploration, the U.S. commercial space industry and other U.S. Government users.*

**Pathways to Mars:** *Mars is the ultimate destination for human exploration; but it is not the best first destination. Both visiting the Moon First and following the Flexible Path are viable exploration strategies. The two are not necessarily mutually exclusive; before traveling to Mars, we might be well served to both extend our presence in free space and gain experience working on the lunar surface.*

**Options for the Human Space Flight Program:** *The Committee developed five alternatives for the Human Space Flight Program. It found:*

- *Human exploration beyond low Earth orbit is not viable under the FY 2010 budget guideline.*
- *Meaningful human exploration is possible under a less constrained budget, ramping to approximately $3 billion per year above the FY 2010 guidance in total resources.*
- *Funding at the increased level would allow either an exploration program to explore Moon First or one that follows a Flexible Path of exploration. Either could produce results in a reasonable timeframe."*

*Options*

In its Summary Report, the review committee presented five integrated options for a human space flight program. Those options, along with a summary table of the options as presented in the review committee's Summary Report, are provided below.

*"The Committee was asked to provide two options that fit within the FY 2010 budget profile. This funding is essentially flat or decreasing through 2014, then increases at 1.4 percent per year thereafter, which is less than the 2.4 percent per year used to estimate cost inflation. The first two options are constrained to that budget.*

*Option 1. Program of Record as assessed by the Committee, constrained to the FY 2010 budget. This option is the Program of Record, with only two changes the Committee deems necessary: providing funds for the Shuttle into FY 2011 and including sufficient funds to de-orbit the ISS in 2016. When constrained to this budget profile, Ares I and Orion are not available until after the ISS has been de-orbited. The heavy-lift vehicle, Ares V, is not available until the late 2020s, and worse, there are insufficient funds to develop the lunar lander and lunar surface systems until well into the 2030s, if ever.*

*Option 2. ISS and Lunar Exploration, constrained to FY 2010 budget. This option extends the ISS to 2020, and it begins a program of lunar exploration using Ares V (Lite). The option assumes Shuttle fly-out in FY 2011, and it includes a technology development program, a program to develop commercial crew services to low Earth orbit, and funds for enhanced utilization of ISS. This option does not deliver heavy-lift capability until the late 2020s and does not have funds to develop the systems needed to land on or explore the Moon.*

*The remaining three alternatives are fit to a different budget profile—one that the Committee judged more appropriate for an exploration program designed to carry humans beyond low Earth orbit. This budget increases to $3 billion above the FY*

*2010 guidance by FY 2014, then grows with inflation at a more reasonable 2.4 percent per year.*

*Option 3. Baseline Case—Implementable Program of Record. This is an executable version of the program of record. It consists of the content and sequence of that program—de-orbiting the ISS in 2016, developing Orion, Ares I and Ares V, and beginning exploration of the Moon. The Committee made only two additions it felt essential: budgeting for the fly-out of the Shuttle in 2011 and including additional funds for ISS de-orbit. The Committee's assessment is that, under this funding profile, the option delivers Ares I/Orion in FY 2017, with human lunar return in the mid-2020s.*

*Option 4. Moon First. This option preserves the Moon as the first destination for human exploration beyond low Earth orbit. It also extends the ISS to 2020, funds technology advancement, and uses commercial vehicles to carry crew to low Earth orbit. There are two significantly different variants to this option.*

*Variant 4A is the Ares Lite variant. This retires the Shuttle in FY 2011 and develops the Ares V (Lite) heavy-lift launcher for lunar exploration. Variant 4B is the Shuttle extension variant. This variant includes the only foreseeable way to eliminate the gap in U.S. human-launch capability: it extends the Shuttle to 2015 at a minimum safe-flight rate. It also takes advantage of synergy with the Shuttle by developing a heavy-lift vehicle that is more directly Shuttle-derived. Both variants of Option 4 permit human lunar return by the mid-2020s.*

*Option 5. Flexible Path. This option follows the Flexible Path as an exploration strategy. It operates the Shuttle into FY 2011, extends the ISS until 2020, funds technology development and develops commercial crew services to low Earth orbit. There are three variants within this option; they differ only in the heavy-lift vehicle.*

*Variant 5A is the Ares Lite variant. It develops the Ares Lite, the most capable of the heavy-lift vehicles in this option. Variant 5B employs an EELV-heritage commercial heavy-lift launcher and assumes a different (and significantly reduced) role for NASA. It has an advantage of potentially lower operational costs, but requires significant restructuring of NASA. Variant 5C uses a directly Shuttle-derived, heavy-lift vehicle, taking maximum advantage of existing infrastructure, facilities and production capabilities.*

*All variants of Option 5 begin exploration along the flexible path in the early 2020s, with lunar fly-bys, visits to Lagrange points and near-Earth objects and Mars fly-bys occurring at a rate of about one major event per year, and possible rendezvous with Mars's moons or human lunar return by the mid to late 2020s.*

*The Committee has found two executable options that comply with the FY 2010 budget. However, neither allows for a viable exploration program. In fact, the Committee finds that no plan compatible with the FY 2010 budget profile permits human exploration to continue in any meaningful way.*

*The Committee further finds that it is possible to conduct a viable exploration program with a budget rising to about $3 billion annually above the FY 2010 budget profile. At this budget level, both the Moon First strategy and the Flexible Path strategies begin human exploration on a reasonable, though hardly aggressive, timetable. The Committee believes an exploration program that will be a source of pride for the Nation requires resources at such a level."*

| | Budget | Shuttle Life | ISS Life | Heavy Launch | Crew to LEO |
|---|---|---|---|---|---|
| **Constrained Options** | | | | | |
| **Option 1: Program of Record (constained)** | FY10 Budget | 2011 | 2015 | Ares V | Ares I + Orion |
| **Option 2: ISS + Lunar (constrained)** | FY10 Budget | 2011 | 2020 | Ares V Lite | Commercial |
| **Moon First Options** | | | | | |
| **Option 3: Baseline - Program of Record** | Less constrained | 2011 | 2015 | Ares V | Ares I + Orion |
| **Option 4A: Moon First - Ares Lite** | Less constrained | 2011 | 2020 | Ares V Lite | Commercial |
| **Option 4B: Moon First - Extend Shuttle** | Less constrained | 2015 | 2020 | Directly Shuttle Derived + refueling | Commercial |
| **Flexible Path Options** | | | | | |
| **Option 5A: Flexible Path - Ares Lite** | Less constrained | 2011 | 2020 | Ares V Lite | Commercial |
| **Option 5B:Flexible Path - EELV Heritage** | Less constrained | 2011 | 2020 | 75mt EELV + refueling | Commercial |
| **Option 5C: Flexible Path - Shuttle Derived** | Less constrained | 2011 | 2020 | Directly Shuttle Derived + refueling | Commercial |

Source: Summary Report of the Review of U.S. Human Space Flight Plans Committee, p. 9

**Ground Rules and Assumptions on Affordability**

According to its analysis presented during the review committee's last meeting held on August 12, 2009, the review committee articulated the following ground rules and assumptions that were followed in its analyses.

- *"Aerospace* [Aerospace Corporation was the contractor used by the review committee to perform cost analyses in support of the review committee's work] *used a 1.51 historical risk factor on all element development costs of all scenarios on the cost to go. A lower (1.25) historical risk factor was used on productive/operations*
- *An additional $200 million was added to the COTS* [Commercial Orbital Transportation Services] *cargo baseline in FY 2011 to incentivize current COTS cargo demonstrations*
- *Except for international partner agreements already assumed for the ISS, all elements were fully costed (for costing purposes only)*
- *For all scenarios, except the Program of Record, assume a technology program starting at $500M in FY 2011 and ramping up to $1.5 billion over five years. Maintain the $1.5 billion annually thereafter. (Assume double counting in other ISS and ESMD* [Exploration Systems Mission Directorate] *lines, so funding is one-half of that.)*
- *For scenarios that assume commercial crew, assume a $2.5B NASA investment over four years beginning in FY 2011*
- *Use Aerospace contract termination/restart model and actual contract termination costs in Cx* [Constellation] *programs*
- *For all scenarios that include refueling, assume technology line funds development and add a $1B one-time cost to flight certify the fuel transfer kit*
- *For all scenarios assuming lunar sorties/outpost, use the Cx* [Constellation] *estimate for the Altair lander and lunar surface system; for the Deep Space options, assume a commercial lunar lander, but a government furnished ascent stage*
- *For options using EELV heavy-lift launch vehicles, cost as if NASA does not build the system and uses NASA infrastructure and workforce only when required to conduct operations*
- *For the Shuttle Derived Systems scenario, assume Side-mount costs (provided by NASA) for the cargo only version*
- *Current program elements (ISS and STS):*
    - *For scenarios with ISS de-orbit in 2016, assume additional $1.5B cost beyond current estimate*

○ *For scenarios with existing Shuttle manifest, assume fly-out to March, 2011."*

**Discussion**

There are multiple aspects of the review committee's assumptions and analyses that Congress will need to understand in order to make an informed judgment about the options presented in the summary report.

*Costs of Deviating from the Congressionally-authorized Program*

Congress authorized the exploration initiative, including the Constellation Program, in the *NASA Authorization Acts* of 2005 and 2008 and encompassing a stepping-stone approach to exploration beginning with robotic and human exploration of the Moon in preparation for exploration missions to other destinations in the solar system. In addition, the 2008 Authorization directs the NASA Administrator to ensure that the ISS remain a viable laboratory through at least 2020. The Summary Report did not include an option that accounts for this Congressionally-authorized scenario, and therefore does not present the President with the option and costs of the program that matches what Congress has authorized by law. The absence of this scenario also makes it difficult to compare the program authorized by law against the alternatives presented by the review committee.

In addition, the summary report did not outline the costs and risks associated with terminating the program of record (or various elements of the Program) or how the review committee weighed those termination costs and risks against the costs and risks of undertaking an alternative architecture.

*Cost Assumptions*

In materials presented at its last meeting held on August 12, 2009, the review committee used cost analyses conducted by the Aerospace Corporation to compare the costs of various options, including the program of record (Constellation). The Aerospace Corporation used a historical risk factor of 1.51 in assessing the costs. NASA has indicated that it already budgeted the Constellation program at a level for which there is a 65 percent confidence that the program will meet its schedule and budget projections. In addition, the Constellation program has reached a level of maturity that would argue risk uncertainty has been reduced. Congress will need to understand whether or not the costs-to-go for the Constellation program have been essentially double-counted costs required for Constellation given that a risk factor was applied on top of NASA's estimates.

In addition, there are different levels of maturity in the options for human space flight systems that the review committee considered, ranging from options that are the concept and view-graph stage to designs that have been studied in depth. Congress will need to understand how the review committee went about estimating and comparing the costs for designs that have such a wide range of maturity levels.

*Safety*

One the one hand, the review committee noted that throughout its report, human safety *"is treated as a sine qua non."* It also notes that *"Ares I was designed to a high standard in order to provide astronauts with access to low Earth orbit at lower risk and a considerably higher level of reliability than is available today."* On the other hand, regarding the alternative human space flight systems reviewed, the report stated that the review committee *"was unconvinced that enough is known about any of the other potential high-reliability launcher-plus-capsule systems to distinguish their levels of safety in a meaningful way."* The report also states that *"New human-rated launch vehicles will likely be more reliable once they reach maturity . . ."* At issue is how the review committee reconciled the emphasis it gave to human safety in its report with the uncertainties the report introduces about how to rate the safety of potential alternative crewed launch systems that exist at very different levels of maturity. Even for a potential human-rated EELV system, which was studied by the Aerospace Corporation, *"Aerospace did not perform estimates of loss of mission (LOM) and loss of crew (LOC) probabilities for the HR Delta IV H options studied . . .. To allow an equitable comparison of HR Delta IV HR Delta IV H to Ares I LOM/LOC a new study . . . would be needed."* The review committee's approach to ascertaining the safety of alternative systems also needs explanation, and in particular the relationship assured by the review committee between reliability and safety. There are many uncertainties regarding safety that Congress will need to understand in assessing the review committee's proposed options.

*International Cooperation*

The review committee's summary report refers to the benefits of an international exploration program, including strengthening of geopolitical relationships, leveraging of resources, and enhancing exploration. However, the report does not discuss the extent to which each option would contribute to or benefit from international cooperation, how international cooperation would evolve over the long-term as part of the options presented, and what international capabilities could potentially be applied to each of the options. In addition, the review committee states, in its summary of key findings, that *"If international partners are actively engaged, including on the 'critical path' to success, then there could be substantial benefits to foreign relations . . .."* Having international partners on the "critical path" would be a significant shift from current approach to partnerships. This leads to questions about the types of risks would this new approach would introduce; how, if at all, the review committee assessed those risks; and the extent to which the review committee found that those risks would be outweighed by the additional benefits from the international collaboration that could be realized.

*Crew Access to Low-Earth Orbit*

The review committee's summary report states that *"There are two basic approaches [to crew access to low Earth orbit]: a government-operated system and a commercial crew-delivery service."* This seems to suggest that the review committee considered crew-access to LEO in an either-or binary fashion, which differs from the congressionally-authorized program to support commercial development of commercial crew services to low Earth orbit, while also retaining the government capability. The review committee suggests, in its summary report that *"it is an appropriate time to consider turning this transport service over to the commercial sector."* It is unclear, however, whether the review committee is suggesting that government capability to launch humans into low Earth orbit be abandoned in favor of as-yet-undeveloped commercial systems—as some of the options suggest—or whether it simply thinks commercial development should be stimulated in parallel to the government program and phased over once the commercial systems have matured. It is also unclear whether or not the review committee considered the strategic implications of not having a government system to launch humans into low Earth orbit. These issues warrant clarification.

*Commercial Services and Potential Cost Savings*

The summary report states that providing human access to low Earth orbit by using commercial crew services *"creates the possibility of lowering operating costs for the system and potentially accelerates the availability of U.S. access to low Earth orbit by about a year, to 2016."* If this is the review committee's rationale for a commercially provided service in lieu of a government-provided service to low Earth orbit, there are several issues that need to be clarified. The Summary Report does not discuss the technical analysis that led the review committee to indicate that commercial services could potentially reduce the gap by about a year or the review committee's level of confidence in that date. In addition, because commercial crew systems are largely conceptual at this stage, it is unclear what assumptions about their potential to meet NASA's human safety requirements that the review committee assumed.

In addition, the summary report states that *"Establishing . . . commercial opportunities could increase launch volume and potentially lower costs to NASA and all other launch-service customers."* The Summary Report does not discuss the level of activity that would be needed to lower the costs of crew transport for the government, when would the government would be able to benefit from those savings, and how much the government could expect to save from using commercial crew services in lieu of government-provided services. Congress will need to understand these issues it evaluates the options presented by the review committee and any decision by the Administration on the future course of the Nation's space flight program.

*$3 Billion Increase*

In establishing scenarios that reflected increases in budget, characterized in the summary report as a "Less Constrained" budget, it is not clear why the $3 billion figure was chosen. No factual basis can be ascertained from the summary report for why $3 billion is the appropriate amount rather than some other amount. Furthermore, to make meaningful comparisons, Congress will need to know whether the $3 billion is phased similarly across all applicable options, what how mission capabilities funded by the increase differ relative to one another, and what the review com-

mittee assumed the annual increases would be to reach the $3 billion level by FY 2014.

**V. Background**

In January 2004, President George W. Bush introduced a *Vision for Space Exploration* that would:

- *"Implement a sustained and affordable human and robotic program to explore the solar system and beyond;*
- *Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations;*
- *Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration; and*
- *Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests."*

According to the Bush initiative, the goals would be achieved through retiring the Space Shuttle as soon as the International Space Station is completed, using the ISS to support exploration goals, carrying out human and robotic lunar exploration activities to enable science and exploration goals, and developing a new crew exploration vehicle to support missions beyond low Earth orbit (with an operational capability to be demonstrated no later than 2014).

Congress authorized the space exploration initiative in two authorization laws, the *NASA Authorization Act of 2005* (P.L. 109–155) and the *NASA Authorization Act of 2008* (P.L. 110–422). (Attachment A provides the Authorization language.) In addition, the 2008 Authorization Act authorized an additional $1 billion to accelerate development of the Ares I crew launch vehicle and the Orion crew exploration vehicle. Ares I and Orion are part of the Constellation Program, which also includes development of an Ares V heavy-lift vehicle needed to carry a lunar lander beyond low Earth orbit that would dock with Orion and transport the crew and cargo to the Moon and other potential destinations. The 2008 Act also directed that the Administrator *"take all necessary steps to ensure that the International Space Station remains a viable and productive facility capable of potential United States utilization through at least 2020 . . .."*

Although NASA was directed by the President to carry out the plan, the Bush Administration did not request a budget adequate to implement the *Vision for Space Exploration* while also maintaining a balanced portfolio of science and aeronautics programs, returning the Shuttle to flight following the *Columbia* accident, and completing the International Space Station. Attachment B depicts the mismatch between the original budget estimates required for NASA to implement the Vision and the Administration budget requests.

According to information that NASA provided to the Subcommittee on Space and Aeronautics in May 2009, NASA's Exploration Systems Architecture Study (ESAS), which formed the basis of the Constellation Program, assumed a total of about $34.4 billion would be required for the program through 2013. According to NASA, funding for Constellation from FY 2007 President's Budget Request through the FY 2009 President's Budget Request covering a period of FY 2006–FY 2013 has remained at about $31.7 billion. The FY 2009 President's budget request for Constellation through 2013 is $2.6 billion less than what ESAS' funding projection for Constellation, according to NASA. In addition, the budget analyses presented by review committee members at the last meeting held on August 12, 2009, state that the President's FY10 budget submittal *"significantly reduces planned funding available to the Constellation program; more than $1.5B (FY09) per year starting in FY13."*

In 2009, President Obama signed into law, the *American Recovery and Reinvestment Act of 2009* (P.L. 111–5), which appropriated $1 billion in Recovery Act funds for NASA. Of that total, $400 million was provided for NASA's exploration activities. In his statement to the Subcommittee on Commerce, Justice, Science and Related Agencies on April 29, 2009, NASA Acting Administrator Scolese testified that NASA has allocated $250M of the exploration Recovery Act funds to Constellation Systems and the remaining $150M to Commercial Crew and Cargo. On August 10, 2009, NASA announced a request for proposals and its plans to use $50 million of Recovery Act funds *"for the development of commercial crew space transportation concepts and enabling activities."*

With its release of the top-line FY 2010 budget request for NASA in February 2009, the Administration, cited several highlights, including *"a robust program of space exploration involving humans and robots," "return Americans to the Moon by*

*2020," "safe flight of the Shuttle through the vehicle's retirement at the end of 2010," "the development of new space flight systems for carrying American crews and supplies to space,"* and the *"continued use of the International Space Station,"* among other objectives.

Later, with the release of the full, detailed FY 2010 budget request for NASA in May 2009, the Administration *"announced the launch of an independent review of NASA's human space flight activities"* and the summary report of that effort is the focus of today's hearing. The FY 2010 budget proposal reduced outyear projections for the Constellation Program by roughly $3.5 billion from that projected in the FY 2009 budget proposal for the FY 2011–FY 2014 period. The FY 2010 budget request also stated that *"Following the human space flight review, the Administration will provide an updated request for Exploration activities reflecting the review's results."* The FY 2010 budget request retained the goal of returning humans to the Moon by 2020, despite the fact that the request would reduce funding for work on lunar related activities required to reach that goal. The FY 2010 budget request for the Ares V Cargo Launch Vehicle ($25 million) and its runout budget for FY 2011 through FY 2014 ($100 million total) is insufficient to initiate full scale development of the heavy-lift launch vehicle that is designed to support exploration missions beyond low Earth orbit. In addition, the five-year budget plan contains no significant funding for the Altair lunar lander. A summary of the President's FY 2010 request for NASA is provided as Attachment C.

In its appropriation bill for FY 2010, H.R. 2847, as discussed in the House Commerce, Justice, Science, and Related Agencies Appropriations Bill, 2010, Report 111–149, the House Appropriations Committee provided appropriations for NASA's exploration program at a level $212 million less than that of the FY 2009 enacted budget and $670 million less than the President's FY 2010 request for NASA's exploration programs. In his statement for the House consideration of H.R. 2847, Subcommittee Chairman Mollahan said: *"Funds are provided in this bill to continue investments in human space flight at the level of last year. Reductions from the budget request should not be viewed by this body as any diminution of certainly my support or the Committee's support in NASA's human space flight activities. Rather, it is a deferral. It is a deferral taken without prejudice. It is a pause. It is a timeout. Call it what you will, it is an opportunity for the President to establish his vision for human space exploration looking at the Augustine report when it becomes available in August, and then for his administration to consider what their vision will be, and then most importantly, certainly for the Committee, Mr. Chairman, to come forward with a realistic future funding scheme for the human space exploration program. We hope it is a vision worthy of the program, and we look forward to realistic funding levels, which we have never had, or haven't had for many, many years, for human space flight."*

The Senate Departments of Commerce, Justice, Science, and Related Agencies Appropriations Bill, 2010, Report 111–34 , stated the following:

> *"Review of U.S. Human Space Flight Plans.—The Committee directs that NASA shall not use the operating plan or reprogramming process as the method of implementing the recommendations of the review. The opportunity for directing a well constructed and thoughtful approach to manned space flight should be as a budget amendment to the 2010 budget request that is received in a manner that is timely for consideration by the Committee, or as part of the 2011 budget request.*
>
> *Ares I and Orion.—The Committee provides the full budget request of $1,415,400,000 for Ares I, the new Crew Launch Vehicle, and $1,383,500,000 for Orion, the Crew Exploration Vehicle.*
>
> *Ares V.—The Committee believes that the Ares V cargo launch vehicle will be a critical national asset for carrying exploration and scientific payloads beyond low Earth orbit to the Moon and beyond. To facilitate the earliest possible start of the development of the Ares V, the Committee recommends a funding level of $100,000,000."*

**Status of Constellation Program**

The Constellation Program, including the Ares I crew launch vehicle and the Orion crew exploration vehicle, the Altair Lunar Lander, and the Ares V launch vehicle, has continued its work during the course of the human space flight review, as directed by the Administration. However, as a result of the review, NASA officials reported that contracts for initial work on the Ares V vehicle—the heavy-lift launcher planned to ferry astronauts and cargo to the Moon—were put on hold pending the results of the Review of U.S. Human Space Flight Plans.

At the time the Administration released the FY 2010 budget request for NASA, the Constellation Program had completed most major procurements, undertaken hardware design, development and test activities, constructed key facilities, completed initial reviews for ground and mission operations, continued preparation for the first flight test of the Ares rocket (Ares I–X), which is scheduled for the end of October 2009, and continued work in preparation for a test of the Orion Pad Abort system. In September 2008, the Ares I rocket passed the preliminary design review, a key milestone that assesses the vehicle's design to ensure its safety, reliability, and alignment with NASA's requirements. In November 2008, the J–2X engine, which is designed to be used as the upper stage of the Ares I and the Earth departure stage of the Ares V launch vehicles, passed the critical design review and proceeded to fabrication and full-testing of the engine. On September 10, 2009, the five-segment rocket motor that will be used on the Ares I rocket was successfully test-fired. In addition, on September 1, 2009, NASA announced the successful completion of the preliminary design review for Orion.

As of early September 2009, NASA reported that $7.7 billion has been spent on the Constellation Program, of which $3.1 billion has been spent on Orion and approximately $3 billion on Ares I. The remainder has been spent on ground and program integration, space suit development, and other activities. According to NASA, the projected budget for Ares I and Orion through 2015 is $35 billion.

**Status of Space Shuttle Program**

The Space Shuttle Program is now entering its 28th year of service. Three orbiters are now left to carry out the remaining launch schedule of six flights, all to the International Space Station. These flights will be providing the remaining nodes, experiments, and spare parts which will enable the station to be utilized as a U.S. National Laboratory. The Space Shuttle is slated to be retired in 2010, with the last flight currently scheduled for September 2010. The FY 2009 budget for the program is $2.98 billion and the FY 2010 budget request is $3.15 billion. The Shuttle program will be completely unfunded by FY 2012, according to the President's FY 2010 request.

**International Space Station Program**

The International Space Station (ISS)'s partners include the United States, nations of the European Space Agency, Russia, Japan, and Canada. The first module of the Station was developed by Russia and placed into orbit in 1998. Shortly thereafter, in 1998, the U.S. launched its first module, which was attached to the Russian node. Since that time, U.S., Russian, European, and Japanese modules, among many other systems, instruments, and equipment have been delivered and assembled as part of the ISS. The Station has been crewed since the year 2000. During the first eight years of ISS operations, scientific research has helped lead *"advances in the fight against food poisoning, new methods for delivering medicine to cancer cells, and better materials for future spacecraft,"* according to a NASA report, *"International Space Station Science Research Accomplishments During the Assembly Years: An Analysis of Results from 2000–2008."* In 2009, the size of the crew doubled from three to six persons, enabling additional crew time to be available for research activities. In its current configuration, NASA characterizes the ISS as 83 percent complete. Six Shuttle flights are manifested to complete the assembly of the Station, which is currently planned to be operated and utilized through 2015. According to NASA, the U.S. has invested approximately $44 billion in the ISS, while combined investment of the U.S. and its partners is valued at over $54 billion.

**Historical Trends of Federal Government Spending on NASA**

According to historical budgetary data, NASA's annual budget authority, on average between FY 1976 and FY 2008, was 0.80 percent of the total federal budgetary authority. For Fiscal Year 2009, NASA's percent of the total federal budget authority is estimated to be 0.43, its lowest in over three decades. The total federal budgetary authority in FY 2010 is estimated to be $3.42 trillion. If one applies the average percentage of total annual budgetary authority for NASA through FY 2008 (.80 percent) to the estimated total budgetary authority for Fiscal Year 2010, the NASA funding level would be $27.5 billion [Versus the FY 2010 request of $18.7 billion].

In terms of discretionary budget authority, on average between FY 1976 and FY 2008, NASA's total budget authority was 2.07 percent of total federal discretionary budget authority. According to the President's budget request, total federal discretionary budget authority in FY 2010 is estimated to be $1.24 trillion. Applying the 2.07 percent historical average of discretionary budget authority for NASA to the

$1.24 estimated total federal discretionary budget authority for FY 2010 would result in a NASA funding level of $25.8 billion.

**Previous Studies and Reviews of Human Space Flight and Exploration**

There have been numerous studies and reviews of potential directions and goals for the Nation's human and robotic exploration program dating back to the early years of the space program, including the report of a 1969 Space Task Group, *The Post-Apollo Space Program: Directions for the Future,"* chaired by Vice President Spiro Agnew, to the 1990 *Report of the Presidential Commission on the Space Shuttle Challenger Accident* (aka the Rogers Commission report), the "90-Day" study that accompanied President George H.W. Bush's Space Exploration Initiative, and the 1990 Synthesis Group report that studied ideas relevant to accomplishing the Space Exploration Initiative, and the report of the Advisory Committee on the Future of the U.S. Space Program, chaired by Norman Augustine. Those reports appear to be consistent in highlighting the importance of a direction for the Nation's human exploration activities beyond low Earth orbit. The *Columbia* Accident Investigation Board (CAIB), which issued its report in 2003, also called attention to the lack of a program for exploration beyond low Earth orbit when it said: *"Review committees . . . have suggested that the primary justification for a space station is to conduct the research required to plan missions to Mars and/or other distant destinations. However, human travel to destinations beyond Earth orbit has not been adopted as a national objective."* Then, in 2004, President George W. Bush announced the *Vision for Space Exploration* (VSE) referenced earlier in this charter.

**Attachment A**

## NASA Authorization Acts of 2005 and 2008
## Provisions Related to the Exploration Initiative

**P.L. 109–155, NASA Authorization Act of 2005**

*(b) VISION FOR SPACE EXPLORATION.—*

*(1) IN GENERAL.—The Administrator shall establish a program to develop a sustained human presence on the Moon, including a robust precursor program, to promote exploration, science, commerce, and United States preeminence in space, and as a stepping-stone to future exploration of Mars and other destinations. The Administrator is further authorized to develop and conduct appropriate international collaborations in pursuit of these goals.*

*(2) MILESTONES.—The Administrator shall manage human space flight programs to strive to achieve the following milestones (in conformity with section 503)—*

*(A) Returning Americans to the Moon no later than 2020.*

*(B) Launching the Crew Exploration Vehicle as close to 2010 as possible.*

*(C) Increasing knowledge of the impacts of long duration stays in space on the human body using the most appropriate facilities available, including the ISS.*

*(D) Enabling humans to land on and return from Mars and other destinations on a timetable that is technically and fiscally possible.*

**P.L. 110–422, NASA Authorization Act of 2008**

**SEC. 2. FINDINGS.**

. . .

*(7) Human and robotic exploration of the solar system will be a significant long-term undertaking of humanity in the 21st century and beyond, and it is in the national interest that the United States should assume a leadership role in a cooperative international exploration initiative.*

*(8) Developing United States human space flight capabilities to allow independent American access to the International Space Station, and to explore beyond low Earth orbit, is a strategically important national imperative, and all prudent steps should thus be taken to bring the Orion Crew Exploration Vehicle and Ares I Crew Launch Vehicle to full operational capability as soon as possible and to ensure the effective development of a United States heavy-lift launch capability for missions beyond low Earth orbit.*

. . .

*(10) NASA should make a sustained commitment to a robust long-term technology development activity. Such investments represent the critically important "seed corn" on which NASA's ability to carry out challenging and productive missions in the future will depend.*

*(11) NASA, through its pursuit of challenging and relevant activities, can provide an important stimulus to the next generation to pursue careers in science, technology, engineering, and mathematics.*

*(12) Commercial activities have substantially contributed to the strength of both the United States space program and the national economy, and the development of a healthy and robust United States commercial space sector should continue to be encouraged.*

**SEC. 401. SENSE OF CONGRESS.**

*It is the sense of Congress that the President of the United States should invite America's friends and allies to participate in a long-term international initiative under the leadership of the United States to expand human and robotic presence into the solar system, including the exploration and utilization of the Moon, near-Earth asteroids, Lagrangian points, and eventually Mars and its moons, among other exploration and utilization goals. When appropriate, the United States should lead confidence building measures that advance the long-term initiative for international cooperation.*

**SEC. 402. REAFFIRMATION OF EXPLORATION POLICY.**

*Congress hereby affirms its support for—*

*(1) the broad goals of the space exploration policy of the United States, including the eventual return to and exploration of the Moon and other destinations in the solar system and the important national imperative of independent access to space;*

*(2) the development of technologies and operational approaches that will enable a sustainable long-term program of human and robotic exploration of the solar system;*

*(3) activity related to Mars exploration, particularly for the development and testing of technologies and mission concepts needed for eventual consideration of optional mission architectures, pursuant to future authority to proceed with the consideration and implementation of such architectures; and*

*(4) international participation and cooperation, as well as commercial involvement in space exploration activities.*

**SEC. 403. STEPPING STONE APPROACH TO EXPLORATION.**

*In order to maximize the cost-effectiveness of the long-term exploration and utilization activities of the United States, the Administrator shall take all necessary steps, including engaging international partners, to ensure that activities in its lunar exploration program shall be designed and implemented in a manner that gives strong consideration to how those activities might also help meet the requirements of future exploration and utilization activities beyond the Moon. The timetable of the lunar phase of the long-term international exploration initiative shall be determined by the availability of funding. However, once an exploration related project enters its development phase, the Administrator shall seek, to the maximum extent practicable, to complete that project without undue delays.*

**SEC. 404. LUNAR OUTPOST.**

*(a) ESTABLISHMENT.—As NASA works toward the establishment of a lunar outpost, NASA shall make no plans that would require a lunar outpost to be occupied to maintain its viability. Any such outpost shall be operable as a human-tended facility capable of remote or autonomous operation for extended periods.*

*(b) DESIGNATION.—The United States portion of the first human-tended outpost established on the surface of the Moon shall be designated the "Neil A. Armstrong Lunar Outpost."*

*(c) SENSE OF CONGRESS.—It is the sense of Congress that NASA should make use of commercial services to the maximum extent practicable in support of its lunar outpost activities.*

**SEC. 405. EXPLORATION TECHNOLOGY DEVELOPMENT.**

*(a) IN GENERAL.—A robust program of long-term exploration related technology research and development will be essential for the success and sustainability of any enduring initiative of human and robotic exploration of the solar system.*

*(b) ESTABLISHMENT.—The Administrator shall carry out a program of long-term exploration-related technology research and development, including such things as in-space propulsion, power systems, life support, and advanced avionics, that is not tied to specific flight projects. The program shall have the funding goal of ensuring that the technology research and development can be completed in a timely manner in order to support the safe, successful, and sustainable exploration of the solar system. In addition, in order to ensure that the broadest range of innovative concepts and technologies are captured, the long-term technology program shall have the goal of having a significant portion of its funding available for external grants and contracts with universities, research institutions, and industry.*

**SEC. 406. EXPLORATION RISK MITIGATION PLAN.**

*(a) PLAN.—The Administrator shall prepare a plan that identifies and prioritizes the human and technical risks that will need to be addressed in carrying out human exploration beyond low Earth orbit and the research and development activities required to address those risks. The plan shall address the role of the International Space Station in exploration risk mitigation and include a detailed description of the specific steps being taken to utilize the International Space Station for that purpose.*

*(b) REPORT.—The Administrator shall transmit to the Committee on Science and Technology of the House of Representatives and the Committee on Commerce,*

*Science, and Transportation of the Senate the plan described in subsection (a) not later than one year after the date of enactment of this Act.*

**SEC. 407. EXPLORATION CREW RESCUE.**

*In order to maximize the ability to rescue astronauts whose space vehicles have become disabled, the Administrator shall enter into discussions with the appropriate representatives of space-faring nations who have or plan to have crew transportation systems capable of orbital flight or flight beyond low Earth orbit for the purpose of agreeing on a common docking system standard.*

**SEC. 408. PARTICIPATORY EXPLORATION.**

*(a) IN GENERAL.—The Administrator shall develop a technology plan to enable dissemination of information to the public to allow the public to experience missions to the Moon, Mars, or other bodies within our solar system by leveraging advanced exploration technologies. The plan shall identify opportunities to leverage technologies in NASA's Constellation systems that deliver a rich, multimedia experience to the public, and that facilitate participation by the public, the private sector, non-governmental organizations, and international partners. Technologies for collecting high-definition video, three-dimensional images, and scientific data, along with the means to rapidly deliver this content through extended high bandwidth communications networks, shall be considered as part of this plan. It shall include a review of high bandwidth radio and laser communications, high-definition video, stereo imagery, three-dimensional scene cameras, and Internet routers in space, from orbit, and on the lunar surface. The plan shall also consider secondary cargo capability for technology validation and science mission opportunities. In addition, the plan shall identify opportunities to develop and demonstrate these technologies on the International Space Station and robotic missions to the Moon, Mars, and other solar system bodies. As part of the technology plan, the Administrator shall examine the feasibility of having NASA enter into contracts and other agreements with appropriate public, private sector, and international partners to broadcast electronically, including via the Internet, images and multimedia records delivered from its missions in space to the public, and shall identify issues associated with such contracts and other agreements. In any such contracts and other agreements, NASA shall adhere to a transparent bidding process to award such contracts and other agreements, pursuant to United States law. As part of this plan, the Administrator shall include estimates of associated costs.*

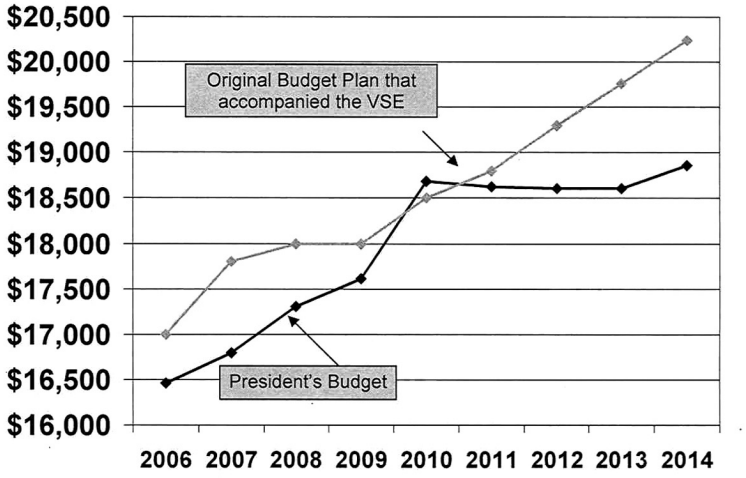
*(b) REPORT.—Not later than 270 days after the date of enactment of this Act, the Administrator shall submit the plan to the Committee on Science and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate.*

**SEC. 409. SCIENCE AND EXPLORATION.**

*It is the sense of Congress that NASA's scientific and human exploration activities are synergistic; science enables exploration and human exploration enables science. The Congress encourages the Administrator to coordinate, where practical, NASA's science and exploration activities with the goal of maximizing the success of human exploration initiatives and furthering our understanding of the Universe that we explore.*

## Attachment B

Comparison of Budget Plan that accompanied the VSE (Vision for Space Exploration) in 2004
with actual/planned President's Budget Requests for NASA
*(in millions of dollars)*



# Attachment C

NASA's FY 2010 Budget Request

| Budget Authority ($M) | FY 2008 | FY 2009 | Recovery Act | FY 2010 | FY 2011 | FY 2012 | FY 2013 | FY 2014 |
|---|---|---|---|---|---|---|---|---|
| **Science** | **4,733.2** | **4,503.0** | **400.0** | **4,477.2** | **4,747.4** | **4,890.9** | **5,069.0** | **5,185.4** |
| Earth Science | 1,237.4 | 1,379.6 | 325.0 | 1,405.0 | 1,500.0 | 1,550.0 | 1,600.0 | 1,650.0 |
| Planetary Science | 1,312.6 | 1,325.6 | | 1,346.2 | 1,500.6 | 1,577.7 | 1,600.0 | 1,633.2 |
| Astrophysics | 1,395.6 | 1,206.2 | 75.0 | 1,120.9 | 1,074.1 | 1,042.7 | 1,126.3 | 1,139.6 |
| Heliophysics | 787.6 | 591.6 | | 605.0 | 672.6 | 720.5 | 742.7 | 762.6 |
| **Aeronautics** | **511.4** | **500.0** | **150.0** | **507.0** | **514.0** | **521.0** | **529.0** | **536.0** |
| **Exploration** | **3,299.4** | **3,505.5** | **400.0** | **3963.1*** | **6076.6*** | **6028.5*** | **5966.5*** | **6195.3*** |
| Constellation Systems | 2,675.9 | 3,033.1 | 400.0 | 3,505.4 | 5,543.3 | 5,472.0 | 5,407.6 | 5,602.6 |
| Advanced Capabilities | 623.5 | 472.3 | | 457.7 | 533.3 | 556.5 | 558.9 | 592.7 |
| **Space Operations** | **5,427.2** | **5,764.7** | **0.0** | **6,175.6** | **3,663.8** | **3,485.3** | **3,318.6** | **3,154.8** |
| Space Shuttle | 3,295.4 | 2,981.7 | | 3,157.1 | 382.8 | 87.8 | 0.0 | 0.0 |
| International Space Station | 1,685.5 | 2,060.2 | | 2,267.0 | 2,548.2 | 2,651.6 | 2,568.9 | 2,405.9 |
| Space and Flight Support (SFS) | 446.2 | 722.8 | | 751.5 | 732.7 | 745.9 | 749.7 | 748.9 |
| **Education** | **146.8** | **169.2** | **0.0** | **126.1** | **123.8** | **123.8** | **123.8** | **125.5** |
| **Cross-Agency Support** | **3,251.4** | **3,306.4** | **50.0** | **3,400.6** | **3,468.4** | **3,525.7** | **3,561.4** | **3,621.4** |
| Center Management and Operations | 2,011.7 | 2,024.0 | | 2,084.0 | 2,119.2 | 2,142.5 | 2,166.1 | 2,189.9 |
| Agency Management and Operations | 834.1 | 921.2 | | 961.2 | 956.9 | 964.5 | 972.3 | 981.5 |
| Institutional Investments | 325.5 | 293.7 | 50.0 | 355.4 | 392.3 | 418.7 | 423.0 | 450.0 |
| Congressionally Directed Items | 80.0 | 67.5 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Inspector General** | **32.6** | **33.6** | **2.0** | **36.4** | **37.0** | **37.8** | **38.7** | **39.6** |
| **NASA FY 2010** | **17,401.9** | **17,782.4** | **1,002.0** | **18,686.0** | **18,631.0** | **18,613.0** | **18,607.0** | **18,858.0** |
| *Year to Year Change* | | *2.2%* | | *5.1%* | *-0.3%* | *-0.1%* | *0.0%* | *1.3%* |

*Following the human spaceflight review, the Administration will provide an updated request for Exploration activities reflecting the review's results.

**Attachment D**

## Members of the Review of U.S. Human Space Flight Plans Committee

— Norman Augustine (Chair), retired Chairman and CEO, Lockheed Martin Corp., and former member of the President's Council of Advisors on Science and Technology under Presidents Bill Clinton and George W. Bush

— Dr. Wanda Austin, President and CEO, The Aerospace Corp.

— Bohdan Bejmuk, Chair, Constellation program Standing Review Board, and former manager of the Boeing Space Shuttle and Sea Launch programs

— Dr. Leroy Chiao, former astronaut, former International Space Station commander and engineering consultant

— Dr. Christopher Chyba, Professor of Astrophysical Sciences and International Affairs, Princeton University, and member, President's Council of Advisors on Science and Technology

— Dr. Edward Crawley, Ford Professor of Engineering at MIT and Co-Chair, NASA Exploration Technology Development Program Review Committee

— Jeffrey Greason, co-founder and CEO, XCOR Aerospace, and Vice-Chair, Personal Spaceflight Federation

— Dr. Charles Kennel, Chair, National Academies Space Studies Board, and Director and Professor Emeritus, Scripps Institution of Oceanography, University of California, San Diego

— Retired Air Force Gen. Lester Lyles, Chair, National Academies Committee on the Rationale and Goals of the U.S. Civil Space Program, former Air Force Vice Chief of Staff and former Commander of the Air Force Materiel Command

— Dr. Sally Ride, former astronaut, first American woman in space, CEO of Sally Ride Science and Professor Emerita at the University of California, San Diego

**Attachment E**

## Statements to the Review of U.S. Human Space Flight Plans Committee

## By Chairman Gordon and Ranking Member Hall

## Committee on Science and Technology

## U.S. House of Representatives

STATEMENT TO THE REVIEW OF U.S. HUMAN SPACE FLIGHT PLANS COMMITTEE

HON. BART GORDON

CHAIRMAN, COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

JULY 17, 2009

Thank you for the opportunity to submit this statement. I regret that I was unable to participate in your June 17th meeting due to prior congressional commitments, and I look forward to meeting with you in person at a later date if you are interested in doing so.

You have asked for a congressional perspective on the human space flight-related policies of the *NASA Authorization Acts* of 2005 and 2008 [P.L. 109–155 and P.L. 110–422, respectively]. I think that the most appropriate way to view the human space flight-related provisions of both Acts is in the context of the overall goals of the legislation, namely, to promote a balanced and robust program of space and aeronautics initiatives at the National Aeronautics and Space Administration and to authorize funding levels commensurate with the tasks that NASA is being asked to undertake. It was the consensus of Congress in its consideration of those Acts that human space flight and exploration is an important component of a balanced NASA portfolio, as well as being in the national interest for geopolitical, technological, scientific, and inspirational reasons. In that regard, I would quote Finding #1 of P.L. 110–422: *"NASA is and should remain a multi-mission agency with a balanced and robust set of core missions in science, aeronautics, and human space flight and exploration."*

With respect to human space flight and exploration, both the 2005 and 2008 Authorization Acts represent a congressional consensus on the importance of completing the International Space Station [ISS] and ensuring its productive utilization in support of research and development activities required for exploration beyond low Earth orbit, as well as basic and applied R&D that could have terrestrial benefits. With respect to the question of what the operational lifetime of the ISS should be, Congress states the following in Section 601 of the *NASA Authorization Act of 2008:*

> *"(a) In General.—The Administrator shall take all necessary steps to ensure that the International Space Station remains a viable and productive facility capable of potential United States utilization through at least 2020 and shall take no steps that would preclude its continued operation and utilization by the United States after 2015."*

In addition, Sec. 601(b) emphasizes the importance of effective utilization of the ISS by directing that the NASA Administrator submit *". . . a plan to support the operations and utilization of the International Space Station beyond fiscal year 2015 for a period of not less than five years."* Thus, while Congress does not explicitly mandate the continuation of the ISS program past 2015 in P.L. 110–422, I believe that the aforementioned provisions reflect a congressional consensus that the productive utilization of the ISS is an important national goal, and the ISS program should not be constrained to an arbitrary termination date.

That said, Congress recognizes that productive operation and utilization of the ISS will be challenging once the Space Shuttle is retired following the completion of its flight manifest. While Congress is very supportive of NASA's plans to use commercial cargo resupply services once they are developed, Congress also wants NASA to have contingency arrangements in place, including international partner resupply capabilities, so that the Nation's utilization of the ISS is not jeopardized. Thus, Sec. 603 of P.L. 110–422 includes a provision that states:

> *"The Administrator shall develop a plan and arrangements, including use of International Space Station international partner cargo resupply capabilities, to ensure the continued viability and productivity of the International Space Station in the event that United States commercial cargo resupply services are not available during any extended period after the date that the Space Shuttle is retired."*

One of the great accomplishments—and strengths—of the International Space Station program has been the durable international partnership that has developed over the program's lifetime, and we believe that anything that can be done by the partnership to increase the post-Shuttle resiliency of the ISS should be encouraged.

It is an unfortunate policy failure that there will be a gap between the retirement of the Space Shuttle and commencement of operations of the follow-on Constellation space transportation system. However, at this point there do not appear to be really good options available that would obviate such a gap. Congress in the *NASA Authorization Act of 2008* makes clear that it considers the most appropriate approach to be development of the follow-on Constellation systems as soon as possible with the goal of providing a system that can both service the ISS until other capabilities become available and support human exploration beyond low Earth orbit. As is stated in Finding #8 of P.L. 110–422:

> *"Developing United States human space flight capabilities to allow independent American access to the International Space Station, and to explore beyond low Earth orbit, is a strategically important national imperative, and all prudent steps should thus be taken to bring the Orion Crew Exploration Vehicle and Ares I Crew Launch Vehicle to full operational capability as soon as possible and to ensure the effective development of a United States heavy-lift launch capability for missions beyond low Earth orbit."*

In support of that position, Congress authorizes an additional $1 billion dollars in P.L. 110–422 above the President's FY 2009 request to accelerate the initial operating capability of the Orion Crew Exploration Vehicle and Ares I Crew Launch Vehicle. Congress is committed to the success of those development projects and wants to ensure that they are brought to operational status in an effective and efficient manner. I thus believe that the threshold for any decision to deviate from the projects of record at this point in their development should be high, e.g., major technical feasibility issues, prohibitive cost growth/schedule delays, or unacceptable safety risk.

It is important to note that both the 2005 and 2008 Authorization Acts make clear that Congress does not view the primary objective of the human space flight program to be just having the capability for Americans to access low Earth orbit, or the two pieces of legislation would not place the emphasis that they do on developing systems to support human missions beyond low Earth orbit, as referenced in both the above-mentioned sections and in Title IV of P.L. 110–422. Thus, if is determined that adjustments are required to the Constellation program of record, priority should be given to timely development of a transportation capability for enabling human missions to the Moon and other destinations beyond low Earth orbit and for ensuring NASA's ability to access the ISS as needed.

Furthermore, while Sec. 902 of P.L. 110–422 seeks to stimulate the development of a commercial crew transportation capability in the United States, the congressional motivation for development of such a capability was not elimination of the post-Shuttle "gap" over the near-term—there was no consensus on that matter when the legislation was being considered by Congress. In addition, Congress is quite clear in Sec. 902(b) of the Act as to the relative priority to be given to federal support of a commercial crew initiative versus funding for NASA's Constellation program:

> *"(b) Congressional Intent.—It is the intent of Congress that funding for the program described in subsection (a)(4)* [i.e., COTS crewed vehicle demonstration program] *shall not come at the expense of full funding of the amounts authorized under section 101(3)(A), and for future fiscal years, for Orion Crew Exploration Vehicle development, Ares I Crew Launch Vehicle development, or International Space Station cargo delivery."*

It is clear from the *NASA Authorization Acts* of 2005 and 2008 that a durable congressional consensus has been achieved on goals and objectives for the Nation's human and robotic exploration of the solar system, as well as on the overall approach to be taken. That is a significant accomplishment, and I would hope that your panel will resist the temptation to propose major departures from that hard-won consensus. It should be noted that Congress's direction for the Nation's exploration initiative is consistent with the broad goals and objectives of President Bush's *Vision for Space Exploration,* a Vision that unfortunately was not accompanied by resources sufficient to realize it as originally articulated without doing damage to other important NASA missions.

The congressional consensus on exploration is summarized by the following provisions from P.L. 110–422:

*Finding #7 "Human and robotic exploration of the solar system will be a significant long-term undertaking of humanity in the 21st century, and it is in the national interest that the United States should assume a leadership role in a cooperative international exploration initiative."*

The legislation elaborates on that Finding in Sections 401 and 402 of the Act:

*Sec. 401: "It is the sense of Congress that the President of the United States should invite America's friends and allies to participate in a long-term international initiative under the leadership of the United States to expand human and robotic presence into the solar system, including the exploration and utilization of the Moon, near-Earth asteroids, Lagrangian points, and eventually Mars and its moons, among other exploration and utilization goals. When appropriate, the United States should lead confidence building measures that advance the long-term initiative for international cooperation."*

*Sec. 402: "Congress hereby affirms its support for—*

*(1) the broad goals of the space exploration policy of the United States, including the eventual return to and exploration of the Moon and other destinations in the solar system and the important national imperative of independent access to space;*

*(2) the development of technologies and operational approaches that will enable a sustainable long-term program of human and robotic exploration of the solar system;*

*(3) activity related to Mars exploration, particularly for the development and testing of technologies and mission concepts needed for eventual consideration of optimal mission architectures, pursuant to future authority to proceed with the consideration and implementation of such architectures; and*

*(4) international participation and cooperation, as well as commercial involvement in space exploration activities.*

With respect to the implementation of the Nation's exploration initiative, both the 2005 and 2008 *NASA Authorization Acts* emphasize the importance of the Moon as a stepping-stone for exploration as well as a potential venue for utilization activities. In that regard, Section 403 of P.L. 110–422 states:

> *"In order to maximize the cost-effectiveness of the long-term exploration and utilization activities of the United States, the Administrator shall take all necessary steps, including engaging international partners, to ensure that activities in its lunar exploration program shall be designed and implemented in a manner that gives strong consideration to how those activities might also help meet the requirements of future exploration and utilization activities beyond the Moon. The timetable of the lunar phase of the long-term international exploration initiative shall be determined by the availability of funding. However, once an exploration-related project enters its development phase, the Administrator shall seek, to the maximum extent practicable, to complete that project without undue delays."*

In addition, while Congress is on record in the 2005 NASA Authorization in support of development of a sustained U.S. human presence on the Moon, Congress wants to maintain flexibility and resiliency with respect to the Nation's lunar activities. Thus Section 404(a) of P.L. 110–422 states:

> *"As NASA works toward the establishment of a lunar outpost, NASA shall make no plans that would require a lunar outpost to be occupied to maintain its viability. Any such outpost shall be operable as a human-tended facility capable of remote or autonomous operation for extended periods."*

While there are a number of other important provisions related to human space flight and exploration contained in the *NASA Authorization Acts* of 2005 and 2008, I will not dwell on them here and instead would refer you to those Acts. However, among them are four considerations that I would highlight that Congress believes need attention in the Nation's conduct of its human exploration initiative. First, as Section 405 of the 2008 Act concludes: *"A robust program of long-term exploration-related research and development will be essential for the success and sustainability of any enduring initiative of human and robotic exploration of the solar system."* Such non-flight project-specific technology development activities have withered at NASA and need to be revitalized. They should be viewed as intrinsic to NASA's exploration effort and its mission as a cutting-edge R&D agency, and they should be robustly funded.

Second, Congress believes that a well-executed exploration program can have significant inspirational and educational benefits. However, the public needs to become engaged for those benefits to be realized. Section 408 ["Participatory Exploration"] of P.L. 110–422 represents an initial attempt by Congress to encourage increased public engagement in the Nation's human and robotic exploration activities by leveraging technologies in the Constellation systems that can deliver a rich multi-

media experience to the public. In addition, Congress believes that the ISS can provide additional opportunities for educational outreach.

Third, Congress believes that NASA should coordinate, where practical, its science and exploration activities to capture the synergies between them. The goal of the coordination should be to maximize the success of the human exploration initiative and to further our understanding of the universe.

Fourth, one of the broad benefits to the Nation of a robust exploration program can be the engagement and encouragement of the commercial sector to the extent practicable. NASA is already undertaking initiatives in that regard in its overall human space flight program, but Congress is encouraging NASA to also look for opportunities to support its planned activities beyond low Earth orbit, such as with respect to the lunar outpost.

In conclusion, there now exists a broad congressional consensus on appropriate goals, objectives, and implementation strategies for NASA's human space flight and exploration activities, as reflected in the *NASA Authorization Acts* of 2005 and 2008. It is now time to ensure that all appropriate steps are taken to maximize the probability of success in achieving those goals and objectives through the projects that are currently under development. That will require a steadfastness of purpose, and I am encouraged that Congress has achieved a durable consensus that I hope will be matched by the Administration once your review has been completed. It will also require resource commitments commensurate with the tasks that the Nation is asking NASA to undertake—we should not pretend that such challenging goals can be achieved "on the cheap." That approach has already been tried, and it has been proved wanting. I hope that your review will provide a clear understanding of what will be required if America is to retain its leadership in human space flight by undertaking the challenging initiatives called out in the *NASA Authorization Acts* of 2005 and 2008.

I would be happy to discuss any of these matters in further detail if you would like to do so.

STATEMENT OF

THE HONORABLE RALPH HALL (R–TX)

RANKING MEMBER, U.S. HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HUMAN SPACE FLIGHT PLANS COMMITTEE

WEDNESDAY, JUNE 17, 2009

CARNEGIE INSTITUTION FOR SCIENCE

I want to thank the Members of this committee for the important work you are doing on behalf of our nation. I also want to thank you for the opportunity to share my views on the human space flight-related policies of the *NASA Authorization Acts* of 2005 and 2008 (P.L. 109–155 and P.L. 110–422 respectively). The views expressed here are primarily mine but I know they are shared by a number of my colleagues.

**America must be the Preeminent Space-faring Nation**

I think it is important to note that the first Authorization Act of 2005 (P.L. 109–155) was the product of a Republican-led Congress and the second Authorization Act in 2008 (P.L. 110–422) was the product of a Democratically-led Congress. Yet, in both cases the intent was the same, to enable NASA to succeed on its current path toward completion of the International Space Station, utilize the Station to carry out world-class research, retire the Space Shuttle after completing its remaining flights without the constraint of a predetermined date, and develop a new launch system capable of taking humans beyond low Earth orbit—a feat the Shuttle cannot do—for the first time since the 1970s. In both of our Authorizations we allocated more money than the Administration requested because in our opinion NASA was being asked to do too much with too little. I am concerned that we cannot continue to be the preeminent space-faring nation without adequate Administration support and appropriate funding.

One of the most important issues facing NASA, and indeed our nation, is the impending retirement of the Space Shuttle, and the subsequent five year gap in independent U.S. access to the $100 billion International Space Station. With the *NASA Authorization Act of 2005,* Congress endorsed the development of the new spacecraft and launch vehicles (and I stress launch vehicles plural) with the goal of launching the new system "as close to 2010 as possible."

In the *NASA Authorization Act of 2008* Congress established the new system as a priority by stating, "Developing United States human space flight capabilities to allow independent American access to the International Space Station, and to explore beyond low Earth orbit, is a *strategically important national imperative* (emphasis added), and all prudent steps should thus be taken to bring the Orion Crew Exploration Vehicle and Ares I Crew Launch Vehicle to full operational capability as soon as possible, and to ensure the effective development of a U.S. heavy-lift launch capability for missions beyond low Earth orbit." As a result, the Act sought to accelerate the development of the new system by authorizing an additional $1 billion in FY09.

Looking longer-term we are very concerned that the current budget request has eliminated funding for the Ares 5 heavy-lift launcher, and the Altair Lunar Lander, without which America is unable to explore beyond low Earth orbit.

The *NASA Authorization Act of 2008* also recognized the Space Shuttle's critical role in completing and utilizing the International Space Station, and added one additional mission, if it could be done safely, to deliver the Alpha Magnetic Spectrometer (AMS). As Authorizers, we are concerned that NASA may be unable to complete the remaining Shuttle missions, including the AMS flight, before the end of 2010. Unless the Administration and the Congress provide funds commensurate with extension, the Agency could be forced to take resources away from the development of Orion and Ares, adding delays that could further jeopardize the 2015 availability, and contribute to further losses of our highly-skilled aerospace workforce.

I, along with many of my colleagues, am not in favor of excessive government spending. But in this time of economic turmoil and growing international technological competitiveness, many of us are in agreement that America's space program is well-established on a path that, if sustained, will ensure our role as the world leader in space exploration and exploitation for decades to come. By pursuing human space flight we challenge our industry and inspire America to dream big and succeed. That is what leadership is all about.

Other countries recognize the strategic importance of the soft power we gained in the world through our audacious leadership in human space flight. The political and

technological stature America has earned through our space program is now sought by other nations eager to demonstrate their hard-won capabilities to the world. The International Space Station in orbit today is a remarkable achievement, bringing together the scientific and engineering talents, and resources of many nations. That achievement would not have been possible without American leadership. But such leadership is built on trust that we will keep our commitments to our international partners. If we continue to under-fund our space program we risk losing the international trust and credibility that is vital for long-term success.

Today, nearly 70 percent of the world's population was not alive to see Neil Armstrong walk on the Moon. Their opinions will be shaped by what happens in the future, not what happened in the past. We should not be in a race with China or any other country. We are the preeminent leader in space. But leadership is temporary. We should ensure that we take the necessary actions to remain the leader in human space flight.

I want to thank the Committee once again for this opportunity to share our minority views.

Chairman GORDON. This hearing will come to order. Good afternoon. I want to welcome our witnesses to today's hearing. And let me also say to our audience, and we are glad to see so many folks here today, that we may very well have some votes on the Floor. We are not sure what is going to quite happen later on. My partner, Mr. Hall, and I have agreed that we are going to try to send someone over as soon as the bell rings so that they can vote and then maybe will be able to come back in so that we can sort of keep things going. I am afraid that some of our witnesses won't be available again for some time, so we need to be able to try to run this through today. So if it gets a little—lots of bells, we are going to try to work our way through that.

And so to the witnesses, let me say you bring significant experience to this afternoon's deliberations, and we look forward to your testimony.

Today's hearing marks the first congressional examination of the summary report of the Review of U.S. Human Space Flight Plans Committee, which was released just last week. We will have two panels of witnesses appearing before us today.

The first panel consists of someone who is no stranger to this committee, Mr. Norman Augustine, an individual with many years of experience in the aerospace field. Mr. Augustine chaired the Human Space Flight Review Committee, and he will present the findings of that review in his testimony today.

The second panel will consist of two witnesses. The first, Admiral Joseph Dyer, is the Chair of the congressionally-established Aerospace Safety Advisory Panel. I believe that as we consider the potential paths of our nation's human space flight program, we need to make sure that we keep safety uppermost in our deliberations, and Admiral Dyer is well-equipped to help us understand the safety issues that need to be considered. The second, Dr. Michael Griffin, currently serves as a Professor at the University of Alabama in Huntsville, and before that, he served the Nation as NASA Administrator. Dr. Griffin was heavily involved in the formulation of the Constellation architecture that has been authorized and for which funds have been appropriated by Congress over the past four years.

Fundamentally I believe what this hearing should be about is determining where we go from here.

I have made no secret in recent years of my belief that the resources given to NASA haven't kept pace with the important tasks that we have asked NASA to undertake. That has caused significant stresses in recent years, and we cannot continue to go down that path.

We either have to give NASA the resources that it needs or stop pretending that it can really do all that has been put on its plate.

So as we proceed today, my focus is on the future. In that regard, I want our witnesses to help the Committee address a number of important questions. First, NASA has been working for more than four years on the Constellation program, a development program in support of which Congress has invested billions of dollars over that same period. As a result, I think that good public policy would tell us that there needs to be a compelling reason to scrap what we have invested our time and money in over these past four years.

Thus we will need to know whether or not the review panel found any major problems with the Constellation program that would warrant its cancellation, such as technical showstoppers, improper cost controls, or mismanagement.

Second, I have no interest in buying a pig in a poke, and I don't think anyone else in Congress or the White House will want to, either. Thus we need to know how we can credibly compare options proposed by the review panel that are still immature.

Do we just pick an option and hope for the best, or will we need to bring our exploration program to a halt for a year or more while the options are fleshed out and then re-evaluated once the specific implications of each are better understood?

And third, safety has to be a significant determination in what we do. The review panel's summary report is largely silent on safety. How do we meaningfully compare the safety implications of the various options proposed by the review panel?

And finally, while the review committee proposed a number of options that it asserted could be done with enhanced funding, what if the Administration or Congress determines that there will be no enhanced funding? Is there any path forward that makes sense in this situation?

Well, we have quite a lot to discus today, and I again want to thank our witnesses for their testimony.

Before closing I should note that while we initially sought the participation of NASA Administrator Bolden at today's hearing, we determined that it would be premature for him to appear until the Administration has developed its proposal to the Augustine Committee's report.

We look forward to having Administrator Bolden later, and we certainly will.

With that said, I will now recognize Mr. Hall for any opening remarks he might like.

[The prepared statement of Chairman Gordon follows:]

PREPARED STATEMENT OF CHAIRMAN BART GORDON

Good afternoon. I want to welcome our witnesses to today's hearing. You each bring significant experience to this afternoon's deliberations, and we look forward to your testimony.

Today's hearing marks the first congressional examination of the summary report of the Review of U.S. Human Space Flight Plans Committee, which was released just last week. We will have two panels of witnesses appearing before us today.

The first panel consists of someone who is no stranger to this committee, Mr. Norman Augustine, an individual with many years of experience in the aerospace field. Mr. Augustine chaired the human space flight review committee, and he will present the findings of that review in his testimony today.

The second panel will consist of two witnesses. The first, Admiral Joseph Dyer, is the Chair of the congressionally-established Aerospace Safety Advisory Panel. I believe that as we consider the potential paths for our nation's human space flight program, we need to make sure that we keep safety uppermost in our deliberations, and Adm. Dyer is well equipped to help us understand the safety issues that need to be considered. The second, Dr. Michael Griffin, currently serves as a Professor at the University of Alabama in Huntsville, and before that, he served the Nation as NASA Administrator. Dr. Griffin was heavily involved in formulating the Constellation architecture that has been authorized and for which funds have been appropriated by Congress over the past four years. As such, he will be able to help this committee better understand the considerations that go into developing a mature human space exploration architecture, which should aid our deliberations as we work to determine the best path forward.

Because that's fundamentally what I believe this hearing should be about—determining where we go from here.

I have made no secret in recent years of my belief that the resources given to NASA haven't kept pace with the important tasks that we have asked NASA to undertake. That has caused significant stresses in recent years, and we can't continue down that path.

We either have to give NASA the resources that it needs or stop pretending that it can do all we've put on its plate. That's especially true for NASA's exploration program, and it's true for the rest of its important missions too.

So as we proceed today, my focus is on the future. In that regard, I want our witnesses to help the Committee address a number of important questions. First, NASA has been working for more than four years on the Constellation program, a development program in support of which Congress has invested billions of dollars over that same period. As a result, I think that good public policy argues for setting the bar pretty high against making significant changes in direction at this point—that is, there would need to be a compelling reason to scrap what we've invested our time and money in over these past four years. Thus we will need to know whether or not the review panel found any major problems with the Constellation program that would warrant its cancellation, such as technical "showstoppers," improper cost controls, or mismanagement. If it didn't, logic would argue that our focus should be on ensuring the success of the current approach, not walking away from it.

Second, I have no interest in buying a pig in a poke . . . and I don't think anyone else in Congress or the White House will want to either. Thus we need to know how we can credibly compare options proposed by the review panel that are immature technically, programmatically, and from a cost estimation standpoint—especially relative to the current program.

Do we just pick an option and hope for the best, or will we need to bring our exploration program to a halt for a year or more while the options are fleshed out and then re-evaluated once the specific implications of each are better understood?

Third, safety has to be a significant determinant of what we do. The review panel's summary report is largely silent on safety. How do we meaningfully compare the safety implications of the various options proposed by the review panel?

And finally, while the review committee proposed a number of options that it asserted could be done with enhanced funding, what if the Administration or Congress determines that there will be *no* enhanced funding—is there any path forward that makes sense in that situation?

Well, we have quite a lot to discus today, and I again want to thank our witnesses for their testimony.

Before closing I should note that while we initially sought the participation of NASA Administrator Bolden at today's hearing, we determined that it would be premature for him to appear until the Administration has developed its response to the Augustine Committee's report.

We look forward to having Administrator Bolden testify at a later date.

With that said, I will now recognize Mr. Hall for any opening remarks he may care to make.

Mr. HALL. Mr. Chairman, I thank you for holding the hearing today. I want to welcome my good friends, Mr. Augustine, Mike Griffin, and Joe Dyer who have agreed to testify before us today. America's space program owes you a great debt of gratitude for the important roles each of you play and continue to play and the amount of your time you have given to this appointment, and I want to thank you for coming and sharing your wealth of knowledge and experience with us today.

In the aftermath of the *Columbia* tragedy, we did some national soul-searching. The *Columbia* Accident Investigation Board admonished us for a "failure of national leadership" that it said contributed to the accident and to NASA's inability to finish earlier programs deemed as hoped-for replacements for the Space Shuttle. The CAIB acknowledged that human space flight is a risky endeavor and observed, "The design of the system should give overriding priority to crew safety, rather than trade safety against other performance criteria, such as low cost and reusability." Crew safety

has always been my number one priority, and I worked toward that, had petitions for it, we have had money set aside for it. Some of it John Glenn used to make a trip, but I was for that because he is one of my fellow senior citizens up here. I don't think that we would be where we are in space today if America hadn't paid so much attention to this very vital concern: safety.

The *Columbia* Accident Investigation Board also encouraged us to clarify our goals in space so it would be worthy of the risks. I was encouraged in February of 2004 when the Bush Administration unveiled the *Vision for Space Exploration* because it gave NASA a clear direction, with measurable goals that had long been lacking. NASA was directed then to complete the International Space Station so it could be used by all the international partners for microgravity research into new vaccines and other promising bio-medical research, as well as research the long-term effects of space flight on humans and go down that road. That Vision also promised to move us beyond low Earth orbit by reestablishing our capabilities that have been lost since 1972 allowing us to return to the Moon, our nearest neighbor in space. It is my opinion that NASA has the greatest chance of success if given a clearly defined destination and the clearly defined design requirements that go with it.

The Congress held many hearings after the Vision was announced, and in the end agreed with the goals and direction of the plan proposed. I think it is important to note that both the 2005 and the 2008 *NASA Authorization Acts* reflect broad, bipartisan, bicameral support for the elements that original Vision. Any administration should carefully consider how difficult that level of consensus is and how difficult it could be to reestablish. Our greatest concern then as well as now has been the inadequate level of funding being requested and the gap between the retirement of the Space Shuttle and development of the follow-on Constellation system. In the ensuing years, these problems have only gotten worse.

I am not a fan of increased spending, but I have always thought our human space flight program gives the United States so much to be proud of and carries within it the promise of significant breakthroughs in health care, defense, and alternative energy technologies.

Mr. Chairman, in many ways it is hard for me to understand why the President is seeking new options at all when there has been an agreed-upon plan for several years. Why don't we just fund the program we have all agreed to? Why should multi-billion dollar bailouts of banks and insurance companies come at the expense of our talented scientists, engineers, and technicians who make the impossible look easy? It might be an impact on our national defense some day. I think many of us think that it would take a very small fraction of our federal budget, just tenths of one percent, to make a significant difference in our human space flight goals. But if even that level of funding is not forthcoming, we have to be very careful how we proceed because we have a lot at stake, and crew safety should be paramount.

Mr. Augustine's panel reports that commercial launch services hold some promise, and our committee has supported the development of several commercially-based ideas such as NASA's Commer-

cial Orbital Transportation System and ISS Cargo Resupply Services, but commercial services should not be considered a cheap substitute for lack of national leadership in human space flight. Our *NASA Authorization Acts* and other legislation of the FAA Office of Commercial Space Transportation have encouraged prize competitions designed to inspire smaller private companies to develop innovative technologies. Just this past Saturday, Armadillo Aerospace of my home town and the smallest county of Texas, Rockwall County, become the first company to qualify for the $1 million top prize of NASA's Northrop Grumman Lunar Lander Challenge at Caddo Mills Municipal Airport. I applaud John Carmack and his team for their innovative and creative thinking. These are exciting and useful ventures, but in our desire to save money, let us not forget that you get what you pay for, and when it comes to transporting humans into space, our overriding priority should be crew safety, not lowest cost or reusability.

Mr. Chairman, I look forward to the hearing today, and thank you, sir.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

Mr. Chairman, thank you for holding today's important hearing on *Options and Issues for NASA's Human Space Flight Program.* I want to welcome my good friends Norm Augustine, Mike Griffin and Joe Dyer who have agreed to testify before us today. America's space program owes you a debt of gratitude for the important roles each of you have played, and continue to play. I want to thank you for coming and sharing your wealth of knowledge and experience with us.

In the aftermath of the *Columbia* tragedy, we did some national soul-searching. The *Columbia* Accident Investigation Board (CAIB) admonished us for a "failure of national leadership" that it said contributed to the accident and to NASA's inability to finish earlier programs deemed as hoped-for replacements for the Space Shuttle. The CAIB acknowledged that human space flight is a risky endeavor and observed, "the design of the system should give overriding priority to crew safety, rather than trade safety against other performance criteria, such as low cost and reusability." Crew safety is *my* number one priority. I do not think we would be where we are in space today if America had not paid so much attention to this vital concern.

The *Columbia* Accident Investigation Board also encouraged us to clarify our goals in space so they would be worthy of the risks. I was encouraged in February of 2004 when the Bush Administration unveiled the *Vision for Space Exploration,* because it gave NASA a clear direction, with measurable goals, that had been lacking. NASA was directed to complete the International Space Station so it could be used by all the international partners for microgravity research into new vaccines and other promising bio-medical research, as well as research the long-term effects of space flight on humans. That Vision also promised to move us beyond low Earth orbit, by re-establishing our capabilities that have been lost since 1972, allowing us to return to the Moon our nearest neighbor in space. It is my opinion that NASA has the greatest chance of success if given a clearly defined destination and the clearly defined design requirements that go with it.

The Congress held many hearings after the Vision was announced, and in the end agreed with the goals and direction of the plan proposed. I think it is important to note that both the 2005 and 2008 *NASA Authorization Acts* reflect broad, bipartisan, bicameral support for the elements of that original vision. Any Administration should carefully consider how difficult that level of consensus is, and how difficult it could be to re-establish. Our greatest concern then-as-well-as-now, has been the inadequate level of funding being requested, and the gap between the retirement of the Space Shuttle and development of the follow-on Constellation system. In the ensuing years those problems have only gotten worse.

I am not a fan of increased spending, but I have always thought our human space flight program gives the United States so much to be proud of, and carries within it the promise of significant breakthroughs in health care, defense, and alternative energy technologies.

Mr. Chairman, in many ways it's hard for me to understand why the President is seeking new options at all when there has been an agreed upon plan for several years. Why don't we just fund the program we've all agreed to? Why should multi-billion dollar bailouts of banks and insurance companies come at the expense of our talented scientists, engineers and technicians who make the impossible look easy? I think many of us agree that it would take a very small fraction of our federal budget, just tenths of one percent, to make a significant difference in our human space flight goals. But if even that level of funding is not forthcoming, we must be very careful how we proceed because we have a lot at stake, and crew safety should be paramount.

Mr. Augustine's panel reports that commercial launch services hold some promise, and our committee has supported the development of several commercially-based ideas such as NASA's Commercial Orbital Transportation System and ISS Cargo Resupply Services, but commercial services should not be considered a cheap substitute for lack of national leadership in human space flight. Our *NASA Authorization Acts* and other legislation for the FAA Office of Commercial Space Transportation have encouraged prize competitions designed to inspire smaller private companies to develop innovative technologies. Just this past Saturday, Armadillo Aerospace of Rockwall, Texas became the first company to qualify for the $1 million top prize of NASA's Northrop Grumman Lunar Lander Challenge at Caddo Mills Municipal Airport. I applaud John Carmack and his team for their innovative and creative thinking. These are exciting and useful ventures, but in our desire to save money let us not forget that you get what you pay for, and when it comes to transporting humans into space our overriding priority should be crew safety, not lowest cost or reusability.

Mr. Chairman, I look forward to today's hearing, and I yield back my time.

Chairman GORDON. Thank you, Mr. Hall. If there are other Members who wish to submit additional opening statements, your statements will be added for the record at this point.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good afternoon. Thank you, Mr. Chairman, for holding today's hearing to review and discuss the summary report of the National Aeronautics and Space Administration (NASA) Review of U.S. Human Space Flight Plans Committee.

I am pleased the review committee completed its survey of NASA's human space flight program in a timely and effective manner. In reviewing the summary report, I identified three areas I look forward to hearing the witnesses address.

First, the review committee concluded that human space flight will not be sustainable under NASA's current budget, and I understand the review committee's view that an increase of $3 billion over several years will allow NASA to continue human space flight programs. However, I would like to know if the review committee considered Congress' frequently cited concerns regarding NASA's budget management abilities when determining that such an increase in funding would be necessary. I believe Congress and NASA should work together to ensure that these funds are appropriately and efficiently used.

Second, as a strong supporter of Science, Technology, Engineering, and Math (STEM) education programs, I was concerned to see NASA's cut its budget request for STEM programs by $43 million for Fiscal Year 2010. I would like to hear if the review committee considered other measures to prepare the next generation of astronauts and aerospace engineers. It is vitally important for our nation to attract new engineers and scientist to ensure the U.S. remains competitive in the 21st century. Does the review committee have any recommendations to provide Congress on how we can work with NASA and the Administration to fulfill those needs?

Third, as Chairman of the Aviation Subcommittee on the Transportation and Infrastructure Committee, I was interested in the review committee's findings regarding commercial entities and low Earth orbit travel. I would like to hear from our witnesses how the involvement of commercial carriers would be more efficient than a government program and how Congress can assist NASA in bringing about a commercial space program, should such an option be considered.

I welcome our two panels of witnesses, and I look forward to their testimony. Thank you again, Mr. Chairman.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Good afternoon, Mr. Chairman. Welcome, distinguished witnesses.

Mr. Augustine, I am delighted to see you here. I would like to commend your leadership on the U.S. Human Space Flight Plans Committee. Your work is, and has been, well-respected by Congress. I look forward to your presence next week at my Science and Technology Brain Trust. Your words will inspire many young people, who will be in the audience.

The American public has been inspired by manned space flight since the space program was created, in the 1950s. Generations of young people have seen video footage of a man walking on the Moon and have said to themselves, "I want to do that!" Thousands of American children aspire to go to Space Camp. Others take professional paths toward engineering to work in the space industry.

Aeronautics and space research have yielded unimaginable benefits. From lasers to Magnetic Resonance Imaging (MRI) technology, from satellites to water purification systems, NASA research has touched many aspects of our daily lives.

I want to thank the U.S. Human Space Flight Plans Committee for its 120-day review of feasibility and options for space flight into the next decades. The Committee brought different perspectives and specialized expertise together, into one package, to help guide policy-makers as they make decisions about federal funding into space flight.

As I have said before, NASA is incredibly important to Texas. The Johnson Space Center, just south of Houston, is a major economic engine for our state.

In reviewing some of the Committee's perspective on short-term Space Shuttle planning, it recommends that, "the current Shuttle manifest should be flown in a safe and prudent manner."

However, the Committee also surmised that, "The U.S. human space flight program appears to be on an unsustainable trajectory.

It is perpetuating the perilous practice of pursing goals that do not match allocated resources. . . . Space operations become all the more difficult when means to not match aspirations."

The Science Committee makes great efforts to make budget and funding recommendations that align with a responsible expenditure of public resources. With a deep recession, many federally-funded programs have also suffered from budget cuts. It seems to me that goals should be revised as anticipated funding streams change.

The Committee is right. Grand plans mean little if the financial support is not present. During tight economic times, it is better to focus on safety first, then on a NASA program that may be more modest in scope, but is efficient and goal-oriented.

As Michael Griffin stated in his testimony, "the Commission didn't find anything wrong with the current program, didn't find anything safer, more reliable, cheaper, or faster. The roots are healthy. So, why throw away four years and $8 billion pulling up the flowers?"

I agree. We must not undo strides made in a healthy program. I look forward to more study of the Committee's recommendations as human space flight moves forward.

[The prepared statement of Chairwoman Giffords follows:]

PREPARED STATEMENT OF CHAIRWOMAN GABRIELLE GIFFORDS

I want to join Chairman Gordon in welcoming our distinguished set of witnesses, and I look forward to their testimony. Today we will be discussing no less than the future of America's human space flight program—the program that I think every politician in Washington and across the country points to when we talk about America's great innovation and technological superiority. I know that each of our witnesses today will bring important insights to our deliberations.

Yet as we start this hearing, I have to say that I am extremely frustrated, in fact, I am angry. With all due respect to Mr. Augustine and his panel, I have to say that I think we are no further ahead in our understanding of what it will take to ensure a robust and meaningful human space flight program than we were before they started their review. In fact, I'd argue that we have lost ground.

Let's review the facts.

Probably the most important finding of the Review of U.S. Human Space Flight Plans is the panel's determination that there is a serious mismatch between the challenges that we have asked NASA to meet and the resources that have been provided to the agency. In other words, we can't get anywhere worth going to under NASA's projected budgets. Well, we certainly didn't need an independent commis-

sion to tell us that. That's been painfully obvious for some time now. And the impact of that shortfall is that the good work being done by NASA's civil servants and contractors risks being undone.

I'm glad they highlighted the problem, but it's not exactly news to anyone who has been involved in the budget battles of recent years. Don't get me wrong. I'm not denigrating the work done by Mr. Augustine and his panel. Mr. Augustine has an excellent reputation and I know that he has put a lot of work into this commission.

They have given us a sobering reminder that our position as the world's leading space-faring nation is not a given—we continually need to re-earn that preeminent position through our actions, and we can't just rest on past laurels. The rest of the world has discovered space too, and we are seeing the emergence of impressive capabilities in other countries that we need to take seriously.

That said, I think the men and women of NASA have demonstrated that they are up to the challenge. Over the past four years, they have moved from initial concepts into design and development of the Constellation systems. They have successfully completed a number of important design reviews, have undertaken test activities—including test-firing just last week the five-segment booster that will power the Ares I rocket into space and planning for a test flight of the Ares I–X rocket at the end of next month. And they've done all of this even though the budgetary sands keep shifting under them, taking away resources that they thought they could count on and forcing them continually to replan and rephase even while they are trying to complete the hard technical and programmatic work that has to be done if Constellation is to succeed.

So when it was announced that Mr. Augustine would be leading an independent review of the Nation's human space flight program, I *thought* that they would take a hard look at the Constellation program and tell us what should be done to maximize its chances for success.

But that's not what they did. Instead of focusing on how to strengthen the exploration program in which we have invested so much time and treasure, they gave only glancing attention to Constellation—even referring to it in the past tense in their summary report—and instead spent the bulk of their time crafting alternative options that do little to illuminate the choices confronting Congress and the White House.

And so where does that leave us? Well, in place of a serious review of potential actions that could be taken to improve and strengthen the Constellation program, we have been given set of alternative exploration options that are little more than cartoons—lacking any detailed cost, schedule, technical, safety or other programmatic specifics that we can be confident have been subjected to rigorous and comprehensive analysis and validation.

So, I have to ask my colleagues on the Committee—what are we to do with this report? In the absence of evidence of mismanagement or technical or safety "showstoppers"—none of which the Augustine panel has indicated has occurred in the Constellation program—can any of us in good conscience recommend canceling the exploration systems development programs that Congress has funded for the past four years on the basis of the sketchy alternatives contained in the panel's report?

I know that I can't justify doing so, and I would suspect that you can't either. Hoping that "maybe things will work out" if we try something new is no substitute for the detailed planning and design and testing that has been the hallmark of successful space flight programs in the past. Nor do we gain anything by confusing hypothetical commercial capabilities that might someday exist with what we can actually count on now to meet the Nation's needs. We've made that mistake in the past, and we've suffered the consequences.

So I have to say that I just don't get it. I don't see the logic of scrapping what the Nation has spent years and billions of dollars to develop in favor of starting down a new path developed in haste and which hasn't been subjected to any of the detailed technical and cost reviews that went into the formulation of the existing Constellation program.

For the Nation's sake, I hope that we can break this cycle of false starts in our nation's human space flight program. It does not serve America well. As far as I can tell, the Constellation program's only sin is to have tried to implement a very challenging program with an inadequate budget. Yet, some would now advocate walking away from that program, not because it is not performing, but because we are unwilling to face the truth that, as Mr. Augustine said in testimony before our Committee more than five years ago, "it would be a grave mistake to try to pursue a space program 'on the cheap'."

I hope that the Administration and this Congress finally take those words to heart and do the right thing. The future of America's human space flight program is at stake.

[The prepared statement of Mr. Mitchell follows:]

PREPARED STATEMENT OF REPRESENTATIVE HARRY E. MITCHELL

Thank you, Mr. Chairman.

On May 7, 2009, the Office of Science and Technology Policy, Executive Office of the President, launched an independent review of planned U.S. human space flight activities with the goal "of ensuring that the Nation is on a vigorous and sustainable path to achieving its boldest aspirations in space."

Today we will examine the summary report of this review as well as discuss the implications and related issues for NASA.

NASA conducts vital research and development projects that help us learn about our surroundings.

Arizona State University, which is located in my district, is home to researchers who work on many of these important NASA research projects.

To maintain America's competitiveness in science and technology, we must do more than merely keep up. We must lead, and commit ourselves to providing the resources necessary to keep us at the forefront of this kind of cutting edge research and development.

I look forward to hearing more from our witnesses about the findings of this report.

I yield back.

## Panel I:

Chairman GORDON. First up is Mr. Norman Augustine who is currently servicing as the Chair, Review of the U.S. Human Space Flight Plans Committee and is the former CEO of Lockheed-Martin and was the lead author of the National Academies 2005 Report, *Rising Above the Gathering Storm,* which was the foundation for the first major legislation that this committee passed last year. And again, our country will be forever grateful to you I think as years go along. Your report and our legislation will be thought of as landmark legislation and will help our country do just what it says, compete.

So Mr. Augustine, you are now recognized.

### STATEMENT OF MR. NORMAN R. AUGUSTINE, CHAIR, REVIEW OF U.S. HUMAN SPACE FLIGHT PLANS COMMITTEE

Mr. AUGUSTINE. Thank you very much, Mr. Chairman. Mr. Hall, Members of the Committee, I would with the Committee's permission like to submit a written statement for the record and just briefly summarize it here.

Chairman GORDON. Without objection.

Mr. AUGUSTINE. To begin with, I should acknowledge the colleagues on this committee who have devoted a remarkable amount of time and effort to putting together the findings that I will be describing today. I would also like to thank NASA for the terrific support they have given to our committee. That support has been invariably straightforward, responsive, and in the can-do spirit of NASA. Also I should acknowledge the Aerospace Corporation which our committee hired to work directly for the Committee to give us an independent arm to do more detailed analysis of costs and schedules, programmatics, technical issues than we could perform ourselves.

Our committee had 10 members. It included scientists, engineers, educators, business executives, astronauts, former presidential appointees, retired general officer. In other words, it was a rather diverse committee that has come to what I believe to be a unanimous set of findings.

As you know, we were only allowed 90 days to conduct our work, and the reason for that is that we were trying to match the budget cycle with which this committee is so familiar. Having said that, you should be aware of the limitations that are placed on our work because of that amount of time.

It is very important for me to emphasize that we were not asked to make recommendations, and we have not done so. We were asked to offer options or alternatives and assessments, and that is what we have done and so that is what I will talk about today.

First of all, when seeking a destination for the Human Space Flight Program, it was our view that above all else, Mars stands out, a human landing on Mars because Mars more closely matches the Earth than any other planet. It is physically reachable, a solid surface. It has materials on the surface of the planet. It has an atmosphere of sorts, and it is clearly the goal to be sought. But having said that, it is our view, and I realize that many don't agree with us, that from a safety standpoint we are not prepared to undertake a program to go directly to Mars at this point in time. There is a great deal of additional homework to be done, some of a rather fundamental nature before we set out on a mission directly to Mars.

The various parameters our committee considered led to over 3,000 possible options for us to consider. We sought to narrow that down to a manageable group, and in so doing obviously everyone's favorite option isn't there. But we do have five families of options that we think are broadly representative of the choices before our nation, and one can modify those options in some cases with relative ease. One of those options of course is the current plan that is now being pursued. That plan we have called the Program of Record and is our baseline option. We define the plan as being the program that NASA has told us it is pursuing and the budget that goes with it. We have used the budget that the Office of Management and Budget has told us is appropriate to that plan.

I would note in echoing your views, Mr. Chairman, that ongoing programs should only be changed for compelling reasons, and we have tried at each of our alternatives to cite the strengths and the weaknesses of each of the alternatives, and each has both strengths and weaknesses. I won't because of lack of time in this statement describe the other four options, but they are in the report we published or on the internet, and I am sure you have copies of them. They are listed in my written statement that you have.

The reluctant bottom-line conclusion of our committee, if you will, is that the current program as it is being pursued is not executable, that we are on a path that will not lead to a useful, safe human exploration program, and the reason for that, the primary reason, is the mismatch between the tasks to be performed and the funds that are available to support those tasks. It also came as a considerable disappointment to this committee that we were unable to find any alternative space program, a human space flight pro-

gram, that would be worthy of this country that could be conducted for the funding profile now in place. We examined one derivative, a number of derivative programs based on one additional budget, and we found that by adding approximately $3 billion to the budget over the years and accounting for inflation over time in realistic fashion, that America could have a choice of a number of exciting, challenging, important, inspirational human space flight programs.

I will close with three quick observations, one is that we have sought to be relatively conservative in our estimates of cost, schedule and performance, and we do that because it reflects our dissatisfaction with the record of our profession at doing these things in the past, estimating that is. Secondly, we believe that NASA has too long been placed in a position of been trying to accomplish more than the resources that it is given permit. We believe that to be wasteful and worse yet, very hazardous when dealing with such a challenging field as human space flight which is highly unforgiving. And finally on that point, human space flight is obviously, as everyone in this room knows, very risky. We place people in danger. We place the Nation's reputation on the line, and it is our belief that if we hope to be a space-faring nation over the years, that we have to recognize that there will be setbacks, and we should do everything we can to prevent them. But this is, in the vernacular, a risky business.

Finally, on behalf of the Members of the Committee, I would like to thank you and the Administration for the confidence that they have placed in us to review what has truly become a symbol of America's leadership in the world.

Thank you very much.

[The prepared statement of Mr. Augustine follows:]

PREPARED STATEMENT OF NORMAN R. AUGUSTINE

Mr. Chairman and Members of the Committee, thank you for this opportunity to share with you the principal findings of the Review of the U.S. Human Space Flight Plans Committee. I will speak on behalf of the members of our committee and will do my best to reflect our consensus views. As you are aware, our final report has not yet been published; however, our decision-making deliberations were all conducted in public under FACA rules so I believe what I have to say will come as no surprise to anyone.

First, I would like to acknowledge the contributions and extraordinary effort of each of my colleagues on the Committee. Their names and primary affiliations are appended to this statement. I would also like to acknowledge the forthright, responsive and highly professional support we received from NASA as well as from the Aerospace Corporation, the latter of which the Committee employed to provide independent technical and cost assessments.

The Committee was comprised of ten members having highly diverse backgrounds. It included astronauts, scientists, engineers, former presidential appointees, business executives, educators and an Air Force retired General Officer—each with considerable space experience. Due to the exigencies of the budget process we were asked to complete our task in ninety days—which we did, with the exception of finalizing and printing our report. The latter will be available soon.

Our assigned task was to identify alternative courses that the U.S. might pursue in the area of human space flight. One such alternative, of course, is to continue the present program. As noted in the Committee's report, changes to ongoing programs are generally warranted only for compelling reasons. Each alternative identified by the Committee is accompanied by a discussion of its strengths and weaknesses.

It was agreed that at least two of the alternatives would be compatible with the FY '10 budget plan extended through FY '20. We were also asked to examine the current plans for the Space Shuttle and International Space Station and, if appropriate offer alternatives thereto. It is important to note that we specifically were not

asked to make a *recommendation* as to a future course of action. That decision is, of course, the purview of the President and the Congress.

Before addressing destinations and architectures the Committee sought to identify appropriate goals for human space flight. There are many possibilities that can be cited: strengthening the economy, conducting science, repairing and upgrading spacecraft on orbit, promoting international ties, protecting against asteroids and comets, encouraging science education, and more. It is, however, the Committee's view that although each of these benefits is important in its own right, none can, by itself, justify the cost and risk of human space flight. Rather, the *raison d'être* for such activity must, and in our view can, be founded upon charting a course for the expansion of civilization into the solar system. In so doing, one derives the leadership benefits of being among the world's space-faring nations—a nation that is committed to exploration, seeking knowledge, advancing engineering capabilities, inspiring its citizens, and motivating its young people to consider careers in science and engineering. To a not inconsiderable degree it is intangibles that justify the human space flight program, intangibles such as those that today help maintain America as a leader among the world's nations. The Apollo Program is an appropriate example.

In carrying out the charge to identify options the Committee narrowed over 3,000 theoretically possible outcomes to a set of five alternative integrated space programs. These can be thought of as representative families, since one can interchange certain elements among the individual alternatives. The Committee's attempt was, of course, to keep the number of nominal options to a manageable size.

The alternatives offered include the ongoing program, Constellation—that is, the Program of Record and the Budget of Record—and four primary alternatives, some having derivatives or "sub-cases."

Two of the five alternatives were in fact constrained to the current budget profile for human space flight. The first of these was the Program of Record; that is, today's program, modified to fly-out the Shuttle in 2011 rather than 2010 and including sufficient funds to de-orbit the International Space Station (ISS) in 2016 according to plan. Under this existing approach the Ares I launch vehicle and Orion capsule are unlikely to become available until after the ISS has been de-orbited. The heavy-lift vehicle, Ares V, would, in our judgment, become available in the late 2020s; however, there are inadequate funds to develop the exploration systems the Ares V is intended to support. The Committee concludes that this is not an executable option due to the incompatibility of the budget plan and the program plan.

The Committee's review noted that the Constellation Program has encountered technical difficulties of the type not unexpected of undertakings of this magnitude—problems which, given adequate funds and engineering attention, should be solvable. This was not, however, a significant factor in the overall conclusion with respect to the viability of the Program of Record.

The second of the options, also constrained to the current budget profile, flies-out the Shuttle in FY '11, but extends the use of the International Space Station for five years, to 2020. This option includes a robust technology development program—something the Committee believes has been lacking at NASA in recent years—and relies on commercial firms to launch cargo and crews to the ISS as soon as demonstrated capabilities exist. It includes development of a somewhat less capable version of the Ares V, known as the Ares V (Lite). This option is deemed capable of execution but cannot provide the space-borne hardware required to support a viable exploration program. In fact, the Committee could find no program within the current budget profile that would enable a viable exploration effort.

Given these findings, the Committee examined three options that exceeded the present budget plan. The most defensible funding profile, purely from a program execution standpoint, is one that linearly increases to $3B above the FY '10 guidance by FY '14 and then increases by an estimated annual inflation rate of 2.4 percent.

The first of these budgetarily less constrained options is termed the Baseline Case. It is the present Program of Record with funds added to extend Shuttle operations into 2011 and, as now provided in the budget plan, to de-orbit the ISS in 2016. This program would permit a human return to the Moon in the mid '20s and begin laying the groundwork for a flight to Mars.

The second of the budgetarily less constrained cases is actually a family of variants that would extend ISS operations to 2020, provide funds for its de-orbit, and fund a strong technology program in support of ISS utilization and an eventual human landing on Mars. It would use commercial launch services for new access to low Earth orbit. There are, however, significant differences between the two variants under this option. The first of these variants would develop the Ares V (Lite) to support a human lunar landing in the mid 2020s—after which focus would

turn to a human Mars landing. The second variant would extend the use of the (recertified) Space Shuttle to 2015 and be accompanied by the development of a Shuttle Directly-Derived heavy-lift vehicle in place of the Ares family—with the eventual possibility of in-orbit refueling. This is the only practicable option the Committee could find to close the at least five-year gap during which the U.S. will, as currently planned, rely upon Russian launch services to lift U.S. astronauts to the International Space Station.

The third budgetarily less constrained case follows a rather different path of exploration from that heretofore pursued by the U.S. The Committee terms this option the "Flexible Path" and defines it as achieving periodic milestones prior to a Moon or Mars landing. These initial accomplishments could include a lunar fly-by, a Mars fly-by, a visit to a Lagrange point, an asteroid rendezvous, and possible landings on the moons of Mars, Phobos and Demos.

In summary, with the existing budget plan it would be reasonable to extend the use of the ISS for five years and to conduct a robust technology development program. The Committee concludes that no rational exploratory program can be funded under the existing funding constraint and that plans for America's space exploration program would de facto be halted and human operations limited to low Earth orbit.

With the less constrained budget option, requiring approximately $3B per year in additional funding, a sound exploration program could be conducted. The reason for this seemingly "dead space" between the two budget options is, simplistically stated, that for sixty percent of the needed funds, one cannot go sixty percent of the way to Mars.

Each of the implementable options that was identified has its own set of benefits and liabilities that the Committee has sought to address. The findings of this effort are discussed in the Summary Report. The assessment gives overarching priority to safety and, as is noted in the Summary Report, the Committee believes considerable caution is in order when comparing analytical results in this area with flight results. Similarly, the Committee has sought to be conservative in its cost estimation practices—reflecting dissatisfaction with historical experience on a broad spectrum of programs. Finally, in defining a "Program of Record" the Committee has relied upon NASA's current program plan and the President's budget profile, the latter as provided by the Office of Management and Budget.

In the opinion of this committee, as well as that of most of the persons with whom the Committee has had contact, NASA has for too long sought to operate in an environment where means do not match ends. In the unforgiving arena of human space flight this is a particularly hazardous policy to embrace.

The Committee also notes that NASA has become a mature organization, an organization long protected from restructuring Centers, facilities and personnel cadres. The consequence is an organization with high fixed costs of the type that make budgetary options highly limited. While NASA is unarguably the finest space organization in the world and a great national asset, it is overdue for a thorough management assessment of the type the aerospace industry underwent at the end of the Cold War.

The Committee's report will contain more detailed information that it hopes will prove of value. On behalf of my colleagues, I thank you for the trust that has been placed in us to review a pursuit which for decades has come to be a symbol of America's leadership.

**U.S. HUMAN SPACE FLIGHT PLANS COMMITTEE MEMBERS**

Mr. Norman R. Augustine
Retired Chairman & CEO
Lockheed Martin Corporation

Dr. Wanda M. Austin
President & Chief Executive Officer
The Aerospace Corporation

Mr. Bohdan I. Bejmuk
Chair, NASA Constellation Standing Review Board

Dr. Leroy Chiao
Former Astronaut, Former International Space
Station Commander and Engineering Consultant

Dr. Christopher F. Chyba
Professor of Astrophysics Sciences and International Affairs
Princeton University

Dr. Edward F. Crawley

Ford Professor of Engineering
Massachusetts Institute of Technology

Mr. Jeffrey K. Greason
Co-founder & Chief Executive Officer
XCOR Aerospace

Dr. Charles F. Kennel
Director and Professor Emeritus
Scripps Institution of Oceanography
University of California, San Diego

General Lester Lyles
United States Air Force (Retired)

Dr. Sally Ride
President & Chief Executive Officer
Imaginary Lines

BIOGRAPHY FOR NORMAN R. AUGUSTINE

NORMAN R. AUGUSTINE was raised in Colorado and attended Princeton University where he graduated with a BSE in Aeronautical Engineering, *magna cum laude,* and an MSE. He was elected to Phi Beta Kappa, Tau Beta Pi and Sigma Xi.

In 1958 he joined the Douglas Aircraft Company in California where he worked as a Research Engineer, Program Manager and Chief Engineer. Beginning in 1965, he served in the Office of the Secretary of Defense as Assistant Director of Defense Research and Engineering. He joined LTV Missiles and Space Company in 1970, serving as Vice President, Advanced Programs and Marketing. In 1973 he returned to the government as Assistant Secretary of the Army and in 1975 became Under Secretary of the Army, and later Acting Secretary of the Army. Joining Martin Marietta Corporation in 1977 as Vice President of Technical Operations, he was elected as CEO in 1987 and Chairman in 1988, having previously been President and COO. He served as President of Lockheed Martin Corporation upon the formation of that company in 1995, and became CEO later that year. He retired as Chairman and CEO of Lockheed Martin in August 1997, at which time he became a Lecturer with the Rank of Professor on the faculty of Princeton University where he served until July 1999.

Mr. Augustine was Chairman and Principal Officer of the American Red Cross for nine years, Chairman of the Council of the National Academy of Engineering, President and Chairman of the Association of the United States Army, Chairman of the Aerospace Industries Association, and Chairman of the Defense Science Board. He is a former President of the American Institute of Aeronautics and Astronautics and the Boy Scouts of America. He is a current or former member of the Board of Directors of ConocoPhillips, Black & Decker, Proctor & Gamble and Lockheed Martin, and was a member of the Board of Trustees of Colonial Williamsburg. He is a Regent of the University System of Maryland, Trustee Emeritus of Johns Hopkins and a former member of the Board of Trustees of Princeton and MIT. He is a member of the Advisory Board to the Department of Homeland Security, was a member of the Hart/Rudman Commission on National Security, and served for 16 years on the President's Council of Advisors on Science and Technology. He is a member of the American Philosophical Society and the Council on Foreign Affairs, and is a Fellow of the National Academy of Arts and Sciences and the Explorers Club.

Mr. Augustine has been presented the National Medal of Technology by the President of the United States and received the Joint Chiefs of Staff Distinguished Public Service Award. He has five times received the Department of Defense's highest civilian decoration, the Distinguished Service Medal. He is co-author of *The Defense Revolution* and *Shakespeare In Charge* and author of *Augustine's Laws* and *Augustine's Travels.* He holds 23 honorary degrees and was selected by Who's Who in America and the Library of Congress as one of "Fifty Great Americans" on the occasion of Who's Who's fiftieth anniversary. He has traveled in over 100 countries and stood on both the North and South Poles of the Earth.

## DISCUSSION

Chairman GORDON. Thank you, Mr. Augustine. At this point, we will begin our round of questions, but before we proceed, I would like to make a unanimous consent request at the behest of our dis-

tinguished witness, Mr. Augustine has asked that Dr. Edward Crawley, a member of the panel that he chaired, be allowed to join him at the witness table to help answer questions the Committee may have. If there are no objections, then Dr. Crawley, please join us here.

I also have one other unanimous consent. We have other Members of Congress who are not currently Members of the Science Committee that would like to join us today. They have been reminded that any questions they might have will be after the current Members of this committee. And so without objection, Mr. Culberson, Mr. Posey, Ms. Jackson Lee will be allowed to participate if they choose. With no objections, they will be.

Mr. Augustine, I could have saved you some time and money and told you that there weren't enough funds to carry out the existing program if you had asked or had been to any of our meetings.

Mr. AUGUSTINE. We should have changed jobs, sir.

Chairman GORDON. We unfortunately—it is not funny, but we have been pointing out for some time and I think that this is a worthwhile timeout. We cannot continue to kick the can down the road. We have got to decide as a nation what are we willing to pay for and need to move forward. So I thank you for again bringing these topics to the surface. They don't need to be under the rug any longer.

## CONSTELLATION PROGRAM STATUS

So one of the questions that we expected your panel to address was the status of the existing Constellation program, but the Summary Report actually says very little about it. So let me ask you, what is your panel's assessment of the Constellation Program? Is it technically sound and effectively managed within the resources available or is it fatally flawed? If there are areas that need improvement, what are they?

Mr. AUGUSTINE. Mr. Chairman, I would be happy to try to answer that. Certainly with the resources available, the program is I think we would say fatally flawed. It will take so long to do the things that need to be done to develop the hardware that is needed, it will be well beyond many of our lifetimes before we are able to have a really active space flight program. That is with the current budget.

With regard to the program itself——

Chairman GORDON. Excuse me, but would that be the same with any of the alternatives, though?

Mr. AUGUSTINE. That would be.

Chairman GORDON. Okay.

Mr. AUGUSTINE. With regard to the—what was the other point you had? I forgot.

Chairman GORDON. Is it technically sound, effectively managed?

Mr. AUGUSTINE. Oh, yes. Thank you. We did review the program, its management. We believe it to be soundly managed. Technically the program has some significant problems, technical problems, and this is not to be unexpected in a program of this difficulty and this magnitude. We saw no problems that appear to be unsolvable given the proper engineering talent, the attention, and the funds to solve them. Having said that, I would like to turn to my col-

league, Dr. Crawley, and the reason I ask that he be permitted to join me, our committee divided into subcommittees, one of which devoted its attention to putting together these integrated options, and Professor Crawley chaired that subcommittee. Ed, if you would care to add anything to my summary remarks?

Mr. CRAWLEY. No, I think, Norm, you have summarized this quite well at the highest level. There were on our committee a number of people who had actually built space flight hardware, and their general consensus on the assessment of the Constellation Program technically is, as Norm said, that it has problems. All real programs, where you are really building hardware, encounter problems, developmental problems, but we didn't see any of them including some of the famous vibration problem in the Ares I or the vibrocoustic environment, the noise environment, around the Orion that were not surmountable with proper engineering talent and skill which we believe NASA could bring to bear.

So in short——

Chairman GORDON. Sir, do you think in short are the problems with Constellation greater than the other options? And how would you really be able to evaluate the other options since they are at what you would call an immature level in contrast to this more mature level?

Mr. CRAWLEY. Well, Mr. Chairman, that was in fact one of the most difficult challenges that the Committee faced. We were asked to consider and propose a set of alternatives which we faithfully tried to do, but we were very conscious of the my-rocket-in-your-view-graph problem that we called, it, you know, it is always easy for something to look better on a set of view graphs or in a proposal than when you are in the midst of a real development program. Other than to say we were very conscious of this and we tried to the greatest extent to be aware of it in the assessment of the options and the costing of the options, I think that that was basically the judgment process of the Committee.

Chairman GORDON. So as I mentioned earlier, we do have a program that has been authorized we have spent billions of dollars on. And so I don't think you trade what you know for what you don't know if it is equal or a little bit better. So are you prepared to say that one or all of the other options are substantially better than Constellation and worth having a major turn now?

Mr. AUGUSTINE. I think it would be our view just what you said, that there should be a compelling reason to change an existing program, and we believe that the existing program, given adequate funds, is executable and would carry out its objectives. The existing program, just like other programs, does have its difficulties. Some of the other programs rely heavily on existing hardware, for example, closely Shuttle derived hardware, more closely derived.

But the fact remains on the negative side that since for example the Ares I program began, several years have passed, and at this point, we believe it's quite unlikely that the Space Station, the ISS, International Space Station, will have just about completed its useful life, even an extended life, by the time the Ares is available. And so clearly you could do the Ares I. You could do the Ares I and the Ares V. You could close the gap by keeping the Shuttle flying, and you could keep the ISS in space. And the problem gets to be

you have to give up some things early on if you want to have benefits later on. And in our view, the real need of this country is a heavy-lift vehicle, Ares V type or something like that and that that should be the first priority. But to answer your question, Mr. Chairman, given additional funds such as we have identified, we believe the existing program would be a fine program.

Chairman GORDON. Well, that really wasn't the question.

Mr. AUGUSTINE. I am sorry.

Chairman GORDON. Once again, I think we all agree that there is no option that was presented that can be successful with the funds at the current level. So that is the premise. So then we get to, again, the fundamental question is, if we are going to trade in what we have been doing for something new, then I think that the new has to be substantially better. Would everybody agree with that? Is that a fair statement?

Mr. AUGUSTINE. I think we would.

FUTURE OPTIONS FOR NASA

Chairman GORDON. Okay. So are you prepared to say some of these other programs are substantially better than Constellation and worth making that change?

Mr. AUGUSTINE. Well, we have tried very hard not to end up being in a position where we make a recommendation as to a program, but we have pointed out, and we have done that out of fairness to the President and to you not to make it harder for you to make a decision here. So we have been asked to do it this way. But each of the options does have liabilities including the current program. All the others have them, too. Each has their benefits. We have cited those benefits and those liabilities, and it is really up to the decision-maker to make a judgment as to how to weigh those.

Chairman GORDON. You mentioned that there was more documentation on your discussion about Constellation. I assume this is available for us so that we can—more than was in your report?

Mr. AUGUSTINE. I probably should have mentioned that at the outset, Mr. Chairman. We are in the process—you have our summary so far.

Chairman GORDON. Right.

Mr. AUGUSTINE. And we are hard at work preparing the rest of the final report which will be over 100 pages long, and it is close to being written and it is our intent to have it out by the end of the month.

Chairman GORDON. Good. Thank you very much. Mr. Hall, you are recognized.

CLOSING THE SHUTTLE/ARES GAP

Mr. HALL. Mr. Chairman, I thank you. Mr. Augustine, your panel noted that the Constellation program had encountered technical difficulties, and you also noted that the problems were no worse than any other large program, that problems could be solved with time. And you also found the current program had been underfunded and that none of the options you looked at gave NASA

more capability or close the gap. What would it take to close the gap?

Mr. AUGUSTINE. In our view, we looked at a lot of different cases. Maybe I should define for those in the room who aren't familiar with what the gap is. The gap refers to, Mr. Hall, the time after the shut down of the Space Shuttle when the only way the U.S. will have of putting astronauts into orbit is relying on buying seats on Russian launch vehicles, basically. And we looked at various options to close that gap, and absent huge influxes of funds and the willingness to accept more safety risk than we believe is appropriate, there is only one way to close that gap and that is to continue to fly the Space Shuttle beyond the currently planned shut down at the end of 2010.

Mr. HALL. And that amount?

Mr. AUGUSTINE. The cost, sir?

Mr. HALL. Yes, sir.

Mr. AUGUSTINE. The cost of continuing to fly that Shuttle, if you were to do so, has a couple of factors that have to be entered. The first is that in our work we discovered that the Space Shuttle is currently bearing a huge amount of the overhead of NASA, and if the Space Shuttle is shut down, that overhead is going to shift to some other program, probably the Constellation. And so some of the savings numbers one has heard from shutting down the Shuttle are really accounting numbers. On the other hand, there are real savings that we wouldn't have to buy Russian launches if we kept flying the Shuttle. Our belief is that the net cost of continuing to fly the Shuttle a couple of times a year, once or twice, is about $2.5 billion a year. That is the cost issue. I just have to briefly say that there are also safety issues. There have been commissions that have said that we should not continue flying the Shuttle. It is our belief from what we were able to learn that if one were to recertify the Shuttle, very importantly, and it would have to be recertified, then probably it could continue to fly. But the launch rate would be so low that, based on my experience, launching rockets at a very low rate is like doing heart surgery at a very low rate. It is a dangerous thing to do.

Ed would you like to briefly?

Mr. CRAWLEY. No, I think that is substantially correct. We looked at a number of options of accelerating the Orion, Ares, of going to alternatives, putting emphasis on commercial launches to LEO for crew, and really none of them substantially closed the gap from above, as we say. It brought the human capability in earlier. The time to close the gap was with investments in 2008 and 2009 and 2010. Now, here we are on the verge of 2010 and really no expenditure will accelerate significantly a new U.S. capability much earlier than 2015, '16, '17.

## EVALUATING CREW SAFETY

Mr. HALL. Well, we have been told and it has been said that, quote "it couldn't be accomplished under the current budget". I guess what we really would like to know, under what type budget could it be accomplished and from a crew safety point of view since we are talking about that, your report seems to treat all the potential launch options the same, and I guess how did the panel evalu-

ate the crew safety aspect of any option other than the Constellation?

Mr. AUGUSTINE. Well, the safety issue was the number one issue for us to consider, obviously. Our committee had two astronauts that had flown six missions in space. So they were not uninterested in being sure that we all paid attention to the subject of safety. As I said earlier, we thought the right thing to do, the real goal, was to go to Mars, and we discarded that over safety issues. Each of the options we have offered we believe meets a threshold of safety, and I can define that if you want. But we are skeptical of comparing analytical safety calculations with proven safety calculations or reliability calculations and are related to but different from safety. We are skeptical because most of those calculations turn out to not even include factors that have led to most of the failures in the past.

So a great deal of judgment and scar tissue comes into deciding. You could look at the drawings, you could look at the redundancy, you could look at the processes, you could look at the escape capsules and so on, but in the end, a degree of experience and judgment is very helpful. Our committee of course has combined hundreds of years of launching humans into space, and we have tried to exercise that judgment.

Ed, I would ask you to briefly add anything you would like.

Mr. CRAWLEY. Mr. Hall, what we say in our report first is that safety is paramount and that NASA should not go forward with any technical plan that doesn't meet the stringent safety requirements far in excess of the Shuttle's demonstrated safety.

Mr. HALL. Don't you think the Chair makes a lot of sense that we look at safety with that attitude, and in light of the practice of the last year here on Capitol Hill, money is different. It used to be when a million dollars was a lot of money, and then a billion dollars was a lot of money, and now they throw away trillions of dollars and a bailout of $800 billion and immediately threw away about $350 billion to AIG for toxic stock that they ought to work something in to help us span that four-year gap in there and say this because I even consider it a national defense issue.

Mr. CRAWLEY. Unfortunately, our principal finding in this issue of closing the gap, going back to the gap, is that this is really paced by the pace of technical development, that to build a new rocket will take a new human-rated rocket from either where we are in the Ares V, or any fresh start of any type will take at least another five or six years. And I hate to say that, but on this specific point, you know, we examined several acceleration plans and found that they could increase the confidence that we could do it in five or six more years but none of them actually brought the date of likely availability by more than half-a-year or so.

Mr. HALL. Is it that physically it could not be done or it could not be financed?

Mr. CRAWLEY. No, it physically can't be done. There just are pacing items in the development of a new rocket.

Mr. HALL. I thank both of you very much.

Mr. AUGUSTINE. Thank you, Mr. Hall.

Chairman GORDON. And now, appropriately from the Kitty Hawk State, Mr. Miller.

Mr. MILLER. Thank you, Mr. Chairman. I'm glad that you do recognize that North Carolina is the home of flight, not Ohio as some claim from time to time.

Mr. Augustine, the report, the inquiry into the last Shuttle disaster concluded that one of the problems was an excessive reliance on contracting out, on contractual employees rather than those folks in-house, that there was a lack of a kind of critical mass of expertise that came when scientists and engineers worked in the same hall and could kind of hover at the doorway of each other's offices and talk it through. When they are scattered, you lost something. And despite that criticism, I actually asked Sean O'Keefe at a hearing if he embraced that finding because it did not seem consistent with the dogma of the Agency at that time. I didn't get a straight answer, which that really could have been true of any question I ever asked Sean O'Keefe. But since then, NASA has continued to rely upon outside contractors more than just about any other government agency. I think actually the findings are more than any other government agency, including where NASA has developed the technology and has the equipment and has the trained employees and still contracts it out. Parabolic flight, zero-gravity flight that is important in training developed by NASA, we have got the planes sitting on the tarmac, we have got the pilots who know how to fly the planes, who know how to fly parabolic flights to achieve zero gravity for training purposes, and yet we still contract it out, and it is not at all clear why we do that. It is very clear we would save money if we didn't.

### VIABILITY OF THE COMMERCIAL SECTOR TO SUPPORT NASA HUMAN SPACE FLIGHT

I was surprised that one of the findings in the summary report or suggestions is that by relying on the commercial sector, we might shorten the gap, we might close the gap some. What was the basis for thinking that the commercial sector would do it differently from the way NASA would do it if NASA just did it themselves?

Mr. AUGUSTINE. Well, let me deal with that first at sort of the philosophical level you raised, and Ed if you want to add, I will try to be brief to leave you time. I guess I would respectfully not accept that it is true in all cases that the government can do things more cheaply or better than could be done in the private sector. I spent 10 years in government myself. I know what the government can do. I have spent much of my career in the private sector. As I travel around the world, I think that there are many things that the private sector does much better than the government does. At the same time, I think there are many things that only the government can do, and where we get in trouble I believe is when the government tries to do things that the private sector does best or when the private sector does things that the government does best. In this regard, I think the government is best at advancing technology, taking major risks with technology at systems engineering, designing architecture, overseeing programs, assessing their progress at the top-level management of them. But when the government gets to where it is making engineering drawings as is in fact happening in NASA today in some cases, second stage of Ares I being an example, NASA is hiring subcontractors to make engi-

neering drawings which NASA will then take and give to Boeing to build in Boeing's factories, the material the drawings will be made for. In my experience, it is hard to take something from one of our factories to another, let alone from a subcontractor to NASA to Boeing. I think we should watch that very carefully.

So my answer to your question is there are important things that each can do, and it is a real mistake to assume carte blanche that everything should be done in industry or everything should be done in the government.

Mr. MILLER. And I assume the same thing, Mr. Augustine. What I am questioning is whether the bias is so clearly the other way in favor of having something done commercially that is something that traditionally NASA has done itself or had overall supervision of, I mean, we have always relied upon private contractors, but how did you envision the commercial crew transportation working?

Mr. AUGUSTINE. Okay. I will turn to Ed. Let me refer to the bias issue. I think you would find that it is our view that NASA would be better served rather than trucking hardware and people at the low Earth orbit to be pursuing energy exploration program. Let the private sector deliver the mail, if you will, much as the government put the airlines in the business by hauling mail. NASA has an opportunity and is doing this right now with the support of this committee to let the commercial industry grow in the space case. Do you want to speak to our particular case?

Mr. CRAWLEY. Sure. First, Mr. Miller, I want to make it clear in the options we presented, in all of them we continued the work on the Orion capsule that is the primary Crew Exploration Vehicle. We think that that should be continued. And the question really is, should that be also the way that we continue to get to low Earth orbit, to the Space Station, for example, until 2020 as we suggested might be extended.

What we tried to do is to create a second option available for the government to choose, should it choose to, which is to further invest in development in a robust domestic/commercial space industry, and one of the potential services that such a space industry could provide, not without risk, is the delivery of crew to orbit, and particularly to the Space Station in the next decade or so. The potential advantages of this would be that we would be able to build a simpler capsule to go to the Space Station, rather than the very sophisticated and capable Orion's capsule. For reference, in current year dollars, a Gemini capsule is $60 or $80 million. An Apollo capsule is several hundred million dollars, and the Orion recurring cost is about $600 million. So by building a system that is designed just to go to low Earth orbit, it is possible that the recurring cost of the system and the development cost of the system could be significantly less.

The other argument is that in a commercial system, there are other customers than NASA. NASA will be the only customer of the Orion and Ares. In a commercial system, the rocket could be used for NASA science payloads, national security space payloads, we have provided for other possible markets, and the capsule, less obviously there are other markets, but other governments will choose to fly astronauts to the International Space Station in the next decade. The possibility of proving that as a commercially pro-

vided service to other governments is also another potential market.

Chairman GORDON. Thank you, Dr. Crawley. And now the Ranking Member of our Aviation Subcommittee, Mr. Olson, is recognized.

### IMPORTANCE OF FUNDING HUMAN SPACE FLIGHT

Mr. OLSON. Thank you very much, Mr. Chairman. I greatly appreciate that. I would like to thank Mr. Augustine, you and Dr. Crawley, for all your hard work putting this report together. I remember, Mr. Augustine, we met with Mr. Hall back when you first got this assignment, and we asked you to call balls and strikes. I thank you. I think you did a very, very good job with that. I appreciate what all of you did because basically from my opinion, you threw cold water on our face and got us to look at this program realistically and say, if we want to go forward, we need to develop the resources.

And my question for you, Mr. Augustine, is you have been in this business a long time. This is a much more esoteric question, but what, in your opinion, is the importance of human space flight to the Nation because that is a question all of us in this room are going to have to answer soon if we don't find the resources to keep up and develop the manned space flight program as it is envisioned?

Mr. AUGUSTINE. Well, thank you for that question, and that is actually the question we began with. Too often in the past we have said, what destination do we want to go to rather than why do we want to go there, and it is a question in our view we probably have not answered correctly in the past. There are currently many important things the human space flight program permits. It permits the conduct of science, of exploration, inspiration, it has important economic benefits, it impacts education and motivates young people to study math and science and so on and so on. In our judgment, none of those by themselves can justify the cost of human space flight today, that spinoffs into the commercial world or science by itself per se from a human space flight standpoint don't justify these programs. The programs have to be justified we think to a large degree on a tangible basis which makes it no less important, namely to lay the path forward to humans to move into the Solar System. In so doing, who we establish our nation as a leader in an important and challenging area. And it gives our nation the sort of recognition that we get from the Apollo program which had many other benefits, including science and engineering and so forth. But the *raison d'être* I think could not be those other issues. It has to be the intangible of showing that America has the spirit and the ability to play a leadership role in one of the most challenging tasks ever undertaken.

### SHOULD THE COLUMBIA ACCIDENT INVESTIGATION BOARD FINDINGS APPLY TO ALL HUMAN SPACE FLIGHT?

Mr. OLSON. Thank you for that answer. I couldn't agree more. Shifting gears, we have talked a lot about safety, and I just want to ask, do you think the *Columbia* Accident Investigation Board

recommendations regarding safety should apply not just to the Shuttle but to all future human-rated systems?

Mr. CRAWLEY. Absolutely. I think the broad national consensus that emerged from the *Columbia* tragedy is that going to space is a dangerous business. We should do it very carefully and as safely as we possibly can, and that when we put our Americans at risk, we should do it in a way that really goes someplace and does something, really explores the solar system and goes away from the Earth. It is important to actually read carefully the recommendations of the CAIB report to make sure that one understands, for example, that they were very careful about pointing out that crews should not be required for the delivery of cargo. However, they did not actually say the reverse, that it was not allowed to have crew accompany cargo into space. So we actually read the CAIB report, Sally Ride, one of the members, was on the CAIB, and we tried to stay very truthful to the guidance it gave us.

Mr. OLSON. Thank you for that answer. One final question, what can we do to ensure that we don't have another Augustine Commission, 10, 15, 20 years down the road? I mean, we can't continue to second-guess or change course. I know that is a big, loaded question, but I would just like to get your perspectives on that. Thank you.

Mr. AUGUSTINE. I think, first of all, I am 74 years old, so the odds are——

Mr. OLSON. We would love to have you come back.

Mr. AUGUSTINE. Thank you, sir. My mother lived to be 105, so you might see me again.

Mr. OLSON. I will mark it down.

Mr. AUGUSTINE. I think that this committee, as the Chairman has said, had the answer to that question, and that is we need to have goals that are commensurate with the resources we are willing to devote, and obviously the two of us at this table and our colleagues are fans of the space program. But if we can't afford to do it right, then we shouldn't do it. We should back off. It is unfair to the astronauts, it is unfair to the nation, and it is unfair to the people who work at NASA. So we need to get a program that matches, whether it is a big program which most of us would like, or a smaller program, whatever it is, I think you can get to where you won't need to see me again if we could get that match made.

Chairman GORDON. Thank you, Mr. Augustine.

Mr. AUGUSTINE. Thank you.

Chairman GORDON. I hate to start with you, Pete. We are going to be a little more crisp with our time because I want to be sure everybody has a chance, so I don't mean to be discourteous if I have to get in. If Mr. Augustine rope-a-dopes you, you will get a little more time, but otherwise I am going to try to keep it to five.

Now, the Chairman of our Space Aviation and Aeronautics Committee, Ms. Giffords, is recognized.

Ms. GIFFORDS. Thank you, Chairman Gordon, Ranking Member Hall. Both of you have been at this a lot longer than I have, particularly Mr. Hall, so I appreciate your comments, and Mr. Augustine, thank you, Dr. Crawley as well.

It is not every day that we have a chance to discuss the future of America's human flight program, our space flight program. And

I take this day very seriously. I don't think there is any politician in the Congress, in Washington or across the country that doesn't point to America's success in our manned space flight program when we talk about the genius of our country, the innovation and our ability to tackle any challenge that is put ahead of us.

CONCERNS ABOUT COMMISSION'S FINDINGS

That being said, the discussion today in this committee doesn't track directly with what I was able to read in the summary report. I am frustrated by what I read. In fact, I am pretty angry. With all due respect to Mr. Augustine and this panel of experts, and I know you have worked very long and very hard on this and the cumulative expertise that was represented on this panel was strong, but I feel that we were going to receive some recommendations that were going to put us farther ahead than before we received the report, and I think that we have lost some ground. So I would like to review some of the facts.

Probably the most important finding with the review is a panel determination that there is a serious mismatch between the challenges put out in front of NASA and the resources that have been provided to this agency. And as our Chairman so eloquently stated, we all knew that. Those that have been in Congress for a long time see that year after year after year.

In other words, we know that we can't get to where we want to go with NASA's funding at the current level. The impact that that shortfall has has certainly undermined the work of NASA, the civil servants, and the contractors that have undertaken these really Herculean challenges. I am glad that you have highlighted this problem, but again, I am not denigrating the work that has been done. I know of your reputation, Mr. Augustine, and the reputation of the panelists. It is important I think for this country to have a sobering reminder that our position as the world's leading spacefaring nation is not a given, and we have to continually re-earn that reputation by prominent positions that we take through real actions.

The rest of the world, of course, has discovered space, too. We see countries that are moving with some impressive capabilities. The Chinese, of course, come to mind but other countries as well.

I think that the men and women of NASA frankly have demonstrated they are up to the challenge. Over the past four years they have moved from initial concepts into design and development of this Constellation program. They have successfully completed a number of important design reviews, have undertaken test activities including test-firing just last week, the five-segment booster that will power the Ares I rocket into space, and planning for a test flight of the Ares I–X rocket at the end of next month. And they have done all this even through the times with the budgetary sands that are shifting constantly underneath them, taking away resources that they thought they could count on, and forcing them to continually replan and rephase, even while they are trying to complete some of the hardest technological work ever done in the lifetime, programmatic work that is obviously required if Constellation is going to succeed.

So that is when it was announced, Mr. Augustine, that you would be leading this independent review of the human space flight program. I thought that we were going to take a hard, cold, sobering look at the Constellation program and tell us exactly what we needed to do here in Congress with our budget in order to maximize the chances of success. But that is not what I see. Instead of focusing on how to strengthen the exploration program in which we have invested so much time, four years, billions of dollars, we have a glancing attention to Constellation, even referring to it in the past tense in your summary report, and instead, spending the bulk of the time crafting alternative options that do little to illuminate the choices that I think are really confronting the Congress and the White House. So where does that leave us?

I think in place of a serious review of potential actions that could be taken to improve and strengthen the Constellation program, we have been given a set of alternatives that in some sense look almost like cartoons, lacking detailed costs, schedule, technical, safety, other programmatic specifics, that we can't be confident and can't be subjected to the rigorous and comprehensive analysis and validation that NASA is required to go over.

So I guess I ask my colleagues on this Committee, what are we going to do with this report? And I know we are going to see more details. But in the absence of mismanagement or technological showstoppers that the Chairman talked about, none of which the Augustine panel has indicated has occurred in this program, can any of us in good conscience recommend canceling exploration system development programs that Congress has funded and supported over the past four years? I know that I can't justify doing this, and I know this is going to be a discussion that Members on this committee are going to have to discuss.

So, Mr. Chairman, just a couple more minutes. I know I am up against my time. Hoping that maybe things will somehow work out someday if we try something new is not a substitute for the detailed planning and design and testing that has been the hallmark of successful space flight programs of the past. These are successes that all of us as Americans are extraordinarily proud of. Nor do we gain by confusing hypothetical commercial capabilities that might someday exist with what we can actually count on today to meet our nation's needs. We have made that mistake in the past, we don't want to make it again. So I don't see the logic of scrapping what the Nation has spent years and billions of dollars to develop. And for the Nation's sake, I hope that we can break this cycle of false starts that was mentioned by many of my colleagues before. The future of America's human space flight is really at risk, and I am hoping before the panel is dismantled that we can get some real, solid numbers, questions that were asked by some of my colleagues back to this Committee and to the Congress so that we can make decisions as to what to do with our future in manned space flight.

Mr. HALL. Will the gentlelady yield?

Ms. GIFFORDS. Absolutely, Mr. Hall.

Mr. HALL. Would you add to your statement, your great statement, how fair is it to our international partners that are never going to have anymore faith in us and how fair is it to those series

of engineers and the workforce at NASA that have worked generation after generation and bet their future on NASA that are going to be unemployed? And why is it that we have been scratching and clawing to get a little more R&D budget? And why the hell don't we have a march on Washington?

Chairman GORDON. Mr. Augustine, time is running over, but I think that Ms. Giffords has presented you with the threshold question here, so certainly we would like to hear from you.

Mr. AUGUSTINE. I would like to respond to that. First of all, I would remind you again what we were asked to do. We were asked to offer options to the current program, and we have done that. You suggested that the options we have suggested take a step backwards. Four of the six options are a clear step forward. You have spoken as if we have decided to stop the existing program. We have made no such recommendation. One of the options, Option 3 if you look at it, is to continue the existing program but to fund it adequately. So I respect your feelings, but I must question your facts.

Ms. GIFFORDS. Mr. Chairman, Mr. Augustine, I think what this committee would like to see is really the full range of options, you know, continuing to fly the Shuttle, the menu of options, fully funding Constellation, where is that going to take us, not that some day that the commercial space sector is going to step in and be able to create something that they have yet to be able to create. And you know, we can talk a little bit later and go over some of those options. I don't know. It is probably not the right time to be doing this, but I would really like to be able to and I think Committee Members would really like to be able to see with additional funding with Constellation, where does that take us? And I don't see that laid out in this.

Mr. AUGUSTINE. Fully funding the Shuttle is Option 4–B. Fully funding the Constellation program is Option 3. And so the data is there.

Chairman GORDON. Thank you, Mr. Augustine, and we will, as you say in a couple of weeks, we will have the full report. And I am sure that we will have some additional question at that time, and hopefully we will shed more light on some of Ms. Giffords' questions.

Mr. Rohrabacher is recognized.

Mr. ROHRABACHER. Yes, thank you very much. And let me congratulate Chairwoman Giffords for getting right to the point and hitting some very important elements that need to be discussed.

Chairman GORDON. I am glad you agree because she took some of your time.

## FINDING EXTRA $3 BILLION FOR NASA

Mr. ROHRABACHER. Might I remind Mr. Augustine, heart surgery is expensive, and they now have found other ways to do things rather than open-heart surgery. They have endoscopic surgery which is much cheaper and quite frankly, sometimes some people say better than the old, more expensive approach. What we were expecting from your report was something that might be cheaper or more cost-effective, and we didn't get it. And from what I am gleaning from what is being said and what I have been presented

that everyone agrees that there is a $3 billion shortfall in what we need to accomplish our goals. Of what you have suggested as alternatives, other options, are any of those accomplishable without that shortfall?

Mr. AUGUSTINE. You want to deal with that?

Mr. CRAWLEY. No.

Mr. ROHRABACHER. Okay. There you go. So Ms. Giffords' observations that you are just saying this off the top of your heads, not to say that you don't have years of experience behind you as compared to years of action and research on this very issue, you're presenting us something that doesn't have anywhere near the depth of what NASA has already put into this analysis, isn't that correct?

Mr. AUGUSTINE. Well, sir, I think if your point is, is there as much analysis on a future program as on a program in being, the answer is always no.

Mr. ROHRABACHER. Well, I would just suggest this. If you guys didn't come up with a new idea that in and of itself appears to be heading toward a solution which is not that we aren't—Constellation is a perfectly good program. It is just that we are $3 billion short. Now, you didn't come up with anything—all of us know, where are we going to come up with the money? That is really the question here. Are we going to borrow it from China simply by increasing the level of federal expenditures, borrow it from China and pay it back with interest? I, for example, think that it might be—we are throwing money around here in Washington by the hundreds of billions of dollars. Maybe we should take the $150 billion that we gave to AIG and consider that to be income and tax it at a 35 percent tax bracket. That would give us plenty of money, plenty of those $3 billion a year that we need. Yeah, we have been throwing a lot of money around in this city, but we are short-changing our space program. That is what it is all about. And I was hoping, frankly, that we would be getting more creative alternatives from you folks rather than just alternatives that would leave us in this same situation, $3 billion short of being able to accomplish it.

Mr. AUGUSTINE. We think we have given creative alternatives, and I will ask——

Mr. ROHRABACHER. But not to solve the basic problem, which is we are short $3 billion.

Mr. AUGUSTINE. Sir, the problem is to put it very simply, that with 60 percent more money, you can't go 60 percent of the way to Mars and declare victory. It takes a certain amount of money. This comes in chunks, and the chunks are large and unfortunately we are in a situation where absent going to technology that we think would be very unsafe at this point in history, there are no good programs in exploration for this amount of money.

Mr. ROHRABACHER. We have made mistakes in the past, long before a lot of these people were here. I remember advocating a single-stage orbiter which could have gone into two-stage orbit which we believe could have dramatically brought down the cost. We put our money in what, the X–33 and I am sure you are very aware of what happened to the X–33 program. And we ended up, it turned up a total waste of dollars as compared to—we had an option then, the DC–X which was there and according to what you

have already told us today, it is much better to have something where you have something solid rather than just something on a view screen. And we made that incredible, historic mistake back in 1996, I believe it was. Well, we were hoping maybe in this round that you might come up with some other alternatives that would give us some creative approaches.

Mr. CRAWLEY. What we actually uncovered was what we called in the Committee the fundamental NASA conundrum, that it doesn't have enough money to operate its space systems and build a new one.

Mr. ROHRABACHER. Well, but then you had to come up with other options that still don't have enough money for your options. So really, the basic problem is we don't have the money, and you are using that also to come up with your own suggestion by casting dispersions on the hard work that NASA did already on the Constellation program. I find Ms. Giffords' criticism to be totally justified.

Mr. AUGUSTINE. I would respectfully say that I believe that this committee does not cast dispersions on NASA in any way. We offered alternatives. That is what we were asked to do. Each has pros and cons.

Chairman GORDON. Ms. Fudge is recognized.

IMPLICATIONS OF CANCELING ARES I

Ms. FUDGE. Thank you, Mr. Chairman. Thank you both. I have a two-part question. The first one is because I am new at this I want to be sure I am clear.

As I look at your report, are you actually recommending that NASA—or proposing that NASA consider canceling the Ares I Project, which in—from my understanding is significantly safer than the Space Shuttle and replace it with something else? Help me understand that part first.

Mr. AUGUSTINE. Yeah. We have offered a number of options, some of which did not include Ares I, some of which do include Ares I, and with regard to the safety issue, Ares I has had enormous emphasis placed on safety. There is good reason to believe it will be a very safe vehicle.

But, again, this time we are in the reverse position. We know the Shuttle's safety record. We still don't know Ares I.

Ms. FUDGE. So again, are you recommending that we stop with Ares I?

Mr. AUGUSTINE. At least one of our options recommends or contains that.

CONSEQUENCES OF NOT INCREASING NASA'S BUDGET

Ms. FUDGE. Okay. Then let me just ask the second part of my question. If, in fact, and we have all talked about the lack of—or that we don't have enough money to fund the programs we have. Let us just for sake of discussion say that we don't get the $3 billion or get the increase that we have been talking about we need. Tell me in your opinion what, in fact, will happen to NASA, just NASA overall, the various centers, the contractors, the workforce, and this country if we don't fund it at a different level? What—tell me what you see happening.

Mr. AUGUSTINE. Well, that is a very good question. If we don't get additional funding, one option is to continue doing what we are now doing, continue the present program until frankly it falls off the cliff eventually for lack of money, and by that I mean we will build Ares I, we may build Ares V, but we won't have a Lunar Lander and so on or the equipment we need on the Moon or Mars or wherever we end up.

NASA as a whole will continue, I would think, with a very strong robotic program, science program, unmanned. The Human Space Flight Program will basically be confined to the lower orbital Space Station as long as that stays up, and it could have a very strong technology program to lay the groundwork for future human flight into space, things like fuel transfer in orbit, a better understanding of long-duration effects on humans in orbit. But it will be a program I think that would inspire very few people and impact on NASA's workforce would be very large.

Ms. FUDGE. All right. Let me just conclude with this, Mr. Chairman, is that I find, too, that that is unfortunate because I do support very strongly NASA's mission and various U.S. space flight programs. So I thank you, Mr. Chairman.

Chairman GORDON. Thank you, Ms. Fudge.

Ms. FUDGE. I yield back.

Chairman GORDON. Dr. Ehlers is recognized.

## ISS AND MARS

Mr. EHLERS. Thank you, Mr. Chairman. I am not from Texas or California or Florida, and I am not married to an astronaut, so I will try to be as objective as I can.

First of all, Mr. Augustine, I just want to thank you for the work you have done. I am afraid some of my colleagues have given you a rough time which you don't deserve, and I think you have done good work here. The program is not yours or not caused by your work or your committee's work. The problem is caused by the United States Congress, which is not willing to appropriate enough money to fulfill the dreams that we continually talk about having. And I think you have done the government's work under very difficult circumstances.

I was pleased to hear your comment about taking Mars off the table. I have been sitting here for a long time over the years wondering why are we even talking about going to Mars. It is such an incredible expense, particularly if we wish to send someone there and bring them back. It would bleed our entire space program dry of money and remove all other possibilities if we decide we are going to Mars fairly soon. I think we have to look very hard at other types of propulsion which would get us there and possibly bring someone back or resign ourselves to that whoever we send there is going to stay there. And our job from then on is to just send supplies there so that they can survive.

I fail to understand why we should go to the Moon again. We have been there. We know a good deal about its structure. It just seems to be a very expensive venture. Again, is that really, you know, people seem to think that we are going to the Moon to have a launching pad to go to Mars. I don't see that that is particularly feasible either.

Another question is what role should the Space Station play. I mean, it is—I don't think it is a white elephant as some do, but it is not at all clear that its scientific mission is worth the money we are putting into it compared to the other things NASA could do with those funds.

My special concern is what about multi-nation effort. When I first came to the Congress at the request of Speaker Gingrich, I spent two years—almost two years writing a science policy paper, which has guided our efforts to a certain extent. But I pointed out in there that many of the big efforts in science and technology are—have become so expensive that they of necessity are going to have to be multi-nation efforts. We are following that track. We killed the Super-Conducting Super Collider, and instead we combined with CERN on the Large Hadron Collider. We have also taken other steps, for example, in the Space Station we have involved other nations, and we are only happy to take their money and their astronauts. The ITER Reactor has been revised by Japan and France, and we are now joining them in trying to keep that going. We just didn't have the money or weren't willing to allocate the money to develop the ITER.

And so we are following that path in other areas, and I think NASA should be following that same path. I think the era of bragging rights by virtue of being first to do something, I think that era is no longer with us, and I think if we want to go to the Moon, I would like to see it become a multi-nation effort, where we get a lot of contributions from other countries, and they can provide some of the people who would go there as well.

Mars is going to take a lot more work and a lot more money than anyone seems to realize or at least say out loud, but until we get other sources of funds or the Congress is willing to really pay what it is going to cost, I don't see us making the steps that everyone has expressed here, that we would like to take. And I don't think we should berate you for what you are saying when we, in fact, are the major part of the problem because we are simply not allocating the funds that will allow us to do what everyone says we want to do.

I would appreciate your reactions to those comments.

Mr. AUGUSTINE. Well, thank you, Mr. Elhers. A couple of observations.

You raised a point about the International Space Station. We have not talked about that much. I would like to address that briefly and then ask Professor Crawley to talk about the flexible path option that has—is of interest, I think.

With regard to the International Space Station, we did—I think we share your views down the line, particularly with regard to the importance of international programs. The early space, Human Space Flight Program was one of competition. Today it is one of partnership, and one of the options that we have offered and that I think we fairly seriously believe in is that we should extend the ISS for another five years. We say that because we think there is a great deal of important technology to be gained. We believe that if we invested some money in science as opposed to just operations and building the station, which incidentally we could now do, that we would also get science benefits.

The—but the bottom line on the International Space Station from our standpoint is that for us to withdraw from that according to the current plan would totally undermine our position in the international space community and undermine really the overall effort to carry out space activities.

Let me ask Professor Crawley to address——

Chairman GORDON. Quickly if you have something to add.

Mr. CRAWLEY. Yes. Norm has just asked me to sort of fill in one bit of detail. In the area of destinations for exploration we were careful to point out that Mars is not the place we should go to but the place we should go towards as a long-term goal, and that in order to get there there are really two paths we have to follow. We have to learn how to work on a planetary surface as we would at the Moon, and we have to learn to work in free space and to spend longer and longer moving away from the Earth, exploring the near-Earth objects passing by Mars and so forth.

And, in fact, if we spent a decade going to the Moon and then came back to you and said, well, should we now go on a 900-day mission, never having been more than three and a half days away from the Earth, it is unlikely that we would take that step. So we have—in terms of destinations we provided this option of the so-called flexible path of going progressively beyond the Earth's sphere of influence, up to and including into Martian orbit, alongside the option of going back to the Moon and that we should really create a program and an architecture for it that allows us to do both of these things in the future.

Chairman GORDON. Thank you. Dr. Ehlers, Mr. Hall wanted me to let you know he does not hold it against you that you were not born in Texas, just against your parents.

And Dr. Griffith from——

Ms. GIFFORDS. And Mr. Chairman——

Chairman GORDON.—Huntsville, Alabama, is recognized.

Ms. GIFFORDS. Mr. Chairman, and let me just add that my husband is taken.

Mr. EHLERS. I am also not interested.

Chairman GORDON. Okay. Dr. Griffith.

## COMMENTS ON COMMISSION'S FINDINGS

Mr. GRIFFITH. Mr. Chairman, Ranking Member Hall, and Committee Members, thank you. I am actually the District 5 in Alabama Marshall Space Flight.

I actually read this report, and I am hearing that we are disappointed that the Committee did not reach a conclusion for us. It sounds like the uncertainty that we were left with has bothered us, and maybe we are expressing that in a way that is coming out in a difficult manner.

It sounds to me as though we have made a decision. It sounds to me as though we are—we are a country can look in our checkbooks and see what we believe in, and the commission is pointing out to us that right now we are not believing in manned space flight. They are saying to us that unless we are adequately funded, we can't do this on the cheap, pull back, it is not fair to our scientists, our young men and women who are interested in science. It is not fair to the country. It can't be done on the cheap. It is

clear that it can't be done. If we had the $3 billion and we started over again, we are five years behind.

It seems to me that the Committee report was very, very lucid. It basically said we started this whole thing because of safety, the Ares I, the Ares V, our heavy-load vehicle was essential. The Orion is to be kept, the Lunar Lander might be modified, but it certainly doesn't need much, and that what we need as a people, as an American people is that are we willing to accept the challenge from China, India, Russia, and others.

And so we can do this. The technical difficulties are surmountable. We are on the road to success unless we decide we don't want to open our checkbooks and fund it. And so the point was made by Ranking Member Hall that if we can spend or we can afford a $787 billion Stimulus Package but we can't afford $3 billion to meet the challenge of China and respectfully I disagree that we will not always be in a partnership with China, Russia, or India. And I respectfully would submit that this is, in fact, national security, that the future of space is in its infancy, and so those who take the challenge, and it is amazing to me that we are sitting here in this room talking to some major scientists about we cannot afford to meet the challenge after what we have done over the last seven months.

So I think the report is clear. I think we have got enough information here to draw the conclusion, and as a cancer specialist I have had to make decisions based on incomplete information all my life, and we will never have the complete information to draw the certain conclusion that allows us to sleep well every night. We must take the chance. We are on the way. Ares I is on the way, Orion is on the way. We know that the heavy-load vehicle, Ares V, is not an option for America. It is an essential for America.

And so I appreciate very much the commission's report, and I think it gave us options and the decision is will America step up as it did in the '50s, or do we want to lay back and watch China from our living rooms, their equivalent of Walter Cronkite, talk to us about how they landed on the Moon.

So I appreciate very much you being here and thank you.

Chairman GORDON. Thank you, Dr. Griffin—Griffith, and Mr. McCaul is recognized.

Mr. MCCAUL. Thank you, Mr. Chairman. I agree with the comments made just now. We do have a challenge, and I think this commission has thrown the challenge right at Congress, and it is a funding challenge, and we have been saddling our children with tremendous debt over the past year, and in my view not investing enough in their future: innovation, technology, science, national security.

One thing the Committee—point the Committee asserted I think is a very bold assertion that no plan compatible with the FY 2010, budget permits human exploration to continue in any meaningful way, and that was really at the outset. I think that is a challenge the Committee has thrown at the Congress.

### DETERMINING THE $3 BILLION INCREASE

My question is when you get to the $3 billion assessment, how did the Committee arrive at that level of funding, and would NASA

be able to support and sustain a credible Human Space Flight Program, including the Constellation Program at that level of funding?

Mr. AUGUSTINE. We——

Chairman GORDON. If I could add, also, that is not—that is $3 billion over a period of time. You might want to also——

Mr. MCCAUL. 2010. Yeah.

Chairman GORDON.—you might want to clarify that, too.

Mr. MCCAUL. Yes.

Mr. AUGUSTINE. I used $3 billion shorthand. We looked at a number of alternative profiles of building up budgets, and I should say that our original instructions in our charter was to abide with the current budget, period, and we went back and got latitude. We couldn't do our job without looking at alternative excursions. We looked at various families. The one that made the most sense to be rather specific was to increase through 2014, literally up to an additional $3 billion per year and beyond that 2.4 percent, which we believe is a more realistic estimate of inflation, out through 2020, and beyond.

The—we do think NASA could conduct a sensible program with that amount of money. We also think that it is very important that the human space flight part of that program be separated from the Science Program, because the Human Space Flight Program being so large and having so many risks, when problems occur, it tends to eat up the Science Program, and that would not be constructive in our view.

So an additional $3 billion is about 15 percent increase overall for NASA, and we think that—I think both Dr. Griffith and yourself have said it extremely well, and that is this is a budget question, and we are trying to lay it out openly that we are on a path that is going nowhere.

Mr. MCCAUL. And what we want to know as the authorizing committee, and I think the gentlelady from Arizona put it very well also, is what—is this $3 billion figure the amount recommended by this commission to fully fund the Space Flight Program, including—would that also include the Constellation Program?

Mr. AUGUSTINE. It would—one option is to do the Constellation Program, and the answer is yes, it could do that. In our view.

## RISK OF COMMERCIAL VENTURES

Mr. MCCAUL. Okay. I think that is very helpful.

Also, you mentioned the commercial crew services could provide an earlier capability at a lower initial and life cycle cost than the government could achieve, but recognizing the maturity of the design and detail in the Ares and Orion systems already, the amount of infrastructure, capital investment that has been put in these programs—doesn't it seem kind of a stretch to assert that a credible commercial option at this point in time would achieve lower costs and reduce schedule in time?

Mr. AUGUSTINE. Let me ask my colleague to address that.

Mr. CRAWLEY. Well, I think our best assessment, sir, is that it would be comparable in the schedule and at lower costs but not without risk to the government, and one of the obvious risks to the government it would have is the fact that it would be a commercial

venture, and commercial ventures don't always deliver, not necessarily for technical reasons but for business reasons.

So one of the other findings in the report is that even if we pursue a commercial crew path, that the government should always reserve a capability to deliver a crew to orbit as well, and there are various ways of doing that by building different families of rockets, but we thought it would be irresponsible of us to propose that we solely base the future of low Earth orbit access for crew on a commercial venture.

Mr. MCCAUL. My time is about ready to expire. Just in conclusion, Mr. Chairman, I hope we take a look at this commission's report and the amount that is recommended in terms of authorization dollars to fully fund the Space Flight Program. I think that is one of the strongest recommendations we have out of this. Thank you.

Chairman GORDON. Mr. McCaul, I will assure you, this discussion will continue over—as we go through our authorization.

Ms. Edwards is recognized.

## NASA SKILLS AND R&D

Ms. EDWARDS. Thank you, Mr. Chairman, and thank you to our witnesses today.

First let me just say that I share in our Subcommittee Chairwoman's comments that I expected something different all summer, and I haven't been on this committee long but just been waiting almost with bated breath for the report so that we could move forward, and I feel like we are now in this kind of nowhere land. And although I don't really have an interest in necessarily being the first to do something, I do think it is important that we are concerned that the something that we do is significant, that we have outlined a purpose, and then we say what is the budget that it takes to get us there. And I feel like we were working—the Committee in some ways was working backwards. Here is the money, and this is what we can do with it instead of setting—saying, here is the vision, and this is what we want to achieve.

And it isn't a destination. It is not a place. It is kind of bigger than that. You know, is it—what are the research and technology and scientific goals, and if it is the Moon first and then Mars that gets us to that goal, that is a really different set of questions than just saying we want to go to the Moon, and we want to go to Mars and setting forth a destination.

I really do worry that although you may believe that, you know, that what you have outlined here or a set of options, every single headline that I have read over the last couple of weeks, you know, basically is saying we are going to ditch the Human Space Flight Program, and so that is the message that has gone out to a public that is already invested in the direction that we are heading now with Constellation. That is the message that goes out in a very tough economic environment. It is the message that goes out to our scientists and researchers, the civilians at NASA and our contracting community.

And I think it is really hard now, in fact, to regroup and to recoup some of the positive moving direction that many of us felt when the President, upon his inauguration, actually spoke posi-

tively about the need to invest in this kind of scientific research and technology and to carry out, you know, a vision, even a boiler plate one that was laid out by President Bush and setting another vision, and there is this degree of uncertainty now.

Now, I know that as a Congress and as an authorizing committee we are going to have to come back and really digest this to figure out how to move forward, but just as I close, Mr. Augustine, I wonder if you could comment to us your assessment about the sustainability of the workforce and the skills to carry out human space flight given the options that you laid out. And whether the Committee really looked at the implications for the workforce in terms of being able to sustain it, both our civilian capacity within NASA but also in our outside contracting community that might say, wow. They don't really know what they want to do with this program. Let us figure out some other business models.

And I wonder as well if you could comment about the research and scientific and technical capacity with each of the options and how, you know, one or two of them, if we pursue those directions, might maintain those over the course of the next several years as we get some of these systems back on line.

Mr. HALL. The gentlelady yield?

Ms. EDWARDS. Yes.

Mr. HALL. You know——

Ms. EDWARDS. Of course, Mr. Hall.

Mr. HALL.—I sure agree with what you are saying. I just, you know, I don't think it hurts to have one old geezer in the United States Congress who remembers, and you don't remember because you were probably in grade school at the time the United States of America bypassed its chance to be the technological leader in the entire world when we turned down a $500 million investment in the Super Collider. And as I look back on that that day, that $500 million, if I can—I am not much on math, Mr. Chairman, there is three things I couldn't do in math, that is add and subtract, so I am not sure about—but isn't 500 million a half of one billion, and we need $3 billion for several years here.

If we just—if we can't say that and get more of the R&D percentage, we are letting this Congress down, and when we point our finger at this commission here, at anybody else and don't know that there is three fingers pointing back at the United States Congress, we are the ones that haven't appropriated that money. We are the ones that haven't stepped forward to fund the Space Station the way we should have funded it, and our children are the losers.

Now, we ought to take that on, and I am not joking about a march on Washington, and it would be handled mostly by high school and college youngsters, because they are the ones that really know what they are losing.

I yield back my time.

Chairman GORDON. Mr. Augustine.

Mr. AUGUSTINE. Yes. I will try to be very brief. You raised a number of good points that we should address, Ms. Edwards.

The—with regard to the skills question, we viewed that in two contexts. One is the overall workforce and then just a basic employment issue. We also addressed it from the standpoint of unique skills that the Nation needs to maintain if it wants to be in the

Human Space Flight Program. Each option has a different impact in those areas just as it does in most other areas. Some options have relatively little impact. Some have very large impact. For example, continuing the Space Shuttle has the least impact in that area. Other options not so.

The—with regard to the research and science community issue, I have testified before this committee before, so I won't repeat other than to say that in my view that is one of the most important issues that we are dealing with here is how to preserve that capability in this country.

And finally, I would just note that, again, we have been asked to offer alternatives. We have offered only one conclusion, and the only conclusion we have made is that the current program doesn't have enough money to be completed. Beyond that we have offered choices for you and for the Administration to make decisions. So you have got the tough job.

Chairman GORDON. But all of those also need more money. Is that correct?

Mr. AUGUSTINE. All the viable ones do. Yes.

Chairman GORDON. Okay. Thank you, Ms. Edwards, and Ms. Kosmas.

WORKFORCE SUSTAINABILITY

Ms. KOSMAS. Thank you, Mr. Chairman, and thank you, Mr. Augustine, for being here and Dr. Crawley. I appreciate your hard work as well. Many of the sentiments you have heard today are echoed by me, and I also appreciate the opportunity of having chatted with you prior to the appointment of the Committee in the conference call where we discussed what you would be looking at over that time period and your acceptance of my comments since I wasn't able to be there when you were at Cocoa Beach near the Kennedy Space Center.

I have sort of a practical question. I am like everyone else, bemoaning the fact, quite frankly, that we didn't fund over the years the program that we have been assigned to do and that NASA was either unable to or unwilling to get the funding necessary to move forward with the parallel programs that made up the most current vision for manned space exploration.

But I wanted to ask something fairly specific. My colleague alluded to it, but I am not sure that we actually got a specific answer in light of the way it unfolded. But I wanted to suggest that the original criteria that you identified, was part of your review, was going to include an assessment of workforce, and a summary of your review included no specific reference to workforce issues.

So as you probably know, I serve as the representative for the Kennedy Space Center, and I am very concerned about the need to preserve the highly-skilled workforce that we have there. I think this has an immense impact, not only on our local economy but also across the Nation as many other communities are affected by the Space Program. And I personally believe that it is essential that we maintain a professional and viable workforce in order that we can ensure the leadership of this nation and our innovation and competitiveness, which I think is also critical to national security as we move forward in space exploration.

So if you can suggest to me why—originally it was, as I say, one of the criteria that you suggested you were going to address, but the summary does not speak to the workforce. So can you discuss how the sustainability of the workforce and the expertise needed to pursue your human space flight options differs under the options that are proposed. And also of the options that you have forwarded to the Administration, which one in your opinion offers the best protection for the human space flight workforce and the industrial base that we currently have?

Mr. AUGUSTINE. Ed, would you like to address that?

Mr. CRAWLEY. Yes. Thank you for the question. Let me explain that in the final report there will actually be an evaluation of these options against 12 parameters which were just briefly mentioned: science, the contributions to technology, the preparation for exploration, the potential to involve internationals, the stimulation of the commercial community, the public engagement, the degree to which it engages the American people, the cost, the safety, the schedule, and the workforce——

Ms. KOSMAS. Uh-huh.

Mr. CRAWLEY.—so that in—without going into all of that detail in the summary report, it will be forthcoming. Now, specifically on the question of workforce, what we did is we looked at what the key skills that are needed for our future in space and how the options would preserve them or not—or allow them to atrophy. And there—the problem is that the options, the difference of the options tend to do different things. So, for example, the ones that continue to use the solid rocket boosters like Ares I and Ares V, preserve that aspect of our national capability and workforce skills. Some of the other options tend to preserve other aspects of the workforce skills.

The one piece that does come through, however, is the options that have some variance or another that preserve, that extend the Shuttle or Shuttle Heritage Systems, do tend to preserve the workforce capabilities preferentially.

SPACE SHUTTLE RECERTIFICATION

Ms. KOSMAS. Okay. I appreciate that. It doesn't seem to be one of the ones that you have highlighted, however, as—I know you tried to come with a balanced approached of these are the options and not really to suggest necessarily which one would be your first choice, but I didn't notice in the recommendation or in the review that you had made any specific comments with regard to recertification of the Shuttle Program or extension of the Shuttle Program, which as you say, would preserve the workforce to the best, to the maximum amount possible.

So did you investigate the option of recertifying the Shuttle Program for a complete recertification?

Mr. AUGUSTINE. We did look at that. That is option 4B, and the recertification that we pointed to is the one that followed the recommendations of the *Challenger* failure analysis.

Mr. CRAWLEY. The CAIB.

Mr. AUGUSTINE. The CAIB and that option is present, and it is, as my colleague says, is the one that is probably the least disrup-

tive to the ongoing workforce. And it is also the only option that closes the gap.

Chairman GORDON. Thank you, Mr. Augustine. Ms. Johnson is recognized.

Ms. KOSMAS. Thank you.

Ms. JOHNSON. Thank you very much, Mr. Chairman.

POSSIBILITIES WITHOUT $3B INCREASE

Mr. Augustine, let me thank you for the report and also thank you for agreeing to be a part of my science and tech brain trust next week. You did not make a specific recommendation, because that depends on a lot of things, the money, but of course, I have read somewhere that we had exhausted much of the research possibilities in the Space Station. I don't know how true that is, but I do know that the space exploration has given us more results than any other type of research that we can use.

What is possible without that injection of money? What do we have in the budget? Have we put something together for NASA already? Okay.

Not being—I am certain that we don't have it but we still might do it, but without the $3 billion and say 1, what would be possible to do to continue the program?

Mr. AUGUSTINE. The—we looked at an option at 1-1/2 billion add-on, and the—it does not permit you to conduct an active exploration program. It does permit you to continue the International Space Station out through 2020, it permits you to add some additional funds so that you can make more use of the Space Station while it is there. One of the problems so far is that the money has gone to constructing the Space Station and maintaining it and not to using it. We now have an opportunity to use it.

With that amount of money you also have the opportunity to rebuild the technology program at NASA, which has atrophied a great deal over the years. And so you could have a very strong science and technology program, you could continue the International Space Station, but there would be no exploration. We would still be trapped 368 miles above the Earth.

INSPIRING STUDENTS WITH NASA'S CURRENT BUDGET

Ms. JOHNSON. We would be able to continue to involve students now, that is, having a great effect as to their directions for the future?

Mr. AUGUSTINE. I think clearly that is one of the things we would like to see done.

Ms. JOHNSON. Are we—well, I know that high school students especially are involved in a lot of the space exploration activity. What about future staff? Would you have to lay off people and they go someplace else and get grounded, and what would that do for encouraging young people to continue in science and engineering?

Mr. AUGUSTINE. With the current program I guess it would probably require some layoffs, but if we kept spending the same amount of money we are now spending, we might need different kinds of people but presumably you could have more or less a comparable workforce. The—one of the challenges that NASA has

today is that the—so much of their cost is fixed. Their overhead is fixed, and there is very little latitude to make these trades. A major layoff at NASA would be a very great de-motivation to young people considering going into the Space Program. I think it would be a very unfortunate thing.

At the same time I think it is our view that NASA really does need to address its overhead, is its overhead too large so that it doesn't have the latitude to do some of these exciting things. I would—I lived through the restructuring of the aerospace industry at the end of the Cold War when our industry lost 680,000 employees, dedicated people who made great contributions, but the industry had to do that in order to survive. And NASA may have to do some restructuring of its workforce to survive.

Ms. JOHNSON. You know, the Johnson Space Station is extremely important to the State of Texas, and I just imagine wherever we have portions of it, it is just as important to them. If we have to make a reduction, do you have a recommendation as to how we do that, what levels of activity and——

Mr. CRAWLEY. We don't actually—no is the simple answer. That was a layer of detail that we didn't get into.

Ms. JOHNSON. Uh-huh.

Mr. CRAWLEY. But we do have a finding in the report which I think we would all strongly support on the Committee is that NASA really needs to be given some latitude to do its job. It needs to be able to allocate the resources and assign the tasks and develop the capabilities to prepare itself for going forward, and I think there is an important role in the Congress in working with the Administration and with the new Administrator of NASA to realign the agency such that its skills and knowledge base are aligned with its goals.

Chairman GORDON. Thank you, Ms. Johnson, and Mr. Grayson is recognized.

## SERVING PRESIDENT KENNEDY'S VISION FOR THE SPACE PROGRAM

Mr. GRAYSON. Thank you, Mr. Chairman.

On September 12, 1962, President Kennedy said words that I think we are all familiar with, but I am going to repeat them. He said, "We choose to go to the Moon. We choose to go to the Moon in this decade and do the other things not because they are easy but because they are hard. Because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept."

Let us assume that President Kennedy was right about the purpose of the Space Program. He was right to say that the purpose of it is to organize and measure the best of our energies and skills so that we push the envelope, we find out what human beings are capable of, and in doing so we learn more about the universe, about science, and about ourselves. If that is correct, which of these five options best serves that purpose?

Mr. AUGUSTINE. I believe I would say that any of the last three options, three, four, or five, would satisfy that purpose. Each would have somewhat different costs, somewhat different risks, somewhat different objections.

One option that we have raised that has generally not been raised in the past and that I don't want to endorse but I point out only because it is different, is the last option called the flexible path option, and Ed, I would ask you to describe it. I think it would be of interest to the Committee.

Mr. CRAWLEY. I think I would agree with Norm. One of the things we struggled with, frankly, was the perception on the part of the American people, and we ran a very open process in this committee. We allowed postings, e-mail communication, we twittered and so forth. Difficulty as one of the Members mentioned of explaining why it is that we are going back to the Moon and the options which structurally aren't very different, you wouldn't build very different boosters, you wouldn't build very different capsules, but frame the program in the sense that we are exploring space, that we are going ultimately to Mars, that we are going to follow a flexible path and learn how to work in space to go beyond the sphere of influence of the Earth, to visit the asteroids that might cross our paths and someday damage our planet, to go and do a fly-by of Mars while also some time in the '20s setting foot again on the Moon.

It created a context and a message that would really inspire people, I think Americans, to do the hard things as the famous Rice University speech you quoted inspires us to think about.

Mr. GRAYSON. All right. Tell me more. Tell me more specifically about why you think that the last three options and particularly Option 5 would do so much to measure the best of our energies and skills, teach us more about ourselves and about the Universe.

Mr. CRAWLEY. Well, we go into space for many reasons. One is to understand our place in the Universe, the common people, the American people to understand our place, and we think that if we go progressively deeper into space, visiting on every opportunity new places, circling the Moon once just to show our friends and competitors that we can do it, going and visiting places on the beginning of the super highway through the inner Solar System, going and visiting the asteroids, doing swing-bys of Mars, demonstrating that we can go deep into space and repair scientific observatories, much as the Hubble Space Telescope repair missions did in low Earth orbit, that these things will create both the image and the reality that our Space Program is doing new, challenging, hard things.

Now, the reality is going to the surface of the Moon is also hard, and we will find out how hard it was when we try to do it in 40 or 50 years, and we will frankly find out how lucky we were in going six times to the surface of the Moon and returning the astronauts safely as the President, President Kennedy also said.

So it is—the challenge is more apparent. The scientific return is more real when or if we will visit places we have not been, we will work with robotic spacecraft in a new way by circling planets and sending down probes and interacting with them.

So we really think that we did create some part of a new vision for the program in what we call option five, the flexible path at about the same expenditure and with about the same equipment that you would use in the other ones.

Mr. GRAYSON. Mr. Augustine, do you want to add anything to that?

Mr. AUGUSTINE. No. I think he has covered it very well. Thank you.

Mr. GRAYSON. Thank you, too. By the way, in the same speech the President asked why does Rice play Texas, and I was wondering if the Ranking Member could address that.

Chairman GORDON. Dr. Baird is recognized, Baird is recognized.

HAS NASA EVER BEEN FULLY FUNDED?

Mr. BAIRD. Thank the Chairman. I thank our witnesses for your outstanding work. I think you have performed a real service to the country as you have done before, Dr. Augustine, with the——

Mr. AUGUSTINE. Thank you.

Mr. BAIRD.—Above the Gathering Storm report. I need, I think, to take just a second to observe that one of my colleagues said a moment earlier, we have been doing a lot of deficit spending over the last year. My recollection was that the deficit was near zero. In fact, there was a surplus when President Clinton left office and that the national debt doubled and the foreign borrowing of this country doubled during the Administration of President Bush. So just—I think records matter.

And I just have to say I am a passionate supporter of human space flight, but I think we have to pay for it, and I find it rather interesting that so many of my colleagues on the other side of the aisle who have entertained folks over the last few weeks who have screamed about federal spending and the federal deficit, et cetera, are now saying, well, just, I mean, it is just $3 billion. It is just $3 billion.

I would just ask, first of all, did the prior Administration ever fully fund or the prior Congresses ever fully fund the Space Mission to meet the objectives laid out by the Bush Administration?

Mr. AUGUSTINE. That is a difficult question we spent a lot of time trying to understand, and it is probably a good question for the GAO to investigate and not for us. My understanding as best as we could draw it, is that when the Constellation Program was put together, the then Administrator of NASA I think made a genuine effort to find out what funds that NASA should be able to expect in the future and made a decision for a program based upon that honest attempt. Whatever the reasons there is not that much money available today, and but there is a sub-plot to this, and that is for the Ares Program and the Ares I Program and the Orion Program, in the near years those programs will receive basically all the money that they were expected to get in the first place. So they didn't take a cut. NASA as a whole did take a cut.

Mr. BAIRD. Did it receive sufficient money to enable us to achieve the goal of landing a man on Mars and returning them safely to Earth?

Mr. AUGUSTINE. If you take the number that the then Administrator of NASA was using, and I am not going to try to argue whether he had a reason to believe that or not, he could speak to that, but you would have had enough money in our opinion. As it has turned out, there is not that much—enough money.

Mr. BAIRD. Okay.

Chairman GORDON. The problem also is the balloon mortgage. There may have been enough money a long time, but it ballooned——

Mr. BAIRD. I understand that well, and that was the next point. You know, the near costs. I mean, we saw the sketches of those missions and astronauts happily working under large geodesic domes that were somehow transported up there by massive vehicles and landed softly and then constructed in a non-friendly atmosphere. It was, you know, as if we had transported these giant cranes up, and that is a significant lift capacity that I don't think we have.

But I commend you for being honest with this body, and I wish this body would be honest with itself and say, we can't on the one hand decry federal deficits and then on the other hand say, oh, it is just $3 billion.

And which brings me to my next point. Would you support repealing tax cuts to fund this?

Mr. AUGUSTINE. Sir, that is beyond my pay rate. I am sorry.

Mr. BAIRD. Maybe I should ask some of my colleagues on the other side of the aisle who decry the spending. Mr. Griffith, Dr. Griffith had it right, and I think you gentlemen have it right. We got to fish or cut bait, and I believe passionately that it is the mission of our species to explore and to actually leave the solar system at some point, but it is going to cost us, and we have to decide whether we want to spend that.

And I believe it is the mission of this country to lead the world in that. We are going to fall behind. I think it is very likely that my kids are going to watch somebody from another country walk on the Moon, whereas I watched Americans walk on the Moon. But we can't have it both ways. We can't have multiple unfunded wars, continued expansion of entitlement programs, continued tax cuts, and then say we want a few billion dollars here or there to expand our science effort. We can't have it. We are going to have to decide what is worth paying for, and I think you have done this nation a great service by owning that and saying—and making us look in that mirror and I applaud you for it. I think it is worth spending, and if it is worth spending, it is worth paying for, and we have to decide how to do it. But it is not worth saying we are going to add another $3 billion in debt to our kids so that we don't have to pay the taxes today. That is not worth doing.

I thank you, and I yield back.

Chairman GORDON. Mr. Wu, you are recognized.

## INTERNATIONAL COOPERATION FOR HUMAN SPACE FLIGHT

Mr. WU. Thank you very much. Mr. Baird, I thought you were a psychologist, not an economist. That is a dismal analysis but economic reality. Yeah.

I—perhaps it is in the spirit of continuing human space exploration at levels we can afford that I want to ask this question or this set of questions. I know that you all would prefer not to recommend between the different options that you have laid out in the report, but I would like to ask you about the different consequences that the different options have for international—in two ways, competition, and cooperation.

I think that there is some—there is tremendous potential for real competition developing between the different space-faring nations, and there is some prospect for cooperation also, and therefore, in sharing some of those costs and having a true human space effort. If you all could both address the consequences of the different options for cooperation and competition internationally.

Mr. AUGUSTINE. Mr. Wu, let me address the basic point and then ask my colleague to address the specific options. I think the basic point is that there are many, many advantages we think to international cooperation. We believe that the ISS has been extremely successful in setting up a management structure that involves a very large number of nations, I think it is 17 now, that works. And that management structure we believe could be broadened to go pursue exploration programs beyond Earth orbit, low Earth orbit. And so we believe the basis if there if we don't destroy it by shutting down the Space Station suddenly.

Turning to the individual options briefly——

Mr. CRAWLEY. Yes. I would agree with Norm. The—what we very clearly heard was that the basis for any real international venture in space was to deliver on our obligations on the Space Station, that this was an essential step in the future, and to dedicate the Space Station in the decade or so which we imagine it to operate in the future, to addressing many of the technical issues that we will have to face in exploration and developing the technologies and demonstrating them on the Space Station.

With respect to the specific options, I don't think that the options that we have presented really distinguish themselves greatly by the degree to which we could involve international partners in them.

## AMERICAN LEADERSHIP IN SPACE

Mr. WU. Let me just jump in. If you look at the other nations' priorities, don't some of them emphasize say a landing on the Moon rather than not going deeply into the gravity well?

Mr. CRAWLEY. I think that we didn't see a strong indication of that. We saw that they were looking for America to provide leadership, that they are comfortable with American leadership in an international space endeavor, and that they look for us to sort of at least initially lay out a course but involve them very early in that process. And structure the program, whichever one of the options is chosen, so that they can play real meaningful roles. We heard this very frequently from the international partners, and you know, there are real assets there. If we look at the combined space agency budgets of even just we will call it our traditional allies, they represent now a substantial fraction of the NASA budget collectively.

Mr. WU. Now, does that include India and China, or both India and China are outside——

Mr. CRAWLEY. No.

Mr. WU.—the 17 nation——

Mr. CRAWLEY. They are not involved in the Space Station now, although there is some interest in extending to them, but if you just look at the budgets of the European Space Agency and its member states, its principle member states, France, Italy, Ger-

many, the United Kingdom, and Canada, and Japan, you would already have about 60 percent of the budget of NASA, and you would have real capability. I mean, the robotic capability of the Canadians, the propulsive capability of the Europeans, the on-orbit robotics and laboratory capability of the Japanese. One could craft a global enterprise here which America could lead.

Mr. WU. And if you added India and China to that budgetary mix, would you be coming up close to 100 percent?

Mr. CRAWLEY. Well, the next principle one is the Russian program, which, of course——

Mr. WU. But they are in.

Mr. CRAWLEY. They are in now.

Mr. WU. Yeah.

Mr. CRAWLEY. It is a little bit more difficult to assess because of buying power parity. The Indians still have a modest program. The Chinese it is a little hard to define exactly how large their program is as you might know because of the way they budget or don't budget for the—reveal the budgetary details.

Mr. WU. They do work with non-Arabic numerals.

Chairman GORDON. Thank you, Mr. Wu, and Ms. Jackson Lee, you were patient, and you will be our clean-up hitter.

## CURRENT STATE OF NASA

Ms. JACKSON LEE. Mr. Chairman, allow me to thank both you and the Ranking Member for your courtesies as well as the Members of this very, very fine committee. I am an alumna of the Committee, but my heart is very much engaged in this process. And I would like to think that I am not from California or Texas, or I am not from Florida, but I am from America, and I believe this is an American question about where we stand as relates to our next steps.

I note, Mr. Augustine, and you are very right, reading from your opening statement that you were assigned the task, the Committee was assigned to task to identify alternative courses that the U.S. might pursue in the area of human space flight. Were you directed early on about how you should conclude? Did your tasks include the elimination of human space flight, and here is where we would like you to find yourself? Were you given those kinds of instructions?

Mr. AUGUSTINE. We were given no direction of any kind like that.

Ms. JACKSON LEE. So there was no bias that you felt that came from in particular the Administration or anyone that you had to report to?

Mr. AUGUSTINE. I need to say that we were told—I was given no bias of any kind except that in our initial job description, if you will, we were told to abide by the budget run out through 2020, that we were given, and we were told to phase out the Shuttle in 2010. And when I saw that, I went back to the Administration and said that, you know, we can't do our job if we are given that kind of constraints, and they very quickly said, fine. Go ahead.

Ms. JACKSON LEE. Excellent, and I——

Mr. AUGUSTINE. We had total freedom.

Ms. JACKSON LEE. I am going to be rapid fire with my questions. In your travels to our different centers, did you find qualified and

competent staff, degreed individuals, capable and competent in terms of research and cutting-edge technology?

Mr. AUGUSTINE. Absolutely. I have worked with those people——

Ms. JACKSON LEE. So we have some positive assets in the respective centers.

Mr. AUGUSTINE. Without question.

Ms. JACKSON LEE. I would just want to put on the record a quote by the President, President Kennedy that said, "We do these things not because they are easy but because hey are hard." So here is my overall question. It seems as if we have nailed the—we have got the hammer, we are hitting the nail, and the nail now is this $3 billion, that if we were to be given that $3 billion right as we speak, and we then follow one of your other instructions, which is the possibility of restructuring in terms of looking closely at our overhead, recognizing the human resources that we have, do we have a viable program in the Constellation?

Mr. AUGUSTINE. Yes, I think so. I think our committee believes so.

Ms. JACKSON LEE. So then in essence we have a roadmap. I would like to suggest that a roadmap that includes failure is not an option, and when I say that, I believe that we may possibly as we move forward in space have to go it alone. I am a big believer without collaborators. I have worked on this committee without collaborators. We are very active, particularly the International Space Station.

Do you perceive us having the present skill set of NASA employees and supporting—support staff, academicians and others, to be able to design a 21st century, 22nd century space program?

Mr. AUGUSTINE. There are some unknowns yet that have to do with the effects of cosmic radiation on the human body, long duration exposure to zero-G's and the moving into a gravity well. So there are some unknowns, but the general answer would be, yes, we have the talents available to have a fine exploration program.

Ms. JACKSON LEE. And a quick question. Is there value in the American Space Program, the Human Space Program in particular?

Mr. AUGUSTINE. The simple answer to that is yes. Before I think you were able to join us we talked a little bit about the reasons we feel that way, but it would seem to us there is value, and I have to caution, of course, that all ten of us come from the world of the space programs.

Ms. JACKSON LEE. And I understand, and I was here when you said inspiration education. I would rather focus on, as I conclude, I do believe this is going to be a national security issue, and I am now on homeland security. I would rather we be the leaders in space for a variety of reasons because of the values of this nation, because we are kind, because we believe in, if you will, an attitude of peace as opposed to aggressive actions, in this instance against Earth, and frankly with the talent that you say is present in our space centers around America, it would be a shame to recreate the max movies, where we go to Florida and Alabama and Texas and other places and see rusting space centers.

I think you have given us a roadmap. I think the President and the White House have something to work this, and I believe this

Congress has an obligation to the American people to find $3 billion. Whether or not we do it in a bipartisan manner, which I think we absolutely can, I think it is an absolute imperative that we encourage the brilliance and the scientific abilities of those who are working in space exploration now to continue their work, to be funded, and to use some of the instruction that you have given us to make it the most solid world space program that the world has ever seen.

And, Mr. Chairman, I thank you for allowing me to be an American today and at the same time being a Texan because we sure want the Space Station and the Space Program and Human Space Flight to survive.

Chairman GORDON. Thank you, Ms. Jackson Lee.

Ms. JACKSON LEE. Let me thank you and yield.

Chairman GORDON. You are always welcome back here, and so in conclusion let me say, Mr. Augustine and Dr. Crawley, thank you for spending the afternoon with us. More importantly, thank you for the work that you put into this report.

This committee has a very serious responsibility this year of providing a NASA authorization, which will really lay the foundation for the future of NASA, if not for the coming decade, a couple of decades. So we want to continue with this discussion. We are going to try to get it right, and we appreciate you helping us.

And so we will now call up our second panel.

Mr. AUGUSTINE. Thank you, Mr. Chairman.

Mr. CRAWLEY. Thank you, Mr. Chairman.

[Recess.]

## Panel II:

Chairman GORDON. We are on a timeframe here, so I would hope everybody would make their well wishes crisp, and the second panel will take their seat, and we will get started as soon as Dr. Griffin takes his seats. Thank you.

Okay. Thanks for your patience, and I think hopefully you found the first panel as informative as we did, and as we introduce our witnesses here, first, Vice Admiral Joseph W. Dyer, who is the Chair of NASA's Aerospace Safety Advisory Panel and the President of the Government and Industries Robots Division at iRobot Corporation. Thank you for joining us.

And also we have Dr. Michael Griffin, who served as NASA Administrator from 2005 to 2009, and now has the glamorous title of Eminent Scholar and Professor for Mechanical and Aerospace Engineering at the University of Alabama in Huntsville.

So welcome you both, and Admiral Dyer, you know the rules here. Won't you proceed?

### STATEMENT OF VICE ADMIRAL JOSEPH W. DYER USN (RET.), CHAIR, AEROSPACE SAFETY ADVISORY PANEL, NASA; PRESIDENT, GOVERNMENT & INDUSTRIAL ROBOTS DIVISION, iROBOT CORPORATION

Admiral DYER. Thank you very much, Chairman Gordon, Ranking Member Hall, distinguished Members. Thank you for the opportunity to be with you today. I respectfully request to submit a writ-

ten statement and would note that in that written statement that we reference the 2008 ASAP report submitted to this panel earlier this year.

Chairman GORDON. Without objection.

Admiral DYER. I represent the views of the Aerospace Safety Advisory Panel today, and I will emphasize the remarks we also shared, the panel shared via—with the Augustine Committee on the 14th of July of this year. I will restrict my remarks to safety and safety-related opportunities and issues.

In general, we are very respectful and appreciative of the work that Mr. Augustine and the panel have done. We do note that the tempo and time limited their consideration of safety, and we think that additional focus and energy in that arena is important.

The summary report does as we discussed in the first panel reference current plans for the Constellation Program against a number of conceptual alternatives, and here we would offer a word of caution that you have heard already. That is that PowerPoint will always outshine programs of record, but perhaps it is worth pausing for a minute and looking at why is that the case? Why is that true?

I would submit, sir, that it is that professional, peer, and public reviews during the accomplishment of real work of program of records highlight technical challenges, they discover cost stress, they reveal the realities of conducting high-risk business in an unforgiving environment, and highlighted and publicized are all the challenges of carrying out a program.

Future concepts, conceptual concepts do not yet have the benefit of this reality testing. Therefore, we believe that any new design must be substantially better to justify starting over.

Speaking of starting over, we believe that doing so surely and substantially would extend the gap of the Nation's ability to transport humans into space. The ASAP does not, I will emphasize that again, does not support extending the Shuttle beyond its current manifest.

Also discussed in the report of the Augustine Committee is the Commercial Orbital Transportation Services Project. We believe that NASA needs to take a more aggressive role in articulating human rating requirements to the COTS Project. There is—the project, COTS Project are not currently subject to human rating standards. There is no proven ability to transport—that they will be able to transport NASA personnel in a satisfactory function as of yet, and there is no indication that it could close the gap between Shuttle and a future program.

We do agree strongly with the panel in two areas, and that would be both budget and unmanned systems. The imperative to achieve a better harmony among requirements, resources, and acquisition strategy is something that should be undertaken with great speed and great interest. Without it there is an inevitable pressure to shortcut good process in the face of budget shortfall, and it is the most damning infliction upon proper safety and good design.

We also agree that unmanned systems have a strong role to play both stand-alone and integrated with astronauts. Historically, the scientific community has been the user of unmanned systems,

much so manned space. NASA will be better served, we believe, by developing a better process by which manned and unmanned systems are integrated, and undertakings as diverse as construction and mining we believe demands the case.

We would like to see more emphasis on the next major program, be it a continuation of Constellation or an alternative to have strong, strong emphasis on safety, and we note that major change is most often—rides on the back of dedicated people with a major program and a strong role to play.

Mr. Chairman, perhaps the most important message I would like to share with you today is that the panel would make a case or would hope to champion a broader discussion of risk. Let us be honest. Lives will be lost in the human exploration of space. We are lucky to have brave men and women that are willing to undertake that challenge, but the panel believes that there is a need for greater dialogue about risks and that NASA, the White House, and the Congress must all shoulder the burden of risk and the necessity of being more transparent with the citizens of our country regarding that risk.

In closing, Mr. Chairman and Ranking Member Hall, distinguished Members, we would note that the new NASA Administrator, Charlie Bolden, has been a member of our panel for the last several years. We take great comfort and great confidence in his stand of the watch at this time and look forward to his leadership.

Thank you, sir.

[The prepared statement of Admiral Dyer follows:]

PREPARED STATEMENT OF VICE ADMIRAL JOSEPH W. DYER

Chairman Gordon, Ranking Member Hall and distinguished Members, thank you for the opportunity to appear before you today. As requested, I would like to present the perspective of the NASA Aerospace Safety Advisory Panel with regard to the Options and Issues for NASA's Human Space Flight Program.

The Aerospace Safety Advisory Panel (ASAP) was originally established under Section 6 of the *NASA Authorization Act,* 1968 (42 U.S.C. § 2477). In 2005, the ASAP authority was modified under Section 106 of the *NASA Authorization Act of 2005* (P.L. 109–155).

The ASAP's charge is, among other things, to advise the NASA Administrator and the Congress with respect to the hazards of proposed or existing facilities and proposed operations with respect to the adequacy of proposed or existing safety standards, and with respect to management and culture related to safety.

My goal this afternoon is to share with the Committee much of the same information I shared with the Review of U.S. Human Space Flight Plans Committee on 14 July of this year. I shall restrict my remarks to safety and safety-related opportunities and issues.

In general, the ASAP is both respectful and appreciative of the summary report released by the Review of U.S. Human Space Flight Plans Committee. They quickly conducted a broad and far reaching review of current plans and potential alternatives. The ASAP does believe the tempo and time available prevented the thorough consideration of risks and safety challenges that we would have liked to have seen.

We note that the Review of U.S. Human Space Flight Plans Committee summary report compares current plans for the Constellation program with a number of conceptual alternatives. Here, we offer a word of caution—PowerPoint presentations addressing future programs will always out-shine current programs of record. Why is that the case? It is because current programs have garnered the professional peer and public review during the accomplishment of real work. Technical challenges will have been discovered, cost stress will have been revealed, and the reality of conducting high risk business in an unforgiving environment will have been highlighted and publicized. Future concepts do not yet have the benefit of this reality testing. This experience led to one of the ASAP's prime recommendations presented to the Review of U.S. Human Space Flight Plans Committee. Specifically, the ASAP be-

lieves that if Constellation is not the optimum answer, then *any other new design must be substantially superior to justify starting over.*

"Starting over" would surely and substantially extend the gap in the Nation's ability to transport humans into space. As it is directly related, I want to share the ASAP's strongly held position regarding the Shuttle: *ASAP does not support extending the Shuttle beyond the current manifest.* The substantiation of this recommendation is addressed in the Aerospace Safety Advisory Panel 2008 Annual Report, which I respectfully request be included in the hearing record.

The ASAP's 2008 Annual Report also addresses the NASA Commercial Orbital Transportation Services (COTS) Project. The Panel noted NASA needs to *take a more aggressive role articulating human rating requirements for the COTS Project.* COTS vehicles currently are not subject to the Human-Rating Requirements (HRR) standards and are not proven to be appropriate to transport NASA personnel. There is no evidence that the COTS vehicles will be completed in time to minimize the gap between Shuttle and the follow-on program. Additionally, we note that NASA, and at least one of the COTS funded partners, hold widely divergent views as to what is required for human-rating.

An area where the ASAP and the Review of U.S. Human Space Flight Plans Committee are in strongest possible agreement is with regard to budget. The ASAP has noted the need for NASA and the Congress to address an *imperative to achieve better harmony among requirements, resources and acquisition strategy.* The inevitable pressure to shortcut good process in the face of a budget shortfall is THE most damaging infliction upon a proper safety culture and the conduct of good design.

Making better use of robots is another area where the Review of U.S. Human Space Flight Plans Committee and the ASAP have made similar recommendations. The ASAP believes unmanned systems—both stand alone and integrated with astronauts—offer potential to reach farther and to improve safety. The ASAP has highlighted the role of unmanned systems in support of human exploration in the next decade requires clarification by NASA. Historically, NASA robots have been embraced mostly by the scientific community and to a much lesser extent by human space flight programs. NASA will be well served to better develop the process by which manned and unmanned systems are integrated. Undertakings as diverse as construction and mining demand coordinated manned and unmanned systems design.

Given good direction, consistency of purpose, and sufficient resources, *Constellation, or an alternative program, offers a one-time opportunity for safety to be better hard-wired into overall NASA processes.* Experience shows one of the best ways for a large organization to advance the state of art of its processes is to institutionalize procedures developed by a major new program that is highly motivated and staffed with the best and brightest. We would have liked for the Review of U.S. Human Space Flight Plans Committee to have more strongly highlighted this point as well.

Lastly, the ASAP would like to champion a broader discussion of risk. Lives will be lost in future human exploration of space. We are lucky to have brave men and women willing to undertake exploration in support of mankind even in the face of these risks. We believe there is need for greater dialogue about risk and that *NASA, the White House and the Congress must all shoulder the burden of risk and the necessity of being more transparent with the citizens of our country regarding that risk.*

Chairman Gordon, Ranking Member Hall, and distinguished Members, in closing I would like to note that the new NASA Administrator, Charlie Bolden, has been a member of the ASAP for the last several years. We know him very well and take strong comfort in his ability to lead the Agency during these challenging times. I thank you again for the opportunity to appear today.

# ASAP PUTS & TAKES

- **CULTURE**
  - Constellation Program Offers a One-time Opportunity for Safety to Be Better Hardwired into Overall NASA Processes
  - Experience Shows One of the Best Ways for a Large Organization to Advance the State of Art of Its Processes is to Institutionalize Procedures Developed by a Major New Program that is Highly Motivated and Staffed with the Best and Brightest
- **CONSTELLATION** -- ASAP Believes that If Constellation is Not the Optimum Answer, Any Other New Design Has to Be Substantially Superior to Justify Starting Over
- **SHUTTLE** -- ASAP Does Not Support Extending the Shuttle from a Safety Standpoint
- **COTS** -- NASA Needs to Take a More Aggressive Role Articulating Human Rating Requirements for the COTS Program
- **UNMANNED SYSTEMS** -- The Role of Unmanned Systems in Support of Human Exploration in the NASA of the Next Decade Requires Clarification
- **BUDGET**
  - Properly Balance Cost, Schedule, and Required Performance
  - Better Harmony Among Requirements, Resources and Acquisition Strategy
  - "BRAC"
- **SHOULDERING RISK**
  - More Open Communication with American Public
  - A NASA, Congressional and Whitehouse Responsibility
- **LEADERSHIP**

VADM Joseph W. Dyer, USN (Ret.), NASA ASAP Chair / Cell: 410-610-2935

BIOGRAPHY FOR VICE ADMIRAL JOSEPH W. DYER

Joe Dyer leads the Government and Industrial Robots Division. He comes to iRobot from a career in the U.S. Navy. Dyer last served as the Commander of the Naval Air Systems Command, where he was responsible for research, development, test and evaluation, engineering and logistics for naval aircraft, air launched weapons and sensors. His naval career also included positions as naval aviation's chief engineer, commander of the Naval Air Warfare Center, Aircraft Division and F/A–18 program manager. Earlier in his career, he served as the Navy's chief test pilot. Dyer holds a Bachelor's degree in chemical engineering from North Carolina State University and a Master's degree in finance from the Naval Post Graduate School in Monterey, California. He is an elected fellow in the Society of Experimental Test Pilots and the National Academy of Public Administration. Dyer chairs NASA's Aerospace Safety Advisory Panel.

Chairman GORDON. I think that our confidence will be well-founded.

Dr. Griffin, is recognized.

**STATEMENT OF DR. MICHAEL D. GRIFFIN, EMINENT SCHOLAR AND PROFESSOR, MECHANICAL AND AEROSPACE ENGINEERING, UNIVERSITY OF ALABAMA, HUNTSVILLE**

Dr. GRIFFIN. Thank you, Mr. Chairman. Chairman Gordon, Ranking Member Hall, Members of the Committee, thank you for inviting me here today for this important discussion. If there is anywhere in Washington where I feel at home, it is in front of this committee.

You have asked for my perspective on the report of the Committee to review U.S. human space flight plans or their summary report and the issues that you should consider as it deliberates the future of U.S. human space flight.

Now, I addressed many of those technical and programmatic concerns in the summary report in my written testimony, which I would like to enter for the record.

Chairman GORDON. Without objection, so ordered.

Dr. GRIFFIN. And I would be happy to answer any questions I could during your later question and answer period, but I want to focus a few thoughts in my opening statement on other matters.

The future direction of our nation's space enterprise matters greatly to everyone here, and that was obvious from the prior discussion that you really care. Well, we really care as well. As the Committee pointed out, as the Augustine Committee pointed out, human space flight is fundamentally about the strategic goal of human expansion into the Solar System. The last time human beings contemplated decisions with such a momentous future impact the result was the settlement of the new world by Europeans.

We are here today because they made the decisions that they made, and I think we want to create the kind of a world where our remote descendants will be able to say the same thing.

At least that was the path we were on until the release of NASA's 5-year budget ran out projection this last May, and at this time a year ago as I discussed with this committee, the original budget for exploration they put forth had already been eroded by some $12 billion to pay for other things. Now, the budget submitted this past May erodes that further to the point where some $30 billion has been now—if those plans were to go forward, removed from space exploration plans in the future.

This has been amply noted in the hearing so far. I won't comment further. The issue is money. That issue renders mute all other debate as to whatever destinations we might pursue, whether they are the Moon, the near-Earth asteroids, Mars, or any debate about how we might get there. On the 40th anniversary of Apollo 11, this is a sobering thought. Coming so soon after the *Columbia* accident and two authorization Acts by the Congress to set NASA on course to carry out worthy and inspirational endeavors, I hope I am not the only one who finds it shameful that we are in this position.

I am reminded of the warning made by the young President Kennedy before a joint session on Congress on May 25 of 1961, when he called upon our nation to go to the Moon. "If we were to go only halfway or to reduce our sights in the face of difficulty, in my judgment it would be better not to go at all." The Congress and the Nation then responded, but with the budget in front of us we are poised to behave not like the Kennedy Administration but the Nixon Administration, where after spending literally a fortune to develop the spaceships of Apollo, we threw them away. We spent 80 percent of the money building them, 20 percent of the money using them, and they are gone.

So do today's leaders want to be remembered like John Kennedy or Richard Nixon? That is the choice before us. Which choice best serves America? I think that is a rhetorical question.

So I believe the recommendation that matters most from the Augustine Committee is this. "Meaningful human exploration is possible under a less-constrained budget, ramping to approximately $3 billion a year above FY 2010, guidance and total resources." Well, while this may seem like a lot of money, I think I would like to put it in perspective.

If we had just kept NASA level in constant dollars since 1993 across two Presidential Administrations, no gains and no cuts, we would have more money in the NASA budget today than the Augustine Committee is recommending be put there now.

Can anyone tell me, can anyone here tell me what as a nation we bought with the money we supposedly saved by cutting the budget for NASA in the last 15 years? I know what we bought with Apollo, and I can tell you what has been lost from NASA in the last 15 years as a result of those cuts.

So the question is does this Congress believe strongly enough in the direction that it set into law with the *NASA Authorization Act of 2005 and 2008?* I hope so. Time is of the essence. OMB starts making decisions, concrete decisions in November, and they become very hard to reverse. The NASA Administrator is simply one voice among many when asking for resources from the Administration. The stronger voice comes from you ladies and gentlemen, speaking with one voice that NASA's budget needs an increase.

Back in 1994, we embarked upon an experiment of cutting the NASA budget by 20 percent in real dollars. I think we are here today because we didn't like how that experiment turned out. Do we want to keep doing it?

I will conclude by saying again that the question before us—pardon me. I will close by saying that that comment which was first asked in the Halls of Congress 48 years ago. "If we are to go only

halfway or to reduce our sights in the face of difficulty, in my judgment it would be better not to go at all."

Thank you.

[The prepared statement of Dr. Griffin follows:]

PREPARED STATEMENT OF MICHAEL D. GRIFFIN

Chairman Gordon, Ranking Member Hall, and Members of the Committee:

Thank you for inviting me to appear before this committee to discuss our nation's plans for human space flight, and the findings of a highly respected Commission chartered to review those plans. For this Hearing, I have been asked to provide my perspective on the Commission's summary report, especially as it relates to NASA's Constellation Program and the issues that Congress needs to consider as it deliberates the future of U.S. human space flight. I am honored to have been asked.

I will begin by acknowledging my own gratitude to the Commission for highlighting, front and center, many issues with which I grappled for four years during my term as Administrator. The Commission has offered many observations with which I most strongly agree. Among these are:

- the reaffirmation of the fundamental strategic goal of human expansion outward into the solar system;
- the explicit enunciation of both intangible and concrete reasons—what I once labeled 'real' vs. 'acceptable' reasons—for human expansion into space;
- the absolute criticality of stable policy direction to the success of such an effort, and the resources to implement that direction, across presidential administrations;
- the recognition of the impact of substantial, consistent, long-term real-dollar budget cuts at NASA (more than 20 percent in the last 15 years);
- the plain acknowledgement that more money is required if worthy goals are to be attained, and that without such funding, worthy goals in human space flight beyond the International Space Station (ISS) will not be achieved;
- the identification of a specific amount for a proposed increase, $3 billion annually, rather than merely stating a requirement for "more money";
- the value of U.S. leadership in a program of human expansion into space, while still embracing strategically critical contributions by international partners;
- the distinct but complementary natures of scientific discovery and human space flight in the expansion of the human frontier;
- the requirement to implement this expansion with a transportation infrastructure designed to last decades and enable numerous destinations;
- the importance of heavy-lift launch systems to that implementation scheme;
- support for the continuation of ISS operations through 2020 (and I would add "at least 2020");
- the need for and benefit of a focused effort in technology development and maturation as part of the overall space exploration enterprise.

The Commission is to be further congratulated for its forthright willingness to engage some of the more contentious questions in what has been a long-term but still unsettled policy discussion. There are a number of "hot-buttons" in the report that have been and will continue to be debated passionately until finally settled by decisions and actions. Among these questions are:

- whether or not there is a need for independent U.S. Government human access to space, and if not, the identification of those entities upon which we are willing to depend for such access;
- whether or not it is in the larger interests of the United States to invite international partnerships in regard to capabilities which are on the so-called "critical path" to a desired common goal;
- the degree to and roles in which the U.S. Government should foster the development, and embrace the capabilities, of "commercial space" in the furtherance of national goals;
- the proper role of NASA in guiding the human expansion into space, and in particular NASA's disparate functions as 'innovator and technology developer'

vs. 'designer/developer/smart buyer' of new systems, and 'system operator' vs. 'service customer.'

I have my own opinions on these matters, as do many others in the space policy community, and am pleased to share them if asked. Some of those opinions I hold in common with some members of the Commission; in other cases 'not so much.' But the larger point is that these matters of national policy remain unsettled. I am truly gratified to see such substantive matters being raised by the Commission. They deserve correspondingly substantive debate, followed by decisive action.

So, at the strategic level, I believe that the Commission has done an excellent job of raising issues that matter and providing clear indications as to what the worthy and proper course for the Nation's future in space should be.

At the same time, however, the Commission also addresses numerous tactical issues concerning how to go about achieving the goals they support, and offers views as to the merits of various implementation approaches considered during their deliberations. I think it is fair to say that I am less enamored of their treatment of these tactical issues than I am of their strategic assessments.

I believe that this is an important distinction to make, and that both strategy and tactics are important. Non-specialists will, and should, place great weight on the findings of this Commission. Where key tactical assessments and findings are at variance with those of knowledgeable and experienced practitioners, it can result in a level of public discord such that it becomes difficult for policy-makers to know how to proceed. Thus, it will be important to consider carefully many specific points which were addressed by the Commission before decisions are made by the President and finally codified into law—or not—by the Congress.

The Commission notes, correctly, that NASA's Constellation program followed a design-to-cost strategy according to the budget profile of FY 2005. NASA's budget as stipulated in 2005 was essentially constant in real dollars, with only a slight increase above inflation. Since then, it has since suffered some $30 billion of reductions to the amount allocated to human lunar return, including $12 billion in just the last five fiscal years.

The Commission notes that "Given the funding originally expected, the Constellation Program was a reasonable architecture for human exploration." In an earlier public statement, Commissioner Sally Ride noted that, "the program comes pretty close to performing as NASA advertised it would. . . . NASA's planning and development phase of Constellation was actually pretty good." A veteran of the investigations of both the *Challenger* and *Columbia* accidents, Sally has seen her share of troubled programs, and so this comment was one I found telling.

Thus, one wonders why the Commission failed to recommend as its favored option the simplest one possible—providing the funding necessary to do the job. Of all the options considered, this is the most straightforward. Yet it was not recommended. Other options are possible, of course, and the Commission would have been remiss not to explore them as well. But not to include this one is, in my view, simply wrong.

I say this because the civil space policy of the United States; e.g., "what NASA does," has been a matter of law since the passage in December 2005 of the *NASA Authorization Act.* This came about only after a full 23 months of fulsome, healthy, and productive debate on the merits of President George W. Bush's announcement of the "Vision for Exploration" in January 2004. The "Vision" itself was a response to another presidential commission, the *Columbia* Accident Investigation Board, which noted as a root cause of the *Columbia* accident the lack of a long-term strategic vision for NASA—a finding which I supported then and support now. In my view, the Congress extended and improved upon the original "Vision" in passing that Act, and did so again in 2008. On both occasions Congressional support for NASA's direction was heavily bipartisan.

Thus, when President Obama took office in January 2009, he inherited a civil space policy which had, in its essentials, survived six years of vigorous scrutiny, a space agency which had transformed itself to execute that policy, and could do so in a reasonable (if not very aggressive) timeframe on a constant-dollar budget as stipulated in 2005. The Commission itself speaks of the need for stability in direction and funding, if NASA is to make reasonable progress and to be accountable for so doing. In my view, then, the most important question that Congress could ask of the new Administration and its Commission is this: exactly why does the policy which we have established in law—twice!—need to be changed?

We cannot discuss the civil space budget, budget stability, or future plans for human space flight without also addressing the future of the ISS. Certainly, the Commission fully recognized this point in their deliberations and in their Summary Report. However, the report devotes considerable attention to the issue of poten-

tially decommissioning the ISS in 2016, trading the funds required for its extension against those required for the expansion of human space flight beyond LEO.

I must be clear. In my opinion, any discussion of decommissioning and de-orbiting the ISS is irrelevant to the consideration of serious programmatic options. While it is certainly true that the Bush Administration did not provide funding for ISS past 2015, it was always quite clear that the decision to cancel or fund the ISS in 2016 and beyond was not within the purview of that administration to make. In the face of strong International Partner commitment to ISS and two decades of steadfast Congressional commitment to the ISS, it has never been and is not now realistic to consider decommissioning it in 2015, or indeed on *any* particular date which can be known today. The United States will not take unilateral action to cancel an international program which is the centerpiece of human space flight in every one of its fifteen participating nations, just because a particular date arrives on the calendar.

It has long been known that some $3+ billion per year will be required to sustain ISS operations past 2015. Failure to plan for this is, and has been, a glaring omission in the Nation's budgetary policy. Thus, sustained funding of the ISS as long as it continues to return value—certainly to 2020 and quite likely beyond—should have been established by the Commission as a non-negotiable point of departure for all other discussions.

The United States is now the majority owner of a 450 ton laboratory in space, a facility without compare. The fact that it took too long to build and that we spent more money on it than we should have is irrelevant to future decisions. We have it. We should use it to the maximum possible extent, for as long as we can make it last. But we must also go beyond ISS. The existence of future exploration programs cannot be traded against sustenance of the ISS on an "either-or" basis, as if that were a realistic option. If the Nation is to have a viable human space flight program, *the requirement to sustain ISS while also developing new systems to go beyond low Earth orbit is the minimally necessary standard.* If the Nation can no longer meet that standard, then it should be so stated, in which case any further discussion of U.S. human exploration beyond LEO is moot for the next two decades.

The Commission correctly addresses, front and center, concerns about the looming "gap" in independent U.S. access to LEO and to the ISS after the Space Shuttle is retired. To deal with this problem, the preference for "commercial" options for cargo and crew delivery to low Earth orbit appears throughout the Summary, together with the statement that "it is an appropriate time to consider turning this transport service over to the commercial sector." It must be asked: what commercial sector?

At present, the only clearly available "commercial" option to lift Orion as designed is the European Ariane 5, designed from the outset to be human rated. Even so, Arianespace has estimated that several years would be required to prepare the Ariane 5 and its processing infrastructure to meet the demands of human space flight. I believe this to be correct. Launching a redesigned Orion crew vehicle on Ariane 5 is certainly a valid choice in the context of an international program. However, as an alternative to an independent U.S. Government capability for human transport to LEO, it is a valid choice if, and *only* if, the U.S. is willing to give up independent access to low Earth orbit, a decision imbued with enormous future consequences. Are we really ready to take that step?

With an appropriately enlightened U.S. Government policy there may one day be a domestic commercial space transportation sector. Such a policy could, as the Commission correctly notes, follow along the path laid out by government sponsorship of commercial air transportation in the last century (for cargo, by the way, not passenger traffic). No one in the space community wants that capability to exist more than I. But it does not presently exist, and will not exist in the near future; i.e., substantially prior to the expected availability of Ares I and Orion, if properly funded.

The key point is this: the existence of a guaranteed U.S. Government option for cargo and crew delivery to ISS is what allows government to take prudent risks to help bring about the development of a viable commercial space sector.

The Commission acknowledges the "risk" associated with its recommendation, but is not clear about the nature of that risk. If no government option to deliver cargo and crew to LEO is developed following the retirement of the Space Shuttle, the U.S. risks the failure to sustain and utilize a unique facility with a sunk cost of $55 billion on the U.S. side, and nearly $20 billion of international partner investment. The Russian Soyuz and Progress systems, even if we are willing to be dependent upon Russia and are willing to pay whatever is required for their use, simply do not provide sufficient capability to utilize ISS as was intended. Further, they represent a single point failure in regard to such utilization. In my view, to hold the support and utilization of the ISS hostage to the emergence of a commercial space sector is not "risky," it is irresponsible.

The Commission claims that safety "is not discussed in extensive detail because any concepts falling short in human safety have simply been eliminated from consideration." Similarly, the Commission was "unconvinced that enough is known about any of the potential high-reliability launcher-plus-capsule systems to distinguish their levels of safety in a meaningful way." For those of us in the human space flight community, this is a "hot button." The Commission has dismissed out of hand the extensive work that has been done to assure that Constellation systems offer the safest approach in comparison to all other presently known systems. This is simply unacceptable. Work of high quality in the assessment of safety and reliability has been done, and independently validated discriminators between and among various system options do exist, whether the Commissioners believe so or not. Further, the Summary Report is confusing as regards the distinction between "reliability" and "safety," where it is discussed at all. The former is the only criterion of interest for unmanned systems; for manned systems, there is an important difference due to the existence of an abort system and the conditions under which that abort system can and must operate. Nowhere is this crucial distinction discussed.

The Commission recommends consideration of a lunar mission architecture featuring a dual-launch of the Ares V Lite vehicle, instead of the Ares I/Ares V Constellation baseline. The rationale for this recommendation is difficult to understand, because economic considerations favor Ares V over Ares V Lite. Ares V costs 12 percent more to develop than Ares V Lite, but carries 14 percent more payload to LEO and 20 percent more payload to the Moon (50 mt vs. 60 mt). Even more importantly, the operations cost for the dual-Ares V Lite lunar mission concept is several hundred million dollars higher than the baseline plan, for the same reference program of two human and two cargo missions to the Moon each year.

The Commission agrees that a heavy-lift launcher is needed for human space exploration beyond LEO. Because of the economies of scale inherent to the design of launch vehicles, the cost-per-pound of payload to orbit nearly always improves with increasing launch vehicle size. Thus, a heavy-lift vehicle should be designed to be as large as possible within the constraints of the facilities and infrastructure available to build and transport it. This provides the greatest marginal capability at the lowest marginal cost.

The use of "fuel depots" as recommended in the Summary Report is equally difficult to understand. The Ares V offers the lowest cost-per-pound for payload to orbit of any presently known launch vehicle design. An architectural approach based upon the use of numerous smaller vehicles to stock a fuel depot is inevitably more expensive than putting the necessary payload up in larger pieces. Further, a fuel depot requires a presently non-existent technology—the ability to maintain cryogenic fuels in the necessary thermodynamic state for very long periods in space. This technology is a holy grail of deep-space exploration, because it is necessary for both chemical- and nuclear-powered upper stages. To embrace an architecture based upon a non-existent technology at the very beginning of beyond-LEO operations is unwise.

Finally, there are a number of concerns as to the methodology by which the Commission reached some of its conclusions.

When trying to assess the relative merits of multiple options for an engineering design—in this case the design of space flight architectures—the core requirement to allow meaningful comparisons is to fix the goals and constraints so that these "boundary conditions" are common for all. In the Commission's report, various options are presented which are not linked by common goals and constraints. Instead, differing options with different constraints are presented to reach disparate goals, rendering it impossible to develop meaningful cost/schedule/performance/risk comparisons across them. These options possess vastly differing levels of maturity, yet are offered as if all were on an equal footing in regard to their level of technical, cost, schedule, and risk assessment.

Significantly, *no* trade study was performed to assess how well each of the options considered by the Commission performed in meeting the goals and constraints of the existing U.S. civil space policy, as it is governed by the *NASA Authorization Acts* of 2005 and 2008.

The Commission cites "independent" cost estimates for Constellation systems. There is no acknowledgement that these are low-fidelity estimates developed over a matter of a few weeks, yet are offered as corrections to NASA's cost estimates, which have years of rigorous effort behind them.

As one example, it is common in cost analysis to apply a large historical cost growth factor to preliminary estimates for new designs. The size of the factor depends on the nature of the work being done and the maturity of the original estimate. Work done by Aerospace Corporation to model cost growth in certain classes

of robotic space systems suggests that a growth factor of about 50 percent might be appropriate for the design and development of a new system. Hence, that factor was applied to the assessment of "clean sheet" options offered to the Commission. However, the same factor was also applied to NASA's Constellation element designs. This is, effectively, "double counting." Historical growth factors were incorporated into Constellation costs from the very first, and are reflected in delivery schedule projections for the various system elements, Ares I, Orion, etc. To apply a new "growth factor" on top of those in the original models is misleading.

The Commission does not acknowledge NASA's commitment to probabilistic budget estimation techniques for Constellation, at a 65 percent cost-confidence level—higher than has ever been the case in the past. This is a fundamental break from past practice at the agency, a key to providing more realistic information on program status to agency managers and external stakeholders.

If the Commission believes that NASA is not using state-of-the-art methodologies to estimate costs, or is misrepresenting the data it has amassed, it should document its specific concerns. Otherwise, the provenance of NASA's cost estimates should be accepted, as no evidence has been supplied to justify overturning them.

"Technical problems" with Ares I are cited several times in the Summary Report, without further discussion. Knowledgeable observers in and out of NASA would disagree strongly as to the severity of such problems. Constellation's "technical problems" are on display because actual work is being accomplished. Other options have no problems because no work is being done. There are never any technical problems on viewgraphs.

To this point, in *The Rickover Effect: How One Man Made a Difference,* Theodore Rockwell recalls a priceless observation by Adm. Hyman Rickover. When confronted with a situation in which a variety of alternative concepts were being advocated to—and around—Rickover in place of the pressurized water reactor design he favored for the nuclear navy, Rickover noted that there were two kinds of reactors, "paper reactors"; i.e., new reactor concepts, and "real reactors." A paper reactor has the following characteristics:

- It is simple.
- It is small.
- It is cheap.
- It is lightweight.
- It can be built very quickly.
- Very little development is required; it can use off-the-shelf components.
- It is in the study phase; it is not being built now.

In contrast, a real reactor has the following characteristics:

- It is complicated.
- It is large.
- It is heavy.
- It is being built now.
- It is behind schedule.
- It requires an immense amount of development on apparently trivial items.
- It takes a long time to build because of its engineering development problems.

Does any of this sound familiar?

Finally, the Commission did not do that which would have been most valuable—rendering a clear-eyed, independent assessment of the progress and status of Constellation with respect to its ability to meet the goals which have been established in two successive *NASA Authorization Acts,* followed by an assessment of what would be required to get and keep that program on track. Instead, the Commission sought to formulate new options for new programs, treating these options as if their level of maturity was comparable to that of the baseline upon which NASA has been working now for more than four years. This ignores the established body of law which has guided NASA's work for the last four years and which, until and unless that body of law is changed, must serve as the common standard for any proposed alternative to Constellation as the "program of record" for the Nation's existing human space flight program.

With the above having been said, where do we go from here? In the end that is the only important question. Let me be as clear as possible on a further point. When I noted above that the best option is to restore funding, I do not want to mislead this committee. It is not possible to recover fully, in terms of schedule, personnel morale, and programmatic decisions, from the damage which has been done to

NASA and to Constellation by reductions in funding, particularly in the last couple of years, when the program has moved into full-bore execution. Past decisions and actions are a form of sunk cost. So I do not propose to render the program somehow magically "whole" by restoring past funding cuts. That cannot be done. But NASA does know—or can shortly assess—what is necessary to get Constellation back on track with regard to the best achievable schedule, *from where we are today,* for regaining access to LEO, returning to the Moon, exploring some of the near-Earth asteroids, and eventually voyaging to Mars.

The details will, as I say, best come from NASA. However, I can suggest what I think might be the most viable alternative if we remain committed both to continuing ISS operations and to human exploration beyond LEO, yet cannot return all of the money to the NASA budget that has been removed in the last few years.

In such a case, at least in my opinion, it would be logical to delay lunar lander development in order to make progress on the other elements. I don't think it is a very good idea to try to make it "smaller" or somehow less capable in some other way. Current planning is for a crew of four on the Moon. Carrying two pairs of two EVA crew members is very logical, for all the reasons that apply to Shuttle today. It also has the advantage of providing ample opportunities for crew from international partners.

If that rationale is accepted, then I think it makes more sense to delay the lander development than to compromise the design of a machine that will be in use for a very long time. So, the Altair lunar lander would be built when the money to do so becomes available. Ares I and Orion should be completed as quickly as possible to support ISS, and then Ares V should be built. They should not all be done in parallel; that causes them to stretch out and costs more in the long run. It makes more sense to start some elements later. In the meantime, once Ares V becomes available but prior to human lunar return, Orion could be used for some of the "Flexible Path" options cited by the Commission. Such options were, in fact, considered from the first during ESAS. The use of Constellation hardware for destinations that were not included in the Vision for Space Exploration (as initially stated) was a core part of our thinking during ESAS. I considered that to be a strong point of the chosen architecture—it was flexible about destinations. An Orion spacecraft that can take care of itself for six months around the Moon can go a lot of other places.

I think that some variant of the approach outlined above makes the most sense going forward. It would position us as well for the future as we can be, given where we are today, unless a substantial sum of money can be allocated to the original plan for lunar return by 2020.

The Summary Report suggests inviting international partners into the critical path of program development. This is a valid alternative if we are willing to depart significantly from prior policy. Europe, Japan, or Russia could build a lunar lander just as well as could the United States. Politically and culturally, this would be a big step. I sat in front of this Committee, with a different Chairman, when former Administrator Dan Goldin was advised in very direct terms to "keep Russia off the critical path on the ISS." But, if we wanted to be more "inclusive," we could decide that the United States will develop the heavy-lift launcher and deep-space crew vehicle, but a return to the Moon will depend upon international partner contributions. I personally do not favor such an approach, but it is a technically feasible option.

I would like to close with a quote from the Commission's Summary Report: "Finally, significant space achievements require continuity of support over many years. One way to ensure that no successes are achieved is to continually pull up the flowers to see if the roots are healthy. (This committee might be accused of being part of this pattern!)"

I couldn't agree more. As I see it, the Commission didn't find anything wrong with the current program, didn't find anything safer, more reliable, cheaper or faster. The roots are healthy. So, why throw away four years and $8 billion pulling up the flowers? Let's apply some plant nutrient and watch them grow.

This, to me, is our best option for re-affirming a stable civil space policy.

Thank you.

## DISCUSSION

Chairman GORDON. Thank you, Dr. Griffin. I will remind you that Congress did appropriate every dollar that the last few—or over the last few years it had been asked to.

SHUTTLE EXTENSION

Admiral Dyer, in your statement you made a very definitive statement concerning no extension of the Shuttle. Now, is that period or was that in context to 2020, in that—and would you extend it if it was recertified or if there was a mission or two missions that came up in the next, you know, short period that seemed to be very important? Is there still a period that you wouldn't go one more?

Admiral DYER. Three quick comments with regard.

The first is the thing that scares us most is that kind of serial extension. Point number one. Point number two, we take this position because we think the risk is more than we should ask folks to shoulder, and we don't think there is full transparency with regard to that risk. Thirdly, the time to extend the Shuttle in the panel's opinion was several years ago when the supply chain was still intact and when there was an opportunity to move forward with the Measure Program. A number of folks, myself included, who had—who participate on the panel, have been or have lived through the extension of a number of Department of Defense aircraft programs after they were supposed to terminate. It is never a good experience.

I would offer one other caution. Could you with significant money and with recertification extend the Shuttle? Yes. The money would be impressive. It would have to go well through the supply chain, and the risk of finding things demanding even more resources during recertification is a real risk.

Chairman GORDON. Well, I think that is a thoughtful answer, but I, you know, then I could understand the incremental of going one more, one more, but with that same thought, I mean, is the amount we have the perfect amount? Why not one less? I mean, should not that decision maybe be reviewed at the time rather than this far out?

Admiral DYER. You know, we see in the military world that the operational commander always has the authority to proceed in the face of absolute requirements, and it would be an equivalent position in the opinion of the panel. The Shuttle is risky, it is becoming more so an extension beyond that which is planned through the current manifest we believe would be unwise.

CONSTELLATION PROGRAM WITH BUDGET AUGMENTATION

Chairman GORDON. Thank you. Excuse me. Thank you, sir, and Dr. Griffin, in your written statement you said that you believe that the approach you have laid out would—or pardon me. Within your written statement do you believe that the approach you laid out would deliver a viable Constellation-based exploration program on the same level of budgetary augmentation as the Augustine panel proposed?

Dr. GRIFFIN. I am not sure I understand your question. I do agree with the Augustine panel's——

Chairman GORDON. Microphone.

Dr. GRIFFIN. I am sorry. I am not sure I fully understand your question. I do agree with Norm's conclusion that if $3 billion a year were added to the program, that the Nation could have a viable space exploration program, continuing the Constellation develop-

ment, and featuring a return to the Moon some time in the early to mid-2020s with other destinations as possible choices according to the flexible path option if so desired by the policy-makers of that time.

Chairman GORDON. I am for—because we maybe called, and I want everybody to have an opportunity to participate, Mr. Hall, you are recognized for five minutes.

EFFECT OF NASA BUDGET CUTS

Mr. HALL. Thank you, sir. Dr. Griffin, you have a history of long service to the Nation and particularly to NASA, and I don't know of anybody that I think knows more about NASA or has more interest in it and gave more hard time to it than you have given, and I appreciate it.

Do you remember when President Clinton came aboard? Is it your recollection that he put Vice President Gore kind of in charge of overseeing the NASA thrust?

Dr. GRIFFIN. Yeah. I do know that NASA's primary interface in that time was with Vice President Gore, and it was to Vice President Gore that our Space Station redesign plan and associated inclusion of Russia in the partnership was primarily briefed. Yes, sir.

Mr. HALL. And do you remember that Gore came to this committee and told us that we had to have a 25 percent cut in our budget?

Dr. GRIFFIN. I believe that was Mr. Goldin who——

Mr. HALL. I think Mr. Gore did it—said that to Mr. Golden.

Dr. GRIFFIN. That may well have been, sir. I don't—I was not involved in that discussion.

Mr. HALL. But you remember the discussion took place.

Dr. GRIFFIN. Yes.

Mr. HALL. It was in the papers and everybody knew about it.

Dr. GRIFFIN. I do remember.

Mr. HALL. And do you remember that Sensenbrenner and Mr. Boehlert were Chairman and the first runner up over on the Republican—on the Democratic side?

Dr. GRIFFIN. Yes. I——

Mr. HALL. And on the Republican side then——

Dr. GRIFFIN.—sat in front of Mr. Sensenbrenner on more than one occasion.

Mr. HALL. Boehlert was more of a Democrat than he was a Republican, but he was a good man, did a good job, and I like him. I don't have anything against him, but he was Chairman, and Sensenbrenner was his—I don't know to call Sensenbrenner. He was second in command there. And over on the Democratic side was a guy named George Brown, and I was his first lieutenant I guess the way it was, and we, with Boehlert, I believe, we all four agreed that we would tell Golden to cut that budget skillfully, or we were going to cut it with a butcher knife or a baseball base, unskillfully. We didn't know how to cut it that far without endangering safety of the pilots.

And for him to cut it and if he didn't cut it, we were going to, and do you remember that he did cut?

Dr. GRIFFIN. Yes, sir, I do.

Mr. HALL. About what percent do you remember that he cut it to?

Dr. GRIFFIN. Well, during the 1990s the NASA budget was reduced in real dollars by about 20 percent.

Mr. HALL. Do you have any recollection of the budget cut being in excess of 30 percent?

Dr. GRIFFIN. No, sir.

Mr. HALL. How much did Mr. Goldin during his tenure cut the budget? What percent?

Dr. GRIFFIN. Well, NASA—I would have to say, sir, having been one, that NASA Administrators neither raised nor cut the budget. I would say that the only thing I could honestly say is that during the 1990s, the NASA budget went down by about 20 percent in real dollars.

Mr. HALL. From what it was when——

Dr. GRIFFIN. From what it was in 1993.

Mr. HALL. Yeah. Did that have any effect on the program, on the NASA program, and if so, what was that effect?

Dr. GRIFFIN. Well, the effect over the last decade and a half of that downtrend has been to damage the efficiency with which NASA's programs have been executed and to stretch them out because as I think you gentlemen know quite well, when we cut budgets, we hardly ever remove corresponding programs from the suite of activities. Federal agencies are directed to continue their programs at a slower pace to fit the available budget, and that is greatly damaging to their efficiency.

Mr. HALL. And I think it was their feeling at that time that Mr. Goldin probably did a good job of cutting the budget, but what was the effect of it?

Dr. GRIFFIN. Well, again, to cause most programs to stretch out and to cause our operations to continue with less efficiency than would have been desired. The earlier speakers made the point that NASA has too much overhead. I agree. NASA has the overhead associated with a larger agency.

Mr. HALL. And do you remember that NASA was taking a lot of hard licks from the public at that time and from some people close to NASA that were taking a view of the NASA thrust to the extent that this Congress came within one vote of destroying the Space Program in this country. Do you remember that?

Dr. GRIFFIN. I remember we came within one vote of losing the Space Station.

Mr. HALL. And it seems to me we have been going downhill ever since, despite the hard work that you put in on it and the money that you have asked for it and the money that you have almost demanded for it, and we haven't really backed you up and that we have not as I use the term, scratched and clawed and fought for those advance, that $3 billion per year advance over what we are spending, which is a small percent of the overall R&D that anything as important to this country, important to the youth of this country, the future of this country, as our Space Program.

Dr. GRIFFIN. Yeah. I agree.

Mr. HALL. Are you going to comment on that some?

Dr. GRIFFIN. Well, I think it is as Mr. Gordon pointed out, Chairman Gordon pointed out, the last President did not request the

funds necessary, the one before that did not request the funds necessary, and the current President is not requesting the funds necessary, and I believe the question for the Congress will be do you wish to go along with that or not.

Mr. HALL. So you really and truly put it right back on the Congress, don't you?

Dr. GRIFFIN. Sir, Article 1 gives Congress the power of the purse.

Mr. HALL. I agree with you, and I think we can do better, and I think we have got to start doing better. We got to start making some demands on something as important as the Space Program is to the United States of America and to the free world.

I yield back my time.

Chairman GORDON. Thank you, Mr. Hall. Just to briefly continue on your history lesson, in 1993, President Clinton and Vice President Gore inherited at that time what was the world's largest budget deficit. They turned that deficit in five years into a surplus that actually started paying down the debt. They did that not by having a vendetta against NASA but rather having to make tough choices and cuts across the board, passing things like limited number of time you can be on welfare and make tough choices.

I think our country—I just want to put that in perspective. Hopefully we can start getting back to a surplus soon, paying down the debt——

Mr. HALL. Would the Chairman yield?

Chairman GORDON. Yes, sir.

Mr. HALL. It is my recollection that that was done with a Republican Congress, and that is when I switched parties.

Chairman GORDON. Well, actually, Mr. Hall, that was done without a single Republican vote and but I don't—and we don't need to get into that past history, but that——

Mr. HALL. I am going to lose every battle I have with the Chairman. He has got the gavel.

Chairman GORDON. Well, that was then. Now is now, and we are trying to move forward. And Ms. Giffords is recognized.

Ms. GIFFORDS. Thank you, Mr. Chairman, Mr. Hall, and Admiral Dyer, Dr. Griffin.

## COMMERCIAL TRANSPORTATION TO THE ISS

We have heard a lot here today, and without dispute the thing that brings us together is really our love for a Manned Space Flight Program for the hard work that is done by NASA. So there is strong support, but specifically we are in this room today to talk specifically about this Augustine Report, and all of us respect Norm Augustine. This man is an extraordinary asset to our country. I like many talk about the *Gathering Storm Report* as one of the real roadmaps that we have to U.S. competitiveness.

But that being said, I think it is important to actually read the language, and I don't know how many of the Committee Members actually took the time to read the report. It is not specially long. It is somewhat complex, but, Mr. Chairman, if you will allow me, quoting directly from page 6. "The current Constellation Program Plan is to use the government-operated Ares I launch vehicle and the Orion Crew Capsule. However, the Committee found that be-

cause of technical and budget issues the Ares I schedule no longer supports the ISS."

Again, let me repeat. "Because of technical and budget issues the Ares I schedule no longer supports the ISS." We heard Mr. Augustine today say that basically no other option or alternative actually at this point with the funding levels currently would support the ISS either.

Going on, this is on page 7. "The United States needs a way to launch astronauts to low Earth orbit, but it does not necessarily have to be provided by the government. As we move from the complex reusable Shuttle back to a simpler, smaller capsule, it is an appropriate time to consider turning this transport service over to the commercial sector. This approach is not without technical and programmatic risks, but it creates the possibility of lower operating costs for the system and potentially accelerates the availability of U.S. access to low Earth orbit by about the year of 2016. The Committee suggests establishing a new competition for the service in which both large and small companies could participate."

So that is really where I think the misunderstanding and the miscommunication takes place, and I am sorry that Mr. Augustine isn't with us, but I guess I have some serious reservations about the willingness of the Committee to essentially bet the farm on the yet-to-be-developed commercial crew capabilities to support the ISS in the lower-Earth orbit or LEO as we refer to it.

I think everyone here supports a commercial space sector. I think we all want to see that developed, and we hope that happens, but I don't believe that we can be responsible stewards of the taxpayer dollars if we let hope and ideology trump the evidence, and specifically on the one hand the report asserts that the commercial system could accelerate the availability of U.S. access to LEO by about a year.

But on the other hand, I see that the commercial companies that are trying to achieve essentially a much less challenging objective of delivering not people but actually cargo to LEO are struggling. For example, the NASA data indicates that SpaceX, a fine company doing incredible work out in California, has now slipped the readiness review for their first demonstration mission by almost two years from their initially-planned date. And another illuminating data point in Dr. Ride's Scenario of Affordability Analysis Charts, she states that one of the review committee's assumption was, and I quote, "An additional $200 million was added to the COTS cargo-based line in fiscal year 2011, to incentivize current COTS cargo demonstration."

Now, given that the companies involved in COTS and this demonstration project were just awarded $3.5 billion as a contract to transport the cargo to ISS, how on Earth did the review panel justify giving them another $200 million, and again, I just want to find out if that 3.5 billion is not enough of an incentive, and how can we especially have confidence in this report when looking at this commercial alternative, there are no specifics in terms of the safety for the crew, the costs actually as well that is going to go into, you know, developing this, and all of those specifics and details that NASA is responsible for but we really don't see presented in this.

So, you know, I turn to the Chairman and to members of the panel to make sure that I am understanding this correctly, and, again, I know that you didn't—you don't come up with the report, but, you know, if you could give us some insight into how this happened and hopefully we can hear from, you know, Mr. Augustine as well to get some more specifics as this committee and the President, I mean, essentially, this whole exercise was to give a menu of options to the President and to the Congress to determine how we move forward.

Admiral DYER. I think speaking from the perspective of the ASAP we would agree with much of what you have said, Congresswoman. We note that there is a wide gap between the COTS partners' belief that they are human rating and that they are designing to human rating, vis-à-vis that which NASA believes would be required.

Now, we have been critical of NASA here because, frankly, NASA has been whistling by the graveyard in this regard in that they have not engaged with the COTS contractors in terms of what it would take to transport NASA personnel into space.

Dr. GRIFFIN. Well, I certainly would say that I agree that at this point you are—to use your words, betting the farm on commercial transportation, is unwise. I have said so in writing. Now, I am one who believes that as with airplanes and air transport, there will be a day when the U.S. Government as one option can turn to commercial providers, but that day is not yet, and it is not soon.

Also, I would say that the definition of a commercial provider is not one that you create by pumping in hundreds of millions or billions of government dollars. Typically we call that a prime contract. A commercial provider develops the capability on his own nickel and then searches for a customer. Now, I am in favor of incentives in government policy such as anchor tendency. I was in favor of providing some seed money, indeed, I created the COTS Program which provided that seed money.

But to confuse the expectation that one day commercial transport of crew will be there, to confuse that expectation with the assumption of its existence today or in the near-term, I think is risky in the extreme. And it is risky because it holds hostage a $75 billion laboratory in space that this committee has authored 20 some votes in support of and I would say expects to see utilized to its fullest in the years ahead.

Chairman GORDON. Thank you, Dr. Griffin, and Ms. Giffords, you raise very serious and legitimate questions. Hopefully within the next couple of weeks we will have additional meat on the bones in terms of the remainder of the report, the report which will then need to be digested and more questions asked, and I know you will play as Chairman of the Space and Aeronautics Subcommittee, will play a very, very important role in that, as well as your partner, Mr. Olson, who is the Ranking Member, who is recognized now for five minutes.

## TRANSFORMING NASA EXPERTISE TO PRIVATE INDUSTRY

Mr. OLSON. Thank you very much, Mr. Chairman. I would like to follow along the lines of questioning from my Chairwoman down there, and this is a question for you, Admiral Dyer.

Up to this point, only NASA has had experience with setting requirements designing for human-rated launch systems. How difficult would it be to transfer that insight and experience to the private sector? Are the processes and requirements for human rating well understood by the commercial launch companies? How—would they be held to the same standards as NASA?

Admiral DYER. I think there is two pieces of that, sir. The first is NASA in their articulation of what is required for human ratings is in the midst of change, in a state of flux. There is much goodness associated with it because it is a change from specificity or direction to one of imposing good judgment. How good judgment is to be defined is a bit fuzzy from the Aerospace Safety Advisory Panel's perspective. So that is a part of it.

The second part of it is once it can be clearly articulated what the human ratings process is to be, I think, yes, sir, it can be transferred to a COTS partner, but you have to start——

Mr. OLSON. Yes, sir.

Admiral DYER.—and that hasn't been an issue.

Mr. OLSON. Dr. Griffin, do you care to comment?

Dr. GRIFFIN. I don't think I have anything to add to what Admiral Dyer said. We had a long and close relationship during my tenure at NASA and his tenure as Chair of the ASAP, and I think we pretty much see things very similarly.

CONTINUATION OF CONSTELLATION DEVELOPMENT

Mr. OLSON. Thank you for that answer, and I have got a question for you, Dr. Griffin. Again, Constellation Program is progressing, and just last week the Orion passed a major milestone as you know through its preliminary design review.

My point is should we continue the development of the Constellation? I mean, how much has already been spent on the program, and what is going to be lost if we stop in the next year or so?

Dr. GRIFFIN. Sir, I obviously, you know, from my written statement do agree with you or the import of your remarks. I think we should continue on with where we are, but I would agree with Mr. Augustine, who is an old and valued friend, that we have come to a point where we cannot continue on unless the program is properly funded. The Committee's, the Augustine Committee's service in pointing out that the train wreck is right in front of us is very valuable.

So I think we should continue. I think we have to fund it properly. Had the Committee—this hearing is not about Constellation or about who comes up with what alternative to support the goal of human space flight. Had the Committee been able to surface an option which was clearly better than what was going on today, they would have had to get out of my way to rush toward it. The issue is not what hardware we use to accomplish the goal. The issue is the strategic goals. The Committee did not, I would predict, cannot surface a better option than where we are today, so our choice is stay on path, funding it appropriately, or determine that the United States is not going to go beyond the Space Station. That was what Mr. Augustine said would happen. If we tense not have the extra funding, the United States agreement go beyond Space

Station. I think that that is not a worthy future for the United States in space.

Mr. OLSON. Thank you for those comments. I couldn't agree more, and sort of to follow up on that and some comments from the previous panel, there is a big difference in spending $3 billion and investing $3 billion, and I think the Augustine panel was asking us to invest $3 billion, and I strongly, strongly support that, and I appreciate your comments to that effect as well.

Dr. GRIFFIN. I think that it was——

Mr. OLSON. Mr. Chairman, I yield back my time.

Chairman GORDON. I am sorry, Mr. Olson. What was that?

Mr. OLSON. I yield back my time. You are up.

Chairman GORDON. Thank you, and Mr. Rohrabacher, thank you for your patience, and you are—what we are going to do is you will have the last question on your side. Ms. Giffords said that she would like to ask another question, and then if that is the case, then we will conclude, because we have votes that will be shortly.

Mr. ROHRABACHER. All right. Thank you very much. Let me just note for the Chairman that when we did, when the budget was balanced, it was a Republican Congress as our Ranking Member noted, and the example that you gave of the great savings of the Welfare Reform that passed, it passed the Republican Congress after being vetoed three times by the President over the issue of whether illegal aliens should receive welfare benefits or not. Eventually he gave in, and that is why we balanced the budget.

Chairman GORDON. Well, that and 1993, vote that accompanied that to set in motion the various cuts.

Mr. ROHRABACHER. All right.

Chairman GORDON. But anyway——

Mr. ROHRABACHER. But I do want to——

Chairman GORDON.—at the end of the day we all worked together and got it done.

BUDGET LIMITATIONS AND MISCALCULATION

Mr. ROHRABACHER. All right. We did, and I—but I do want to bring up history, because history does relate to what we are talking about here, because what we are really talking about here is $3 billion, and all I keep hearing is isn't it sad that we are not allocating $3 billion more and how NASA, we—their budget went down at the time when we balanced the budget, along with everybody else's budget in the government.

But let us take a look at the money that was spent. In 1996, how much did the mistake of putting money into the X–33 cost NASA? Mr. Griffin? Admiral?

Dr. GRIFFIN. I don't know.

Mr. ROHRABACHER. Several billion dollars. All right. What about NPOESS? How much does that cost NASA and American taxpayers?

Dr. GRIFFIN. Sir, NPOESS is an Air Force Program. NASA is a——

Mr. ROHRABACHER. Good.

Dr. GRIFFIN.—member of the Joint Program Committee but has no money in, has no power for NPOESS.

Mr. ROHRABACHER. Well, that is a good—let me put it this way. I consider NPOESS to be, maybe not a NASA program, but I have always considered it as part of the Space Program, and maybe I am wrong because we are dealing with the same companies that we deal with and okay. I understand it is $14 billion, it is a $14 billion program. There is five or six satellites and none of them have been launched so far.

Okay. If it is not money supposedly going to NASA, maybe that money should have gone to NASA then. I don't know, but there is $14 billion that we don't have anything to show for it. A couple billion dollars is the extra three.

Tell me about Space Station. How much has Space Station gone over the—its original budget request?

Dr. GRIFFIN. President Reagan directed that a Space Station be built for $8 billion, and the best estimate that I was able to obtain while running NASA was that the United States had spent or would spend by the time of station completion about $55 billion, and the partners collectively have spent maybe 20 or will spend maybe 20 by the time it is deployed.

Mr. ROHRABACHER. So it is almost, you know——

Dr. GRIFFIN. It is a factor of ten.

Mr. ROHRABACHER. Factor of ten. And what about the Space Shuttle itself, which I remember was sold as something that would bring down the cost of getting into orbit? How much has that gone over the expectations?

Dr. GRIFFIN. The Space Shuttle was sold or was directed by President Nixon to be developed by—within $5.8 billion. NASA's cost estimate at that time was that it would cost around $9 billion and ultimately to develop the Shuttle, about $9.9 billion in then-year dollars, not today's dollars, was spent. The projected cost of the Space Shuttle depends on how old you are and what the lowest cost you remember was, but was invariably in the range of 14 to 16 to $18 million a launch. Today it is probably 20 times that.

Mr. ROHRABACHER. 20 times that. So let me just suggest that when we are talking about we don't have the $3 billion that maybe if NASA would have been doing a better job and let us include also totally the American Space Program because I will include NPOESS in that, and maybe if we had a Space Program, not just NASA but altogether it was better managed that we would have the money to do what we needed to do.

And it is not to say that we can't look for new resources. I think that now that we are in this fix that maybe stimulus money would be something that would be looked at. Also I talked about this idea that we would tax AIG. I know that I did that in jest but let us face it. We gave AIG $150 billion, and now we are arguing about $3 billion for NASA. I mean, what do we get out of the AIG? I will tell you what we got. We got a lot of rich executives who kept their bonuses. This is what we got.

So maybe we should be running things a little bit better. NASA should be doing a better job and maybe Congress should be a better, doing a little bit better job in allocating money in terms of what America's real priorities should be instead of enriching wheeler dealers from Wall Street and maybe give it to the American Space Program.

Thank you very much, Mr. Chairman.

Chairman GORDON. Thank you, Mr. Rohrabacher, and to demonstrated that we are rich in diversity of ideas, Ms. Giffords is recognized.

METHODOLOGY OF COST ASSESSMENTS

Ms. GIFFORDS. Thank you, Mr. Chairman. One of the reasons I love serving on the Science Committee is because I think it is truly one of the most bipartisan, non-partisan committees. So we verged a little bit from this today, but I know the next hearing we are going to get back on track to all of our bipartisan love.

Dr. Griffin, there has been considerable public discussion about whether the cost cited for NASA's Constellation programs are accurate. Could you give us some insight into your thoughts on the costing methodology used in the preparation of the cost assessments for the Review Committee?

Dr. GRIFFIN. Well, NASA's cost estimates for Constellation marked a significant departure, an enormous departure from the way NASA had prepared budgets in the past in the sense that they were prepared in a probabilistic sense, which cost estimation experts can discuss with this committee at great length, and we are prepared to a much higher confidence level. So it represented a departure from older ways of doing business.

I was privileged to be provided the methodology by which the independent cost estimates were prepared for the Augustine Committee, and those independent cost estimates seemed not to recognize that fact at all. So essentially NASA was not being given credit for good behavior, and I would—it is one thing to be slapped about when you are doing poorly, but when you have done well, it would be nice to at least have that acknowledged.

The second thing I would add is that there was no distinction made in the independent cost assessments between—and the phrase has been used here several times today, view graph programs and real programs.

Ms. GIFFORDS. Uh-huh.

Dr. GRIFFIN. NASA's current program, like it or not, has four years of maturity behind it and $8 billion of money spent on it. The cost estimates are becoming firmer. More is known about the program, and yet the independent cost estimation methodology applied a factor of 1.5 for assumed cost growth to all programs, whether young and immature and idealistic or having more scars on them. That is not a good way to do costing. You have to look at the details of the individual program and its level of maturity before you can make a conclusion as to how much likely growth you should expect to see. That was not done.

COMPLETION DATES FOR CONSTELLATION

Ms. GIFFORDS. Dr. Griffin, in terms of, essentially it is a multiple accounting situation, and I look at that in terms of how it much affect the estimated or rejected completion dates for Constellation and also the costs. Can you talk about that a little?

Dr. GRIFFIN. Well, sure. If you believe that the cost is going to be 50 percent higher as one example, and you know because you

have been told what your budget expectations are, then whatever budget you had you should now expect the completion date to be 50 percent greater.

Ms. GIFFORDS. Uh-huh.

Dr. GRIFFIN. But it is worse than that because when we have to account for inefficiencies that go into a program as a result of stretching it out, it always gets worse.

Joe, you look like you want to comment on that. I know you and I have both had substantial DOD experience where programs were stretched out, and it is just never as pretty as you would hope.

Admiral DYER. Congresswoman Giffords, my previous trips to the Hill to testify have always been when I was in uniform, and I had to be well behaved. I have got something I always wanted to share, and you gave me an opportunity.

Resourcing major programs in our country has a lot in kind with airline overbooking. We just plan for an efficiency that is not real, and consequently, programs stretch out, and the overheads are applied over time, and the cost of a program grows dramatically vis-à-vis that which good resourcing would support.

So this harmony, Mr. Chairman, that we appeal for in terms of resources and requirements and acquisition strategy is an important undertaking that if we could fund it at a proper and sustained and stable level would solve many of the problems that Dr. Griffin has highlighted here.

Thank you, ma'am.

Ms. GIFFORDS. And Mr. Chairman, I mean, this is something I think that we really need to tackle on this committee is how do we get to the bottom of these apparent discrepancies so that when we really look at the numbers and the data that we know what the actual numbers and the data really, truly represent. And I think that is just important to hear from our panelists on that because, again, what the panels, at least the summary report has ignited is from a public and from a press standpoint this, you know, this set of beliefs that are out there and now we are finding because of the hearing today and the testimony by our panelists and the questions brought up by Members is that it is just not that, you know, cut and dry.

So, Mr. Chairman, I am looking forward to seeing the full report and working with our panelists and others to try to get to the bottom of this.

Chairman GORDON. Madam Chairwoman, I am looking forward to your hearings as you take the lead in getting to the bottom of it and report back to us.

Ms. GIFFORDS. Thank you.

Chairman GORDON. And so let me conclude by, again, thanking our witnesses today. You have been with us a long time, and I believe we are going to—our timing is going to work out just about right with votes coming up shortly.

I will also announce that the record will remain open for two weeks for additional statements from Members and for answers to any follow-up questions the Committee may ask of the witnesses.

So the witnesses are excused, and the hearing is adjourned.

[Whereupon, at 4:58 p.m., the Committee was adjourned.]

# Appendix 1:

## Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

*Responses by Norman R. Augustine, Chair, Review of U.S. Human Space Flight Plans Committee*

**Questions submitted by Chairman Bart Gordon**

*Q1. What methodology did the review committee use to determine that options would fit within the increased budgetary threshold it established despite options' differing maturity levels and thus greater uncertainty in cost?*

*A1.* On behalf of the Committee, the Aerospace Corporation conducted an affordability analysis on all options using a process that is described in the Final Report. In summary, the analysis outputs key dates, element costs and manifests at the 65 percent confidence level. It also estimates the uncertainty on dates and costs. The affordability analysis corrects the input cost in several ways. First, it estimates a range of expected growth of the cost for each program element from System Design Review (SDR, Start of Phase B) to completion, based on historical data of NASA programs. At the average, this introduces a 51 percent growth from the estimate held at SDR in the cost for development (DDT&E costs). For elements that have not reached their SDR, such as the Ares V or commercial crew service, this full correction was applied. For elements that have passed their SDR, credit was given for subsequent development and maturity of the design. For example, the mean cost of the Orion in the analysis, due to this factor, is only 25 percent higher than would be reported by the Program of Record at the mean. Other, more mature programs, such as the Ares I, receive credit by a similar process. In operations, a 26 percent growth factor was applied to unproven systems, and no growth factor at the mean was applied to existing systems such as the Shuttle or the ISS, or to defined budget items such as the technology program.

NASA Headquarters asked the Program of Record to report cost and schedule at the 65 percent level, and the Committee attempted to report in a consistent manner. Note that on average, the difference between the mean of expected costs and the 65 percent confidence costs adds about 10 percent to all program costs calculated. Finally, the affordability analysis combines the development schedule of all the elements of the program. This process accounts for the additional cost to one element if another element it depends upon slips in its schedule. This integration of elements typically adds about an additional 10 percent to the total program costs, higher in more-constrained budgets, and lower in less-constrained budgets.

The Committee then examined the outputs of the affordability analyses, and it made interpretations to extract from them the primary information of interest, recognizing the inherent uncertainty in the analysis. The reporting by the Committee attempts to focus on its interpretation of the key milestones and associated uncertainties, and the pace of events after the initial milestone.

*Q2a. You testified that you were not asked to make recommendations and had not done so. However, Dr. Crawley testified that the final report would include an evaluation of the options against 12 parameters such as the potential to involve internationals, cost, and safety. If you are not making a recommendation—whether explicit or de facto, what is the purpose of scoring each of the options, which will of necessity result in a ranking of the options?*

*A2a.* In order to conduct an independent review of ongoing U.S. human space flight plans and alternatives, the Committee recognized that it would be important to define a process that would equitably evaluate the wide range of options to be identified. Consistent with the systems engineering approach, it was important to clearly define the set of criteria against which all options would be assessed, and to define an evaluation process that would enable a fair and consistent assessment of each option. Since many of the evaluation criteria are not quantitative, the Committee did not intend that the evaluation would generate a single numerical score; rather, it would provide a basis for comparison across options, highlighting the opportunities and challenges associated with each. Assigning weights to individual figures of merit is within the purview of the ultimate decision-makers.

This was the purpose of scoring each of the options and it was a requirement of the Committee's Statement of Task. At no time did the Committee seek to rank one option against another the overall scoring of the options.

*Q2b. Considering that the options offered by the review committee differ drastically in how well they can be defined at this time in terms of costs, technical risk, schedule, and other programmatic specifics, how can this "apples to oranges" situation result in equitable comparisons?*

*A2b.* Since many of the evaluation criteria are not quantitative, the Committee did not intend that the evaluation would generate a single numerical score; rather, it would provide a basis for comparison across options, highlighting the opportunities and challenges associated with each. Assigning weights to individual figures of merit is within the purview of the ultimate decision-makers, not the Committee.

The Committee deliberated at length in public meetings about the advantages and disadvantages of each option with respect to the twelve criteria used in the scoring. Wherever possible, quantitative analytical assessments were utilized to inform the ratings. In the end, however, it was usually necessary to interpret the available information through the considered judgments of the ten members of the Committee, based on their collectively rather extensive and broad experience in space matters.

*Q3. The summary report notes that "human safety . . . is treated as a sine qua non" throughout its report. At the same time, the report states that the review committee "was unconvinced that enough is known about any of the potential high-reliability launcher-plus-capsule systems to distinguish their levels of safety in a meaningful way."*

*We have seen NASA use state-of-the-art methods like Probabilistic Risk Assessment to provide relative safety assessments of numerous launch vehicles that have been studied. What methodology did the review committee use to ascertain the safety levels of the potential alternative human space flight systems discussed in the report, especially given the range of maturity levels of those potential systems?*

*A3.* Several factors contribute to a launch vehicle's risk: the design itself; the extent to which the limitations of that design are understood; the processes and people involved in preparing, launching and operating the vehicle; and "random" component or system failures. Studies of risk associated with different launch vehicles (both human-rated and non-human-rated) reveal that many accidents are a result of poor processes, process lapses, human error, or design flaws. Very few result from so-called random component failures. The often-used Probabilistic Risk Assessment (PRA) is a measure of a launch vehicle's susceptibility to these component or system failures. It provides a useful way to compare the relative risks of mature launch vehicles (in which the design is well understood and processes are in place); it is not as useful a guide as to whether a *new* launch vehicle will fail during operations, especially during its early flights.

The best architecture to assure such safe access would be the combination of a high reliability rocket and a capsule with a launch escape system. As mentioned previously, the Committee was unconvinced that enough is known about the potential failures of any of the prospective high-reliability launchers plus capsule and launch escape systems to distinguish their safety in a meaningful way. The uncertainty in the safety models is large compared to the differences they predict, among competing systems, and it is clear that many of the failure modes observed in practice are not captured in the safety analysis. Thus, the Committee did not "ascertain the safety levels" of the various launchers. We did include in our assessment those launchers that were relatively well defined and met the criteria specified above—a combination of a high-reliability rocket and a capsule with a launch-escape system.

*Q4. Did the review committee consider the extent to which each option could contribute to extending the existing partnership or enabling further international collaboration? If so, how was that assessment done? Did the review committee examine international capabilities and how they could be leveraged to benefit the various options?*

*A4.* Yes. One of the twelve criteria used to assess the integrated options was "Global Partnerships." Global Partnerships was defined as: "provid(ing) the opportunity to strengthen and expand international partnerships in the human space flight program. These would include existing international partners, but should not preclude expansion to new partners, and would allow partners to participate in such a way that their contribution occasionally may be on the critical path to mission success. Participation by other countries will be advantageous not only from the perspective of encouraging global cooperation, but also in terms of creating opportunities for synergistic research, risk reduction and cost-sharing and technology interchange."

*Q5. What cost, scheduled, and human-rating assumptions were used in the development and assessment of options that rely on "commercially provided" crew transportation systems? What prices were assumed for the provision of those services to the government?*

*A5.* See section 5.3 Crew Launch to Low-Earth Orbit of the Committee's Final Report for a full discussion of the cost, schedule, and human-rating assumptions used in the development of the Committee's findings on commercially provided crew transportation systems.

The Committee assumed a recurring cost of $200M per flight for commercial crew transportation services.

*Q6. In considering options that rely on commercial crew transportation services to the space station (post-Shuttle), if the commercial crew capability does not meet NASA's human safety requirements or could not be ready in time to service the ISS, what fall-back alternatives did the Committee assume would be available to access the International Space Station with U.S. astronauts, and how quickly did the Committee assume those alternatives would be available?*

*A6.* The Committee suggested that all new NASA-developed vehicles, including heavy-lift launchers, be designed so that they are *human-ratable,* i.e., could be reasonably human rated at some point in the future. This is a compromise between human rating them at inception and not human-rating them at all. It preserves the option to human rate in the future at lower cost. NASA would benefit from this approach so that it could use its heavy-lift launcher as a backup crew vehicle with Orion, should the commercial providers fail to deliver for any combination of business and/or technical reasons.

The availability of a human-rated heavy-lift launch vehicle depends on the type and configuration of the launch vehicle design and the available funding.

*Q7. The review committee found that the "Investment in a well-designed and adequately funded space technology program is critical to enable progress in exploration." How important is such technology development to the ability to implement the options presented by the review committee?*

*A7.* An adequately funded space technology program was not deemed critical to the implementation of Options 1, 2, or 3 and hence was not included in the content of those options. The technology program was much more important to the successful implementation of Options 4 and 5 and was consequently included in the content of those options. However, none of the options presented by the Committee required a significant technological breakthrough.

*Q8. The summary report states that: "NASA should be given the maximum flexibility possible under the law to establish and manage its systems." What flexibility does the review committee envision NASA needing that the agency does not have today?*

*A8.* There are several examples of this included in the Final Report, including:

- Programs need to be planned, budgeted and executed so that development and operations can proceed in a phased, somewhat overlapping manner.
- NASA should be allowed to reenergize its space technology program and not allow it to be sacrificed for other short-term exigencies.
- The NASA Administrator, who has been assigned responsibility for the management of NASA, needs to be given the authority to manage the organization. This includes the ability to restructure NASA's resources, including its workforce and facilities, to meet mission needs.
- Managers of programs need clear lines of responsibility and associated authority.
- NASA should have the authority to move funds from one human space flight budget line to another, and to obtain new funds earlier than the typical two-year budgetary delay.
- NASA and its human space flight program are in need of stability, having been redirected several times in the last decade.
- NASA should have the ability to allocate work among centers to reflect their legitimate ability to contribute to the tasks to be performed, not simply to maintain a fixed workforce.
- NASA should have the ability to acquire a strengthened systems engineering capability and would be able to encourage, or at least permit, the movement of particularly talented individuals back and forth between government and industry, as was widely done during the Apollo program.

**Questions submitted by Representative Ralph M. Hall**

*Q1. The Committee recommends increasing the current budget by $3 billion per year by 2014, asserting that such an addition would support a viable human exploration program. How did the Committee arrive at $3 billion per year and what is the level of confidence that—even at this higher funding level—NASA would be able to support and sustain a credible human space flight program?*

*A1.* While it was formulating integrated options, the Committee quickly realized that viable options could not be found within the constrained budget. It then examined potential increases in the budget that would enable a sustainable and executable human space flight program. By examining several different potential expenditure profiles, the Committee arrived at this investment level that would provide for the extension of the ISS, allow progress towards exploration beyond LEO, and make an investment in technology. It provided a useful standard by which various options could be compared in a meaningful way.

*Q2. In your oral testimony you said it was your committee's view, ". . . that there should be a compelling reason to change an existing program, and we believe that the existing [Constellation] program, given adequate funds, is executable and would carry out its objectives." About how much additional money would be necessary to execute the current program with the current milestones, including an Ares V heavy-lift capability? How much money would be required, and how should it be allocated, to close the gap?*

*A2.* The Committee did perform an affordability analysis of the current Constellation Program, unconstrained by budget whatsoever. This option contained only two slight variations from the Program, instituted by the Committee: the provision for the Shuttle to be flown out in 2011; and additional funds for the retirement/transition of the ISS in 2016, after withdrawal of U.S. participation at the end of 2015.

As assessed by the Committee, this case delivers Ares I/Orion in late 2016, achieves human lunar return by the early 2020s, and a human-tended lunar outpost a few years later. These are very close to the dates held internally by the Constellation Program. However, the Committee's analysis indicates that in order to achieve the milestones on that schedule, the Program requires in real-year dollars (stated at 65 percent confidence):

- About $145 billion over the period from 2010 to 2020, which is:
  - About $45 billion over the guidance of the President's FY 2010 budget through 2020, and
  - About $17 billion more than what is provided in the "less-constrained budget."
- The expenditures reach $14 billion per year in FY 2016, about $2 billion above the "less-constrained budget" and $5 billion over the FY 2010 budget for that year.
- The expenditures reach over $16 billion per year at their peak in FY 2019, $3 billion above the "less constrained budget" and $7 billion over the FY 2010 budget for that year.

With respect to the gap, if the Shuttle is retired in 2011, the Ares I plus Orion will become available in 2016 or 2017, producing a gap of about five to six years. If the Shuttle is extended, within a fixed budget, the funds that would have paid for the development of the Ares I and Orion will be further limited, and that will delay their availability until late in the 2010s, producing a gap of at least several years at that time. Additionally, the infrastructure changes and workforce transition required for Ares I would be delayed. The gap is not closed, but shifts to the future. The only way to close the gap in U.S. crew launch is to extend the Shuttle to 2015 and to commission a commercial service for transporting crew to low Earth orbit—which, because it is potentially less expensive to develop, may, at some risk, be available by 2016, even with extension of the Shuttle. Other than this scenario, the Committee found no way to close the gap.

Additional funding is required for Shuttle extension. Assuming that many of the current fixed costs must be carried somewhere in the NASA budget, the relevant cost is the marginal cost of flying the Shuttle. There are two factors to consider in estimating this cost. First, if the Shuttle extension is coupled with a strategy to develop a more directly Shuttle-derived heavy-lift vehicle as opposed to the Ares family, there would be synergy that takes maximum advantage of existing infrastructure, design and production capabilities. Second, since the Shuttle would be available to carry crew to and from the ISS, there would be some savings because the

U.S. would not need to purchase Russian Soyuz flights (the present plan), although the necessity of maintaining a crew rescue capability could offset these savings to a degree.

*Q3. Mr. Crawley stated that the development of the Ares and Orion are, ". . . paced by the pace of technical development, that to build a new rocket will take a new human-rated rocket from either where we are in the Ares, or any fresh start of any type will take at least another five or six years." Given the significant progress that the Constellation program has already made, what is the rational for implying that "any fresh start of any type" has an equal chance of being successfully developed in the same time frame as completing the Constellation program?*

*A3.* The original 2005 schedule showed Ares I and Orion available to support ISS in 2012, only two years after scheduled Shuttle retirement. The current schedule maintained by the Constellation Program now shows that date as 2015, but with a relatively low schedule confidence factor and little schedule slack on the critical path. The Committee commissioned the Aerospace Corporation to perform an independent assessment of the technical, budgetary and schedule risk on the Constellation Program. The results of the analysis indicate to the Committee that, under the FY 2010 budget profile, there is likely an additional delay of at least two years, and perhaps as much as four, indicating the Ares I and Orion would not be available until the late 2010's.

Regarding the comparison of the development schedule of the Constellation Program with the other integrated options, the Committee employed the Aerospace Corporation to conduct an affordability analysis, described in detail in the Final Report. This analysis combines the development schedule of all of the elements of the program and outputs key dates, element costs and manifests at the 65 percent confidence level. It also estimates the uncertainty of dates and costs. The Committee then examined the outputs of the affordability analyses, and made interpretations to extract from them the primary information of interest, cognizant of the inherent uncertainty in the analysis. The reporting by the Committee attempts to focus on its interpretation of the key milestones and associated uncertainties, and the cadence of events after the initial milestone.

The Committee examined the technical feasibility of utilizing a commercial service to transport crew to low Earth orbit. First, it is a statement of fact that all of the U.S. crew launch systems built to date have been built by industry for NASA. The system under contemplation is not much more complex than a modern Gemini, which was built by U.S. industry over 40 years ago. It would consist of a three- or four-person crew taxi, launched on a rocket with a launch escape system. It would have an on-orbit life independent of the ISS of only weeks, but potentially be storable at the ISS for months. Such a vehicle would re-enter the Earth's atmosphere from the speed of orbital flight, rather than the significantly higher speed for which Orion is designed. Its smaller size makes possible the option of landing on land, potentially reducing operations cost when compared to a sea landing.

Recently, several aerospace companies began developing new rockets and on-orbit vehicles as part of the commercial cargo delivery program. Several other U.S. companies are contemplating orbital passenger flight. There is little doubt that the U.S. aerospace industry, from historical builders of human spacecraft to the new entrants, has the technical capability to build and operate a crew taxi to low Earth orbit in a timeframe consistent with that assumed by the Committee.

*Q4. In oral testimony you explain that several of the options seek, "to further invest in development in a robust domestic/commercial space industry." Since this would presumably entail a new initiative over-and-above the currently budgeted COTS and the Cargo Re-supply Services contract, how much additional new funding would be required to do this?*

*A4.* Given a properly structured procurement, estimates the Committee received from potential providers for the price of reaching initial demonstration flight of a crew-taxi capsule ranged from $300 million to $1.5 billion. For estimating purposes, the Committee assumed that three contracts were initiated, and one competitor subsequently dropped out, suggesting an expected cost to NASA of between $2 billion and $2.5 billion. In addition, the Committee believes that if a commercial crew program is pursued, NASA should make available to bidders a suitable version of an existing booster with a demonstrated track record of successful flight, adding to the program cost. The best preliminary estimate of the Committee was about a $3 billion program for the fraction of the design, development, test, and evaluation (DDT&E) effort that would be borne by NASA. After multiplying by the historical growth factors and other multipliers associated with 65 percent confidence esti-

mating, the cost carried in the Committee's final estimate of the cost of the program to NASA is about $5 billion.

*Q5. In Dr. Griffin's testimony he believes, "at present, the only clearly available 'commercial' option to lift Orion as designed is the European Ariane 5." The Committee was presented with proposals from United Launch Alliance regarding the use of the American-built Delta 4 heavy. What did the Committee conclude regarding its feasibility? Would it be worthwhile for NASA to further examine Delta 4 heavy as an option for launching Orion?*

*A5.* The DOD (Air Force) has indicated that it is technically feasible to human-rate the EELV systems, as verified for the Committee by an independent Aerospace Corporation study. The Committee has no opinion on whether it would "worthwhile" for NASA to do so.

*Q6. In your oral testimony you said, "our belief is that the net cost of continuing to fly the Shuttle a couple times a year . . . is about $2.5 billion a year." Does that estimate include the cost to restart the closed production lines for the external tanks, and recertify the system? If not, how much additional money would be required? Considering that Ares assumes the use of some Shuttle facilities and infrastructure once the Shuttle is retired, would continuing to fly the Shuttle further delay the development schedule of the Ares and Orion?*

*A6.* The costs to extend the Shuttle to 2015 assumed by the Committee are shown in the following table.

| ($M, Real Year) | FY10 | FY11 | FY12 | FY13 | FY14 | FY15 | FY16 | FY17 | Total |
|---|---|---|---|---|---|---|---|---|---|
| Shuttle Ext. to 2015 | 3300 | 3100 | 2700 | 2700 | 2700 | 2700 | 800 | 200 | 18200 |

The foundational estimate for these costs is based on the data provided by the NASA Sidemount Team—Block 1/2 Sidemount Cost Team Estimate, Space Shuttle Program Assessment Office, July 2009. These estimates include the costs of restarting all necessary production lines and recertifying vendors and the orbiters themselves.

Regarding the question of the effect of extending the Shuttle on the development schedule of the Ares and Orion, the only Integrated Option completed by the Committee that extended the Shuttle was Option 4B. That option assumed commercial crew transportation to LEO, not Ares/Orion. Thus, the effect on Ares/Orion of extending the Shuttle was not determined by the Committee.

**Questions submitted by Chairwoman Gabrielle Giffords**

*Q1. What is the break-down of the $3 billion dollar wedge (on a per year basis if possible) proposed by the review committee and how would the increase be phased in over the five-year period?*

*A1.* See table below.

| | " Constrained" FY 2010 Budget ($B) | "Less Constrained" $3 Billion Augmentation ($B) |
|---|---|---|
| FY 2009 | 8.599 | 8.599 |
| FY 2010 | 9.387 | 9.387 |
| FY 2011 | 9.024 | 9.774 |
| FY 2012 | 8.817 | 10.317 |
| FY 2013 | 8.617 | 10.867 |
| FY 2014 | 8.681 | 11.681 |
| FY 2015 | 8.802 | 11.961 |
| FY 2016 | 8.925 | 12.248 |
| FY 2017 | 9.05 | 12.542 |
| FY 2018 | 9.127 | 12.843 |
| FY 2019 | 9.305 | 13.151 |
| FY 2020 | 9.436 | 13.467 |
| FY 2021 | 9.568 | 13.79 |
| FY 2022 | 9.702 | 14.121 |
| FY 2023 | 9.838 | 14.46 |
| FY 2024 | 9.975 | 14.807 |
| FY 2025 | 10.115 | 15.162 |

*Q2. In your written statement, you described the five integrated options as "representative families, since one can interchange certain elements among the individual alternatives." What do you mean by that statement? Since the options are described as "integrated" and presumably were evaluated on that basis, in what manner do you believe that elements could be interchanged? Given your statement, what is the relevance for Congress of the options that you have included in your summary report?*

*A2.* The Integrated Options were prepared in order to understand the interactions of the five key decisions described in the Summary and Final Reports, particularly with regard to cost and schedule. By formulating the Integrated Options, the Committee did not mean to constrain the possible final decision, but only to inform it. Other reasonable and consistent combinations of the choices are obviously possible (each with its own cost and schedule implications), and these could also be considered as alternatives. The Integrated Options evaluated are intended to be representative of the families of options that exist, yet without presenting an unmanageable number of alternatives. The Committee, in keeping with its charter, expresses no preference among these families, but does discuss the various advantages and disadvantages with respect to the evaluation criteria (without weighing those attributes).

*Q3. The summary report states: "the ISS should be funded to enable it to achieve its full potential: as the Nation's newest national laboratory, as an enhanced test bed for technologies and operations techniques that support exploration, and as a framework that can support expanded international collaboration." What level of funding did the review committee assume was needed for utilization, and was funding for the enhanced utilization included in the $3 billion increase that the Committee state was needed for meaningful exploration? What level of funding was assumed for ISS operations beyond 2015?*

*A3.* For the period FY 2010–2020, the costs associated with utilization in the "enhanced utilization" scenario was $2,077M (Real Year). This amount includes: multi-user system support (MUSS) functions, National Laboratory enabling functions, and expenses associated with conducting productive scientific, technological and industrial research and development (R&D), as well as educational projects designed to stimulate students to pursue careers in science, technology, engineering and math (STEM) for the future. It does not include cargo and crew transportation services. In addition, "enhanced utilization" assumes research investments planned by non-NASA entities under National Laboratory initiative (e.g., NIH, USDA, NSF, private firms and non-profits), and those investments are not included in the number above.

Regarding whether this funding was included in the $3B increase, the Committee did not assume specific budget wedges went with individual cost items. For those options that included enhanced ISS utilization, the costs associated with that were included in the affordability analysis for that option, whether the option was constrained to the FY10 budget profile or used the "less constrained" budget profile.

Regarding the level of funding for ISS operations beyond 2015, the following funding profile includes all functions necessary to safely operate and maintain the ISS in a continuously crewed and payload-operating mode, including: program management; systems engineering, analysis and integration; sustaining engineering of spacecraft elements and distributed systems; mission flight and ground operations; and safety and mission assurance.

| ($M, Real Year) | FY16 | FY17 | FY18 | FY19 | FY20 | Total |
|---|---|---|---|---|---|---|
| System Ops and Maintenance | 1398 | 1316 | 1315 | 1280 | 1228 | 6537 |

*Q4. In developing cost estimates for each of the review committee's options, the Aerospace Corporation used a risk factor of 1.5 based on historical data. Was that factor inclusive of launch system developments or mainly instruments and satellite systems?*

*A4.* The Aerospace Corporation has been involved in numerous past studies identifying the main causes of cost growth and schedule delays in NASA programs and projects. During this independent analysis, Aerospace has compiled a database of NASA missions, including both Human Space Flight and Non-Human Space Flight missions. The database captures cost growth as measured from the formulation phase start (approximately Phase B in NASA terminology), through launch. Projects in the database include: science missions, exploration missions, and there were also a limited number of ground operations projects within the database. The majority of the missions are satellite systems, but launch vehicle development projects are included as well.

On average, the 77 historical NASA Projects (human space flight, non-human space flight, ground operations) included in the database and used for Aerospace's affordability analysis for the Committee demonstrated 51 percent cost growth from formulation start (~Phase B) to launch. Human space flight missions—Gemini, Apollo, Mercury, Space Station and Shuttle—exhibited higher mean cost growth at ~100 percent. While it could be argued that using the ~100 percent cost growth factor is more appropriate for the elements in the Integrated Options because those elements are human space flight projects, the Committee chose to go with the mean historical growth factor of 51 percent which represented the average of a large body of NASA missions, so as not to over-penalize the cost growth effect.

*Q4a. Given that NASA's Constellation program's cost estimates were being held to a 0.65 confidence level, what was the rational for applying an additional 1.5 cost risk factor to the Constellation program's cost estimate?*

*A4a.* On behalf of the Committee, the Aerospace team conducted an affordability analysis on all options using a process that is described in the Final Report. In summary, the analysis outputs key dates, element costs and manifests at the 65 percent confidence level. It also estimates the uncertainty on dates and costs. The affordability analysis corrects the input cost in several ways. First, it estimates a range of expected growth of the cost for each program element from System Design Review (SDR, Start of Phase B) to completion, based on historical data of NASA programs. At the average, this introduces a 51 percent growth from the estimate held at SDR in the cost for development (DDT&E costs). For elements that have not reached their SDR, such as the Ares V or commercial crew service, this full correction was

applied. For elements that have passed their SDR, credit was given for subsequent development and maturity of the design. For example, the mean cost of the Orion in the analysis, due to this factor, is only 25 percent higher than would be reported by the Program of Record at the mean. Other, more mature programs, such as the Ares I, receive credit by a similar process. In operations, a 26 percent growth factor was applied to unproven systems, and no growth factor at the mean was applied to existing systems such as the Shuttle or the ISS, or to defined budget items such as the technology program.

NASA Headquarters asked the Program of Record to report cost and schedule at the 65 percent level, and the Committee attempted to report in a consistent manner. Note that on average, the difference between the mean of expected costs and the 65 percent confidence costs adds about 10 percent to all program costs calculated. Finally, the affordability analysis combines the development schedule of all the elements of the program. This process accounts for the additional cost to one element if another element it depends upon slips in its schedule. This integration of elements typically adds about an additional 10 percent to the total program costs, higher in more-constrained budgets, and lower in less-constrained budgets.

The Committee then examined the outputs of the affordability analyses, and it made interpretations to extract from them the primary information of interest, recognizing the inherent uncertainty in the analysis. The reporting by the Committee attempts to focus on its interpretation of the key milestones and associated uncertainties, and the pace of events after the initial milestone.

*Q4b. Given that the options differed widely in their levels of technical and programmatic maturity, why was the same 1.5 factor applied to Constellation and each of the other options?*

*A4b.* The 1.5 factor was not applied uniformly to Constellation and/or the other options. Cost growth factors were uniquely applied to the options depending on the level of maturity of the systems. See the answer to question 4a above for an explanation of the process the Committee used.

**Questions submitted by Representative Alan Grayson**

*Q1. You commented in your testimony that extending the Space Shuttle is "probably the least disruptive" option "to the ongoing workforce. And it's also the only option that closes the gap."*

*Q1a. Specifically, how would extending the use of the Space Shuttle affect NASA and contractor workforces?*

*A1a.* 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.

*Q1b. What effects would the expiration of the Shuttle have on these workforces?*

*A1b.* The Space Shuttle is currently operated by a skilled workforce of over 12,500 individuals whose experience and expertise in systems engineering, systems integration, inspection, ground operations and assembly, test and checkout, and mission planning and operations have been developed and honed over decades. Once the Shuttle is retired, NASA and its contractors will be forced to shed or reassign much of that workforce due to the length of the gap in human space flight activity. Of these 12,500 workers, 1,500 are civil servants who, under current practices, will likely retain their jobs even though there is no program to which they can easily transition. The jobs in the contractor structure will likely be lost.

*Q1c. What other benefits might option 4(b) offer?*

*A1c.* The use of more Shuttle-derived components lowers the development cost somewhat, and accelerates by about a year the availability of heavy-lift. But, the date of first availability is still in the early 2020s at best, due to budget constraints and likely extension of the ISS. Therefore, even if a Shuttle-derived vehicle is developed, and the Shuttle is extended, there is about a decade of gap in heavy-vehicle operations.

Option 4B also has the benefit of scoring well in the area of "Programmatic Sustainability" because NASA is flying Shuttle missions between 2011 and 2015.

*Q2. Would it be beneficial for NASA to begin planning for funding the Space Shuttle through 2011? Would it make sense for the recipients of task orders, regarding the Shuttle extension, to price out for 2011, knowing that this creates no legal liability to NASA?*

*A2.* Yes, it would be beneficial for NASA to understand the options for funding the Space Shuttle through 2011.

Regarding the question of the pricing of task orders, that question is best posed to NASA as the Committee did not study this issue in any detail.

*Q3. Your review committee presented several options regarding the future of U.S. manned space exploration. Of these options, 4(b) would extend the Space Shuttle through FY 2011. Given the Committee's emphasis on safety, what evidence support option 4(b) as a safe choice?*

*A3.* Although a thorough analysis of Shuttle safety was not part of its charter, the Committee did examine the Shuttle's safety record and reliability, as well as the results of other reviews of these topics. The Shuttle is one of the few launch vehicles that have flown a sufficient number of times to be considered "mature." It has suffered two accidents in its 128 flights, so its demonstrated success rate is 98.4 percent. Considerable effort has also been expended to develop a Probabilistic Risk Assessment for the Shuttle. That PRA shows a reliability of 98.7 percent, with the greatest contributor to risk coming from the threat of micrometeorite or debris damage while in orbit. Other launch vehicles in development have better PRAs, indicating that once they reach maturity, they will carry less risk than the Shuttle. In comparing Shuttle reliability to that of other launch vehicles, however, the most important factor is actual flight experience. The Shuttle completed its first 24 missions successfully before the *Challenger* accident; after returning to flight, it flew successfully 87 times before the *Columbia* accident, and has flown successfully 15 times since. This is not to say that future vehicles will not be more reliable—they likely will be—but the Shuttle has reached a level of maturity that those launch vehicles will not reach for many years.

ANSWERS TO POST-HEARING QUESTIONS

*Responses by Vice Admiral Joseph W. Dyer, USN (Ret.), Chair, Aerospace Safety Advisory Panel, NASA; President, Government & Industrial Robots Division, iRobot Corporation*

**Questions submitted by Chairman Bart Gordon**

*Q1. Your safety panel believes that the Constellation Program or an alternative option, offers a one-time opportunity for safety to be better "hard-wired" into overall NASA processes.*

*Q1a. Can you expand on why you feel this is such a unique opportunity in NASA's history?*

*A1a.* Major programs like Constellation offer a rare opportunity to set a new vector and to evolve the culture of an institution like NASA. The way business is done on the Constellation program offers a chance to build safety into the fabric of NASA's overall engineering and management work processes. A successful integration of safety into the Constellation program would give all of NASA's stakeholder's assurance that safety was integrated into the design from the very start, and not considered as a critical extra, yet separate, requirement.

*Q1b. What does this say about NASA's current institutional focus on safety?*

*A1b.* NASA made significant progress in improving safety following the *Columbia* accident and via implementing recommendations put forth by the CAIB. The safety culture continues to further improve. However, the Constellation program offers the opportunity to accelerate the positive change and to make it a deep and lasting part of NASA's culture because BIG programs like Constellation typically are the birthing place for future leaders. Additionally, new processes and new technologies are derived for and come from major programs. Constellation offers a way to train future NASA leaders in the best safety practices.

*Q2. I understand that your safety panel believes that if Constellation is not the selected option, then any other new design needs to be* "substantially superior to justify starting over."

*Q2a. What evidence would you want from an alternative option to gauge that its safety is* "substantially superior"*?*

*A2a.* We would expect a level of detailed and validated analysis that at least approaches what present in the current NASA program of record. This includes design validation, test, and analysis of the test results. We have yet to see these data from the current funded COTS partners who seemed to be claiming Human Rating.

NASA must seek crew survivability even when the mission fails. The risk of loss of crew should be significantly less than the risk of loss of mission.

*Q2b. In your view, what is the risk of starting over without such substantial difference being clearly identified in advance?*

*A2b.* The risk in starting over without strong confidence that the selected alternative is substantially better is that one arrives at the same point having expended more time and money. Untested alternative plans almost always outshine programs that have undergone deep analysis and significant testing.

*Q3. How concerned should we be that Loss of Crew and Loss of Mission for alternative vehicles were not estimated nor safety estimates verified in the analysis of options by the review committee?*

*A3.* It comes as no surprise that Loss of Crew and Loss of Mission (LOC/LOM) were not estimated nor was concrete safety estimates given for alternative vehicles. Such data requires intensive analysis that is based on specific facts that include actual design and performance information for these vehicles. In the case of the alternative vehicles, this information was either not available or did not exist. Even if this information did exist and was available, the Committee did not have the resources or the time to conduct such an analysis. Therefore, great caution should be exercised with regard to employing alternative vehicles whose LOC/LOM characteristics are unknown in comparison to other vehicles whose design and associated data is far more mature and well defined. A prudent decision in this regard is only possible when comparing "apples to apples."

*Q4. Is a high-reliability launch system equivalent to a high-safety launch system for crew transfer Applications? If not, what additional factors need to be considered?*

*A4.* No, safety depends on much more than just reliability; and, crew safety is far broader than system reliability. NASA must assure crew survivability even after system failure. (This is why we put ejection seats in fighter jets.) The Constellation's abort system is an example of such a system and should be considered an ABSOLUTE requirement in any manned spacecraft.

Even the most reliable rockets that we can make still have a probability of anomaly on any given launch that is unacceptably high for crewed applications. Having inherent robustness and effective safety systems to protect the crew is essential to a Human Rated system.

Robustness and the ability to continue to function even after subsystem failures are also critical to crew safety. Safety approaches such as these are the reason that the Loss of Crew probabilities can be so much lower than the Loss of Mission probabilities.

*Q5. In your prepared statement, you note that* "NASA needs to take a more aggressive role articulating human rating requirements for the COTS Project."

*Q5a. What steps does NASA need to take that it is not already taking to ensure that commercial crew vehicles meet NASA's human rating requirements?*

*A5a.*

1. More than two years into the COTS program, NASA still has not delineated the specific human rating requirements applicable to the NASA-crewed COTS mission. While some within NASA acknowledge their responsibility to define human rating requirements that are necessary to certify the COTS vehicle as "human-rated," others within the Agency continue to delay perhaps out of concern of giving further momentum to COTS vehicle development in lieu of a more traditional NASA approach which they believe to be better and safer.

   The ASAP has expressed some urgency with regard to Human Rating and COTS vehicles. This urgency was communicated in the following recommendation from its 2009 third quarterly meeting: "Recent events make it likely that use of commercial vehicles to transport NASA crews to LEO will occur much sooner than most had planned. While the Panel recognizes that authority and direction to proceed has not yet been formally given to NASA, it also recognizes that systems to meet this need are already under development by COTS vendors. If these systems are ever to provide the level of safety expected for NASA crews, it is imperative that NASA's criteria for safety design of such systems be agreed upon and provided to such COTS enterprises. This issue is becoming more focused and more urgent. Human rating of COTS for the delivery of NASA astronauts into space is now one of the Panel's primary concerns. Recommend that COTS HR requirements be established as soon as possible and promulgated to those that seek to design systems for this future mission."

2. As a minimum, the ASAP believes that NASA should begin a dialogue with the funded COTS partners to address the requirements for human rating. While some efforts have begun to do this, recent ASAP discussions with one of the funded COTS partners indicates that they continue to have a major misunderstanding about the scope of the human rating requirements applicable to the entire mission involving NASA crew transport.

3. Additionally, the funded COTS partners, the Congress and Executive stakeholders should clarify how much or how little they will be involved in the design, certification and operation of the NASA-crewed vehicles in order to verify that the funded COTS partners are compliant with the human rating requirements. For a NASA program, this effort would typically include: determining the adequacy of deliverable products including hazard analyses and risk assessments; evaluating the design at major milestone reviews; and, performing audits and evaluations of the human rating process.

*Q5b. Does the ASAP have specific safety requirements in mind with regards to human rating?*

*A5b.* The ASAP believes that the recently revised NASA human rating requirements provides an excellent baseline for developing human rating requirements for NASA-crewed COTS. NASA Procedural Requirements (NPR) 8705.2B, Human Rat-

ing Requirements for Space Systems, issued May 6, 2008, updated requirements and captured lessons learned applicable to the development and operations of crewed space systems developed by NASA. It is the intent of NASA that this document be tailored specifically for each NASA program. Tailoring of the NPR in developing human rating requirements for NASA-crewed COTS would provide assurance that similarity in developing human-rating programs for a NASA crew on a COTS vehicle and that for a NASA crew on a NASA-developed vehicle would optimally achieve an equivalent level of safety for the NASA crew. The challenge for NASA will be in determining how much engagement with the COTS contractors is required to insure the intent of the NPR is met.

*Q5c. What does the commercial sector need to be willing to do?*

*A5c.* The commercial industry thus far appears to be very supportive and willing to meet the requirements and provide the necessary evidence to show that they are compliant. This said, they must first have a better understanding of what the requirements are, and then they need to incorporate those requirements into the design of their vehicles, including the development of the necessary analyses, assessments, and tests to show that the system is adequately safe for a NASA crew. The longer the delay in achieving an understanding of what the requirements must be, the harder it will be for the funded COTS partners to alter their designs.

**Questions submitted by Representative Ralph M. Hall**

*Q1. Crew safety is a paramount concern. The designs for the Ares and Orion are intended to maximize crew safety. NASA claims that the Ares/Orion will be about 10 times safer than the Shuttle with the probability of loss of crew at 1 in 2850 for Ares/Orion.*

*Q1a. Is this a credible estimate for Ares/Orion?*

*A1a.* The ASAP is not able to answer this question independent of NASA's expertise. However, we have closely observed the quality of the NASA engineers that have performed this analysis. We hold them in highest regard and have faith that they are better schooled and experienced to render such opinion than any others.

*Q1b. Do you believe that any commercial human-rated launch system should be held to the same level of safety?*

*A1b.* If transporting NASA astronauts into space, yes.

*Q2. In your testimony you said that the Aerospace Safety Advisory Panel believes that any proposals to replace the existing Constellation program need* "to be substantially superior to justify starting over." *In your view, do any potential options have substantially superior crew safety?*

*A2.* We have not seen compelling evidence that would indicate potential options are substantially superior.

ANSWERS TO POST-HEARING QUESTIONS

*Responses by Michael D. Griffin, Eminent Scholar and Professor, Mechanical and Aerospace Engineering, University of Alabama, Huntsville*

**Questions submitted by Chairman Bart Gordon**

*Q1. The review committee asserted that a $3 billion per year wedge (reached by FY 2014) added to the President's FY10 exploration funding runout would be sufficient for the alternative human exploration program options identified in its summary report to be carried out on the timetables contained in the report. Do you agree with the review committee's assessment? If not, why not? What would be required to develop credible estimates of cost, schedule, and technical risk for any of the non-Constellation options, and how long would it take to do so?*

*A1.* Broadly speaking, I agree with the review committee's assessment that a sustained increase of some $3B/year in NASA's budget is sufficient to attain worthy goals, including: (1) completion of the ISS, and continued use of that facility past 2015, (2) replacement of the space shuttle with a new crew transportation system, (3) human lunar return and the establishment of a lunar outpost, and 4) development of the technology and systems required for a voyage to Mars. I do not agree that presently-held goals for these accomplishments; e.g., replacement of the shuttle by 2015 or lunar return by 2020, can be achieved by means of a graduated "wedge" in spending to reach the additional $3B. A more abrupt increase is needed if previously planned schedules, or something close to those schedules, is to be achieved. For example, the difference between a five-year ramp to a $3B increase, and an immediate increase, is $7.5B. This is a significant difference in total available funding, at a crucial time. There is presently no funding in the NASA budget for sustained ISS operations past 2015, and NASA's Exploration Systems budgets have already been eroded by some $12B relative to the level provided by the President's budget in 2005. Given these facts, attainment of reasonable schedules (e.g., deployment of Ares/Orion around 2015, return to the Moon soon after 2020) requires an immediate and significant boost in NASA's funding.

*Q2. Based on your experience, what methodology could be used to ascertain the safety levels of the potential alternative human space flight systems discussed in the report, especially given the range of maturity levels of those potential systems? How concerned should we be that Loss of Crew and Loss of Mission were not estimated nor safety estimates verified in the analysis of options by the review committee?*

*A2.* The best methodology available today to assess relative safety levels of potential human space transportation system alternatives is the informed use of probabilistic risk assessment (PRA) techniques. This is a well-established discipline which, when systematically applied, yields conclusions concerning the relative merits of various system approaches that are accepted by the community of practice in system design and safety analysis. The fact that the Augustine Committee chose to ignore entirely the entire discipline of quantitative risk analysis is, in my opinion, unacceptable. Real differences in system performance exist, can be identified, and can be taken into account when comparing alternative systems. These factors have not only a human dimension, involving as they do the potential for determination of the risk levels to which U.S. and international partner astronauts will be exposed, they also have financial implications. Each of the three fatal human space flight accidents this nation has sustained has resulted in collateral damage measured in many billions of dollars—and that is a very conservative estimate. On financial grounds alone, to advocate the development and deployment of a new government space transportation system that fails to incorporate reasonably available safety practices, would be an unsound practice. That the Committee took no note of these issues is a significant concern.

*Q3. What, in your view, are the most significant technologies needed to support any of the alternative options going forward? How mature are those technologies? Do any of those technologies require breakthroughs? Have the technology development risks of the various options been appropriately addressed and compared in the Augustine panel's review?*

*A3.* Regarding the options put forth by the Augustine Committee, certain recommended paths do in fact involve or assume technology which does not presently exist and is unlikely to exist in the timeframe of interest in pursuing those options.

For example, the use of so-called "propellant depots" as an enabling element of space exploration beyond low Earth orbit, is ill-advised. The zero-propellant-boiloff technology required for such depots does not presently exist. This is in fact an important technology, and will be crucial for Mars exploration irrespective of what technique is ultimately employed to reach that planet. But to put the development of that technology in series with human lunar return or other activities short of the first voyage to Mars is unwise.

Similarly, the assumption that there will exist near-term commercial human space transportation capability, and that such presumed capability should guide our plans to support and utilize the ISS, is equally ill-advised. I have no doubt that commercial human space transportation can and will be accomplished, hopefully first by U.S. providers. But until and unless it does, planning for the support of the ISS by means of such capability is, again, unwise.

As another example, the Augustine Committee recommends proceeding forward on a mission to visit a near-Earth asteroid as an alternative to human lunar missions. The clear implication is that such a mission would be easier and cheaper to accomplish than a lunar mission. In point of fact, the contrary is true. Any near-Earth asteroid mission will require in-space stays of at least many months, and maybe a year or more, far from home, with in some cases no option for an early return in the event of problems. The required total energy to reach any known asteroid target substantially exceeds that necessary to reach the Moon, and in many cases exceeds that necessary to reach Mars. There are many aspects of near-Earth asteroids which make them very interesting targets for future human missions; however, such missions are not properly sequenced ahead of lunar missions insofar as their technology readiness is concerned.

In general, I think it may be said that the Augustine Committee offers numerous recommendations and options for which the actual technical readiness required to accomplish them does not exist, or is at a very immature state of development, yet the Committee sets these alternatives forth as if they were on par with existing programs underway at NASA and its contractors.

Finally, I cannot leave this topic without noting that, in my view, the issues facing the U.S. space program in the near future are not primarily issues of technology. They are issues involving the choice of goals, and the resolve to commit the Nation to the path toward those goals, once chosen, for a sufficient period to reach them. At no time was this fact more clearly visible than in the immediate aftermath of the *Columbia* accident, when the lack of long-term strategic planning for the Nation's space program was directly cited by the *Columbia* Accident Investigation Board as a contributory factor to that accident. This was remedied by the enunciation of worthy goals for the program in the *Vision for Space Exploration* by President Bush in 2004, and twice endorsed and enhanced by the Congress in the NASA Authorization Acts of 2005 and 2008. What is needed now is to hold course toward those goals, not the further and continued exploration of various possible goals and various possible means of reaching them, as regrettably exemplified by numerous options put forth by the Augustine Committee.

*Q4. The sustainability of the workforce, critical skills, and industrial base needed to carry out human space flight programs in the future are important considerations in determining the appropriate path forward. What is your view on how Congress should factor in those considerations when choosing among alternatives?*

*A4.* The Nation's human space flight program is, in my opinion, a strategic national asset with regard to the perception and reality of U.S. leadership in the conduct of large technically challenging enterprises at the very edge of human accomplishment, and the creation and sustainment of the industrial base to accomplish such things. In the context of the U.S. industrial base as a whole, even an enterprise on the scale of human space flight—a $10 billion per year effort—is a niche activity. It is an extremely challenging and difficult niche, but a niche just the same, and when such activities are not sustained in a predictable way, their practitioners of necessity find employment in other areas. This occurred during the poorly orchestrated transition between Apollo and Shuttle, and it is happening again as we prepare to retire Shuttle and transition to . . . what? This lack of certainty is devastating to the technical professionals who sustain the space program, and to the many, many third- and fourth-tier contractors who support the program. We are losing those contractors by the day, and the uncertainty as to our future national commitment to a stable human space flight program is making it worse.

*Q5. How, in your view, should international capabilities be leveraged to support human space flight and exploration going forward? What is your view on how*

*the ISS should be used to further the development of international partnerships in support of human exploration?*

*A5.* I think the first point that must be made in regard to "international capabilities" is that they are in fact not *our* capabilities; they are furnished by our partners—at their option—either cooperatively in support of programs which are judged meritorious by those partners, or they are furnished on a contractual basis, for money. The first approach characterizes our relationship with the Canadian, European, and Japanese space agencies on ISS, while the latter properly describes our relationship with the Russian Space Agency. Given these facts, I consider it to be unwise in the extreme to place international partner capabilities in the so-called "critical path" toward key national goals. Thus, if it is important to the United States to maintain clear preeminence in space exploration and exploitation, to be a clear leader among nations in this area—and I believe that it should be—then the ability to reach low Earth orbit without our own national systems should never be "offered up" for international cooperation. Similarly, the next step—the ability to again reach the surface of the Moon on our own terms—is not appropriately sacrificed to the demands of partnership. We should wish our partners well in the development of their own such capabilities, should they wish to develop them. But we should give ours away. Thus, international partnerships should be negotiated and arranged on our part with a view toward expanding and enhancing the space enterprises in which we engage, but not in a manner that allows others to control whether they are possible at all.

The ISS is key to the future of long-term human space exploration—i.e., beyond the Moon—in two ways: understanding human physiological requirements for space flight and finding ways to meet them, and developing systems capable of sustaining human presence in space for the length of time necessary for a voyage to Mars. If we didn't have a space station, we would need one to meet these objectives. These questions will not be answered by 2015, or 2020, or any date certain. For this reason, the ISS should be sustained and supported by the Congress as long as it is practical and reasonable to do so.

**Questions submitted by Representative Ralph M. Hall**

*Q1. Dr. Griffin, the review committee report suggests that now is the time to consider using commercial services for delivery of cargo and crew to low Earth orbit. With regard to crew, you appeared to take strong exception to that assumption. Why do you feel so strongly that the U.S. must have a government developed and government owned capability to deliver humans to space?*

*A1.* I take "strong exception" to that assumption because the most casual glance at the overall U.S. aerospace industry reveals that, at present, the capability to provide commercial service to the International Space Station for either cargo or crew. The former will likely be available within several years, assuming that we extend the planned lifetime of the ISS so as to make commercial investments in such capability a reasonable proposition. Crew capability will mature some years after that; it is simply not consistent with 50+ years of space flight history to suggest that new, entrepreneurial firms seeking to develop commercial human space flight capability will successfully do so in the near-term.

Now, I am one who believes that the U.S. Government should take all reasonable steps, as a matter of policy, to aid in the establishment commercial space transportation services for both cargo and crew. Appropriate incentives could include guaranteed "anchor tenancy" markets when capability is demonstrated, tax incentives, small amounts of "seed" capital, and other inducements for private investors. However, such incentives should not go so far as to include a plan to hold ISS support, resupply, and utilization hostage to the appearance—or the lack thereof—of commercial space transportation services. That is foolhardy.

If we believe, as I do, that space transportation in general and human space flight in particular is a valuable strategic asset for the United States, then it is essential that this asset be preserved and protected. It becomes a responsibility of the U.S. Government to insure that it continues to exist, to provide, protect, and promote it by various means. One of the means is the fostering of the presently nascent commercial industry; another is to ensure that government capability to accomplish the mission is always available.

*Q2. Assuming that we fly the International Space Station until 2020 or later, and NASA is able to get a budget increase similar to the $3 billion per year that Mr. Augustine's panel recommended; when in your opinion could NASA deliver*

*the Constellation system (Ares I and Orion) to support the Space Station, and when would we be able to return to the Moon?*

*A2.* If NASA receives a $3B increase as recommended by the Augustine Committee, and a substantial amount of this money is made available immediately, then I believe that Ares I/Orion can be kept on track to deliver crew and cargo to ISS in 2015, and human lunar return can be accomplished by the early 2020s.

**Questions submitted by Chairwoman Gabrielle Giffords**

*Q1. What do you mean by "commercial" space flight? What was your intention (given that definition) in establishing COTS, and how do you think government should involve "commercial space" in future plans?*

*A1.* By "commercial" space flight, I adhere to the conventional use of the term with regard to commercial industry, business practices, etc. A "commercial" space flight enterprise would be one in which the founders and owners of that enterprise develop a business plan to furnish cargo/crew transportation service to low Earth orbit, raise funding from private capital sources (possibly with some small amount of government "seed money") to support that plan, complete their product development, demonstrate that it works, and then offer service to government and other industry customers. A commercial space flight enterprise is NOT one in which the government is asked to provide billions of dollars on the front end in order to initiate the development. My intention in putting for the COTS program as NASA Administrator was to provide the "seed funding" mentioned above; in my own opinion, such seed funding should rightly be no more than five percent or so of the likely total to be needed. If the enterprise is to be "commercial," then the money at risk must be largely private funding.

It must be understood that I offer no objection to the expenditure of government funds through traditional negotiated contracts ("prime contracts," in the jargon of the business) for the development of government space transportation capability. To the contrary, I strongly advocate that we do just that, *whether or not* commercial capability is brought into being. Government space transportation is a strategic asset for our nation; it's existence should not depend upon whether or not commercial providers also exist, any more than we eschew the use of government aircraft merely because private alternatives exist.

However, I must make the key point that in the above case, such negotiated contracts are hardly of a "commercial" nature. To label a new, entrepreneurial space flight enterprise "commercial" simply because it is not a traditional large prime contractor is to misuse the term completely.

When and as commercial space flight capability does come into being, I believe it should be the policy of the U.S. Government to use it to the maximum extent possible, consistent with basic guidelines including standards on safety, economics, and maintenance of strategic government capability.

*Q2. In your written statement, you state that Ares I and Orion should be completed as quickly as possible to support ISS, and then Ares V should be built. You indicate that they should not all be done in parallel because that would cause them to stretch out and cost more in the long run. The Augustine panel's summary report asserts that funding the program of record (not including an extension of ISS) would enable Ares I/Orion in FY 2017 and a return of humans to the Moon by the mid-2020s. Do you agree with the review committee's assessment, and if not, why not?*

*A2.* If the money suggested by the Augustine Committee is restored to NASA, then I believe Ares I/Orion could still be delivered by 2015. I believe the cost and schedule estimates produced by Aerospace Corporation for the Augustine Committee were conservatively biased; without such biases, the competing alternatives offered by the Committee would not look so favorable. The Augustine Committee report makes a clear effort to treat all options "equally," in some sense. However, all options are not in fact equal. Constellation cost and schedule estimates have some four years of maturity and refinement underlying them. The other alternatives discussed by the Committee have no such maturity, and in some cases are merely ideas. Yet, all are presented as if they are equally suitable as potential future alternatives.

*Q3. What accounts for the apparent discrepancy between NASA's Constellation program cost and schedule estimates and those developed by the Aerospace Corporation for the Augustine review committee? How can Congress resolve that discrepancy?*

*A3.* The Augustine Committee cost estimates, performed by The Aerospace Corporation, are exceptionally conservative. This was done, as best I can determine from outside the deliberations of the Committee, because arbitrary cost and schedule growth factors were applied to all options considered by the Committee. It is my understanding that a 50 percent growth factor was applied to NASA cost estimates. However, what the Committee apparently did not understand, or did not credit, was that conservative growth factors were already incorporated into NASA's estimates, which were professionally performed in accordance with the accepted state-of-the-art. The "bottom line" is that there was clear evidence of "double counting" the cost reserve for NASA programs, which makes the Constellation option appear unfavorable in comparison to others.

Numerous contractors exist with the capability to do state-of-the-art cost estimation. That expertise can be brought to this task, and a new, independent assessment of Constellation costs developed. However, NASA is a government agency; one does not properly hire contractors to review and judge the work of government agencies. In any case, much of NASA's cost estimation work has involved the use of external contractors reporting to NASA managers, so it could be difficult to obtain a new cost estimate for the Constellation Program without relying upon contractor personnel who already have a vested interest in the outcome. Nonetheless, if the necessary independence can be assured, a new estimate can be developed for comparison to NASA's estimate.

*Q4. What information does Congress and the White House need to adequately evaluate the Constellation program versus the other options offered in the summary report? In light of the sketchy schedules, low fidelity of cost estimates of options, and uncertainty of relative risks provided so far, other than for the current Constellation program, how can Congress go about comparing the risks, costs, and safety of each option in a meaningful manner? In your view, which exploration strategy currently is the lowest risk with regards to projected costs, technical risk, and ability to meet schedules, assuming resources are matched to the tasks?*

*A4.* In my view, Congress and the White House must trust NASA, as a government agency, to furnish to Congress the information necessary to make decisions as to the Nation's forward path in human space flight. I believe that NASA has furnished faithful estimates as to the resources required to complete the Constellation program, and can adequately assess the potential utility of other options, if asked to do so. If the Nation did not have NASA to manage the publicly-funded space program of the United States, one would have to create an entity to do so. That entity would be subject to the same criticisms by many and various self-interested parties as has been NASA. That would not change the fact that the U.S. Government must have such an entity to make decisions as to the allocation of public funds in support of national space goals. NASA is that entity today, and the agency should receive the support of Congress in making and adhering to difficult decisions.

In my view, the Constellation Program as presently envisioned offers the safest, lowest cost, lowest technical risk, most certain technical path toward the goals enunciated for NASA by the *NASA Authorization Act of 2005,* and renewed by the Congress in 2008. These goals—to finish the ISS, to retire the Shuttle and replace it with a new and safer system for human access to low orbit, to return to the Moon, to establish the capability for a permanent outpost on that body, and to prepare the way for later voyages to Mars—are the proper goals for our space program, and should be retained and supported by the Congress.

*Q5. The Augustine review committee's Flexible Path option envisions excursions to multiple destinations in the solar system. How does the Flexible Path's multi-destination approach compare to that of the Constellation program? What was the reason for selecting the Moon as the initial destination under the Constellation-enabled architecture?*

*A5.* It is not fully or widely appreciated that Constellation *is* a "multi-destination" architecture. The Constellation system can reach every destination—the Moon, near-Earth asteroids, Lagrange points, Martian moons, and Mars itself—which has been offered up as a possibility in the so-called "Flexible Path." The so-called "Flexible Path" option is a thinly-veiled attempt to bypass the Moon as a near-term exploration destination, primarily to save the money required to build a lunar lander and support a future lunar base. It is an attempt to claim a great, forward-looking space program, without actually have to pay for it. The so-called "Flexible Path" is actually less "flexible" than Constellation, because it will not (if put into place) enable a human lunar return in the near-term.

It is also not widely understood that NASA did not "select" the Moon as the initial Constellation destination. The Moon as a destination was recommended by Presi-

dent Bush in the initial *Vision for Space Exploration* in 2004, and ratified, twice, by the Congress in 2005 and 2008. In designing the initial elements of Constellation to go first to the Moon, NASA is carrying out its instructions, not self-generating them.

With that said, I believe that in fact the Moon is the proper initial post-ISS destination. The Moon is proving to be a most interesting place, scientifically, based on the returns from a spate of recent robotic missions to that body. The Moon is the closest destination available to us; we can learn how to venture in deep space for long periods of time, and live off-planet, while remaining only three days from home in the event of an emergency. The Moon is far easier to reach, on far a more regular schedule, than any of the near-Earth asteroids. The Moon is much easier to reach than the moons of Mars, which themselves can be more difficult to reach than the Martian surface itself. By utilizing the ISS and the Moon, we will develop the technology and experience to voyage, later, to all of these other destinations and many more. But the Moon comes first, in my view.

# Appendix 2:

## Additional Material for the Record

AEROSPACE
*Assuring Space Mission Success*

Gary P. Pulliam
Vice President

The Aerospace Corporation
Civil and Commercial Operation
1000 Wilson Blvd., Suite 2600
Arlington, VA 22209-3090
703.812.612

CORPORATE OFFICES:
2310 E. El Segundo Blvd.
El Segundo, CA 90245-4609
310.336-0098

www.aero.org

March 19, 2010

The Honorable Gabrielle Giffords
Chairwoman
Subcommittee on Space and Aeronautics
Committee on Science and Technology
2320 Rayburn House Office Building
Washington, DC 20515

Dear Madam Chairwoman,

The Aerospace Corporation is pleased to submit responses to questions from the Committee on Science and Technology regarding our support to the Review of U.S. Human Space Flight Plans Committee (the Committee.)

Your letter requested responses related to our analyses performed in support of the Committee, and we have answered in that context. In several areas of questioning, the Committee did not task Aerospace. In some areas, Aerospace has previously performed related studies or analyses for NASA. We are always available to discuss these studies with the committee if desired.

The Committee hired Aerospace to provide technical analyses as directed. We were participants in committee activities only when receiving tasks, discussing ongoing analyses and delivering our products to the Committee. We acknowledge that the Committee received information not known to Aerospace.

Several questions inquire about dates, schedules and costs, and specifically which Committee member directed Aerospace in these matters. The Committee designated Mr. Bo Bejmuk and Dr. Ed Crawley as the two liaisons between the Committee and Aerospace. All tasking was received and executed within this framework. We respond in more detail to specific questions in our responses.

We respectfully submit our responses to the committee. We stand ready to assist the committee in any way possible as you work toward developing the way ahead for NASA.

Sincerely,

Gary P. Pulliam

AEROSPACE
Assuring Space Mission Success

# Responses to
# The Committee on Science and Technology
# Provided by
# The Aerospace Corporation
# March 19, 2010

AEROSPACE
*Assuring Space Mission Success*

**Question 1. The report of the Review of U.S. Human Spaceflight Plans Committee ["Augustine report"] states on page 70 that the Committee estimated that the design, development, test, and evaluation (DDT&E) cost to NASA is $3 billion for a program involving two commercial crew competitors and a NASA-provided "suitable version of an existing booster with a demonstrated track record of successful flight." It then goes on to say that "After multiplying by the historical growth factors and other multipliers associated with 65 percent confidence estimating (as will be discussed in Section 6.3), the cost carried in the Committee's final estimate of the cost of the program to NASA is about $5 billion"**

**a. The validity of the Committee's "final estimate" of $5 billion for commercial crew that was developed by applying historical growth factors and other multipliers to the $3 billion estimate is clearly greatly dependent on the reasonableness of the underlying $3 billion cost estimate to which the correction factors are applied. What was the source of the $3 billion estimate? Did it include all ground support/infrastructure costs? Did Aerospace independently develop or examine the basis for the $3 billion initial estimate for two commercial crew competitors and "suitable version of an existing booster with a demonstrated track record of successful flight"? If not, from where did Aerospace get the cost estimate? If it was from the Augustine panel, who on the panel directed Aerospace to use the $3 billion cost estimate in its subsequent analyses?**

The Aerospace Corporation ("Aerospace") realizes there is considerable discussion around the "$3 billion" figure for a commercial transport capability, and we appreciate you inquiring about our role and perspective. As stated in the question, the Review of U.S. Spaceflight Plans Committee ("the Committee") stated on page 70 their assumption that "NASA should make available to bidders a suitable version of an existing booster with a demonstrated track record of successful flight, adding to the program cost."

Importantly, the Committee also stated on page 70 "The Committee then estimated the cost to NASA of creating an incentive for industry to develop the commercial crew transport capability for crew. This would probably be a significant fraction, but not the entirety of the cost of such a development."

This is the guidance the Committee gave to Aerospace: $3 billion would be carried in our affordability analyses as NASA's portion of the development. Aerospace did not independently develop the basis for the $3B initial estimate. The Committee did not ask Aerospace to independently verify the $3 billion figure. In fact, no verification could be performed given the Committee's statement that this dollar amount was simply NASA's portion of the total cost. Our role, as explicitly outlined in our task statement, was in some cases to develop our own estimates for certain elements where we were asked and qualified to perform the estimate, and in other cases to accept numbers from the Committee itself and/or the NASA analysis team. No traditional independent cost or independent schedule estimates were performed. Aerospace was not privy to all of the background material on the cost of commercially provided services which was provided in closed fact finding sessions to the Committee. In each case, we would seek to understand what was included in the estimate to assure there were no gross omissions or "double booking" and to uniformly apply historical cost growth factors to the NASA portions.

Specifically, the Committee's direction to Aerospace was that the $3 billion figure would include development of the capsule and launch abort system. An additional $400M, including $200M

AEROSPACE
Assuring Space Mission Success

(FY09) for a demonstrator flight and $200M (FY09) was allocated for minor modifications and integration to an existing launch vehicle with a demonstrated record of successful flight.

To our knowledge, this $3B estimate did not include all ground support/infrastructure costs. However, it was acknowledged by the Committee that these costs would be contractor/concep specific, and might be covered by other budget wedges present within a given integrated optic affordability analysis. Also, facilities might be modified or made available to commercial contractors as part of a transition budget line, and then amortized across some number of fligh during commercial operation. After including the $400M described above for a total estimate o $3.4M, Aerospace applied historical cost growth in the same manner as applied to other NASA developments. The Committee's final estimate of the cost of the program to NASA was approximately $5 billion. It was assumed that additional private investment funding would be required to complete the DDT&E.

As Aerospace developed and refined our affordability analyses of various Committee options, the Committee formed a working group of four members: Dr. Crawley, Dr. Ride, Mr. Bejmuk ar Mr. Greason. This working group performed fact finding which provided specific assumptions and ground rules for our affordability analyses. Direction to use the $3 billion figure came to u from Dr. Crawley, who was the lead for the working group; however, the figure was consistentl reiterated by all members of the working group when Aerospace interacted with them during th course of our analyses.

**b. The Augustine report states on page 71 that "The Committee considered other factor that would support this estimate of the incentive cost to NASA. If this is to be a commercial venture, at least some commercial capital must be at risk. Alternate source of capital, including private and corporate investment, would be expected." What was th percentage of the commercial crew development cost that was assumed to be paid for with non-government funds? Did Aerospace independently determine or validate that percentage? If not, what was the source of the percentage, and what is Aerospace's lev of confidence in that percentage estimate?**

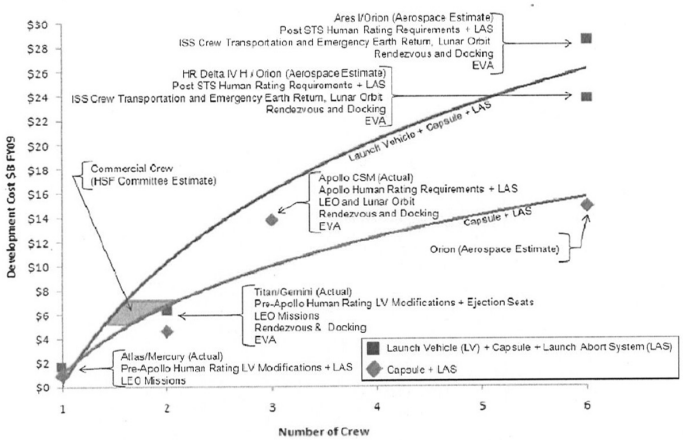
The Committee assumed alternate sources of capital would be expected for the commercial crew development. While we engaged in detailed discussions about the $3 billion figure to be included in our affordability analyses, we did not receive any information about the Committee' view of the percentage required from alternate sources. It is possible the Committee received inputs from other sources not involving Aerospace's analyses. Aerospace is currently performing a business case analysis to address this key issue; however, that work is not yet complete.

**c. Has Aerospace done any analyses to try to estimate the DDT&E cost of a commercial crew transport system? If so, what is the range of costs that Aerospace has come up with at the 65% confidence level for one or more such systems?**

Aerospace has not performed a thorough, independent analysis to estimate the DDT&E cost of a commercial crew transport system. Aerospace did perform a comparison of the Committee cost estimate for the commercial crew system to historical programs as a cross-check on the existence of such a system in this cost range. The figure below shows actual and estimated development cost as a function of crew size for a range of capsule-based crew vehicles and launch vehicles, including Mercury, Gemini, the Apollo Command and Service Module (CSM),

AEROSPACE
*Assuring Space Mission Success*

Orion, Ares I/Orion, and Human Rated Delta IV H / Orion [Note: some of these specific examples for which Aerospace developed estimates will be discussed in later sections]. The lower curve (green) illustrates the cost per crew for the capsule and launch abort system (LAS) only. The upper curve (blue) includes the development cost of the launch vehicle. In the case of Mercury, Gemini, and Delta IV H, the launch vehicle costs are for modifications to existing vehicles to meet the definition for human rating in the era in which they were developed. The estimates for Delta IV H, Ares I, and Orion are for a 65th percentile confidence. In general, as the number of crew increases, the systems become more capable in terms of the degree of human rating, mission performance, and other critical capabilities such as rendezvous and docking and Extravehicular Activity (EVA).




For the purposes of illustration, the range of development costs associated with a commercial crew system is assumed to start at the $5B NASA contribution used by the Committee, and extend upward with an assumed commercial investment in these systems. The use of those resources, and a government acquisition approach from the Mercury–Gemini era, suggests that a single transportation system can be developed to transport a crew size of 1-2 to low Earth orbit (LEO). Gemini is the closest historical program to the commercial crew capsule. While we have chosen to plot development cost vs. crew size, the complexity of the system is a function of human-rating requirements, destination and capability including rendezvous and docking, EVA, etc. We would therefore caution against assuming that a 4-crew capsule would necessarily cost in excess of $12B as these other factors would come into play.

The Committee assumed that two commercial crew systems could be developed (starting with three competitors and down-selecting to two successful developments), within this range of resources, using modern commercial acquisition practices.

AEROSPACE
Assuring Space Mission Success

**d. What would be the likely impact of using the range of costs identified in (c) on the options contained in the Augustine report that assume the use of commercial crew transport services to low Earth orbit? What would be the impact on the costs and timetables associated with those options?**

As Aerospace developed our affordability options, we consistently stated that detailed assessments, estimates, and analyses would be required prior to implementing any new option. We also made these same points in our public presentations. However, the Committee did not ask us to determine likely impacts of identified costs and schedules for the commercial crew concept.

The Committee provided an estimated date of 2016 when a commercial crew capability would become available. If this capability were not available by this date, the backup plan was to continue to procure Russian Soyuz's until the commercial crew capability became available. The commercial crew concept relied on private investment to complete DDT&E and amortize fixed costs during operations to meet a price target. Other Orion-based architectures would not involve cost sharing arrangements, and as a government developed, owned and operated system, the government would incur the full burden of cost growth based on historical factors.

**e. Has Aerospace performed any assessment or analysis of the total DDT&E cost of a human-rated EELV architecture, including the impact of Ares I close-out costs? If so, what did Aerospace determine the cost to be? Does that include the cost of a dedicated EELV launch pad and other ground support infrastructure, or is it assumed that an existing launch pad will be shared between commercial crew operations and national security/civil launch operations?**

In a series of studies performed for NASA that predate the Augustine Committee, Aerospace developed DDT&E costs and lifecycle cost estimates for several human-rated (HR) Delta IV H launch vehicle configurations. Delta IV H was representative of a general class of human-rated Evolved Expendable Launch Vehicle (EELV) launch vehicles. Aerospace was asked to estimate costs to substitute an EELV for Ares I within an Ares I/Ares V architecture. The fact that Ares V was the envisioned end state levied constraints on what options could be considered. Depending on the configuration, DDT&E costs to human rate the Delta IV H range from approximately $5B FY09 to approximately $9B FY09, (65$^{th}$ percentile confidence) not including ground infrastructure development (either new or modified existing) costs. Ground infrastructure development costs were estimated at approximately $2.3B FY09. Aerospace estimated the Ares I contract close-out and contract transition costs to be approximately 0.3 $B FY09. These estimates assumed a conservative interpretation of NASA's human-rating requirements in order to be comparable to Ares I. Furthermore, the launch vehicle and upper stage were sized to lift the fully capable Orion and make maximum use of existing NASA developments including upper stage, test facilities, and Orion avionics. The launch vehicle itself was modified to increase redundancy and margins.

These assumptions are not on a par with what the Committee assumed for "commercial crew" in terms of performance and capability. Most importantly, the Committee assumed the utilization of an existing launch vehicle with flight performance history, whereas the Aerospace EELV studies assumed the launch vehicle would be modified, and a new or modified upper stage would be built.

AEROSPACE
Assuring Space Mission Success

None of the options examined assumed that an existing launch pad would be shared between commercial crew operations and national security/civil launch operations. It was assumed that EELV would leverage the existing launch pad infrastructure planned for Ares I.

**f. In the absence of program management milestones that are used to track development progress and costs, did Aerospace assume proxy activities would be used by NASA to track DDT&E progress by potential commercial crew transportation service providers? What were these proxy activities and was the cost of implementing them by NASA included?**

For the commercial crew transportation services, it was assumed that the COTS A-C activities and milestones were accomplished, and the resultant operational capabilities would be realized as currently planned by NASA. The Committee assumed a one-time $200M investment from NASA to augment the COTS A-C development activities. The commercial crew activities were assumed to be initiated with COTS-D as an open competition that would draw in not only the contractors performing COTS A-C but larger, established aerospace industry contractors. Aerospace made no assumptions regarding program management milestones or proxy activities.

**g. What did the analyses in the Augustine report assume would be the per seat cost and price for the commercial crew transport services included in the options? What was the source of the per-seat cost and price estimates?**

The Committee provided the commercial crew transport service assumptions that assumed a price of $200M FY09 per flight at a rate of 2 flights per year. Using a historical cost growth factor for operational systems, Aerospace increased the cost per flight to $250M FY09. The Committee did not define the crew capacity of the commercial crew vehicle. Based on the 2 Gemini-class crew module discussed above (see question 1c.), the cost per seat would be on the order of $125M FY09 but would vary with crew size.

**h. What size non-NASA market and what non-NASA flight rate were assumed in the per-seat cost and price estimates and resulting cost to the government, and what was the basis of the non-NASA market size and flight rate estimates? Did Aerospace make use of market projections, and if so, who provided those market projections?**

Aerospace was not privy to non-NASA market information the Committee might have received other than what was presented in public sessions. We did not see or review any market projections or flight rate estimates during our support of the Committee. To our knowledge, the Committee received testimony from prospective customers that there is a market for commercial crew transportation to LEO for non-NASA purposes if the price is low enough and safety robust enough. The Committee also received testimony from prospective providers that it is technically possible to provide a commercially viable price on a marginal cost basis, given a developed system.

AEROSPACE
Assuring Space Mission Success

**i. How many competing commercial crew transport systems were assumed to be supported/used in parallel by the government in the options costed by the Augustine panel?**

For estimating purposes, the Committee assumed that three contracts were initiated, and one competitor subsequently dropped out.

**j. In the Augustine report, what was the total annual cost [from development phase through steady-state operations phase] to the government of the commercial crew transport services included in the options, and what was the source of that cost estimate? Did Aerospace independently validate that cost estimate?**

Many of the integrated options incorporated a commercial crew to LEO capability. The Committee defined the NASA costs for the commercial crew transport service to be $3B FY09 DDT&E, with some unspecified amount of private investment to supplement DDT&E and/or ground infrastructure development, along with a $200M FY09 per launch cost. Using historical cost growth factors, Aerospace increased the $3B to approximately $5B, and the $400M per year for operations to the International Space Station was increased to $500M (2 launches).

The total annual cost to the government for commercial crew was based on the affordability analysis on the integrated options provided by the Committee. The $5B allocated for development was spread over 5 years with approximately $1.5B in the peak funding year. The total annual cost during operations was $0.5B per year for two flights per year.

As we stated in our response to question 1c, Aerospace did not independently validate the Committee cost estimate, as our operating parameters stated that other sources of capital would be available to the commercial providers. We did, however, perform a comparison of the Committee cost estimate for the commercial crew system to historical programs as an existence proof of the potential for a system in this cost range.

**k. What characteristics were assumed for the commercial crew transport services included in the options—e.g., how many seats for U.S. astronauts per vehicle, how many flights per year, were the flights carrying NASA astronauts dedicated solely to government crew transfer operations, were the vehicles assumed to be reusable or not, and were the vehicles assumed to meet the International Space Station crew rescue stay-time and performance requirements? What infrastructure was assumed to be provided/maintained by the government?**

The Committee provided the commercial crew transport service assumption of a rate of 2 flights per year. Explicit assumptions of reusability were not provided. There was no assumption made whether the crew capsule was reusable.

The capsule described by the Committee is a crew "taxi." It takes a crew up to the International Space Station (ISS), or other LEO destinations, and potentially a different crew down to Earth. It is not required to provide long on-orbit storage, leave the LEO environment, provide the higher lift to drag (L/D) ratio needed for superorbital reentry (e.g., lunar return), provide habitat volume,

or provide other accommodations for long duration missions. It would have an on-orbit life independent of the ISS of days to weeks, but potentially be storable at the ISS for months. Other characteristics of the commercial crew transport services envisioned by the Committee such as the manner in which crew were manifested on flights, performance requirements, and infrastructure assumptions were not known to Aerospace.

We operated with the assumption that the "crew taxi" would have the capability to ferry 2-4 astronauts to/from ISS. The uncertainty in number of crew was to allow the maximum number of launch vehicle/capsule combinations to be considered, and not preclude offers at different price and capability points. There was no assumption provided regarding commercial pilots relative to civil servant passengers. The vehicle would fly twice per year at the $200M FY09 per vehicle ($250M with cost growth factor applied) for a total of $500M per year. If the number of seats was on the low end of the range (i.e., 2 crew instead of 4), this would clearly have implications for the number of vehicles that would be required to meet a static requirement and might require more frequent flights of a smaller (but perhaps less costly vehicle).

**Question 2. On page 71, the Augustine report states that "a [commercial crew] capability in 2016 could be estimated with reasonable confidence." Was that schedule estimate independently developed or validated by Aerospace or was Aerospace simply directed to use it in subsequent analyses? If the latter, who was the source of the estimate and what was the basis of the estimate?**

The Committee provided the schedule estimate for the commercial crew scenario as an input assumption, which was then used for the subsequent affordability analyses. As Aerospace developed and refined our affordability analyses of various Committee options, the Committee formed a working group, that performed fact finding and provided specific assumptions and ground rules for our affordability analyses. Dr. Crawley, as the lead of the working group, gave this information to Aerospace. Estimates to the Committee from providers ranged from three years to five years. This produced a start in early FY2011, assuming a year for program realignment.

Aerospace did not independently develop or verify the schedule estimate for the commercial crew capability.

**Question 3. Has Aerospace performed any analysis or assessment of the length of time it would take to develop, demonstrate, and contract for an operational commercial crew transport service for use by U.S. government astronauts? If so, what was the result of that assessment? What would be the impact of using that schedule estimate in the analysis of the options included in the Augustine report?**

Aerospace has not performed any analysis or assessment of the length of time it would take to develop, demonstrate, and contract for an operational commercial crew transport service. Aerospace examined the development time associated with human rating the Delta IV H launch vehicle and ground system. In that case, the ground processing and launch infrastructure was the critical path item with a 5-7 year development period, but the human rating modifications for the launch vehicle were close behind. If initiated this year, these estimates are consistent with an operational ground processing and launch infrastructure for commercial crew in the 2016 time frame.

AEROSPACE
*Assuring Space Mission Success*

**Question 4. What are the acquisition-related steps that would need to be followed by the government in the development and procurement of as-yet-to-be-developed commercial crew transport services, e.g., development of a COTS-like demonstration program; COTS RFP preparation and release; competition for COTS awards; negotiation of COTS agreements; DDT&E phase; demonstration phase; RFP preparation and release for commercial crew transport contracts; contract competition, award, negotiation, potential protest resolution, etc.; and certification for operations involving U.S. astronauts before commencing commercial crew transport services to the International Space Station? Historically, how long has it taken to complete such acquisition steps in the development of new aerospace systems to be used by the government?**

This is a critical question. While we raised these questions in the development of our work for the Committee, we were not tasked to develop this analysis. Subsequent to the release of the Committee Report, we have met with the NASA Administrator and key staff to discuss these issues. To our knowledge, NASA is currently evaluating these steps. Based on Aerospace's prior experiences on a wide range of government acquisition activities, the acquisition-related steps are numerous, and include such steps as described in the Question 4 above. These steps typically take on the order of many months.

**Question 5. What role did Aerospace play in the development and analysis of the options contained in the Augustine report? For example, did Aerospace develop all of the assumptions and input data for the different options or were there circumstances under which you were directed to use specific input data or assumptions by members of the Augustine panel? If the latter, what specific input data or assumptions was Aerospace directed to use by panel members and in each case who directed you to use them? Did Aerospace independently validate those input data or assumptions?**

Aerospace had no role in the development of Committee options, nor were we present when they were developed. The Committee passed new options to us for affordability analyses as they developed them. A large and diverse NASA and Aerospace team supported the discussions of the ground rules and assumptions for each of the options.

The input data for the options came from a variety of sources. Costs for the various elements were generated by combining data from the Constellation Program (PMR09 and PMR08 Rev1B data) with analogies and additional NASA or Aerospace data sources, when available, to inform the cost data and assumptions for systems that deviated substantially from the Constellation Program.

Our role was to integrate inputs from multiple sources and assure consistent treatment of all elements throughout the assessment process. Aerospace evaluated the manifest for a given integrated option architecture to assure that the number, type, phasing, and size of vehicles were appropriate for the stated mission objectives and destinations. Costs for government-developed systems were benchmarked against data that Aerospace and/or the NASA analysis team had access to. Aerospace used analysis products from studies performed to answer earlier Committee questions on the Constellation Program, International Space Station (ISS), and launch vehicle concepts to cross-check the Committee inputs. The EELV human-rating studies, which pre-date the Augustine Committee, were used as appropriate to estimate EELV-based architectures and capture infrastructure and industrial base maintenance costs. NASA estimated shut down and transition costs were included as appropriate.

AEROSPACE
*Assuring Space Mission Success*

**Question 6. What is required to be able to proceed to carry out any of the options included in the Augustine report with a high confidence level understanding of its cost and schedule? Given the time and resource constraints that Aerospace faced, what is the difference between what Aerospace did to support the development of the options and what is needed for a high confidence level understanding of the cost and schedule of each option?**

As stated previously in this response, to the Committee, in public, and to the NASA Administrator, the only appropriate forward path is to develop detailed program baselines. These include detailed schedules, program baseline cost estimates, independent cost estimates, and comprehensive discussions with potential vendors. This is the normal approach Aerospace takes and the process requires several months after a program baseline is developed.

Our work in support of the Committee was at a higher, more general level. The Committee repeatedly stressed to Aerospace that we were not directed to develop executable baselines, schedules, and costs. Rather, we were to treat various options as consistently as possible to allow the Committee to develop top level findings, such as an assessment of the technical risk posture for Constellation as currently being performed, budget availability to execute the program of record, and general availability dates for other options (some of which had not entered the design phase). We realize the tendency to treat Aerospace's work as executable baselines. While we stand solidly behind the work we did for the Committee, it is important to reiterate what we were asked to accomplish.

Given the schedule constraints on the Committee, Aerospace performed cost and schedule analyses at the appropriate level to address the high-level questions posed within the compressed timelines. Certainly, with more time and resources, analyses with greater fidelity could have been performed. However, Aerospace did not determine the time and resources required to provide more detailed cost and schedule analyses of each option.

**Question 7. How was the confidence gained from actual progress in completing DDT&E activities factored into Aerospace's cost and schedule estimates for options incorporating the program of record?**

Aerospace built cost baselines for each of the scenarios that incorporated data from a variety of sources, including NASA-supplied data, estimates generated by Aerospace, and assumptions defined by the Committee members. Historical mean cost growth factors based on actual historical performance of 77 NASA system developments were derived. These factors were applied consistently and appropriately across the options, taking into account systems already in development, such as Constellation, versus concepts in earlier stages of development. Credit for cost growth already incurred is applied to Constellation program elements that are underway. In contrast, the historical cost growth factor is applied in full for projects not yet initiated.

**Question 8. How long did Aerospace have to carry out the cost estimation and schedule analyses for each of the options considered by the Augustine panel? What caveats, if any, would Aerospace apply to the results of its analyses?**

AEROSPACE
Assuring Space Mission Success

Aerospace's team supported the Committee on a compressed timeline when evaluating the affordability of integrated options. The full set of options evaluated included, but were not limited to, the Constellation Program and other architectures that targeted various beyond LEO destinations, including: lunar surface, Near Earth Objects (NEOs), Lagrange points, and others. These cases were analyzed over the course of several weeks.

The framework for the affordability analysis was assembled from existing software, databases and algorithms over the course of a couple of months. It benefited from several years of Aerospace and NASA investment. Once the framework was established and validated, the affordability analyses for each of the integrated options provided by the Committee were performed on short timelines, typically a few days. In order to compare in-development systems with "paper concepts," a uniform affordability analysis methodology, informed with historical cost growth data, was applied to each option. Our direction from the Committee was to focus on capturing the macro-level issues versus delving into substantial detail on various systems.

As previously stated, our only caveat was that these analyses were directed and developed to be used as guideposts for comparison among options. We do not claim them to be traditional independent analyses of all the elements of each program.

**Question 9. Did Aerospace perform an Independent Cost Estimate (ICE) or Independent Schedule Estimate (ISE) for the Constellation program or its major elements? What would be required to do an ICE and ISE, and how long does Aerospace estimate it would take to complete them?**

Aerospace did not perform a traditional parametric or grass-roots Independent Cost Estimate (ICE) or Independent Schedule Estimate (ISE) for the Constellation Program or its major elements. In order to perform an ICE/ISE for the Constellation Program or its major elements, Aerospace would require technical, design and programmatic data depending upon the phase of the project. The required elements for an ICE/ISE include: design description documents, project Work Breakdown Structure (WBS) definitions and descriptions, Master Equipment Lists (MEL) containing mass, a description of power modes by subsystem, a block diagram of launch vehicle and capsule (or other elements), descriptions of the launch vehicle and capsule subsystem including heritage, lists of hardware suppliers, and an Integrated Master Schedule with major development milestones.

Based on past experience that includes ICE assessments of elements of the Constellation Program such as Ares V and Altair, an ICE/ISE of the Program or its major elements would typically be a multi-month (~3 to 6 month) process. A traditional ICE/ISE also includes a project and/or program level reconciliation. Aerospace was tasked to perform a high-level schedule assessment of Constellation, which found that there was a potential 3-4 year impact to the Orion / Ares I Initial Operational Capability (IOC) milestone due to the effects of the FY10 budget reduction, technical cost-risks, and ISS extension to 2020.

**Question 10. What would be required to do an ICE and ISE for a proposed commercial crew transport system, and how long does Aerospace estimate it would take to complete them?**

The data and timeline required to perform an ICE/ISE for a proposed commercial crew transport system depends on the level of maturity of the systems and the technical and programmatic

AEROSPACE
Assuring Space Mission Success

data available for the assessment. For systems early in their development lifecycle or with a limited amount of available data, the time required to perform these analysis may be less than estimated in Question 9, but may have a higher level of uncertainty in the results. For more mature designs, with a larger set of technical and programmatic data, the time to conduct a complete analysis may be similar to those required to perform an ICE/ISE for the Constellation Program and its major elements (please see Question 9).